REGION 10 ADMINISTRATOR
SEATTLE, WA 98101

City and Borough of Sitka
Wastewater Treatment Plant
Application for a Modified NPDES Permit
Under Section 301(h) of the Clean Water Act

Final Decision of the Regional Administrator
Pursuant to 40 CFR Part 125, Subpart G

I have reviewed the attached evaluation analyzing the merits of the City and Borough of Sitka's request and application for a variance from secondary treatment requirements of the Clean Water Act pursuant to Section 301(h) of the Act for the City and Borough of Sitka wastewater treatment plant. It is my decision that the City and Borough of Sitka be granted a variance pursuant to Section 301(h) of the Act for the City and Borough of Sitka wastewater treatment plant in accordance with the terms, conditions, and limitations of the final 301(h)-modified NPDES permit AK0021474.

My decision is based on available information specific to the discharge from the City and Borough of Sitka wastewater treatment plant. It is not intended to assess the need for secondary treatment in general, nor does it reflect on the necessity for secondary treatment by other publicly owned treatment works discharging to the marine environment.

Under the procedures of permit regulations at 40 CFR Part 124, public notice and comment regarding the draft version of this decision and accompanying NPDES permit were made available to all interested persons.

This decision shall become effective on January 7, 2025, unless a request for review is filed. If a request for review is filed, this decision is stayed. Requests for review must be filed by January 6, 2025, and must meet the requirements of 40 CFR 124.19. All requests for review should be addressed to the Environmental Appeals Board. Those persons filing a request for review must have filed comments on the tentative decision. Requests for review from other persons must be limited to the extent of the changes made from the tentative decision to the final decision. EPA regulations regarding the effective date for the decision and requests for review procedures are set forth in 40 CFR 125.15, 125.19 and 125.20.

The Notice of Final Decision will also be posted on the EPA Region 10 website.

/signed/ 11-15-2024
Casey Sixkiller
Regional Administrator

City and Borough of Sitka Wastewater Treatment Plant

Application For A Modified NPDES Permit Under Section 301(h) Of The Clean Water Act

Decision Document

December 2024

United States Environmental Protection Agency
Region 10
1200 6th Avenue
Seattle, WA 98101

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1) INTRODUCTION

The City and Borough of Sitka, Alaska, ("the City," "the applicant," "CBS," or "the permittee") has requested a renewal of its variance (sometimes informally called a "waiver" or "modification") under Section 301(h) of the Clean Water Act (the Act or CWA) from the secondary treatment requirements contained in Section 301(b)(1)(B) of the Act.

The United States Environmental Protection Agency, Region 10 (EPA) approved the City and Borough of Sitka's first request for modification of secondary treatment requirements and issued its first CWA Section 301(h)-modified National Pollutant Discharge Elimination System (NPDES) permit on March 14, 1983 [AK0021474]. The most recent NPDES permit was issued on November 27, 2001, became effective on December 31, 2001, and expired on January 2, 2007 (hereinafter, referred to as the 2001 permit). A timely and complete NPDES application for permit reissuance was submitted by the permittee on June 5, 2006. Pursuant to 40 CFR 122.6, the permit has been administratively continued and remains fully effective and enforceable.

The 301(h) variance is being sought for CBS' Wastewater Treatment Plant ("WWTP" or "the facility"), a publicly owned treatment works (POTW). The applicant is seeking a 301(h) variance to discharge wastewater receiving less-than-secondary treatment from a single outfall into the Middle Channel of Sitka Sound. Secondary treatment is defined in the regulations at 40 CFR Part 133 in terms of effluent quality for total suspended solids (TSS), biochemical oxygen demand (BOD_5), and pH. Pursuant to 40 CFR 133.102, secondary treatment requirements for TSS, BOD_5, and pH are as follows:

TSS: (1) The 30-day average concentration shall not exceed 30 mg/l;

(2) The 7-day average concentration shall not exceed 45 mg/l; and

(3) The 30-day average percent removal shall not be less than 85%.

BOD_5: (1) The 30-day average concentration shall not exceed 30 mg/l;

(2) The 7-day average concentration shall not exceed 45 mg/l; and

(3) The 30-day average percent removal shall not be less than 85%.

pH: The pH of the effluent shall be maintained within the limits of 6.0 to 9.0 pH standard units.

The City requested a modification for TSS and BOD_5; the City did not request a modification for pH.

This document presents EPA Region 10's findings and conclusions as to whether the applicant's proposed 301(h)-modified discharge (proposed discharge) will comply with the criteria set forth in sections 301(h) of the Act, as implemented by regulations at 40 CFR Part 125, Subpart G, and Alaska Water Quality Standards (Alaska WQS), as amended.

2) DECISION CRITERIA

Under Section 301(b)(1)(B) of the Act, POTWs in existence on July 1, 1977, are required to meet effluent limits based on secondary treatment as defined by the Administrator of EPA ("the Administrator"). Secondary treatment is defined by the Administrator in terms of three parameters: TSS, BOD_5, and pH. Uniform national effluent limitations for these pollutants were promulgated and included in NPDES permits for POTWs issued under Section 402 of the CWA. POTWs were required to comply with these limitations by July 1, 1977.

Congress subsequently amended the Act, adding Section 301(h), which authorizes the Administrator, with State concurrence, to issue NPDES permits that modify the secondary treatment requirements of the Act with respect to certain discharges. P.L. 95-217, 91 Stat. 1566, as amended by P.L. 97-117, 95 Stat. 1623; and S303 of the Water Quality Act of 1987. Section 301(h) provides that:

> *[T]he Administrator, with the concurrence of the State, may issue a permit under section 402 [of the Act] which modifies the requirements of subsection (b)(1)(B) of this section [the secondary treatment requirements] with respect to the discharge of any pollutant from a publicly owned treatment works into marine waters, if the applicant demonstrates to the satisfaction of the Administrator that:*

(1) there is an applicable water quality standard specific to the pollutant for which the modification is requested, which has been identified under section 304(a)(6) of [the CWA];
(2) the discharge of pollutants in accordance with such modified requirements will not interfere, alone or in combination with pollutants from other sources, with the attainment or maintenance of that water quality which assures protection of public water supplies and the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife, and allows recreational activities, in and on the water;
(3) the applicant has established a system for monitoring the impact of such discharge on a representative sample of aquatic biota, to the extent practicable, and the scope of the monitoring is limited to include only those scientific investigations which are necessary to study the effects of the proposed discharge;
(4) such modified requirements will not result in any additional requirements on any other point or nonpoint source;
(5) all applicable pretreatment requirements for sources introducing waste into such treatment works will be enforced;
(6) in the case of any treatment works serving a population of 50,000 or more, with respect to any toxic pollutant introduced into such works by an industrial discharger for which pollutant there is no applicable pretreatment requirement in

effect, sources introducing waste into such works are in compliance with all applicable pretreatment requirements, the applicant has in effect a pretreatment program which, in combination with the treatment of discharges from such works, removes the same amount of such pollutant as would be removed if such works were to apply secondary treatment to discharges and if such works had no pretreatment program with respect to such pollutant;

(7) to the extent practicable, the applicant has established a schedule of activities designed to eliminate the entrance of toxic pollutants from nonindustrial sources into such treatment works;

(8) there will be no new or substantially increased discharges from the point source of the pollutant into which the modification applies above that volume of discharge specified in the permit; and

(9) the applicant at the time such modification becomes effective will be discharging effluent which has received at least primary or equivalent treatment and which meets the criteria established under [section 304(a)(1) of the CWA] after initial mixing in the waters surrounding or adjacent to the point at which such effluent is discharged.

For the purposes of this subsection the phrase "the discharge of any pollutant into marine waters" refers to a discharge into deep waters of the territorial sea or the waters of the contiguous zone, or into saline estuarine waters where there is strong tidal movement and other hydrological and geological characteristics which the Administrator determines necessary to allow compliance with paragraph (2) of this subsection, and [section 101(a)(2) of the Act]. For the purposes of paragraph (9), "primary or equivalent treatment" means treatment by screening, sedimentation, and skimming adequate to remove at least 30 percent of the biological oxygen demanding material and of the suspended solids in the treatment works influent, and disinfection, where appropriate. A municipality which applies secondary treatment shall be eligible to receive a permit pursuant to this subsection which modifies the requirements of subsection (b)(1)(B) of this section with respect to the discharge of any pollutant from any treatment works owned by such municipality into marine waters. No permit issued under this subsection shall authorize the discharge of sewage sludge into marine waters. In order for a permit to be issued under this subsection for the discharge of a pollutant into marine waters, such marine waters must exhibit characteristics assuring that water providing dilution does not contain significant amounts of previous discharged effluent from such treatment works. No permit issued under this subsection shall authorize the discharge of any pollutant into saline estuarine waters which at the time of application do not support a balanced, indigenous population of shellfish, fish and wildlife, or allow recreation in and on the waters or which exhibit ambient water quality below applicable

> *water quality standards adopted for the protection of public water supplies, shellfish, fish and wildlife or recreational activities or such other standards necessary to assure support and protection of such uses. The prohibition contained in the preceding sentence shall apply without regard to the presence or absence of a causal relationship between such characteristics and the applicant's current or proposed discharge. Notwithstanding any of the other provisions of this subsection, no permit may be issued under this subsection for discharge of a pollutant into the New York Bight Apex consisting of the ocean waters of the Atlantic Ocean westward of 73 degrees 30 minutes west longitude and westward of 40 degrees 10 minutes north latitude.*

On August 9, 1994, EPA promulgated final regulations implementing these statutory criteria at 40 CFR Part 125, Subpart G. The regulations provide that a Section 301(h)-modified NPDES permit may not be issued in violation of 40 CFR 125.59(b) which requires, among other things, compliance with provisions of the Coastal Zone Management Act, as amended, 16 USC 1451 *et seq.*, the Endangered Species Act (ESA), as amended, 16 USC 1531 *et seq.*, Title III of the Marine Protection Research and Sanctuaries Act, as amended, 16 USC 1431 *et seq.*, the Magnuson-Stevens Fishery Conservation and Management Act, as amended, 16 USC 1801 *et seq.*, and any other applicable provisions of local, state, and federal laws or Executive Orders.

In accordance with 40 CFR 125.59(i), the decision to grant or deny a CWA Section 301(h) waiver shall be made by the Administrator[1] and shall be based on the applicant's demonstration that it has met all the requirements of 40 CFR 125.59 through 125.68, as described in this 301(h) Decision Document (301(h) DD). EPA has reviewed all data submitted by the applicant in the context of applicable statutory and regulatory criteria and has presented its findings and conclusions in this 301(h) DD.

3) SUMMARY OF FINDINGS

Based upon review of the data, references, and empirical evidence furnished by the applicant and other relevant sources, EPA Region 10 makes the following findings regarding the statutory and regulatory criteria:

1. The applicant's proposed discharge will comply with Alaska WQS for dissolved oxygen and turbidity. [CWA Section 301(h)(1); 40 CFR 125.61]
2. The applicant has demonstrated it can consistently achieve Alaska WQS and federal CWA Section 304(a)(1) water quality criteria beyond the zone of initial dilution (ZID). [CWA Section 301(h)(9); 40 CFR 125.62(a)]
3. The applicant's proposed discharge, alone or in combination with pollutants from other sources, will not adversely impact public water supplies or interfere with the protection

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[1] The authority to make decisions on the eligibility of publicly owned treatment works for variances from the secondary treatment requirements of the Clean Water Act pursuant to Section 301(h) of the CWA has been delegated to the Regional Administrators.

and propagation of a balanced, indigenous population (BIP) of shellfish, fish, and wildlife, and will allow for recreational activities in an on the water. [CWA Section 301(h)(2); 40 CFR 125.62(b), (c), (d)]

4. The applicant has a well-established and adequate program to monitor the impact of its proposed discharge on aquatic biota and has demonstrated it has adequate resources to continue the program. These monitoring requirements will remain enforceable terms of the permit. [CWA Section 301(h)(3); 40 CFR 125.63]
5. The applicant's proposed discharge will not result in any additional treatment requirements on any other point or nonpoint sources. [CWA Section 301(h)(4); 40 CFR 125.64]
6. The applicant will develop an industrial pretreatment program and will continue to implement its nonindustrial source control program, consisting of public outreach and education designed to minimize the amount of toxic pollutants that enter the treatment system from nonindustrial sources. [CWA Section 301(h)(7);40 CFR 125.65; 40 CFR 125.66]
7. There will be no new or substantially increased discharges from the point source of the pollutants to which the 301(h) variance applies above those specified in the permit. [CWA Section 301(h)(8); 40 CFR 125.67]
8. The 301(h) modified permit contains special conditions in the form of effluent limitations and mass loadings, schedules of compliance, and monitoring and reporting requirements [40 CFR 125.68]
9. The discharge is not expected to conflict with applicable provisions of State, local, or other Federal laws or Executive Orders, and is expected to comply with the Coastal Zone Management Act of 1972, as amended, 16 USC 1451 et seq.; the Endangered Species Act of 1973, as amended, 16 USC 1531 et seq.; Title III of the Marine Protection, Research and Sanctuaries Act, as amended, 16 USC 1431 et seq.; and the Magnuson-Stevens Fishery Conservation and Management Act, as amended, 16 USC § 1801 *et seq.*
10. The applicant has demonstrated the proposed discharge will comply with federal primary treatment requirements. [CWA Section 301(h)(9); 40 CFR 125.60]

4) DECISION

Based on the findings in Section 3, above, EPA has concluded that the applicant's proposed discharge will comply with the requirements of CWA Section 301(h) and 40 CFR Part 125, Subpart G. Accordingly, EPA has decided to grant the applicant a CWA Section 301(h) variance and renew their 301(h)-modified NPDES Permit AK0021474.

5) DESCRIPTION OF TREATMENT SYSTEM

The City and Borough of Sitka's Wastewater Treatment Plant is a primary treatment plant that began operation in 1984. The facility has a peak design flow of 5.3 million gallons per day (mgd). The existing outfall discharges to the Middle Channel of Sitka Sound at a depth of 85 feet below mean lower low water (MLLW). The outfall location is 57° 02' 53" N, 135° 21' 13" W, near the airport.

The treatment plant currently serves a population of approximately 8,500 and was designed for a population of 10,500. Sitka's population has held steady over the last several years and the facility does not project a population increase during the term of the proposed permit. Peak design flow is 0.23 meters^3/second (5.3 mgd) and average daily design flow is 0.08 meters^3/second (1.8 mgd). The average flow in 2000 was 1.4 mgd. In accordance with 40 CFR 125.58(c), the facility is a "small applicant."

The collection system is a separate sanitary sewer system consisting of approximately 50 kilometers (31 miles) of mains and interceptors and 59 lift stations (27 are residential lift stations). Treatment consists of comminution of 90% of the sewage entering the treatment plant (Japonski, Alice, and Charcoal Islands wastewater is injected into the force mains beyond the comminutor), manually-cleaned bar rack, grit removal, and primary clarification (with scum skimming, sludge removal). Sludge from the clarifiers is thickened and dewatered. Thickener supernatant is returned to the treatment system prior to the clarifiers. Sludge is buried in a local biosolids landfill.

The effluent is discharged through the existing 1,676 meters (5,500 feet) long marine outfall, which ends in a diffuser at a depth of 25.9 meters (85 feet) below MLLW.

See Appendix A for facility figures, area maps, and the treatment process flow diagram.

6) DESCRIPTION OF RECEIVING WATERS

A. General Features

The facility discharges to the middle channel of Sitka Sound. Information indicates that the receiving water could be considered either open ocean or saline estuary, based on geographic and oceanographic characteristics (Tetra Tech, 1988). EPA believes this analysis remains applicable to the conditions in Sitka Sound. Therefore, EPA determined that it is most appropriate to classify the receiving water as open ocean, in recognition of the absence of a significant salinity gradient during the year and the physical characteristics of Sitka Sound in the vicinity of the outfall (EPA 1989 Decision Document).

The middle channel of Sitka Sound is classified in Alaska WQS as classes IIA(I)(ii)(iii), B(I)(ii), C and D, for use in aquaculture, seafood processing, industrial water supply, water contact and secondary recreation, growth and propagation of fish, shellfish, aquatic life and wildlife, and harvesting for consumption of raw mollusks or other raw aquatic life.

B. Currents and Flushing

According to NOAA, the mean tide range at Sitka, Alaska (Station ID: 9451600) from 1983 to 2001 is 7.7 feet, with a diurnal range of 9.9 feet and a mean tide level of 5.3 feet above MLLW (NOAA 2022a). The maximum tide level is 15 feet above MLLW level. The minimum tide level is 4.1 feet below the MLLW level. More detailed information on currents and flushing is available in the 1988 permit application questionnaire and 2001 Permit Fact Sheet.

In August 1979, Sitka Sound was observed to have wind-driven currents that produced a net eastward displacement of surface water. Currents in Sitka Sound rotate clockwise and tend to transport water to the mouth of the Sound under ebb flow conditions (CBS 1988).

7) PHYSICAL CHARACTERISTICS OF THE DISCHARGE

A. Outfall/Diffuser Design and Initial Dilution

Pursuant to 40 CFR 125.62(a)(1), the outfall and diffuser must be located and designed to provide adequate initial dilution, dispersion, and transport of wastewater to meet all applicable WQS at and beyond the boundary of the ZID during periods of maximum stratification and during other periods when discharge characteristics, water quality, biological seasons, or oceanographic conditions indicate more critical situations may exist.

The existing marine outfall consists of 5,500 feet of 24-inch pipe and 197 feet of diffuser located at approximately 85 feet (25.9 meters) below MLLW. The diffuser consists of 54 feet of 24-inch pipe, 65 feet of 20-inch pipe, 26 feet of 16-inch pipe, 26 feet of 14-inch pipe, and 24 feet of 10-inch pipe. There are sixteen round, 4-inch, bell-mouthed ports, located at 0° from the horizontal along the length of the diffuser. The ports are spaced alternately left and right of the pipe on 13 feet centers, 18 inches above the seabed. The average daily design flow rate for each port is 79.26 gallons per minute at 1.8 mgd.

Zone of Initial Dilution (ZID)

Section 301(h)(9) of the CWA and 40 CFR 125.62 require 301(h) discharges to meet state WQS and federal 304(a) criteria at the boundary of the ZID, which is the region of initial mixing surrounding or adjacent to the end of the outfall pipe or diffuser ports. The ZID may not be larger than allowed by mixing zone restrictions in applicable WQS, as per 40 CFR 125.58(dd). The dilution ratio achieved at the completion of initial mixing at the edge of the ZID is used to determine compliance with these requirements. Dilution is defined as the ratio of the total volume of the sample (ambient water plus effluent) to the volume of effluent in the sample. The ZID is not intended to describe the area bounding the entire mixing process or the total area impacted. Rather, the ZID, or region of *initial mixing* is the area of rapid, turbulent mixing of the effluent and receiving water and results from the interaction between the buoyancy and momentum of the discharge and the density and momentum of the receiving water. Initial dilution is normally complete within several minutes after discharge. In guidance, EPA has operationally delimited the ZID to include the bottom area within a horizontal distance equal to the water depth from any point on the diffuser and the water column above that area. Beyond the ZID boundary (i.e., after initial mixing is complete), the effluent is diluted further by passive diffusion processes and far-field ambient receiving water conditions. The ZID is not inclusive of this far-field mixing process.

The prior permit used a dilution factor of 122:1 based on the critical summer season and the diffuser design at that time. EPA has refined the dilution factor using more current information and available effluent and receiving water data.

EPA modeled the discharge to determine the dilution achieved at the edge of the ZID using recent effluent and receiving water data provided by the applicant (2016-2021). In accordance with the *1994 Amended Section 301(h) Technical Support Document* (301(h) TSD), EPA used data reflecting critical discharge and receiving water conditions to determine dilution under critical conditions. The dilution modeling report is included in Appendix F.

According to the model, the discharge achieves initial mixing and a dilution of 87:1 at 80 feet from the outfall at a depth of approximately 80 feet within two minutes of discharge. EPA used 87:1 dilution as the basis for determining compliance with 301(h)(9) and 40 CFR 125.62. Consistent with the recommendations in the 301(h) TSD for setting spatial boundaries for the ZID, EPA has established the spatial dimensions of the ZID which include the entire water column within 60 feet of any point of the 25-foot diffuser. In its final CWA Section 401 Certificate of Reasonable Assurance (401 certification) the Alaska Department of Environmental Conservation (ADEC) authorized acute and chronic dilution factors of 46:1 and 76:1, respectively. These dilutions fall within the boundary of the ZID.

8) APPLICATION OF STATUTORY AND REGULATORY CRITERIA

The sections below describe the statutory and regulatory requirements of 301(h) discharges and explains the basis for the permit conditions.

A. Compliance with Primary or Equivalent Treatment Requirements [CWA Section 301(h)(9); 40 CFR 125.60]

Under CWA Section 301(h)(9) and 40 CFR 125.60, the applicant must demonstrate it will be discharging effluent that has received at least primary or equivalent treatment at the time the 301(h)-modified permit becomes effective. 40 CFR 125.58(r) defines primary or equivalent treatment as treatment by screening, sedimentation, and skimming adequate to remove at least 30 percent of the biochemical oxygen demanding material and other suspended solids in the treatment works influent, and disinfection, where appropriate. To ensure the effluent has received primary or equivalent treatment, 40 CFR 125.60 requires the applicant to perform monitoring of their influent and effluent and assess BOD_5 and TSS removal rates based on a monthly average.

Applicants for 301(h) waivers request concentration and loading (lb/day) limits for BOD_5 and TSS based on what the facility can achieve. Therefore, the technology-based requirements for POTWs with 301(h) waivers are established on a case-by-case basis taking into consideration facility performance, and the federal primary treatment standards.

1. Total Suspended Solids

EPA reviewed influent and effluent monitoring data for TSS between November 2016 and September 2021. A summary table and graphical representation of the data is provided below.

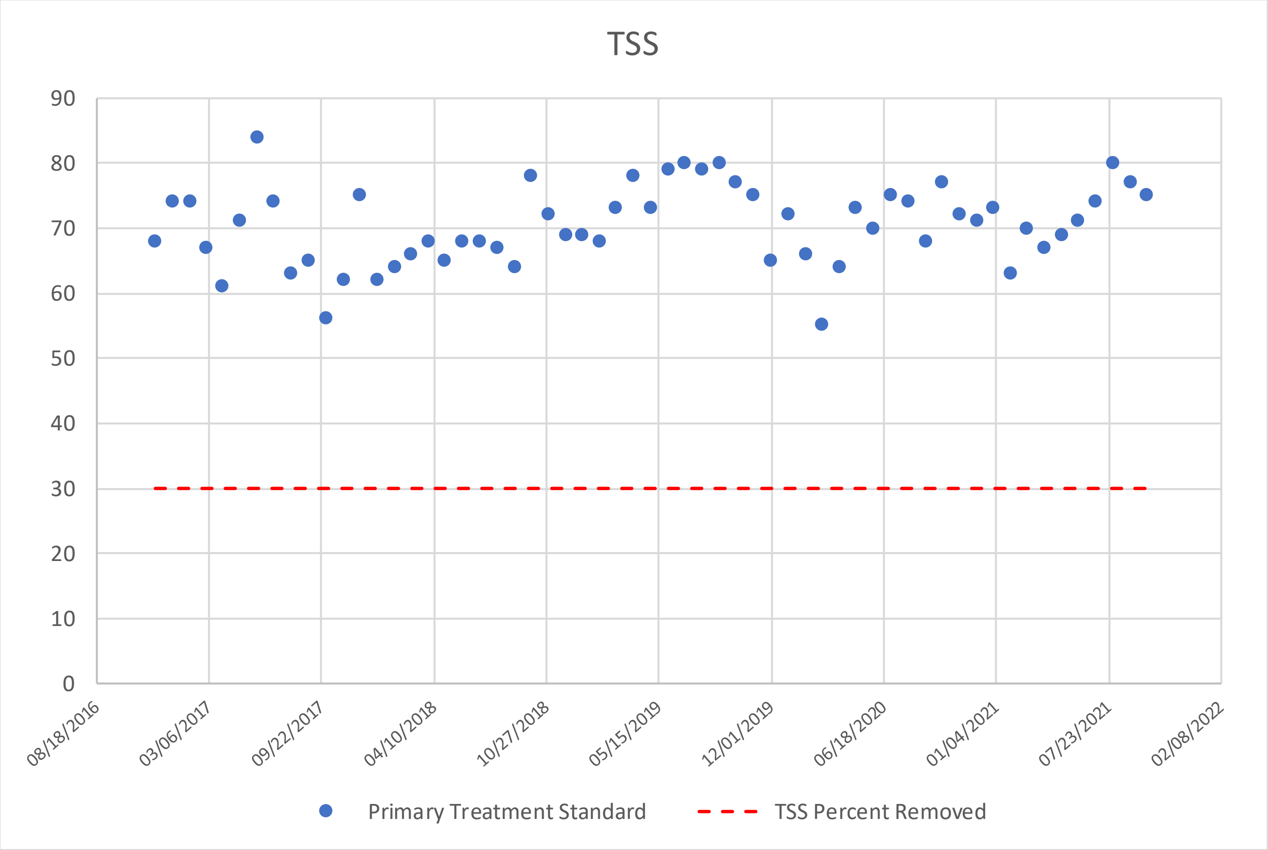

Figure 1. Minimum Monthly TSS Removal (2016-2021)

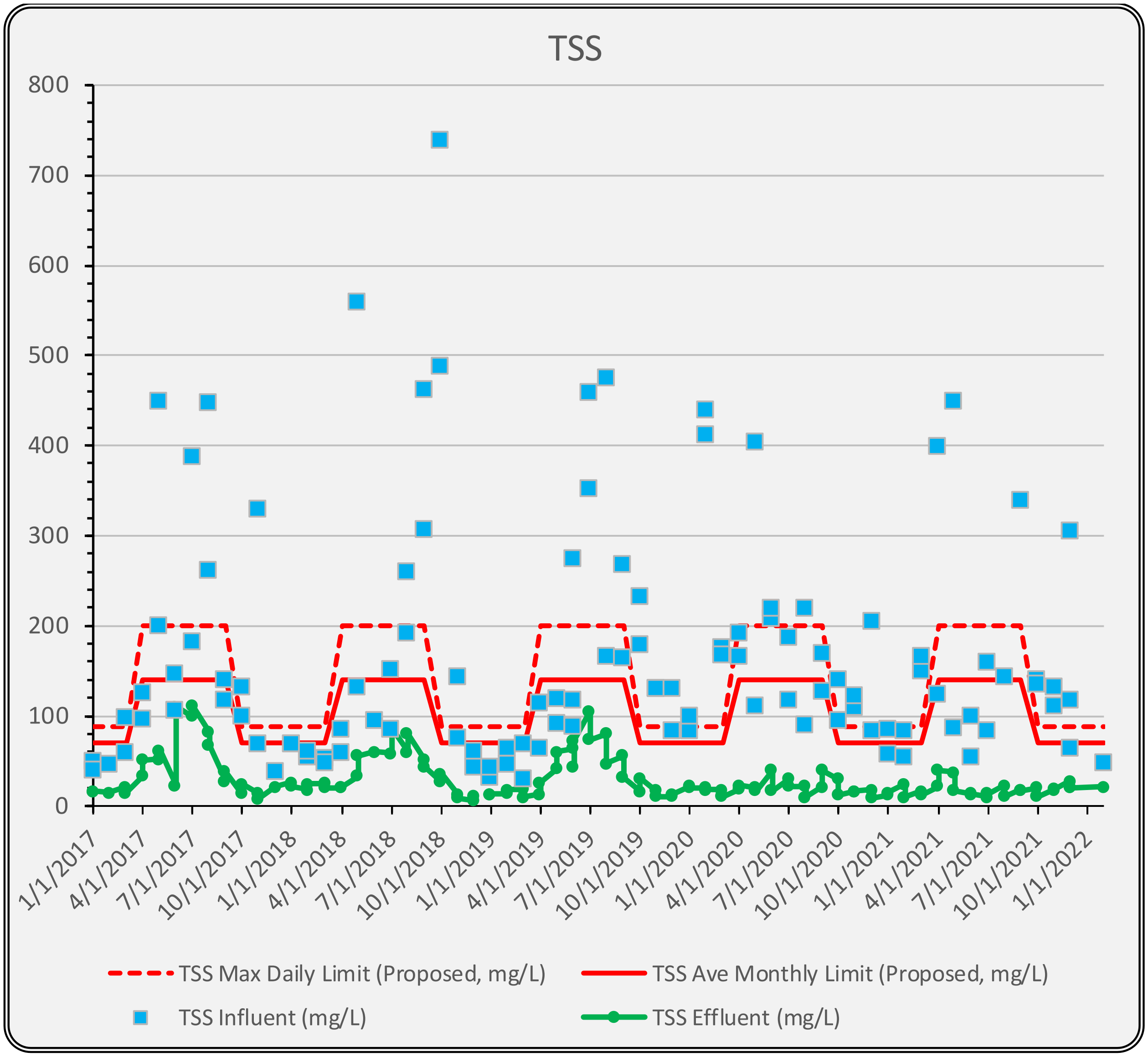

Figure 2. Monthly Influent and Effluent TSS Concentrations (mg/L)

The applicant achieved the minimum 30% removal requirement for TSS 100% of the time with the lowest monthly removal being 55% on February 29, 2020. Between 2016 and 2021 the facility achieved an average of nearly 71% removal of TSS, with maximum percent removal efficiencies as high as 84%.

Table 1. Influent and Effluent TSS Data (2016-2021)

Statistic	Influent, TSS, mg/L	Effluent, TSS, mg/L	Percent Removal
PROPOSED LIMIT	---	58 (daily max)/ 73 (mo avg)	≥30%
COUNT	59	59	59
MEAN	129	35	71%
MINIMUM	56	21	55
MAX	254	60	84
STDV	36.9	8.8	6.1
CV	0.3	0.2	0.1
5th	83.3	23.0	61.9
95th	188.1	50.2	80.0

The applicant has demonstrated that it will be discharging effluent that has received at least primary treatment for TSS when the 301(h)-modified permit becomes effective. [CWA section 301(h)(9) and 40 CFR 125.60].

2. Biochemical Oxygen Demand

EPA reviewed influent and effluent data for BOD_5 between 2016 and 2021. A summary table and graphical representation of the data is provided below.

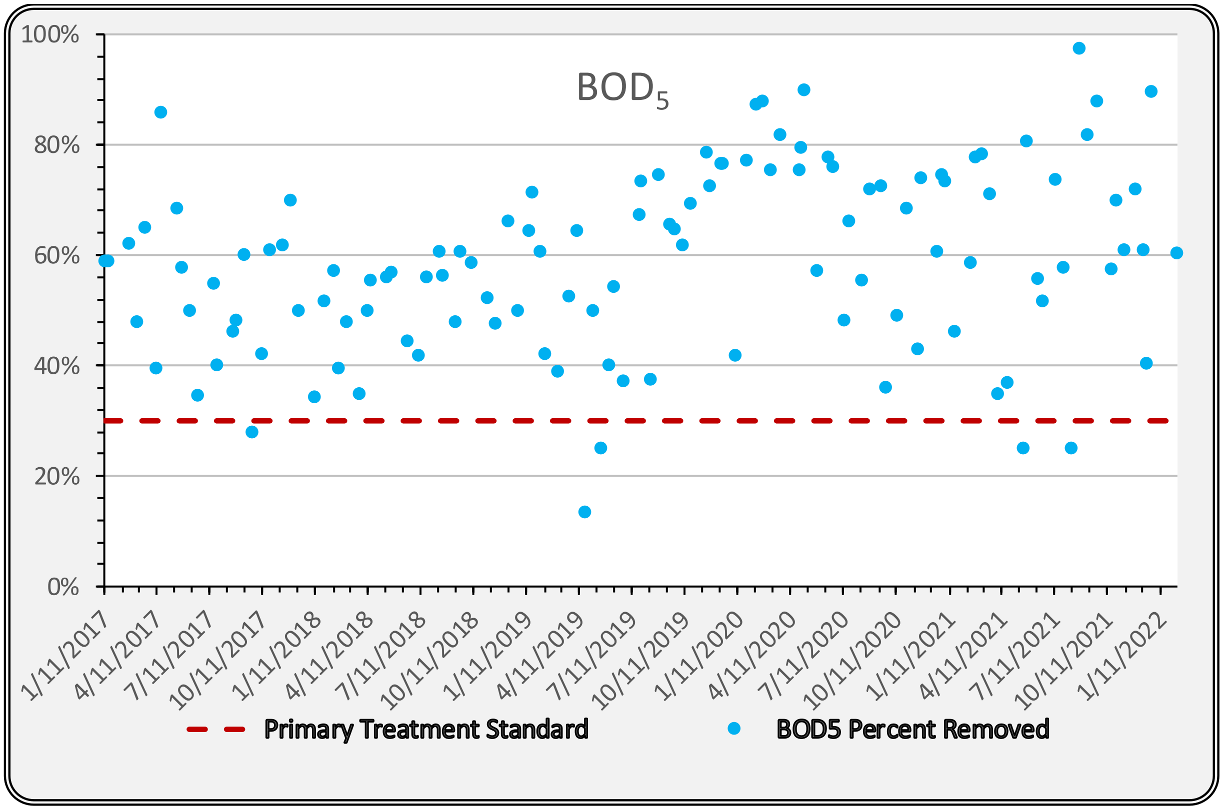

Figure 3. Minimum Monthly BOD5 Removal (2016-2021)

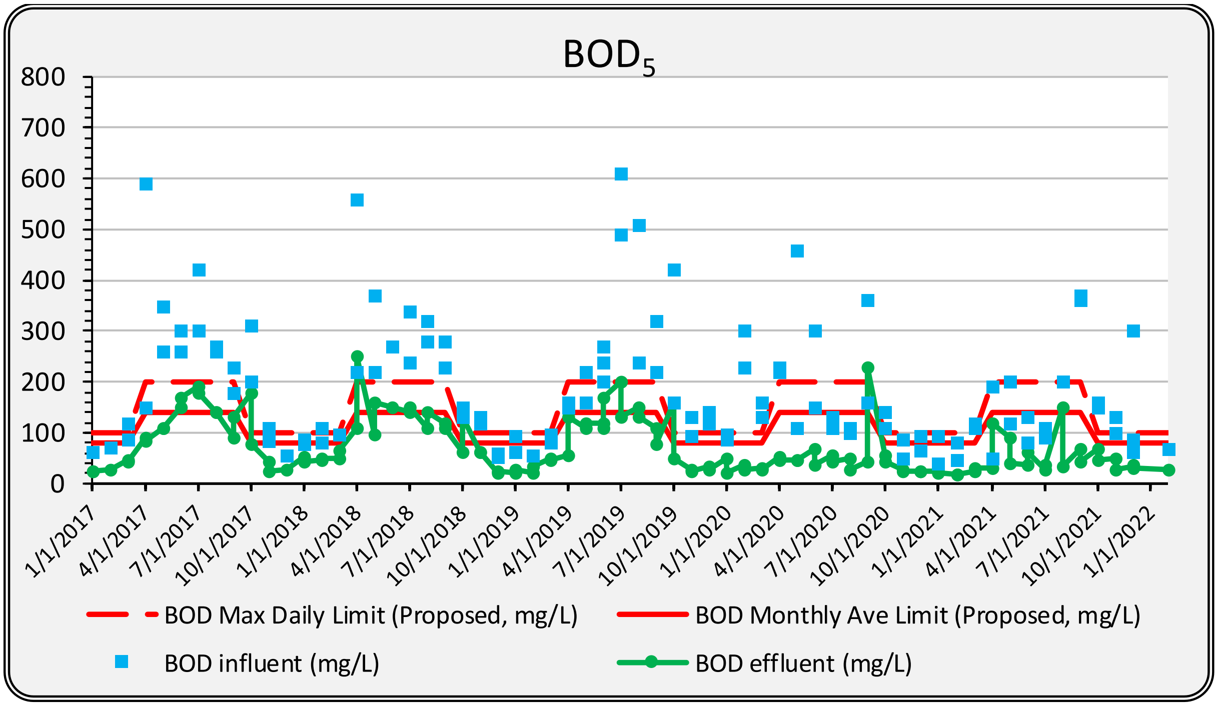

Figure 4. Monthly Influent and Effluent BOD5 Concentrations (2016-2021)

The facility achieved the minimum 30% removal requirement for BOD_5 100% of the time with the lowest monthly removal being 30% in January 2018. Between 2016 and 2021, the facility achieved an average of 42% removal of BOD_5, with maximum percent removal efficiencies as high as 57%.

Table 2. Influent and Effluent BOD5 Data (2016-2021)

Statistic	Influent, BOD_5, mg/L	Effluent, BOD_5, mg/L	Percent Removal
LIMIT	---	200 (daily max)/ 180 (mo avg)	≥30%
COUNT	59	59	59
MEAN	153	85	42%
MIN	78	45	30%
MAX	271	134	57%
STDV	41	21	5.5
CV	0.3	0.2	0.1
5th	216	117	49
95th	97	55	34

The applicant has demonstrated that it will be discharging effluent that has received at least primary treatment for BOD_5 when the 301(h)-modified permit becomes effective. [CWA section 301(h)(9) and 40 CFR 125.60].

B. Attainment of Water Quality Standards Related to TSS and BOD_5 [CWA 301(h)(1); 40 CFR 125.61]

Under 40 CFR 125.61, which implements Section 301(h)(1) of the CWA, there must be WQS applicable to the pollutants for which the modification is requested, and the applicant must demonstrate that the proposed discharge will comply with these standards. The applicant has requested modified secondary treatment requirements for BOD_5, which affects dissolved oxygen (DO), and TSS, which affects the color or turbidity in the receiving water. The State of Alaska has water quality standards for DO and turbidity.

1. Turbidity and Light Transmittance/Attenuation

Alaska WQS applicable to the estuarine waters of Sitka Sound provide that turbidity shall not exceed 25 nephelometric turbidity units (NTU), may not interfere with disinfection, may not cause detrimental effect on established levels of water supply treatment, and may not reduce the depth of the compensation point for photosynthetic activity by more than 10% (Table 3). In addition, turbidity may not reduce the maximum Secchi disc depth by more than 10%. Alaska WQS for turbidity can be found in Appendix E.

The applicant collected Secchi disc depth data in Sitka Sound in July 2018 and July 2020 at the following sites:

Station A: Western edge of the ZID
Station B: Eastern edge of ZID reference stations
Station C: Reference station west of discharge
Station D: Reference station east of discharge

Stations C and D are considered reference sites, and Stations A and B are ZID boundary sites. Monitoring results are presented in Table 3. Sitka did not collect turbidity data.

Table 3. Secchi Disk Depth in Sitka Sound

	2018	**Percent Difference 2018**	**2020**	**Percent Difference 2020**	**Average Percent Difference**
Station A-western edge of the ZID	24 ft	11.1%	17 ft	5.6 %	8.4 %
Station C-reference station west of discharge	27 ft		18 ft		
Station B-eastern edge of ZID reference stations	26 ft	Not Applicable	19 ft	5.0 %	4.4 %
Station D- reference station east of discharge	25 ft		20 ft		
Source: 7/2018 & -7/2020 CBS receiving water monitoring					

EPA evaluated Secchi disk data from July 2018 and July 2020 and found that while there was one measurement exceeding 10% by one percent, the other two instances were well below the state standard of not reducing Secchi disk depth more than 10%. In another instance, the Secchi disk depth at the reference station was greater than the ZID station depth, indicating better conditions at the ZID compared to the reference station. The facility also had consistent TSS reduction well above the required 30% reduction. Lastly, the final permit contains a narrative limitation prohibiting the discharge of floating, suspended or submerged matter of any kind in concentrations that would impair designated beneficial uses.

Based on the above analyses, the proposed discharge is expected to comply with Alaska WQS for turbidity and light transmittance/attenuation.

2. Dissolved Oxygen (DO)

The effect of the effluent discharge on DO can occur in the nearshore and far-field as effluent mixes with the receiving water and the oxygen demand of the effluent BOD_5 load is exerted. Pursuant to 40 CFR 125.61(b)(1) and 125.62(a)(1), the applicant must demonstrate that the proposed discharge will comply with water quality criteria for DO and that the outfall and diffuser are located and designed to provide adequate initial dilution, dispersion, and transport of wastewater such that the discharge does not exceed criteria at and beyond the ZID. Alaska WQS for DO applicable to the estuarine waters of Sitka Sound provide that DO may not be less than 5.0 mg/L except where natural conditions cause this value to be depressed, and in no case may DO levels exceed 17 mg/L [18 AAC 70.15(a)(i)]. Alaska WQS for DO are shown in Appendix D.

In accordance with the procedures outlined in the 301(h) TSD, Section B-11, p.188 and p. 194, EPA conducted a near-field and far-field analysis to estimate the impacts on DO levels in the vicinity of the discharge. Analysis of DO impacts can be found in Appendix E and summarized below.

Near Field DO Impacts

For CBS, the following values were used for the near field DO analysis:

DO_a = 12.4 mg/L (worst case from station C, modeling indicated station C was limiting for DO and other parameters).

Do_e = 4 mg/L (min value effluent DO)

IDOD = 3 mg/L (from Table B-3 in TSD)

S_a = 87 (ZID dilution)

$DO_f = DO_a - (DO_a + IDOD – DO_e)/S_a$ = 12.4mg/L + (4 mg/L – 3 mg/L - 12.4 mg/L)/(87)=12.3 mg/L

The near-field DO reduction is approximately 0.1 mg/L under worst case condition. Therefore, the Alaska WQS of no less than 5 mg/L and no greater than 17 mg/L are not violated.

Far Field Analysis

To assess the potential for far field impacts to DO, the final BOD_5 concentration after initial mixing was determined using the simplified procedures described in Appendix B of the 301(h) TSD and outlined in Appendix E of this 301(h) DD. The calculation resulted in a final BOD_5 concentration of 3.0 mg/L after initial mixing, a concentration that is not anticipated to cause or contribute to any measurable far field DO impacts beyond the ZID. Therefore, the Alaska WQS of no less than 5 mg/L and no greater than 17 mg/L are not violated.

Suspended Solids Accumulation

Impacts to DO concentrations resulting from the discharge of wastewater can also be assessed by examining the accumulation of suspended solids. 40 CFR 125.62 states that wastewater and particulates must be adequately dispersed following initial dilution so as not to adversely affect water use areas. The accumulation of suspended solids may lower DO in near-bottom waters and cause changes in the benthic communities. Accumulation of suspended solids in the vicinity of a discharge is influenced by the amount of solids discharged, the settling velocity distribution of the particles in the discharge, the plume height-of-rise, and current velocities. Hence, sedimentation of suspended solids is generally of little concern for small discharges into well-flushed receiving waters.

The questionnaire submitted by the applicant in 2006 states there are no known water quality issues associated with the accumulation of suspended solids from the discharge.

To evaluate the potential impact of solids sedimentation, a simplified approach for small dischargers that are not likely to have sediment accumulation related problems can be found in Figure B-2 of the 301(h) TSD. To use Figure B-2 of the 301(h) TSD to evaluate whether steady state solids accumulation will result in sufficient sediment accumulation to cause a 0.2 mg/L oxygen depression, the TSS mass emissions rate is needed, as well as plume height-of-rise. The mass emission or loading rate was calculated using the TSS concentration limit, facility design flow, and a conversion factor (Loading (lbs/day)) = 58 mg/L X 5.3 mgd X 8.34= 2,564 lbs/day, 1,163 kg/day. Plume height-of-rise was calculated to be 80 feet (24 meters), using the approach on page B-5 in the 301(h) TSD, which involves multiplying the water depth at the point of discharge (100 feet at MLLW) by 0.6 meters. When a height-of-rise of 24 meters and a loading rate of 1,163 kg/day are input in Figure B-2, steady state accumulation is well below the line at which greater than 0.2 mg/L oxygen depression is expected. Per the 301(h) TSD, no further analysis is needed to demonstrate that accumulating solids will not result in unacceptable DO depressions. See Appendix E for additional details.

Based on the above analyses of DO depletion and suspended solids accumulation, the proposed discharge is expected to comply with Alaska WQS for DO.

C. Attainment of Other Water Quality Standards and Impact of the Discharge on Shellfish, Fish And Wildlife; Public Water Supplies; And Recreation [CWA Section 301(h)(2); 40 CFR 125.62]

CWA Section 301(h)(2) requires that the proposed discharge not interfere, either alone or in combination with other sources, with the attainment or maintenance of that water quality which assures protection of public water supplies and protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife, and allows recreational activities in and on the water. Pursuant to 40 CFR 125.62(a), the applicant’s outfall and diffuser must be located and designed to provide adequate initial dilution, dispersion, and transport of wastewater such that the discharge does not exceed, at and beyond the ZID, all applicable EPA-approved state WQS and, where no such standards exist, EPA's CWA Section 304(a)(1) aquatic life criteria for acute and chronic toxicity and human health criteria for carcinogens and noncarcinogens, after initial mixing in the waters surrounding or adjacent to the outfall. In addition, 40 CFR 125.59(b)(1) prohibits issuance of a 301(h)-modified permit that would not assure compliance with all applicable NPDES requirements of 40 CFR Part 122; under these requirements a permit must ensure compliance with all WQS.

Attainment of water quality criteria for DO and turbidity was previously discussed. However, in accordance with 40 CFR 125.62(a), the applicant must also demonstrate that the proposed discharge will attain other WQS, including those for pH, temperature, toxic pollutants, and bacteria. EPA used Alaska WQS and the processes described in the 301(h) TSD and the 1991 *Technical Support Document for Water Quality-based Toxics Control* to determine whether the proposed discharge has the reasonable potential to cause or contribute to an excursion above Alaska WQS, to calculate water quality-based effluent limits (WQBELs), and to assess compliance with CWA Section 301(h)(2) and 40 CFR 125.62. To determine reasonable potential, EPA compares the maximum projected receiving water concentration at the ZID boundary to the water quality criterion for that pollutant. If the projected receiving water concentration exceeds the criterion, there is reasonable potential for that pollutant to cause or contribute to an excursion above Alaska WQS, and a WQBEL must be included in the permit. If a permittee is unable to meet their WQBEL it would fail to satisfy CWA Section 301(h)(9) and 40 CFR 125.62 and would be ineligible for a CWA Section 301(h) modification.

Pursuant to 40 CFR 125.62(a)(1)(iv), EPA's evaluation of compliance with WQS must be based upon conditions reflecting periods of maximum stratification and during other periods when discharge characteristics, water quality, biological seasons, or oceanographic conditions indicate more critical situations may exist, commonly referred to as critical conditions.

1. pH

Alaska's WQS provide that pH may not be less than 6.5 s.u. or greater than 8.5 s.u. and may not vary more than 0.2 s.u. outside of the naturally occurring range.

The effect of pH on the receiving water following initial dilution was estimated using Table 1. *Estimated pH Values After Initial Dilution* in the 301(h) TSD and a reasonable potential spreadsheet.

EPA reviewed discharge monitoring report (DMR) data for pH between 2016 and 2021. The facility met the pH limits in the 2001 permit 100% of the time. The maximum and minimum pH values observed were 7.9 s.u. and 6.4 s.u., respectively. EPA used the dilution factor and measured alkalinity, temperature, and pH data to calculate the minimum and maximum pH at the edge of the ZID and found that pH would be between 7.4 s.u. and 7.9 s.u. This is within the range of 6.5 s.u. to 8.5 s.u. and meets Alaska WQS for pH.

The proposed discharge is expected to comply with Alaska WQS for pH after initial mixing at the edge of the ZID.

2. Temperature

Alaska's WQS for water temperature provide that the discharge may not cause the temperatures of the receiving water to exceed 15°C for marine uses and the discharge may not cause the weekly average temperature to increase more than 1°C. The maximum rate of change may not exceed 0.5°C per hour. Normal daily temperature cycles may not be altered in amplitude or frequency.

EPA reviewed surface water and DMR data between 2016 and 2021 to assess whether the modified discharge will comply with Alaska WQS for temperature. The maximum ocean temperature recorded in Sitka Sound during receiving water monitoring in 2018 and 2020 was 12°C, and the maximum recorded effluent temperature between 2016 and 2021 was 15°C. The maximum temperatures in the CBS WWTP's discharge and Sitka Sound are both below Alaska WQS for temperature. Therefore, the proposed discharge is expected to comply with Alaska WQS for temperature after initial mixing at the edge of the ZID.

3. Toxics

Alaska WQS for toxics for marine uses can be found in 18 AAC 70.020(b)(23) and the *Alaska Water Quality Criteria Manual for Toxics* (ADEC, 2008).

To assess whether the proposed discharge will comply with Alaska WQS for toxics after initial mixing EPA reviewed DMR data collected between 2016 and 2021 and the results of three priority pollutant scans performed on the effluent in 2002, 2005, 2007, 2010, 2012, 2015, and 2017.

Several metals were reported above their respective detection limits. Using this data along with DMR data for ammonia, EPA performed reasonable potential analyses using the numeric criteria in the *Alaska Water Quality Criteria Manual* (ADEC 2008) and the processes outlined in the *Technical Support Document for Water Quality-based Toxics Control* (USEPA 1991).

Ammonia, chlorine, and copper have reasonable potential to cause or contribute to a violation of Alaska WQS after mixing. WQBELs have been developed and included in the final permit for ammonia, chlorine, and copper.

The effluent limits developed for ammonia, chlorine, and copper are protective of Alaska WQS, and the proposed discharge is expected to comply with AK WQS for toxics after initial mixing at the edge of the ZID.

4. Bacteria

Alaska's WQS for bacteria are found at 18 AAC 17.020(b)(14).

I. Fecal Coliform (FC)

Alaska's most restrictive marine criterion for FC bacteria concentrations is in areas protected for the harvesting and use of raw mollusks and other aquatic life. The WQS specifies that the geometric mean of samples shall not exceed 14 MPN/100 mL, and that not more than 10 percent of the samples shall exceed:

- 43 MPN/100 mL for a five-tube decimal dilution test;
- 49 MPN/100 mL for a three-tube decimal dilution test;
- 28 MPN/100 mL for a twelve-tube single dilution test;
- 31 CFU/100 mL for a membrane filtration test.

This standard must be met at the edge of the ZID.

On June 26, 2001, ADEC provided final 401 certification that included a mixing zone defined as an arc of a circle with a 1,600 meter radius, centered on the outfall going from one shoreline to the other extending on either side of the outfall line, and extending from the marine bottom to the surface. In the 2001 permit, the number of FC bacteria in the primary treated effluent was not to exceed a 30-day average of 1.0 million FC per 100 mL and a daily limit of 1.5 million FC per 100 mL of sample. Outside this mixing zone the FC concentrations were not to exceed a maximum of 14 FC/100 mL for a monthly average and 43 FC/100 mL for a daily maximum. Facility DMR data from the past 5 years shows FC values ranges from 9,800—998,000 FC/100mL, with a 95th percentile of 856,000 FC/100mL. Summary statistics of DMR data are provided in Table 4 below.

Table 4. FC DMR Summary Data 2016-2021

	# of samples	Min	Max	95th Percentile	Average
Fecal Coliform (FC/100mL)	**59**	**9,800**	**998,000**	**856,000**	**397,000**

CWA Section 301(h)(9) requires 301(h) discharges to meet WQS and federal 304(a) criteria at the edge of the ZID. The current 1,600 meter mixing zone for FC is inconsistent with the statutory or regulatory definition of a ZID: the region of initial mixing surrounding or adjacent to the outfall. ADEC will not reauthorize the 1,600 meter mixing zone for fecal coliform and the point of compliance for all bacteria limits is now the edge of the ZID.

Consistent with Section 301(h)(9) of the CWA and 40 CFR 125.62, EPA used the 76:1 dilution achieved at the edge of the chronic mixing zone within the ZID boundary, to evaluate reasonable potential and assess compliance with CWA Section 301(h)(9) and 40 CFR 125.62.

Using effluent data from 2016 – 2021 and the same process and equations as those used for toxics, EPA conducted a reasonable potential analysis and determined fecal coliform has the reasonable potential to cause or contribute to a violation of Alaska WQS at the point of discharge.

The Alaska DEC included final fecal coliform limitations as a condition of their certification of the permit under CWA Section 401 that come into effect five years after the effective date of the permit. The EPA has incorporated these final limits into the final permit and has established interim fecal coliform limits based upon facility performance.

The interim and final effluent limits for fecal coliform will be protective of Alaska WQS after mixing at the edge of the ZID and will satisfy the requirements of CWA Section 301(h)(9) and 40 CFR 125.63(a).

II. Enterococcus Bacteria

Enterococci bacteria are indicator organisms of harmful pathogens recommended by EPA to protect primary contact recreation for marine waters. The EPA Beaches Environmental Assessment and Coastal Health Act (BEACH Act) requires states and territories with coastal recreation waters to adopt enterococci bacteria criteria into their WQS. EPA approved Alaska's WQS for enterococcus in 2017. The WQS at 18 AAC 70.020(b)(14)(B) for contact recreation specifies that the enterococci bacteria concentration shall not exceed 35 enterococci CFU/100mL, and not more than an 10% of the samples may exceed a concentration of 130 enterococci CFU/100mL.

The 2001 permit does not contain an effluent limitation for enterococcus bacteria because there was no applicable enterococcus WQS in effect when the permit was issued.

40 CFR 122.44(d)(1) requires EPA to account for existing controls on discharges when determining whether a discharge has the reasonable potential to cause or contribute to an excursion of state WQS. The 2001 permit did not require enterococcus monitoring, but it reasons that the high FC loads observed are also indicative of high loads of other pathogens commonly found in WWTP effluents, including enterococcus. With the available FC data and lack of disinfection capacity at the facility, EPA has determined there is reasonable potential for the discharge to cause or contribute to a violation of Alaska WQS for enterococcus. With the available FC data and lack of disinfection capacity at the facility, EPA has determined there is reasonable potential for the discharge to cause or contribute to a violation of Alaska WQS for enterococcus.

The Alaska DEC included final enterococcus limitations as a condition of their certification of the permit under CWA Section 401 that come into effect five years after the effective date of the permit. The EPA has incorporated these final limits into the final permit.

The final effluent limits for enterococcus will be protective of Alaska WQS after mixing at the edge of the ZID and will satisfy the requirements of CWA Section 301(h)(9) and 40 CFR 125.63(a).

D. Impact of the Discharge on Public Water Supplies [40 CFR 125.62(b)]

40 CFR 125.62(b) requires that the applicant's 301(h) proposed discharge must allow for the attainment or maintenance of water quality that assures protection of public water supplies and must not interfere with the use of planned or existing public water supplies. Based on the 2006 Questionnaire submitted by the applicant, there are no existing or planned public water supply intakes in the vicinity of the discharge. Therefore, EPA concludes that the applicant's proposed discharge will have no effect on the protection of public water supplies and will not interfere with the use of planned or existing public water supplies.

E. Biological Impact of Discharge [40 CFR 125.62(c)]

40 CFR 125.62(c) requires that in addition to complying with applicable WQS, the proposed discharge must allow for the attainment or maintenance of water quality that assures the protection and propagation of a BIP of shellfish, fish, and wildlife. A BIP of shellfish, fish, and wildlife must exist immediately beyond the ZID and in all other areas beyond the ZID where marine life is actually or potentially affected by the applicant's discharge. In addition, conditions within or beyond the ZID must not cause or contribute to adverse biological impacts, including, but not limited to, the destruction of distinctive habitats of limited distribution, the presence of disease epicenter, or the simulation of phytoplankton blooms which have adverse effects beyond the ZID, interfere with estuarine migratory pathways within the ZID, or result in the accumulation of toxic pollutants or pesticides at levels which exert adverse effects on the biota within the ZID.

According to the applicant the discharge will not cause adverse impacts to habitats of limited distribution or commercial or recreational fisheries. There have been no known cases of mass mortalities of fish or invertebrates, no increased incidence of disease in marine organisms, and no other known cases of adverse biological impacts. The application materials indicate the discharge does not cause or contribute to significant biological impacts. The discharge is relatively small in volume and is composed of domestic wastewater and leachate from the Kimsham Street Landfill with limited quantities of toxics. Toxic conditions are not expected since the effluent achieves rapid mixing within minutes of discharge, minimizing the potential exposure area.

The 2001 permit required the facility to conduct biological monitoring, which consisted of a benthic survey and sediment analysis for total volatile solids (TVS) at the western and eastern ZID boundaries and at two reference locations. From 1987 to 2018, there were 11 surveys conducted at three locations: at the northwest ZID boundary, 150 feet northwest of the ZID boundary, and a northwest reference station. There was no evidence in these surveys of rippling or settleable solids deposition, or impacts to the benthic community. Video taken of the physical environment at each sampling station showed considerable physical and ecological diversity (CBS 2008; 2018). Based on these studies, it does not appear that excess organic sediment is accumulating around the outfall as compared to stations at the ZID boundary and reference sites. Based on visual observations of the benthic infauna collected in sediment samples, it does not appear that the CBS WWTP's discharge is causing significant changes in the benthic community structure.

The Biological Monitoring Program from the 2002 permit is being largely retained in the final permit with the exception of the TVS component, which has been removed from the permit. For additional information refer to Part 8.G.3.

F. Impact of Discharge on Recreational Activities [40 CFR 125.62(d)]

Under 40 CFR 125.62(d), the applicant's discharge must allow for the attainment or maintenance of water quality that allows for recreational activities beyond the zone of initial dilution, including, without limitation, swimming, diving, boating, fishing, and picnicking, and sports activities along shorelines and beaches. There must be no Federal, State, or local restrictions on recreational activities within the vicinity of the applicant's outfall unless such restrictions are routinely imposed around sewage outfalls.

In its 2006 Questionnaire, the applicant stated that no impacts on recreational activities were expected due to the proposed discharge. Sport fishing, boating, swimming, diving, picnicking and various other beach activities and beach combing activities occur on a small scale but are not common in Sitka Sound due to the cold water temperatures, prevailing winds, climate, and steep glacial terrain. In its 2006 Questionnaire, the applicant indicated that there are no significant commercial or recreational fisheries in the discharge vicinity. No adverse effects linked to the CBS WWTP's discharge have been reported.

The 2001 permit required signs to be placed on the shoreline near the 1,600-meter fecal coliform mixing zone and the outfall line that state primary treated domestic wastewater is being discharged, and certain activities such as the harvesting of shellfish for raw consumption and bathing should not take place within the mixing zone. EPA has retained the requirement to place these signs on the shoreline in the final permit until the final fecal coliform and enterococcus limits are maintained.

The applicant has demonstrated that the proposed discharge meets the requirements to allow for the attainment or maintenance of water quality which allows for recreational activities beyond the ZID.

G. Establishment of Monitoring Programs [CWA 301(h)(3); 40 CFR 125.63]

Under 40 CFR 125.63, which implements Section 301(h)(3) of the Act, the applicant must have a monitoring program designed to provide data to evaluate the impact of the proposed discharge on the marine biota, demonstrate compliance with applicable WQS, and measure toxic substances in the discharge. The applicant must demonstrate the capability to implement these programs upon issuance of a 301(h)-modified NPDES permit. In accordance with 40 CFR 125.63(a)(2), the applicant's monitoring programs are subject to revision as may be required by EPA.

1. Influent/Effluent Monitoring Program [40 CFR 125.63(d)]

40 CFR 125.63(d) requires an effluent monitoring program; the applicant proposes continuation of the current monitoring program. In addition to the 301(h) specific monitoring requirements, Section 308 of the CWA and 40 CFR 122.44(i) require monitoring in permits to determine compliance with effluent limitations. Monitoring may also be required to gather effluent and surface water data to determine if additional effluent limitations are required and/or to monitor effluent impacts on receiving water quality. Throughout the previous permit term (and the administratively continued period), the applicant submitted effluent monitoring data as required by the 2001 permit.

Parameters for which effluent monitoring were required in the 2001 permit include:

- Flow[1]
- BOD_5 [1]
- TSS[1]
- Fecal Coliform
- Ammonia
- pH
- Temperature
- Dissolved oxygen
- Total Residual Chlorine
- Copper
- Chronic Whole Effluent Toxicity
- Toxic Pollutants and Pesticides

[1] Influent monitoring also required

Summary statistics of the effluent data submitted by the permittee between 2016 and 2021 are presented in Appendix C.

The final permit retains largely the same effluent and influent monitoring requirements and includes the new requirement to monitor the effluent for enterococcus and increases fecal coliform monitoring from 1/month to 1/week. Consistent with 40 CFR 125.66, the final permit also includes a new requirement for the permittee to perform whole effluent toxicity (WET) analysis of their effluent quarterly during the first two years of the permit. If WET tests indicate compliance with Alaska water quality standards, then WET testing is reduced to annual monitoring, as described in Permit Part I.C. In addition, monitoring for PFAS has also been included in the final permit.

2. Receiving Water Quality Monitoring Program [40 CFR 125.63(c)]

40 CFR 125.63(c) requires that the receiving water quality monitoring program must provide data adequate to evaluate compliance with applicable WQS. The applicant proposes continuation of the current receiving water monitoring program. As is the case of effluent monitoring, NPDES permits include receiving water monitoring requirements to allow for compliance assessment, and to determine if additional effluent limitations and/or monitoring requirements are necessary in future permitting actions.

EPA is retaining most of the receiving water monitoring program from the 2001 permit in the new final permit. Changes to the receiving water monitoring program include the addition of enterococcus and turbidity to the suite of parameters analyzed and the removal of fecal coliform sampling at the edge of the 1,600 meter mixing zone (Stations 5, 6, and 7). Sampling at the edge of the 1,600 meter mixing zone is no longer required because the 1,600 meter mixing zone is not being reauthorized by ADEC and the compliance for all parameters must be met at the edge of the ZID, which is a rectangle 387 feet (118 meters) in length and 191 feet (58.2 meters) wide, centered on the diffuser of the outfall.

In addition, the EPA has determined that once the facility is able to consistently achieve compliance with the final fecal coliform and enterococcus limits in the permit and has demonstrated ongoing compliance with Alaska WQS at the boundary of the ZID, continued sampling for bacteria in the receiving water is no longer warranted to satisfy the requirements of 40 CFR 125.62(a). By achieving compliance with the final fecal coliform and enterococcus limits the EPA expects that the facility will be able to meet Alaska's WQS for fecal coliform and enterococcus at the edge of the ZID after initial mixing. For additional information refer to the final permit.

3. Biological Monitoring Program [40 CFR 125.63(b)]

40 CFR 125.63(b) requires a permittee to implement a biological monitoring program that provides data adequate to evaluate the impact of the applicant's discharge on the marine biota. Such a program should, at a minimum, allow for evaluation of any ecosystems impacts; any changes in the amount of organic material in the seafloor sediment; any changes to benthic communities; and the effectiveness/bases for permit conditions.

The Biological Monitoring Program in the 2001 permit consisted of a benthic survey and sediment analysis for TVS at the eastern and western ZID boundaries and at two reference locations.

Based on the results of the TVS analysis of sediment, it does not appear that excess organic sediment is accumulating around the outfall as compared to stations at the ZID boundary and reference sites.

Based on visual observations of the benthic infauna collected in sediment samples, it does not appear that the CBS WWTP discharge is causing significant changes in the benthic community structure.

The Biological Monitoring Program from the 2002 permit is being largely retained in the final permit with the exception of the TVS component, which has been removed from the permit.

The 301(h) regulations at 40 CFR 125.63(b)(2) provide that small 301(h) applicants are not subject to sediment analysis requirements if they discharge at depths greater than 10 meters and can demonstrate through a suspended solids deposition analysis that there will be negligible seabed accumulation in the vicinity of the modified discharge. The Sitka WWTP discharges at depths greater than 10 meters and the suspended solids deposition analysis provided below demonstrates there will be negligible seabed accumulation in the vicinity of the discharge.

Figure B-2 in Appendix B of the 1994 Amended Section 301(h) Technical Support Document provides a simplified graphical method for small estuarine dischargers to assess the potential for suspended solids deposition around their outfall using the reported daily solids mass emission rate (y-axis in Fig. B-2) and the height-of-rise of the discharge (x-axis in Fig. B-2). For the discharge height-of-rise, also known as the plume trapping depth, the height-of-rise from dilution modeling should be used, or 0.6 times the water depth, whichever is larger. With a discharge depth of ~26 meters (~85 feet) and a trapping depth of ~10 meters (~32 feet), the height-of-rise of the Sitka discharge is approximately 15 meters (~50 feet); 15.6 meters (~51 feet) was selected for the x-axis in Figure B-2 (0.6 x 26m=15.6m).

The guidance recommends calculating the suspended solids daily mass emission rate using the average flow rate and an average suspended solids concentration. The reported monthly average flow rate from the Sitka WWTP between 2016 and 2021 was approximately 1.6 million gallons per day and the monthly average TSS concentration was 35.4 mg/L. To determine the daily loading of solids the monthly average concentration of TSS was multiplied by the reported average monthly flow and the loading conversion factor of 8.34 (see Footnote 1 in Table 1 of the final permit for more information on mass loading calculations).

35.4 mg/L X 1.6 million gallons per day X 8.34 = 472.4 lbs/day (~214kg/day).

Using this loading rate along the y-axis and 15.6 meters along the x-axis in Figure B-2, the projected steady state sediment accumulation is expected to be well below 25g/m2. The EPA considers this to be a negligible accumulation of sediment.

Therefore, the applicant has satisfied the requirement of 40 CFR 125.63(b)(2) and the requirement to conduct sediment TVS analysis has been removed from the final permit.

H. Effect of Discharge on Other Point and Nonpoint Sources [CWA 301(h)(4); 40 CFR 125.64]

Under 40 CFR 125.64, which implements Section 301(h)(4) of the Act, the applicant's proposed discharge must not result in the imposition of additional treatment requirements on any other point or nonpoint source. Pursuant to 40 CFR 125.64(b), the applicant is required to submit a determination signed by the State of Alaska indicating whether the applicant's discharge will result in an additional treatment pollution control, or other requirement on any other point or nonpoint sources. The State determination must include a discussion of the basis for its conclusion.

ADEC provided the determination required under 125.64 in its final 401 certification. For additional information refer to Part M – State Determination and Concurrence.

I. Urban Area Pretreatment Program [CWA 301(h)(6); 40 CFR 125.65]

Under 40 CFR 125.65, dischargers serving a population greater than 50,000 are required to have a pretreatment program. As previously discussed, the CBS WWTP serves a population of approximately 10,500 people so this provision is not applicable to this analysis; however, since there is an industrial discharge to the WWTP, EPA has included a condition in the permit that requires the facility to develop and implement a pretreatment program (see below for further discussion).

J. Industrial and Nonindustrial Sources and Toxics Control [CWA 301(h)(7); 40 CFR 125.66]

1. Chemical Analysis and Toxic Pollutant Source Identification [40 CFR 125.66(a) and (b)]

Under 40 CFR 125.66(a) and (b), applicants are required to perform chemical testing for toxic pollutants and pesticides and identify the source of any parameters detected.

The 2001 permit required an industrial user survey and toxic chemical analyses of the effluent be submitted with the permit reapplication. As previously discussed, the permittee conducted three toxics pollutant scans, the results of which EPA used in development of the final permit.

2. Industrial Pretreatment Program [40 CFR 125.66(c)]

40 CFR 125.66(c) requires that applicants that have known or suspected industrial sources of toxic pollutants shall have an approved pretreatment program in accordance with the requirements of 40 CFR Part 403 (Pretreatment Regulations).

The facility has one industrial user, the Kimsham Street Landfill. The CBS WWTP receives the landfill leachate via a lift station and force main that connect to the sewer collection system. The CBS WWTP monitors the leachate for metals and other toxics in accordance with a permit issued by the State of Alaska. The Kimsham Street Landfill meets the definition of an industrial source under 40 CFR 125.58(j). Therefore, the permit requires CBS to develop a pretreatment program in accordance with 40 CFR Part 403. Further details of the pretreatment program are discussed in the Fact Sheet and final permit. After CBS develops and EPA approves the pretreatment program, EPA will modify the permit to incorporate the pretreatment program.

3. Nonindustrial Source Control Program [40 CFR 125.66(d)]

40 CFR 125.66(d), which implements Section 301(h)(6) of the Act, requires the applicant to submit a proposed public education program designed to minimize the introduction of non-industrial toxic pollutants and pesticides into the POTW. The applicant must also develop and implement additional nonindustrial source control programs on the earliest possible schedule. The requirement to develop and implement additional nonindustrial source control programs does not apply to a small Section 301(h) applicant that certifies there are no known or suspected water quality, sediment accumulation, or biological problems related to toxic pollutants or pesticides in its discharge.

In the permit application, CBS indicated that they are implementing the permit conditions that require a public education program to address non-hazardous alternatives to hazardous household products and pesticides, and proper disposal of hazardous wastes. These meet the requirements of 40 CFR 125.66(d)(1). EPA has included the previous permit’s public education and outreach program conditions in the final permit.

K. Effluent Volume and Amount of Pollutants Discharged [40 CFR 125.67]

Under 40 CFR 125.67, which implements Section 301(h)(7) of the Act, the applicant's proposed discharge may not result in any new or substantially increased discharges of the pollutant to which the modification applies above the discharge specified in the 301(h)-modified permit. The applicant has applied on the basis of the current discharge and does not propose any new or substantially increased discharges of TSS or BOD_5, the two parameters for which the facility has requested a waiver.

L. Compliance With Other Applicable Laws [40 CFR 125.59]

Under 40 CFR 125.59(b)(3), a 301(h)-modified permit may not be issued if such issuance would conflict with applicable provisions of state, local, or other federal laws or executive orders. As part of the application renewal, the applicant must demonstrate compliance with all applicable Alaska and federal laws and regulations, and executive orders, including the Coastal Zone Management Act, Marine Protection Research and Sanctuaries Act, and the Endangered Species Act.

1. Coastal Zone Management Act

Alaska withdrew from the voluntary National Coastal Zone Management Program on July 1, 2011 (NOAA 2019c); therefore, this requirement is not applicable.

2. Marine Protection, Research, and Sanctuaries Act

Under 40 CFR 125.59(b)(3), no section 301(h) modified permit shall be issued if such issuance would conflict with Title III of the Marine Protection, Research, and Sanctuaries Act (MPRSA), 16 USC § 1431 *et seq.*, which authorizes the Secretary of Commerce (i.e., NOAA) to designate and protect areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational or esthetic qualities as national marine sanctuaries. In the U.S., there are 14 national marine sanctuaries and two marine national monuments, none of which are in Alaska (NOAA 2019d).

The final permit is therefore expected to comply with Title III of the MPRSA.

3. Endangered Species Act

Under 40 CFR 125.59(b)(3), no section 301(h) modified permit shall be issued if such issuance would conflict with ESA, 16 USC 1531 *et seq.* The ESA requires federal agencies to consult with the National Marine Fisheries Service (NMFS) and/or the U.S. Fish and Wildlife Service (USFWS) (collectively, the Services) if their actions could beneficially or adversely affect any threatened or endangered species (ESA-listed species) or such species designated critical habitat.

Pursuant to ESA Section 7, on August 30, 2024, the EPA requested concurrence from the NMFS that renewal of the 301(h)-modified NPDES permit to the Sitka WWTP is not likely to adversely affect the following threatened, endangered, or candidate species or their designated critical habitats:

- Western Distinct Population Segment (Western DPS or WDPS) Steller sea lions, and
- Mexico DPS humpback whales
- Sunflower sea star

On October 15, 2024, the NMFS concurred with EPA's determination that renewal of AK0021474 is not likely to adversely affect any ESA-listed species or designated critical habits under their jurisdiction.

No ESA-listed species or designated critical habitat under the jurisdiction of USFWS were identified.

4. Magnuson-Stevens Fishery Conservation and Management Act

Under 40 CFR 125.59(b)(3), no section 301(h) modified permit shall be issued if such issuance would conflict with the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), 16 USC 1801 *et seq*., which protects against adverse impacts to Essential Fish Habitat (EFH).The MSFCMA requires federal agencies to consult with the National Marine Fisheries Service (NMFS) when any activity proposed to be permitted, funded, or undertaken by a federal agency may have an adverse effect on designated Essential Fish Habitat (EFH) as defined by the Act. The EFH regulations define an *adverse effect* as any impact which reduces quality and/or quantity of EFH and may include direct (e.g., contamination or physical disruption), indirect (e.g., loss of prey, reduction in species' fecundity), site-specific, or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions.

EPA has prepared an EFH Assessment and determined that renewal of AK0021474 will not have an adverse effect on EFH for any managed species.

M. State Determination and Concurrence [40 CFR 125.61(b)(2); 40 CFR 125.64(b)]

Under 40 CFR 125.61(b)(2) the applicant must provide a determination signed by the state or interstate agency(s) authorized to provide certification under 40 CFR 124.53 and 124.54 that the proposed discharge will comply with applicable provisions of state law, including WQS. This determination must include a discussion of the basis for the conclusion reached. Furthermore, pursuant to 40 CFR 124.53 and 124.54, the state must either grant a certification pursuant to Section 401(a)(1) of the CWA or waive this certification before EPA may issue a 301(h)-modified permit. The applicant did not provide this certification at the time of application.

40 CFR 125.64(b) requires applicants to provide a determination from the state or interstate agency(s) having authority to establish wasteload allocations indicating whether the applicant's discharge will result in an additional treatment pollution control, or other requirement on any other point or nonpoint sources. The state determination shall include a discussion of the basis for its conclusion. The applicant did not submit this determination with their application.

The EPA requested that ADEC provide final 401 certification and the determinations under 40 CFR 125.61(b)(2) and 125.64(b) during the public notice period of the draft permit and tentative 301(h) decision. ADEC provided final 401 certification and the requested determinations on September 7, 2023.

9) REFERENCES

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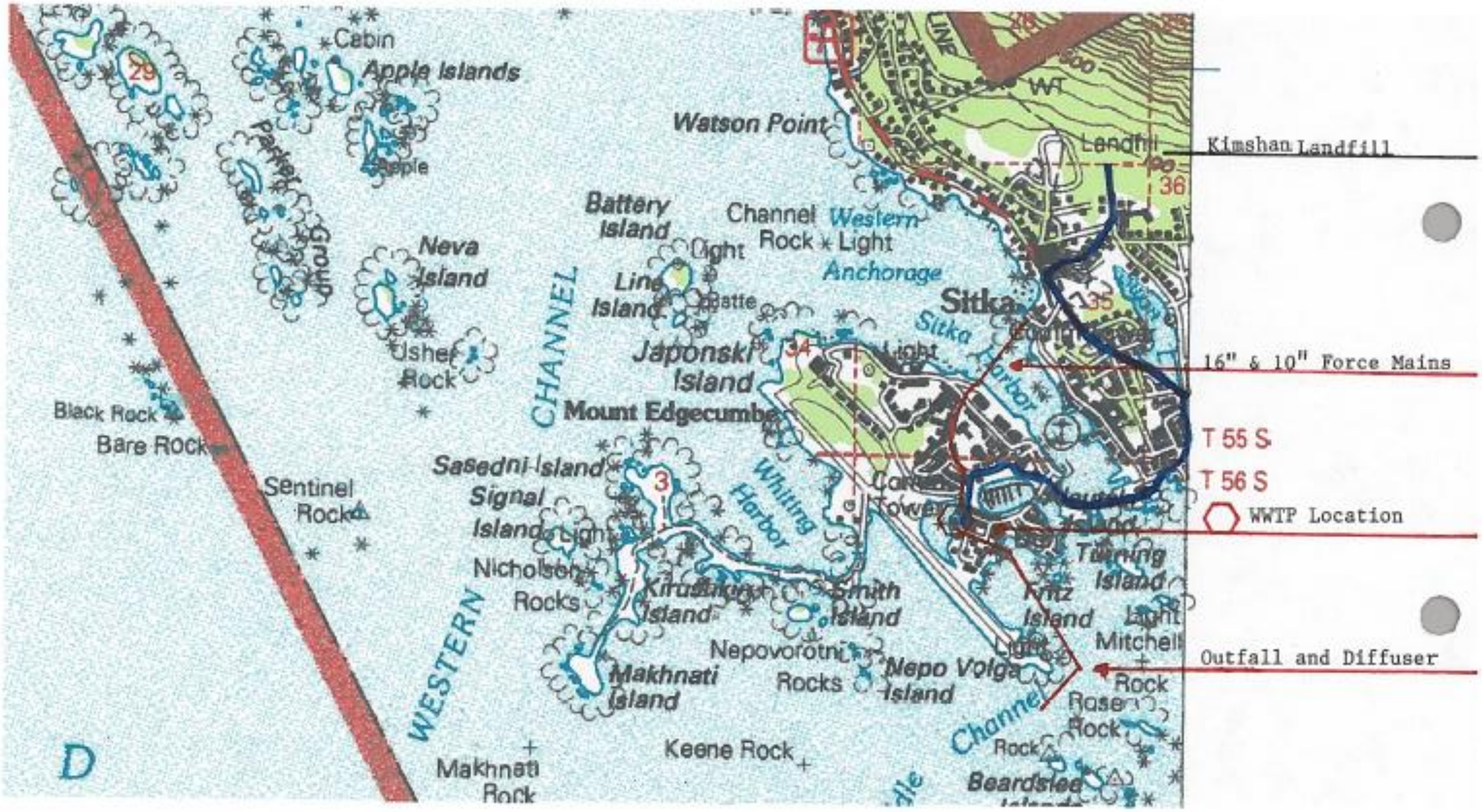
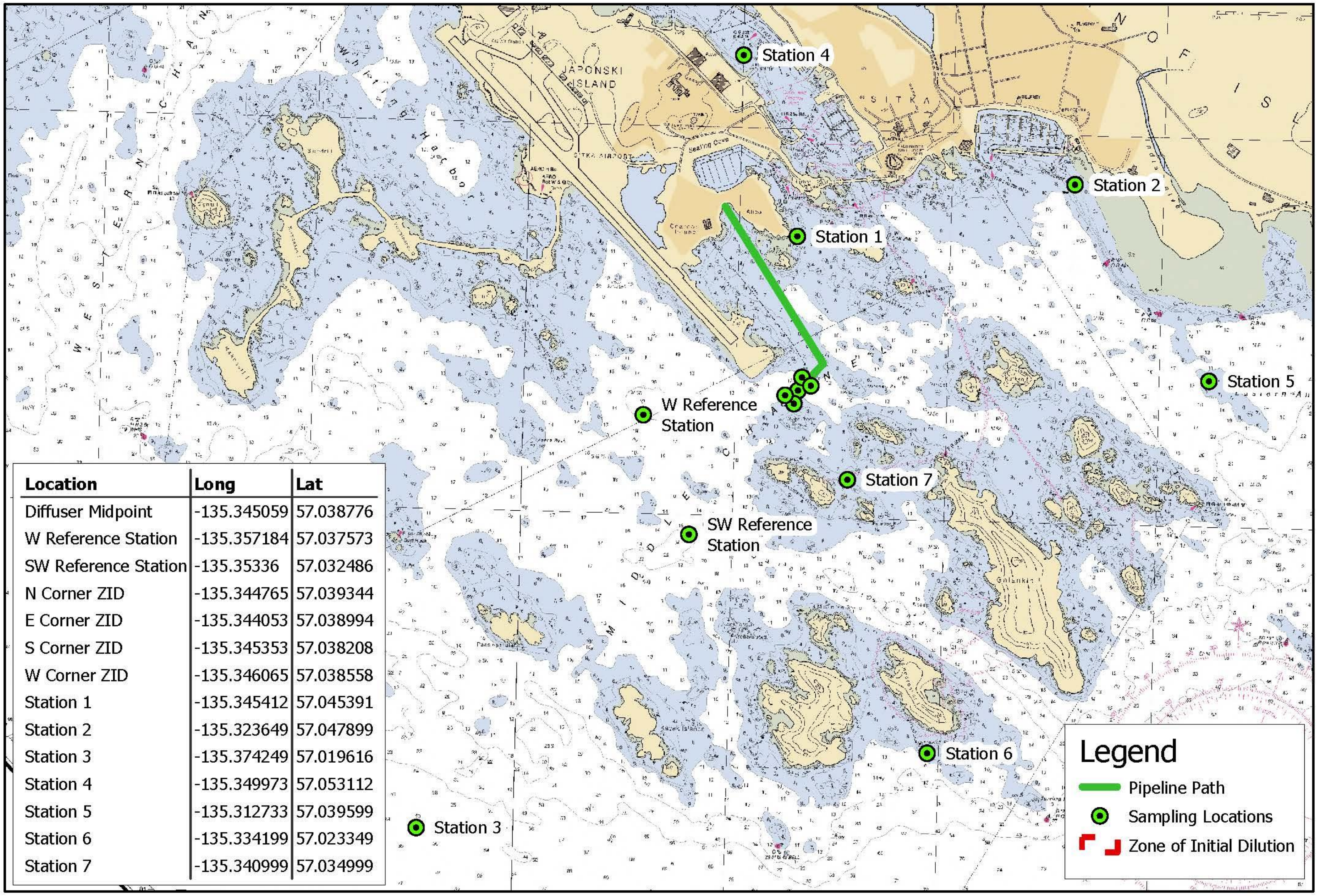
Appendices

A. Facility and Outfall Locations

Attachment A - WWTP, Outfall and Diffuser Location

Sludge Disposal Route

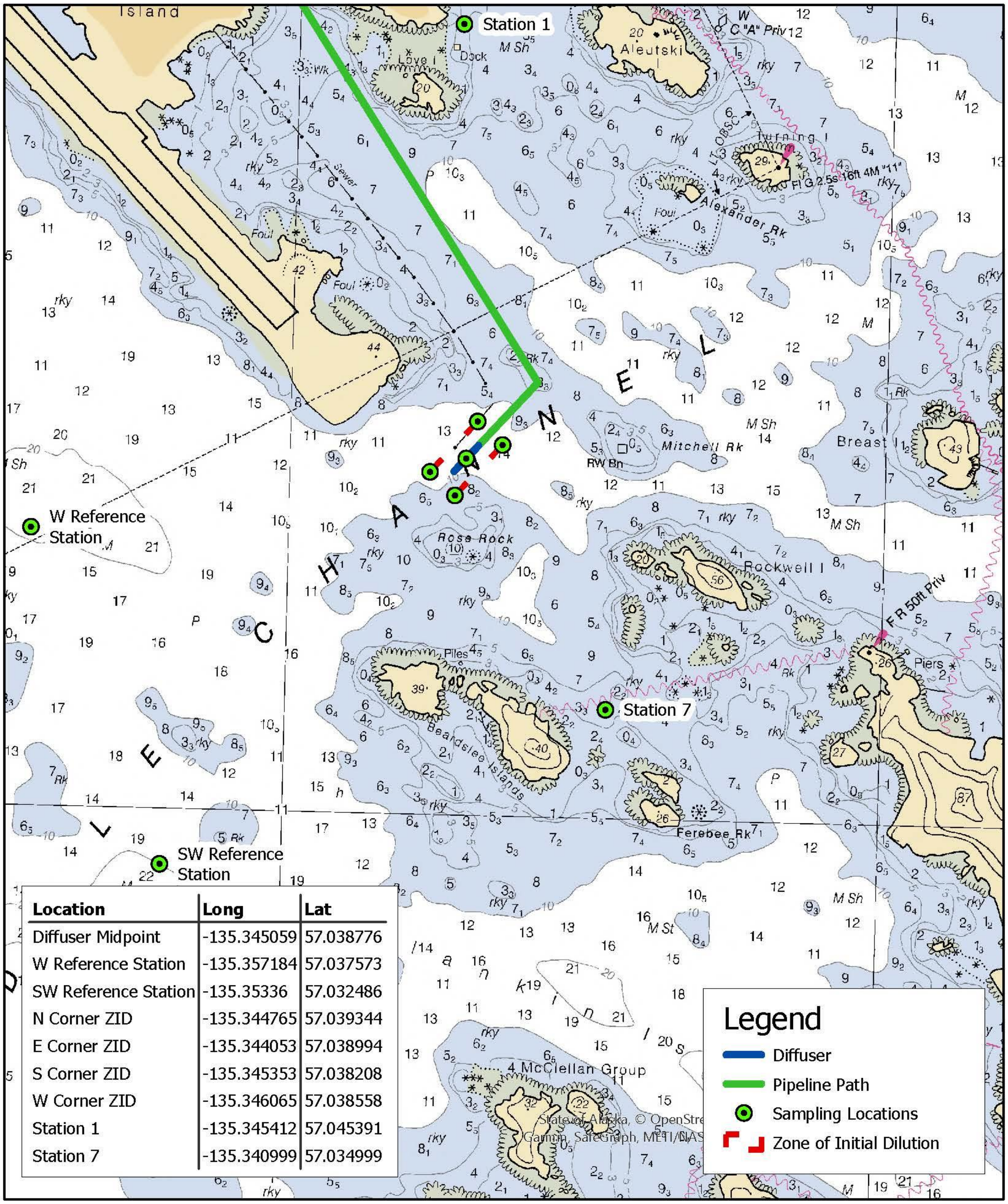




Location	Long	Lat
Diffuser Midpoint	-135.345059	57.038776
W Reference Station	-135.357184	57.037573
SW Reference Station	-135.35336	57.032486
N Corner ZID	-135.344765	57.039344
E Corner ZID	-135.344053	57.038994
S Corner ZID	-135.345353	57.038208
W Corner ZID	-135.346065	57.038558
Station 1	-135.345412	57.045391
Station 2	-135.323649	57.047899
Station 3	-135.374249	57.019616
Station 4	-135.349973	57.053112
Station 5	-135.312733	57.039599
Station 6	-135.334199	57.023349
Station 7	-135.340999	57.034999

Last updated 9/30/2024 to reflect more accurate diffuser midpoint.

Figure 2. Receiving Water Sampling Locations. City of Sitka Wastewater Treatment Plant. NPDES Permit No. AK0021474.



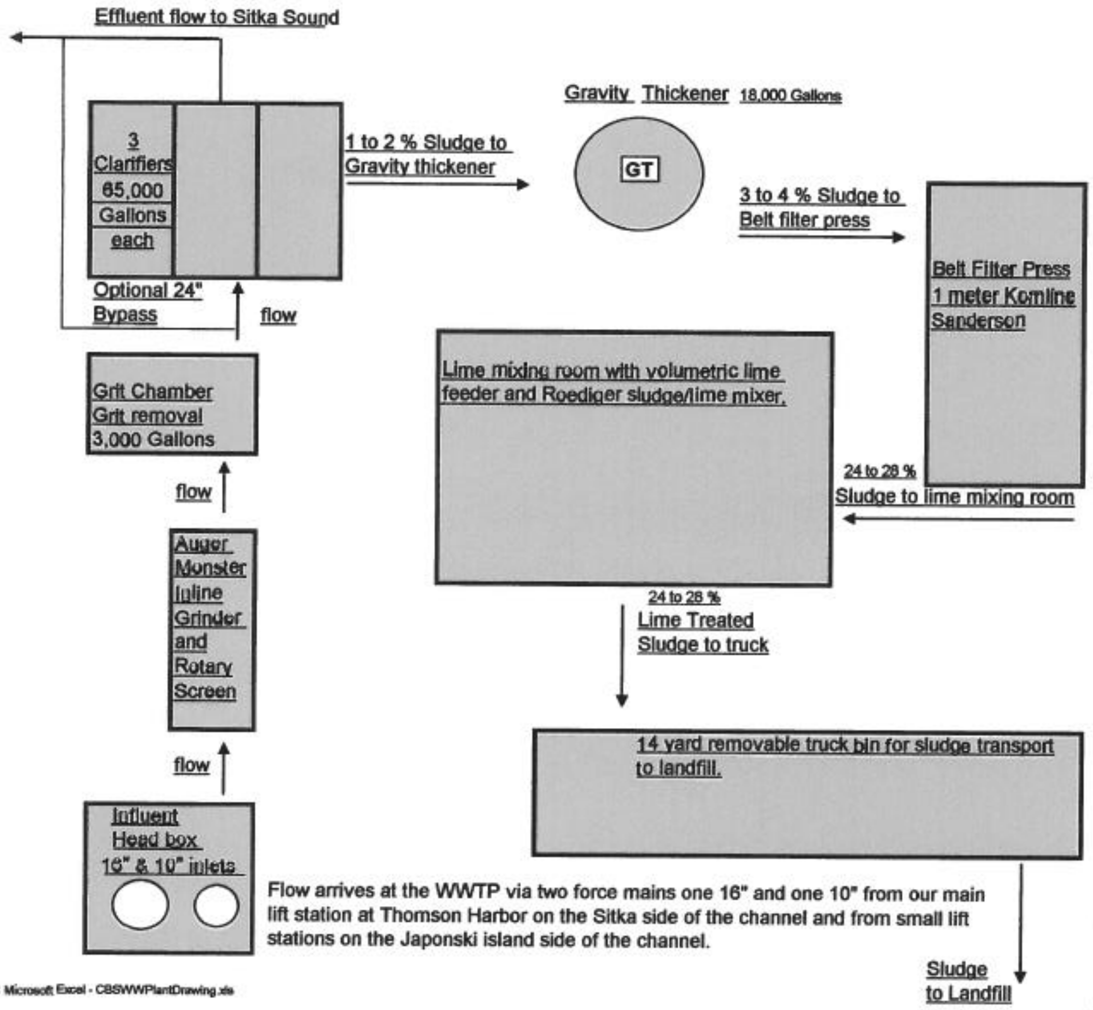
Location	Long	Lat
Diffuser Midpoint	-135.345059	57.038776
W Reference Station	-135.357184	57.037573
SW Reference Station	-135.35336	57.032486
N Corner ZID	-135.344765	57.039344
E Corner ZID	-135.344053	57.038994
S Corner ZID	-135.345353	57.038208
W Corner ZID	-135.346065	57.038558
Station 1	-135.345412	57.045391
Station 7	-135.340999	57.034999

Last updated 9/30/2024 to reflect more accurate diffuser midpoint.

Figure 1. Receiving Water Sampling Locations. City of Sitka Wastewater Treatment Plant. NPDES Permit No. AK0021474.

B. Facility Figures and Process Flow Diagram

Line drawing for flow and sludge processing at CBS 1.8 MGD primary WWTP. With a description of processes for sludge collection, dewatering, storage, treatment and destination. Also included is a summary of methods used for pathogen reduction and vector control.



Flow arrives at the WWTP via two force mains one 16" and one 10" from our main lift station at Thomson Harbor on the Sitka side of the channel and from small lift stations on the Japonski island side of the channel.

File: Microsoft Excel - CBSWWPlantDrawing.xls

Flow arrives at the WWTP in a head box. Then flows to a common header, to a Auger Monster inline grinder and rotory drum screen for removal of larger material. The flow continues to the Grit Chamber where more dense material such as sand and rocks are removed. The grit is dewatered and is pumped into a small container (~250 gallons) for disposal in the 14 yard sludge bin. The flow continues to the clarifiers where sludge settles . The flow then exits the clarifies/plant via 24" glass lined DIP for discharge to the ocean through the diffusor. Sludge from the clarifiers is pumped to the Gravity Thickener at ~ 1 to 2 % solids. Sludge is then pumped twice per/wk to the Belt Filter Press with a consistancy of ~ 3 to 4 % solids. The resulting 24 to 28% sludge cake from the belt fiter press then travels via screw conveyor to the lime mixing room. Lime is added volumetrically and mixed with a Rodiger mixer. The final product with a pH > 12 then travels via screw conveyor to the 14 yard bin on the delivery truck for transport to the landfill.

Pathogen reduction and vector control is achived by the addition of lime. We confirm that the pH is maintained at 12 or higher with bench testing every hour during the press run. pH analysis indicates our product remains at a pH of 12 or higher for at least 22 hours. At the landfill the lime treated sludge is typically buried within 20 minutes of arrival, although our current permit stipulates burial within 4 hours.

C. Summary Statistics of Discharge Monitoring Data (2016-2021)

The water quality data are from discharge monitoring reports (DMRs) from 2016 to 2021.

CBS WWTP DMR Data (2016-2021)

Parameter	Flow, in conduit or thru treatment plant	BOD, 5-day, 20 deg. C	BOD, 5-day, 20 deg. C	BOD, 5-day, 20 deg. C	BOD, 5-day, 20 deg. C	BOD, 5-day, 20 deg. C	BOD, 5-day, 20 deg. C	Solids, total suspended	Solids, total suspended	Solids, total suspended	Solids, total suspended	Solids, total suspended	Solids, total suspended	Nitrogen, ammonia total [as N]	pH	pH	Fecal Coliform	Fecal Coliform	Temperature	Copper, Total Recoverable	Copper, Total Recoverable	Dissolved Oxygen	Chlorine, Total
Monitoring Location	Effluent Gross	Influent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Percent Removal	Influent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Percent Removal	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross
Statistical Base	MO AVE	MO AVG	MO AVG	MO AVG	DAILY MAX	DAILY MAX	MIN % RMV	MO AVG	MO AVG	MO AVG	DAILY MAX	DAILY MAX	MIN % RMV	Monthly 24 HR Composite	INST MAX	INST MIN	INST MAX	MO GEO MN	MX DA AV	MO AVG	DAILY MAX	Minimum Daily Limit	DAILY MAX
Limit Units	MGD	mg/L	mg/L	lb/d	mg/L	lb/d	%	mg/L	mg/L	lb/d	mg/L	lb/d	%	mg/L	SU	SU	#/100mL	#/100mL	C	mcg/L	mcg/L	mg/L	mg/L
Current Limit	Report	Report	140	2100	200	3000	30	Report	140	2100	200	3000	30	Report	Report	Report	1,500,000	1,000,000	Report	243	354	2	0.244
Proposed Limit	Report	Report	140	2100	200	3000	30						Performance Based		8.5	6.5				23	50		
11/30/2016	1.6	144	72	662	82	1041	47	128	38	354	49	580	68	15	7.2	6.8	151201	151201	11	48	48	4	
12/31/2016	1.9	146	75	702	82	759	45	147	35	329	43	402	74	13	7.3	6.9	247385	247385	9	44	44	9	
01/31/2017	2.2	144	74	571	91	643	48	119	31	241	46	303	74	16	7.3	6.9	268823	268823	8	47	47	7	
02/28/2017	2.7	118	67	476	92	575	44	104	34	243	45	304	67	18	7.3	6.8	705744	705744	8	34	34	9	
03/31/2017	1.5	124	72	518	86	554	39	107	40	290	49	349	61	23	7.3	7	898517	898517	7	42	42	6	
04/30/2017	1.5	198	104	604	129	654	44	183	47	273	63	315	71	14	7.4	7	252749	252749	8	47	47	7	
05/31/2017	1.5	271	111	629	130	694	57	254	38	218	46	246	84	21	7.1	7	445965	445965	10	44	44	7	
06/30/2017	1	206	132	720	143	763	36	189	47	258	51	276	74	22	7.2	6.8	276168	276168	12	56	56	6	
07/31/2017	0.8	195	110	670	126	778	42	163	60	362	68	425	63	18	7.1	6.9	233923	233923	13	62	62	8	
08/31/2017	1.8	162	104	764	138	902	35	146	50	377	65	451	65	29	7.1	6.7	287259	287259	14	73	73	6	
09/30/2017	2.9	109	57	744	71	1466	48	118	48	665	55	1344	56	13	7.3	6.7	44777	44777	14	108	108	8	
10/31/2017	2.3	110	72	602	92	668	34	121	45	379	63	531	62	13	7.2	6.8	114118	114118	12	96	96	8	
11/30/2017	1	207	113	773	175	1197	44	178	39	269	45	315	75	16	7.3	7	196932	196932	12	57	57	8	
12/31/2017	1.4	125	75	532	89	644	40	95	36	260	43	332	62	14	7.3	6.8	261549	261549	10	45	45	9	
01/31/2018	1.4	125	87	502	109	585	30	110	39	229	51	291	64	12	7.2	6.9	203215	203215	8	32	32	9	
02/28/2018	1.1	216	121	797	205	1145	36	175	40	275	45	368	66	19	7.3	6.7	655226	655226	7	127	127	8	
03/31/2018	1.1	138	82	528	104	651	40	121	40	257	73	457	68	12	7.4	6.7	185341	185341	8	36	36	8	
04/30/2018	1.1	198	114	643	165	881	40	130	46	262	64	342	65	20	7.2	6.5	226790	226790	10	52	52	7	
05/31/2018	1	148	89	585	97	619	39	124	40	265	51	336	68	17	7.4	6.8	449730	373684	11	56	56	8	
06/30/2018	1	209	104	658	118	738	51	161	52	330	61	412	68	21	7.2	7	287775	287775	13	54	54	4	
07/31/2018	1.2	207	134	932	230	1554	37	159	52	364	69	466	67	17	7.3	6.8	143104	143104	14	55	55	4	
08/31/2018	2	134	82	888	108	1495	39	123	45	510	82	1135	64	14	7.1	6.6	9798	9798	15	189	189	6	
09/30/2018	1.4	171	90	609	105	640	47	141	31	212	39	263	78	22	7.3	6.9	112558	112558	14	58	58	5	
10/31/2018	1.6	136	73	598	122	702	47	111	31	272	36	432	72	12	7	6.6	98368	98368	12	29	29	8	
11/30/2018	1.8	109	67	561	77	604	38	101	30	250	39	270	69	12	7.3	6.5	377056	377056	11	34	34	6	
12/31/2018	1.5	118	71	558	82	605	39	95	29	225	40	275	69	18	7.1	6.6	594198	594198	9.7	46	46	8	

CBS WWTP DMR Data 2016 -2021 (continued)

Parameter	Flow, in conduit or thru treatment plant	BOD, 5-day, 20 deg. C	BOD, 5-day, 20 deg. C	BOD, 5-day, 20 deg. C	BOD, 5-day, 20 deg. C	BOD, 5-day, 20 deg. C	BOD, 5-day, 20 deg. C	Solids, total suspended	Solids, total suspended	Solids, total suspended	Solids, total suspended	Solids, total suspended	Solids, total suspended	Nitrogen, ammonia total [as N]	pH	pH	Fecal Coliform	Fecal Coliform	Temperature	Copper, Total Recoverable	Copper, Total Recoverable	Dissolved Oxygen	Chlorine, Total
Monitoring Location	Effluent Gross	Influent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Percent Removal	Influent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Percent Removal	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross
Statistical Base	MO AVE	MO AVG	MO AVG	MO AVG	DAILY MAX	DAILY MAX	MIN % RMV	MO AVG	MO AVG	MO AVG	DAILY MAX	DAILY MAX	MIN % RMV	Monthly 24 HR Composite	INST MAX	INST MIN	INST MAX	MO GEO MN	MX DA AV	MO AVG	DAILY MAX	Minimum Daily Limit	DAILY MAX
Limit Units	MGD	mg/L	mg/L	lb/d	mg/L	lb/d	%	mg/L	mg/L	lb/d	mg/L	lb/d	%	mg/L	SU	SU	#/100mL	#/100mL	C	mcg/L	mcg/L	mg/L	mg/L
Current Limit	Report	Report	140	2100	200	3000	30	Report	140	2100	200	3000	30	Report	Report	Report	1,500,000	1,000,000	Report	243	354	2	0.244
Proposed Limit	Report	Report	140	2100	200	3000	30						Performance Based		8.5	6.5				23	50		
01/31/2019	1.7	126	70	509	77	624	44	92	28	204	39	338	68	14	7.2	6.6	689464	689464	9	147	147	5	
02/28/2019	1.2	135	75	464	92	514	44	110	30	186	43	240	73	12	7.4	6.8	151582	151582	7	46	46	7	
03/31/2019	1.1	149	85	448	103	524	42	117	24	129	29	148	78	18	7.3	6.5	406389	406389	8	197	197	9	
04/30/2019	0.9	141	83	487	97	534	41	115	30	180	35	202	73	19	7.3	7.1	624343	624343	9	107	107	7	
05/31/2019	1.2	175	90	540	100	661	48	141	29	175	33	231	79	19	7.5	6.8	764883	486089	11	43	43	7	
06/30/2019	1.2	223	98	576	113	631	55	188	38	224	44	252	80	23	7.3	6.7	751136	561985	12	55	55	5	
07/31/2019	0.8	203	109	592	117	656	46	174	36	197	43	226	79	25	7.2	6.6	2009778	552127	15	57	57	5	
08/31/2019	0.9	209	110	618	116	629	45	162	31	174	34	198	80	22	7	6.7	841461	664110	15	45	45	6	
09/30/2019	2.7	135	72	529	90	595	46	117	25	194	30	305	77	15	7.3	6.6	1099550	161971	14	43	43	7	
10/31/2019	1.7	111	55	481	67	527	49	100	23	207	29	301	75	14	7.5	6.6	794788	794788	13	27	27	7	
11/30/2019	3.1	80	45	479	50	560	43	64	21	226	24	336	65	11	7.4	6.5	446874	405929	11	25	25	10	
12/31/2019	1.5	113	58	515	66	647	48	95	27	229	36	258	72	10	7.4	6.7	585790	585790	10	28	28	7.2	
01/31/2020	1.7	89	54	423	64	466	39	68	24	182	36	231	66	12	7.4	6.4	569615	569615	9	38	38	8.4	
02/29/2020	2.6	78	45	555	52	679	36	56	23	279	37	349	55	7.5	7.4	7.1	851162	851162	7.2	31.4	31.4	11	
03/31/2020	2.6	107	70	536	87	575	34	89	32	241	38	283	64	10	7.5	6.8	1373452	836581	8	38	38	9	
04/30/2020	1.9	112	68	537	79	616	39	97	27	205	38	282	73	8.2	7.6	7.2	19797	19797	8.6	37.4	37.4	7.8	
05/31/2020	0.9	153	96	498	111	578	37	136	41	212	50	284	70	18	7.4	6.8	32761	32761	11	36	36	6	
06/30/2020	0.9	187	98	497	108	549	48	190	50	247	87	399	75	10	7.6	7.3	222253	222253	12	34	34	6.3	
07/31/2020	1.4	149	90	507	110	574	38	122	30	170	38	209	74	16	7.5	7.1	489011	489011	13	30.3	30.3	5.7	
08/31/2020	1.3	179	93	597	103	649	45	151	44	281	69	426	68	16	7.4	6.8	489011	489011	14	31	31	5.3	
09/30/2020	1.4	160	87	683	101	773	46	144	33	259	45	342	77	16	7.3	7.2	998303	998303	13	43	43	7.7	
10/31/2020	3.2	117	68	547	83	613	41	85	22	180	26	280	72	16	7.7	7	388697	388697	11	67	67	6.1	
11/30/2020	2.5	138	68	641	89	809	43	115	25	238	29	336	71	12	7.4	7.1	219856	219856	9	21	21	7.7	
12/31/2020	3	178	75	752	151	1272	48	106	24	263	31	295	73	16	7.1	6.8	340799	340799	9	24	24	7	
01/31/2021	1.8	110	68	666	82	896	31	99	30	300	37	488	63	10	7.7	7.2	168862	168862	9	20	20	5.5	
02/28/2021	2	133	76	640	86	680	43	110	33	275	46	430	70	16	7.5	7	918331	918331	8	23	23	6.8	
03/31/2021	2	98	62	671	75	830	35	91	29	339	40	677	67	9	7.9	7.1	58733	58733	7	19.5	19.5	10.1	
04/30/2021	1.4	142	89	687	106	741	37	105	33	256	53	389	69	13	7.7	7.1	1196248	720188	9	24	24	6.3	
05/31/2021	1.1	191	103	727	112	818	45	132	38	266	43	323	71	19	7.6	7.1	850469	850469	10	50	50	8	
06/30/2021	2	190	98	807	106	1090	46	173	45	380	57	628	74	23	7.6	7.4	570150	570150	12	34	34	5.2	
07/31/2021	0.9	219	116	854	124	920	47	183	37	272	49	372	80	23	7.8	7.4	638719	638719	13	34	34	6	
08/31/2021	1.9	168	92	829	108	857	43	162	33	306	37	382	77	23	7.6	7.3	126810	126810	14	44	44	6.9	
09/30/2021	1.2	138	74	726	81	787	46	124	32	318	46	503	75	18.6	7.7	7	167615	167615	13	36.1	36.1	8	
Average	1.6	152.6	84.6	617.7	104.3	753.1	42.4	129.1	35.4	267.2	46.3	375.6	70.5	16.2	7.4	6.9	467541.7	396856.2	10.8	52.7	52.7	7.1	#DIV/0!
Minimum	0.8	78	45	423	50	466	30	56	21	129	24	148	55	7.5	7	6.4	9798	9798	7	19.5	19.5	4	0
Maximum	3.2	271	134	932	230	1554	57	254	60	665	87	1344	84	29	7.9	7.4	2009778	998303	15	197	197	11	0
Count	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	0
Std Dev	0.6	41.4	20.5	117.5	32.8	245.2	5.5	36.9	8.8	84.8	13.6	194.9	6.1	4.6	0.2	0.2	381908.0	265446.0	2.4	36.4	36.4	1.5	#DIV/0!
CV	0.4	0.3	0.2	0.2	0.3	0.3	0.1	0.3	0.2	0.3	0.3	0.5	0.1	0.3	0.0	0.0	0.8	0.7	0.2	0.7	0.7	0.2	#DIV/0!
95th Percenti	2.9	216.3	116.5	831.5	166.0	1291.4	49.2	188.1	50.2	379.1	69.4	632.9	80.0	23.0	7.7	7.3	1109219.8	855897.5	14.1	129.0	129.0	9.1	#NUM!
5th Percentile	0.9	97.1	54.9	474.8	65.8	526.7	34.0	83.3	23.0	174.9	29.0	208.3	61.9	9.9	7.1	6.5	43575.4	43575.4	7.0	22.8	22.8	4.9	#NUM!
90th percenti	2.6	207.4	111.4	777.8	139.0	1101.0	48.0	179.0	47.2	362.4	65.6	508.6	78.2	23.0	7.6	7.2	902479.8	803146.6	14.0	98.2	98.2	9.0	#NUM!
50th percentile																				44.0	44.0	7.0	#NUM!

Ambient Receiving Water Data, 2018 and 2020. (Source: CBS WWTP Receiving Water Quality Monitoring)

	Ambient pH	Ambient DO	Ambient Temperature	Ambient Salinity	Secchi Disk Depth
	Receiving Water	Receiving Water	Receiving Water	Receiving Water	Receiving Water
	Site C-Summer	Site C-Summer	Site C-Summer	Site C-Summer	Site C-Summer
	SU	mg/L	C	ppt	ft
8/14/2018	8.1	9.5	8.4	31	26
8/12/2020	8.1	12.4	12.2	43.7	18
Average	8.1	11.0	10.3	37.4	22.0
Minimum	8.1	9.5	8.4	31	18
Maximum	8.1	12.4	12.2	43.7	26
Count	2	2	2	2	2
Std Dev	0.0	2.1	2.7	9.0	5.7
CV	0.0	0.2	0.3	0.2	0.3
95th Percentile	8.1	12.3	12.0	43.1	25.6
5th Percentile	8.1	9.6	8.6	31.6	18.4

Ambient Receiving Water Quality Data, 2021. (Source: ARRI, 2022. Water Quality Measures in Alaska's Ports and Shipping Lanes, 2021 Annual Report.)

	Ambient Fecal	Ambient Enterococci	Ambient Ammonia as N	Ambient Copper (Dissolved)	Ambient Nickel (Dissolved)	Ambient Zinc (Dissolved)
	Receiving Water	Receiving Water	Receiving Water	Receiving Water	Receiving Water	Receiving Water
	Geo Mean	Geo Mean				
	CFU/100 mL	mg/L	mg/L	µg/L	µg/L	µg/L
	1.1	3.2	0.031	1.02	0.29	4.88
	1.2	3.6	0.016	0.3	0.27	0.59
	1.1	3.2	0.01	3.98	0.28	3.43
	0.9	3.2	0.011	0.21	0.29	0.48
	1.1	7.2	0.024	0.26	0.27	0.54
	2.1	8.2	0.026	0.39	0.29	1.63
	1.8	6.6	0.007	0.61	0.29	2.69
	0.9	3.2	0.014	0.4	0.28	1.77
	1.4	3.2	0.01	0.28	0.28	0.61
	4.6	3.2	0.008	0.14	0.28	0.25
Average	1.6	4.5	0.0	0.8	0.3	1.7
Minimum	0.9	3.2	0.007	0.14	0.27	0.25
Maximum	4.6	8.2	0.031	3.98	0.29	4.88
Count	10	10	10	10	10	10
Std Dev	1.1	2.0	0.0	1.2	0.0	1.5
CV	0.7	0.4	0.5	1.5	0.0	0.9
95th Percentile	3.5	7.8	0.0	2.6	0.3	4.2
5th Percentile	0.9	3.2	0.0	0.2	0.3	0.4

Weekly CBS WWTP TSS Effluent Data, 2016-2021

Date	Influent		Effluent			Date	Influent		Effluent	
	TSS mg/t	TSS lbs.	TSS mg/t	TSS lbs.			TSS mg/t	TSS lbs.	TSS mg/t	TSS lbs.
						2017-01-04	111	722	24	156
2016-08-03	140	1284	49	450		2017-01-11	144	949	46	303
2016-08-09	87	784	45	405		2017-01-18	121	1080	27	241
2016-08-16	95	856	33	297		2017-01-25	101	952	28	264
2016-08-17	113	961	37	315		2017-02-01	103	679	31	204
2016-08-24	126	1040	45	372		2017-02-08	113	763	45	304
2016-08-25	121	1100	37	336		2017-02-15	76	748	25	246
2016-08-31	116	977	40	337		2017-02-22	125	782	35	219
2016-09-07	101	1146	38	431		2017-03-01	144	913	49	311
2016-09-14	99	1726	23	401		2017-03-08	90	646	34	244
2016-09-20	108	955	31	274		2017-03-15	98	776	33	261
2016-09-28	161	1383	31	266		2017-03-22	120	821	42	287
2016-10-05	153	1136	43	319		2017-03-29	84	666	44	349
2016-10-12	149	1081	40	290		2017-04-05	114	865	29	220
2016-10-19	89	1447	32	520		2017-04-13	143	799	52	291
2016-10-25	134	1475	34	374		2017-04-18	168	841	63	315
2016-11-02	130	932	49	351		2017-04-26	305	1806	45	266
2016-11-08	86	889	27	279		2017-05-02	161	1007	37	231
2016-11-16	94	792	33	278		2017-05-09	198	1172	37	219
2016-11-22	206	1529	38	282		2017-05-17	299	1421	38	181
2016-11-29	125	1647	44	580		2017-05-24	344	2152	34	213
2016-12-06	155	1280	27	223		2017-05-31	268	1430	46	246
2016-12-13	128	1026	39	312		2017-06-07	150	801	45	240
2016-12-21	75	982	29	380		2017-06-14	274	1463	50	267
2016-12-28	231	2158	43	402		2017-06-21	135	777	43	247
						2017-06-27	198	1073	51	276
						2017-07-05	146	865	45	266
						2017-07-12	194	1197	68	420
						2017-07-19	145	859	57	338
						2017-07-26	165	1032	68	425
						2017-08-02	223	1451	65	423
						2017-08-09	150	838	51	285
						2017-08-16	123	903	43	316
						2017-08-22	113	1159	40	410
						2017-08-30	121	1050	52	451
						2017-09-06	73	1065	41	598
						2017-09-13	126	999	45	357
						2017-09-20	165	1197	50	363
						2017-09-26	106	2590	55	1344
						2017-10-04	105	1016	34	329
						2017-10-11	109	836	26	199
						2017-10-18	92	829	59	531
						2017-10-25	151	1096	63	457
						2017-10-31	146	1279	43	377
						2017-11-07	285	1997	45	315
						2017-11-15	200	1368	35	239
						2017-11-20	124	817	39	257
						2017-11-29	103	739	37	265
						2017-12-06	103	661	43	276
						2017-12-12	89	868	34	332
						2017-12-19	79	540	29	198
						2017-12-27	109	655	39	234

Weekly CBS WWTP TSS Effluent Data, 2016-2021

(continued)

Date	Influent		Effluent			Date	Influent		Effluent			Date	Influent		Effluent			Date	Influent		Effluent	
	TSS mg/t	TSS lbs.	TSS mg/t	TSS lbs.			TSS mg/t	TSS lbs.	TSS mg/t	TSS lbs.			TSS mg/t	TSS lbs.	TSS mg/t	TSS lbs.			TSS mg/t	TSS lbs.	TSS mg/t	TSS lbs.
2018-01-03	80	647	36	291		2019-01-05	65	564	39	338		2020-02-05	80	861	14	151		2021-01-06	205	1932	33	311
2018-01-10	115	643	34	190		2019-01-09	104	746	29	208		2020-02-12	41	633	21	324		2021-01-13	88	1160	37	488
2018-01-17	118	679	38	219		2019-01-16	103	636	24	148		2020-02-19	65	613	37	349		2021-01-20	47	498	23	244
2018-01-23	113	565	34	170		2019-01-23	108	712	28	184		2020-02-27	38	529	21	292		2021-01-25	47	384	23	188
2018-01-31	123	667	51	276		2019-01-30	80	634	18	143		2020-03-04	64	587	22	202		2021-01-27	107	901	32	270
2018-02-07	168	939	42	235		2019-02-06	87	646	28	208		2020-03-12	94	886	30	283		2021-03-03	63	788	24	300
2018-02-13	83	699	35	295		2019-02-13	145	810	43	240		2020-03-17	85	567	36	240		2021-03-10	130	1084	33	275
2018-02-21	371	2104	36	204		2019-02-20	95	658	22	152		2020-03-23	112	710	38	241		2021-03-17	96	865	25	225
2018-02-28	78	638	45	368		2019-02-27	113	603	27	144		2020-07-01	91	455	35	175		2021-03-24	86	839	22	215
2018-03-07	118	718	38	231		2019-03-06	139	707	29	148		2020-07-08	139	661	38	181		2021-03-31	80	1354	40	677
2018-03-14	103	730	24	170		2019-03-13	104	598	21	121		2020-07-15	128	726	16	91		2021-04-07	108	1000	25	231
2018-03-21	109	718	26	171		2019-03-20	78	462	25	148		2020-07-22	129	871	29	196		2021-04-14	108	874	26	210
2018-03-27	155	970	73	457		2019-03-27	145	665	22	101		2020-07-29	123	780	33	209		2021-04-21	100	684	28	191
2018-05-01	130	1063	39	319		2019-04-03	136	647	31	147		2020-09-02	158	1489	28	264		2021-04-28	105	771	53	389
2018-05-09	134	793	36	213		2019-04-11	105	534	35	178		2020-09-09	110	862	30	235		2021-05-05	104	781	43	323
2018-05-15	101	649	40	257		2019-04-18	123	954	26	202		2020-09-16	159	1074	33	223		2021-05-12	171	1112	40	260
2018-05-23	119	715	33	198		2019-04-23	96	633	29	191		2020-09-23	164	1245	45	342		2021-05-19	143	954	42	280
2018-05-30	135	889	51	336		2019-05-01	140	747	27	144		2020-09-30	131	1038	29	230		2021-05-25	109	845	26	201
2018-06-06	154	912	43	255		2019-05-08	119	983	28	231		2020-10-07	70	531	12	91		2021-06-02	141	1152	39	319
2018-06-14	145	980	61	412		2019-05-15	141	870	28	173		2020-10-14	104	789	22	167		2021-06-09	158	1146	53	385
2018-06-19	164	1067	56	364		2019-05-22	158	909	33	190		2020-10-21	116	813	26	182		2021-06-17	165	1128	40	274
2018-06-26	180	1126	46	288		2019-05-29	145	713	28	138		2020-10-28	50	538	26	280		2021-06-23	224	2466	57	628
2018-07-04	153	957	49	306		2019-06-05	173	923	44	235		2020-11-04	45	522	29	336		2021-06-30	179	1418	37	293
2018-07-11	163	1183	49	356		2019-06-12	200	1101	34	187		2020-11-11	88	881	14	140		2021-07-07	189	1403	36	267
2018-07-18	148	1137	42	323		2019-06-19	200	1485	34	252		2020-11-18	190	1442	28	213		2021-07-14	216	1639	49	372
2018-07-24	175	1211	53	367		2019-06-26	180	1006	40	224		2020-11-23	135	1227	29	264		2021-07-21	175	1343	37	284
2018-07-31	155	1047	69	466		2019-07-02	156	885	34	193		2020-12-02	37	710	14	269		2021-07-28	153	1021	25	167
2018-08-08	159	2201	82	1135		2019-07-10	170	936	35	193		2020-12-09	77	905	25	294		2021-08-04	169	1254	37	275
2018-08-15	108	982	34	309		2019-07-17	189	993	43	226		2020-12-16	93	861	23	213		2021-08-11	185	1527	33	272
2018-08-22	143	1157	36	291		2019-07-24	201	1023	37	188		2020-12-22	125	1188	31	295		2021-08-18	76	1001	29	382
2018-08-29	81	885	28	306		2019-07-31	153	880	32	184		2020-12-29	196	1651	29	244		2021-08-25	219	1900	34	295
2018-09-05	155	1047	39	263		2019-08-07	185	1065	30	173								2021-09-01	154	1361	31	274
2018-09-12	138	863	35	219		2019-08-14	176	954	30	163								2021-09-08	114	1284	38	428
2018-09-18	175	949	26	141		2019-08-21	158	857	30	163								2021-09-15	66	683	7	72.4
2018-09-26	96	945	23	226		2019-08-28	129	753	34	198								2021-09-22	130	1420	46	503
2018-10-02	161	926	36	207		2019-09-04	122	814	24	160								2021-09-29	158	1209	39	312
2018-10-10	108	1297	36	432		2019-09-11	151	756	30	150								2021-10-06	101	901	23	205
2018-10-16	89	1084	28	341		2019-09-18	131	951	22	160								2021-10-13	65	970	20	299
2018-10-24	91	797	18	158		2019-09-25	65	900	22	305								2021-10-20	141	1129	37	296
2018-10-31	108	685	35	222		2019-11-06	68	686	20	202								2021-10-27	108	1234	50	571
2018-11-07	141	917	39	254		2019-11-13	79	817	20	207								2021-11-03	136	1066	36	282
2018-11-14	82	793	24	232		2019-11-21	45	631	24	336								2021-11-10	130	932	38	273
2018-11-20	79	791	27	270		2019-11-26	63	531	19	160								2021-11-17	82	903	38	418
2018-11-28	100	784	31	243		2019-12-04	70	677	23	223								2021-11-23	77	713	32	296
2018-12-06	126	778	40	247		2019-12-11	115	825	36	258												
2018-12-12	71	651	30	275		2019-12-18	118	846	29	208												
2018-12-18	70	601	21	180		2019-12-26	76	963	18	228												
2018-12-26	113	924	24	196																		

D. Alaska WQS

Alaska WQS for Turbidity for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(24) TURBIDITY, FOR MARINE WATER USES	
(A) Water Supply (i) aquaculture	May not exceed 25 nephelometric turbidity units (NTU).
(A) Water Supply (ii) seafood processing	May not interfere with disinfection.
(A) Water Supply (iii) industrial	May not cause detrimental effects on established levels of water supply treatment.
(B) Water Recreation (i) contact recreation	Same as (24)(A)(i).
(B) Water Recreation (ii) secondary recreation	Same as (24)(A)(i).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	May not reduce the depth of the compensation pointfor photosynthetic activity by more than 10%. May not reduce the maximum Secchi disk depth by more than 10%.
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (24)(C).

Alaska WQS for Dissolved Gas for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(15) DISSOLVED GAS, FOR MARINE WATER USES	
(B) Water Supply (i) aquaculture	Surface dissolved oxygen (D.O.) concentration in coastal water may not be less than 6.0 mg/l for a depth of one meter except when natural conditions cause this value to be depressed. D.O. may not be reduced below 4 mg/l at any point beneath the surface. D.O. concentrations in estuaries and tidal tributaries may not be less than 5.0 mg/l except where natural conditions cause this value to be depressed. In no case may D.O. levels exceed 17 mg/l. The concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection.
(A) Water Supply (ii) seafood processing	Not applicable.
(A) Water Supply (iii) industrial	Not applicable.
(C) Water Recreation (i) contact recreation	Same as (15)(A)(i).
(B) Water Recreation (ii) secondary recreation	Same as (15)(A)(i).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (15)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (15)(A)(i).

Alaska WQS for pH for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(18) pH, for marine water uses (variation of pH for waters naturally outside the specified range must be toward the range)	
(A) Water Supply (i) Aquaculture	May not be less than 6.5 or greater than 8.5, and may not vary more than 0.2 pH unit outside of the naturally occurring range.
(A) Water Supply (ii) seafood processing	May not be less than 6.0 or greater than 8.5.
(A) Water Supply (iii) industrial	May not be less than 5.0 or greater than 9.0
(D) Water Recreation (i) contact recreation	May not be less than 6.0 or greater than 8.5. If the natural pH condition is outside this range, substances may not be added that cause any increase in buffering capacity of the water.
(B) Water Recreation (ii) secondary recreation	Same as (18)(A)(iii).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (18)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (18)(A)(ii).

Alaska WQS for Temperature for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(22) TEMPERATURE, FOR MARINE WATER USES	
(C) Water Supply (i) aquaculture	May not cause the weekly average temperature toincrease more than 1° C. The maximum rate of change may not exceed 0.5° C per hour. Normal daily temperature cycles may not be altered inamplitude or frequency.
(A) Water Supply (ii) seafood processing	May not exceed 15° C.
(A) Water Supply (iii) industrial	May not exceed 25° C.
(E) Water Recreation (i) contact recreation	Not applicable.
(B) Water Recreation (ii) secondary recreation	Not applicable.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (22)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (22)(A)(i).

Alaska WQS for Toxics for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(23) TOXIC AND OTHER DELETERIOUS ORGANIC AND INORGANIC SUBSTANCES, FOR MARINE WATER USES	
(D) Water Supply (i) aquaculture	Same as (23)(C).
(A) Water Supply (ii) seafood processing	The concentration of substances in water may not exceed the numeric criteria for aquatic life for marine water shown in the *Alaska Water Quality Criteria Manual* (see note 5). Substances may not be introduced that cause, or can reasonably be expected to cause, either singly or in combination, odor, taste, or other adverse effects on the use.
(A) Water Supply (iii) industrial	Concentrations of substances that pose hazards to worker contact may not be present.
(F) Water Recreation (i) contact recreation	There may be no concentrations of substances in water, that alone or in combination with other substances, make the water unfit or unsafe for theuse.
(B) Water Recreation (ii) secondary recreation	Concentrations of substances that pose hazards to incidental human contact may not be present.
(C) Growth and Propagation of Fish, Shellfish, Other AquaticLife, and Wildlife	The concentration of substances in water may not exceed the numeric criteria for aquatic life for marine water and human health for consumption of aquatic organisms only shown in the *Alaska Water Quality Criteria Manual* (see note 5), or any chronic and acute criteria established in this chapter, for a toxic pollutant of concern, to protect sensitive and biologically important life stages of resident species of this state. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that, singly or in combination, cause, or reasonably can be expected to cause, adverse effects onaquatic life or produce undesirable or nuisance aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests.

(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (23)(C).

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(14) BACTERIA, FOR MARINE WATER USES, (see note 1)	
(E) Water Supply (i) aquaculture	For products normally cooked, the geometric mean ofsamples taken in a 30-day period may not exceed 200fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml. For products not normally cooked, the geometric mean ofsamples taken in a 30-day period may not exceed 20 fecal coliform/100 ml, and not more than 10% of thesamples may exceed 40 fecal coliform/100 ml.
(A) Water Supply (ii) seafood processing	In a 30-day period, the geometric mean of samples may not exceed 20 fecal coliform/100 ml, and not more than 10% of the samples may exceed 40 fecal coliform/100 ml.
(A) Water Supply (iii) industrial	Where worker contact is present, the geometric meanof samples taken in a 30-day period may not exceed 200 fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml.
(G) Water Recreation (i) contact recreation	In a 30-day period, the geometric mean of samples may not exceed 35 enterococci CFU/100 ml, and notmore than 10% of the samples may exceed a statistical threshold value (STV) of 130 enterococci CFU/100 ml.
(B) Water Recreation (ii) secondary recreation	In a 30-day period, the geometric mean of samples may not exceed 200 fecal coliform/100ml, and not more than 10% of the samples may exceed 400 fecalcoliform/100ml.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Not applicable.

(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	The geometric mean of samples may not exceed 14 fecal coliform/100 ml; and not more than 10% ofthe samples may exceed; - 43 MPN per 100 ml for a five-tube decimal dilution test; - 49 MPN per 100 ml for a three-tube decimaldilution test; - 28 MPN per 100 ml for a twelve-tube single dilution test; - 31 CFU per 100 ml for a membrane filtration test (see note 14).

Alaska WQS for Bacteria for Marine Uses

E. Equations and Analysis

1. Section 8.B.1: Attainment of TSS Standard

EPA calculated the maximum change in the concentration of TSS at the edge of the ZID using formula B-32 from the 301(h) TSD. The average weekly TSS limitation of 73 mg/L and the modeled critical initial dilution of 87:1 were used in the equation. The results show a 0.84 mg/L increase in suspended solids in the receiving water after initial dilution, or 1.2%.

Formula B-2

$SS = SSe/Sa$

where,

SS = change in suspended solids concentration following initial dilution

SS_e = effluent suspended solids concentration (73 mg/L)

S_a = critical initial dilution (87:1)

73/87 = 0.84 mg/L

2. Section 8.B.2: Attainment of DO Standard

In accordance with the procedures outline in the 301(h) TSD Section B-11 p.188 and p. 194, EPA conducted near-field and far-field analysis to estimate the impacts on DO levels in the vicinity of the discharge.

Near Field Analysis:

DO_a = 12.4 mg/L (worst case from station C, modeling indicated station C was limiting for DO and other parameters).

Do_e = 4 (min value effluent DO)

IDOD = 3 (from Table B-3 in TSD)

S_a = 87 (ZID dilution)

$DO_f = DO_a - (DO_a + IDOD – DO_e)/S_a$ = 12.4 mg/L- (12.4 mg/L + 3 mg/L – 4 mg/L)/87 = 12.3 mg/L

The near field DO reduction is approximately 0.1 mg/L under worst case conditions, therefore the Alaska WQS of no less than 5 mg/L and no greater than 17 mg/L are not violated.

Far Field Analysis:

The final BOD_5 after initial dilution was also calculated to assess the potential for far field DO using a simplified procedure from Appendix B of the 301(h) TSD. The maximum reported average monthly BOD_5 value is first converted to ultimate BOD_5 by multiplying it by the constant 1.46. The ultimate BOD_5 is then divided by the initial dilution factor (87) to determine the final BOD_5 after initial dilution.

Max BOD_5: 180 mg/L

Ultimate BOD_5: 180 mg/L x 1.46 = 263 mg/L BOD_5

Final BOD_5 after initial dilution: 263 mg/L ÷ 87 = 3 mg/L BOD_5

Final BOD_5 at the boundary of the chronic mixing zone: 263 mg/L ÷ 76 = 3.5 mg/L BOD_5

A final BOD_5 concentrations of 3 mg/L after initial dilution is not expected to cause or contribute to any measurable far field DO impacts.

3. Section 8.C.3. Toxics Analysis

The following mass-balance equation was used to determine whether the discharge has reasonable potential to cause or contribute to an excursion above Alaska WQS:

$$Cd = Ce + \frac{Cu\ (Sa-1)}{Sa}$$

Cd = Resultant magnitude or predicted concentration at edge of mixing zone, µg/L

Ce = Maximum projected effluent concentration, µg/L

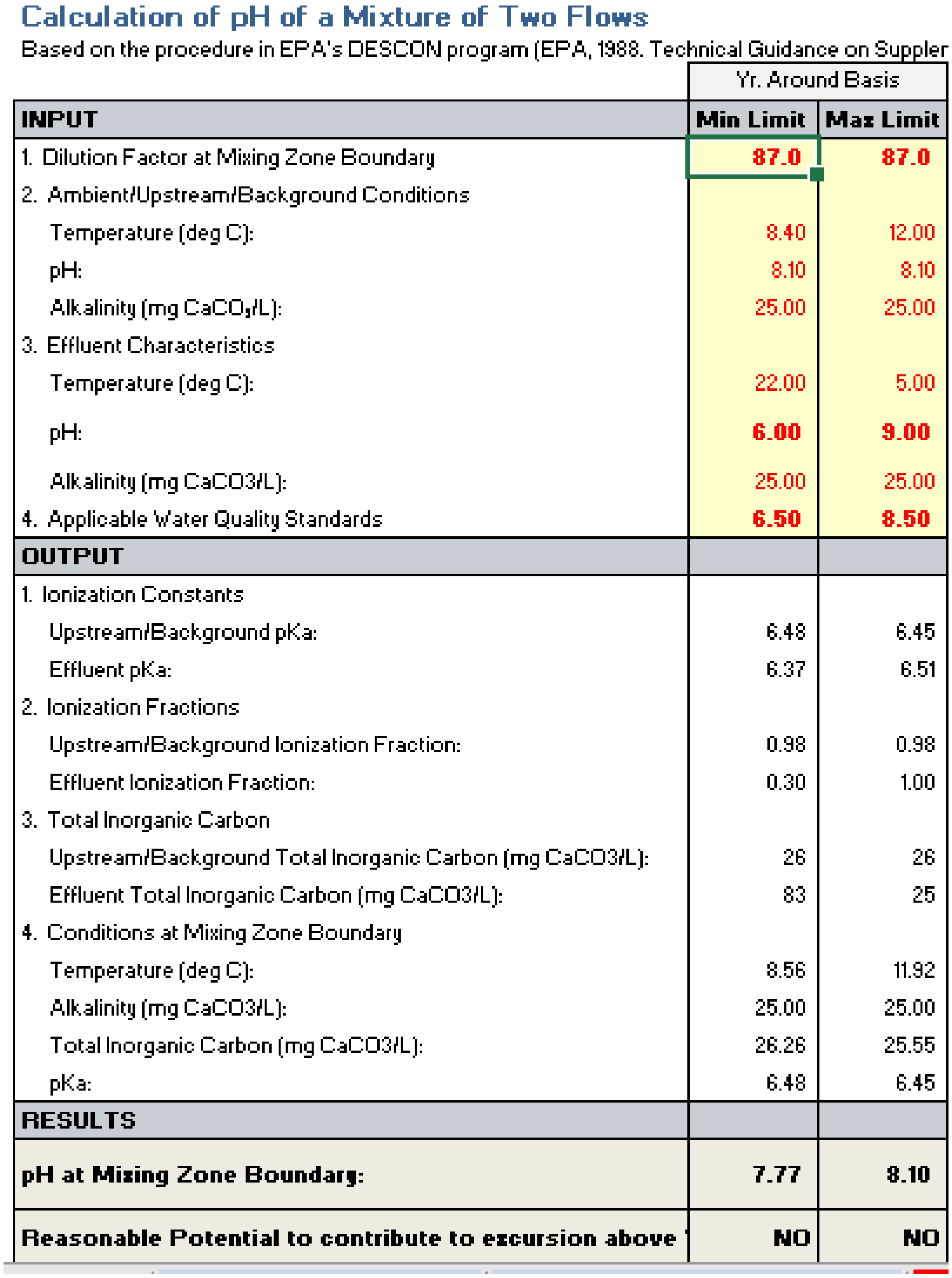
Cu = Background receiving water concentration, µg/L

Sa = dilution factor

The maximum projected effluent concentration (Ce) in the mass balance equation is represented by the highest reported concentration measured in the effluent multiplied by a reasonable potential multiplier. The reasonable potential multiplier accounts for uncertainty in the data. The multiplier decreases as the number of data points increases and variability of the data decreases. Variability is measured by the coefficient of variation (CV) of the data. When there is not enough data to reliably determine a CV (n<10), the TSD recommends using 0.6 as a default value. A partial listing of reasonable potential multipliers can be found in Table 3-1 of the TSD. The resulting maximum projected effluent concentration is then divided by the minimum critical dilution. This product represents the maximum effluent concentration at the edge of the ZID. The maximum effluent concentration at the edge of the ZID is then added to the background concentration, Cu, which is represented by the 95th percentile value from the background data set (the 5th percentile value is used for DO). The sum Cd represents the projected maximum receiving water concentration at the edge of the ZID. This concentration is compared to the water quality criterion to determine whether a water-quality based effluent limitation is needed. If the receiving water concentration at the edge of the ZID exceeds the water-quality criteria a water-quality based effluent limitation is developed. If a permittee is unable to meet their WQBEL they would fail to satisfy CWA § 301(h)(9) and 40 CFR 125.62 and would be ineligible for a 301(h)-modified permit.

A summary of the reasonable potential analyses is presented in the 2023 Fact Sheet for the Sitka WWTP NPDES permit. The Table footnotes indicate the criterion source used to evaluate reasonable potential (i.e., the criterion in effect for Clean Water Act purposes). Chlorine is the only constituent that demonstrated reasonable potential. WQBELs for chlorine are included in the final permit. The effluent limits developed for chlorine are protective of Alaska WQS, and the proposed discharge is expected to comply with Alaska WQS for toxics after initial mixing, satisfying the requirements of CWA § 301(h)(9) and 40 CFR 125.62. For more information on the process used to develop effluent limits refer to Appendix D of the Fact Sheet.

Table 5. Reasonable potential analysis for pH exceedances at the edge of the ZID



Calculation of pH of a Mixture of Two Flows

Based on the procedure in EPA's DESCON program (EPA, 1988. Technical Guidance on Suppler

	Yr. Around Basis	
INPUT	**Min Limit**	**Max Limit**
1. Dilution Factor at Mixing Zone Boundary	**87.0**	**87.0**
2. Ambient/Upstream/Background Conditions		
Temperature (deg C):	8.40	12.00
pH:	8.10	8.10
Alkalinity (mg CaCO$_3$/L):	25.00	25.00
3. Effluent Characteristics		
Temperature (deg C):	22.00	5.00
pH:	**6.00**	**9.00**
Alkalinity (mg CaCO3/L):	25.00	25.00
4. Applicable Water Quality Standards	**6.50**	**8.50**
OUTPUT		
1. Ionization Constants		
Upstream/Background pKa:	6.48	6.45
Effluent pKa:	6.37	6.51
2. Ionization Fractions		
Upstream/Background Ionization Fraction:	0.98	0.98
Effluent Ionization Fraction:	0.30	1.00
3. Total Inorganic Carbon		
Upstream/Background Total Inorganic Carbon (mg CaCO3/L):	26	26
Effluent Total Inorganic Carbon (mg CaCO3/L):	83	25
4. Conditions at Mixing Zone Boundary		
Temperature (deg C):	8.56	11.92
Alkalinity (mg CaCO3/L):	25.00	25.00
Total Inorganic Carbon (mg CaCO3/L):	26.26	25.55
pKa:	6.48	6.45
RESULTS		
pH at Mixing Zone Boundary:	**7.77**	**8.10**
Reasonable Potential to contribute to excursion above	**NO**	**NO**

F. Dilution Modeling Report

The dilution modeling report is attached to the end of this document.

FINAL

Mixing Zone Dilution Modeling for Six Alaska POTWs

Prepared for:

United States Environmental Protection Agency
Cincinnati Procurement Operations Division
Cincinnati, Ohio 45268

USEPA OW Contract: 68HERC20D0010; Task Order: 68HERV21F0114

Technical Support for National Pollutant Discharge
Elimination System (NPDES), Clean Water Act Section 301(h),
and Endangered Species Act Section 7 Implementation
in EPA Region 10 NPDES Permits Section

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Date: August 5, 2021

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MIXING ZONE DILUTION MODELING FOR SIX ALASKA POTWS

For each of the six POTWs of interest in southeast Alaska (Haines, Ketchikan, Petersburgh, Sitka, Skagway, and Wrangell) mixing zone dilution models were developed and applied to predict the steady-state dilution of effluent being discharged into the marine coastal receiving waters. Because of the nature of the discharges and receiving waters, initial dilution models within the EPA-approved Visual Plumes software (EPA 2003) were selected for use. From a modeling perspective, each of the receiving water mixing zones share several important characteristics that led to the selection of Visual Plumes, as opposed to the alternative EPA-approved modeling framework, CORMIX:

- Discharge of buoyant effluent into a deep (20-30 meter), stratified marine water body;
- No shoreline boundaries within 100 meters of the outfalls;
- Relatively small discharge flow rates (0.6-7 MGD); and
- No obstructions in the receiving waters to impede circulation near the outfalls, making tidal build-up of pollutants unlikely.

For each site, appropriate models were applied to predict average dilution at various distances (corresponding to 1-10 times the depth of discharge) from the discharge point, as well as the geometry (depth, width, etc.) of the plume itself. Aquatic life-based mixing zone analyses involve the concept of determining reasonable worst-case values for various parameters because the durations established for these water quality criteria vary for both acute and chronic toxicities (Washington DoE, 2018). The term *reasonable worst-case* refers to the value selected for a specific effluent or receiving water parameter. *Critical conditions* refer to a scenario involving reasonable worst-case parameters, which has been set up to run in a mixing zone model. For this work, steady-state mixing zone models were applied using a combination of parameters (e.g., effluent flow, current speed, density profile) to simulate critical conditions. The predictions were based on input data representing critical conditions demonstrated to minimize the dilution of effluent pollutants. It should be understood that each critical condition (by itself) has a low probability of occurrence.

It should also be understood that mixing zone modeling is not an exact science (Reese et al., 2021). With limited data and numerous variables, mixing zone sizes may be considered best estimates to ± 50%. Sensitivity analysis and comparison of alternative models were used to develop confidence in the dilution model predictions. All simulations explicitly included fecal coliform (FC) as a pollutant, which required the models to simulate bacterial decay in the receiving waters. Maximum effluent (end-of-pipe) FC concentrations were estimated for modeling by applying the EPA (1991) reasonable potential procedure to maximum monthly concentrations reported over the past five years in Discharge Monitoring Reports (DMRs) provided by EPA Region 10. The maximum effluent FC concentrations for each discharge are presented in Table 1 along with the dilution factors required to meet the Alaska marine water quality standards for harvesting for consumption of raw mollusks or other raw aquatic life (18 AAC 70 Water Quality Standards, amended as of March 5, 2020):

The geometric mean of samples may not exceed 14 fecal coliform/100 ml, and not more than 10% of the samples may exceed 43 MPN per 100 mL for a five-tube decimal dilution test.

Table 1. Maximum Effluent FC Concentrations Based on EPA (1991) Reasonable Potential Procedure (Maximum Monthly Concentrations Reported in DMRs Over the Past 5 Years)

City	Haines	Kechikan	Petersburg	Sitka	Skagway	Wrangell
Maximum expected effluent FC (daily max, 99%; n/100 mL)	2,100,000	2,900,000	2,000,000	3,700,000	2,600,00	190,000
Dilution factor[1] required to meet 14/100 mL FC criterion	150,000	210,000	140,000	270,000	190,000	14,000
Dilution factor required to meet 43/100 mL FC criterion	50,000	67,000	47,000	87,000	60,000	4,400

Model predictions of the size of the mixing zones required to attain these dilution factors are presented in the summary of this report.

Most mixing zone simulations required the combination of initial dilution and far-field models. Initial dilution models simulate the "initial mixing region" or "hydrodynamic mixing zone" defined to end where the self-induced turbulence of the discharge collapses under the influence of ambient stratification and initial dilution reaches its limiting value (EPA, 1994). At the end of this region/zone the waste field is established and then drifts with the ocean currents and is diffused by oceanic turbulence.

The initial dilution models included UM3, DKHW and NRFIELD, all contained within the Visual Plumes (VP) framework. Although the three initial dilution models run under the same VP interface, they differ in terms of origin and development, underlying assumptions, empirical datasets, solution techniques and coding. UM3 is a three-dimensional Updated Merge (UM) model for simulating single and multiport submerged diffusers. DKHW is an acronym for the Davis, Kannberg and Hirst model, a three-dimensional model for submerged single or multi-port diffusers. DKHW is limited to positively buoyant plumes and considers either single or multiport discharges at an arbitrary horizontal angle into a stratified, flowing current. NRFIELD is based on the Roberts, Snyder and Baumgartner (RSB) model, an empirical model for multiport diffusers (T-risers, each having two ports for a total of 4-ports) in stratified currents. A shortcoming of each of these initial dilution models in VP is their inability to recognize and address lateral boundary constraints, although that is not a major issue for these Alaskan mixing zone sites. Although the original 2001 version of VP is still available from EPA's CEAM site, it is currently unsupported and known to contain a number of errors (Frick et al. 2010; Frick and Roberts, 2019). We instead used the updated VP version 20, maintained and distributed by the California State Water Resources Control Board, Ocean Standards Unit (https://ftp.waterboards.ca.gov).

The Brooks far-field model was used to extend dilution simulations beyond the spatial bounds of initial dilution. Although this model is incorporated in VP, we also used a stand-alone spreadsheet version of the

---

[1] Dilution Factor, DF = (end of pipe) concentration/mixed concentration.

Brooks model, FARFIELD, that is contained in the Washington Department of Ecology (DoE), *Permit Calculation workbook* (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Water-quality-permits-guidance). FARFIELD calculates dilution using the method of Brooks (1960) and is recommended by Frick et al. (2010) in lieu of using far-field predictions within VP, since the latter does not allow for the use of linear diffusivity as recommended in estuaries. FARFIELD was used to double-check the far-field results in VP, and in some instances to replace them.

The initial dilution models relied upon a variety of data to characterize the effluent, discharge outfall and receiving water. These data are summarized in Table 2. The data were gathered from a number of sources including EPA Region 10 and the State of Alaska; from the permittees as documented in permit files, as-built drawings and charts, etc.; tidal current predictions made by the National Oceanic and Atmospheric Administration (NOAA); and other literature sources found by Internet search.

All six of the POTWs discharge effluent using deeply-submerged outfalls with diffusers and multiple ports (Table 2). Haines and Petersburg both use two-diffuser ports, while the others use multiport diffusers with 6 to 16 ports. Modeling initial dilution from the four sites using multiport diffusers required additional considerations, because these diffusers have opposing ports (ports on both sides of the diffuser pipe that discharge effluent into opposite directions), creating co-flowing and counter-flowing plumes. Counter-flowing plumes are discharged opposing the ambient current and will generally rise and bend back into the direction from whence they came, eventually merging with the co-flowing plumes that are discharged on the opposite side of the pipe in the direction of the current. This is called cross-diffuser merging (EPA, 2003). Two alternative modeling approaches were applied to simulate initial mixing from opposing ports in the UM3 and DKHW models (NRFIELD models cross-diffuser merging directly). The first approach (“half spacing”) treated the diffuser as if all ports are on one side with half the spacing. In the context of merging plumes, this approach works well when the distances of interest are somewhat beyond the point of merging.

The second approach (“downstream only”) involves simulating only downstream ports. This necessitates doubling the flow per port (assuming there is an even number of ports in the diffuser) and increasing the diameter of the ports to maintain approximately the same densimetric Froude number. With this approach only the downstream ports would be used when determining spacing and number of ports. The Washington DoE Permit Writer’s Manual, Appendix C (2018) discusses the merits of these approaches. When possible, we applied both approaches to modeling cross-diffuser merging and compared the results.

We assumed that all ports on a multiport diffuser discharged effluent flow equally and at the same depth. The multiport diffuser at Ketchikan was unique because it was the only diffuser that combined ports of different sizes. Five 6-inch opposing ports were spaced along a 12-inch manifold, and a sixth 12-inch port was located at the manifold’s end. The CORMIX hydraulic module CorHyd (MixZone, 2020) was used to determine the flow distribution between the 6-inch ports and the 12-inch port. At a nominal flow rate of 5.35 MGD, CorHyd calculated that the 6-inch ports would discharge 52% of the flow, and the remaining 48% would be discharged from the 12-inch port. These same percentages were applied to other flow rates at Ketchikan. Initial model simulations suggested that the plumes emanating from the 12-inch port would not merge with the plume from the other ports, due to the 90° difference in port orientations. Therefore, these plumes were modeled separately.

The diffuser port orifice contraction coefficient is an initial dilution model hydraulic parameter that is specified according to how ports are machined in the diffuser pipe wall (EPA, 2003). For all of the outfalls except Sitka, sharp-edged ports were assumed, and contraction coefficients of 0.61 were specified. For Sitka, the port orifices were bell-shaped, so a contraction coefficient of 1.0 was applied.

Tidal current predictions were used to calculate 10th percentile and average current velocities at each site. The tidal prediction location nearest each discharge site was identified and tidal velocity predictions for 2021 were downloaded from the NOAA Tides & Currents web site (http://tidesandcurrents.noaa.gov). These data were imported into a spreadsheet and the predictions for the month in which the critical ambient conditions fell were selected. For Haines, Ketchikan and Skagway, 6-minute tidal velocity predictions were available. The tenth percentile of the absolute value of these velocities were calculated and used as the critical ambient velocity input for mixing zone dilution modeling. For the other locations, only times and velocities for ebb, slack and flood tides were available. The Excel FORECAST function was then used to interpolate hourly values from the tidal velocity predictions, and the tenth percentile of the absolute value of these interpolated hourly values was calculated and used for modeling[2]. These velocities, ranging from 1.4 to 5.9 cm/s, are presented in Table 2. The compass directions of tidal currents (also presented in Table 2) were based on the tidal current predictions, the orientation of the nearest shoreline (presuming currents to flow parallel to the shoreline), and other information from the permit files. The average hourly ebb and flood tidal velocities were calculated similarly and are also presented in Table 2 and were used in the model sensitivity analysis.

The decay of fecal coliform was included in the initial dilution and far-field models by using the Mancini (1978) bacteria model that incorporates four variables (salinity, temperature, solar insolation, and water column absorption) to determine the rate of first-order decay. Summertime solar insolation in southeast Alaska was based upon the models and measurements of Dissing and Wendler (1998). Summertime solar radiation flux, that takes into account both latitude and fractional cloud cover, averaged 190 Watts/m^2 (16.3 Langleys/hr) in the Alexander Archipelago. The bacterial decay model used ambient water temperature and salinity, and a default light absorption coefficient of 0.16, to calculate decay rates of ~0.0002/d. Decay of fecal coliform was found to be insignificant in comparison to physical dilution at the time and space scales of interest for mixing zone analysis.

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[2] Comparison between linear interpolation and cubic spline interpolation of the tidal velocity predictions suggests that linear interpolation may yield average velocities that could be low by a factor of 1.6 to 2.3. The impact of this discrepancy on DF predictions will be demonstrated via sensitivity analysis.

Table 2. Summary of Data Used for Mixing Zone Dilution Modeling

City	Haines	Ketchikan	Petersburg	Sitka	Skagway	Wrangell
Permit	*AK0021385*	*AK0021440*	*AK0021458*	*AK0021474*	*AK0020010*	*AK0021466*
DMR data available	2011-2020	2013-18	2015-2019	2015-20	2007-19	2007-19
DMR data used	2016-2020	2013-2018	2015-2019	2015-2020	2014-2019	2015-2019
Permit Maximum Flow Rate (MGD[3])	2.9	7.2	3.6	5.3	0.63	3.0
monthly[4] average effluent temperature	12.0	14.6[5]	13.2	14.0	14.7	17.3
monthly maximum effluent temperature	15.8	20.5	14.6	15.0	17.3	18.4
Outfall						
distance from shore (m)	549	221	366	114	125	457
depth at LWWD (m)	21.3	29.9	18.3	24.4	18.3	30.5
number of diffuser ports	2 (3rd is capped)	6	2 (3 others capped)	16 bell-shaped	8	16
diffuser length (ft)	30	190	45.9	195	25	240
port diameter (in)	3	5@6", 1@12"	4	4	3	3
Elevation of ports above bottom (in)	8	12	9	18	6	6
Port spacing (ft)	15-30[6]	40 (20’ apart on alternating sides of pipe)	10-34[6]	26 (13’ apart on alternating sides of pipe)	7	32 (16’ apart on alternating sides of pipe)
Port orientation	horizontal	horizontal (opposing/ alternating) + diffuser end	horizontal	horizontal opposing/ alternating	horizontal opposing	horizontal opposing/ alternating

---

[3] Million gallons per day.

[4] Average effluent temperature for month of limited dilution

[5] Average of maximum monthly effluent temperatures (no monthly averages in DMR)

[6] Port spacing is uncertain given information in permit fact sheet.

City	Haines	Ketchikan	Petersburg	Sitka	Skagway	Wrangell
VP discharge angle[7] (degrees)	90	115 (5x6” ports), 205 (1x12” port)	115	300	350	90
Receiving Water						
Water body	Portage Cove, Chinook Inlet	Tongass Narrows, Charcoal Point	Frederick Sound	Sitka Sound, Middle Channel	Tiaya Inlet	Zimovia Strait
tidal range (ft)	14.2	13	15	7.7	14.1	13
data source/file[8] name for ambient data	NA; used Skagway data	AK0021440_Ketchikan_temp_salinity	Petersburg_Receiving Water Data	Sitka Receiving Water Monitoring	Table 2-5_v2	Wrangell FC and RW Monitoring
Ambient salinity/temp profile limiting dilution	Skagway site 1, June 2005	Ketchikan site 3, July 1997	Petersburg site 1, August 2005	Sitka site C, July 2010	Skagway site 1, June 2005	Wrangell site 4, August 2016
NOAA tides & current predictions	Battery Point, Chinook Inlet (SEA0826)	East of Airport (SEA0711)	Cosmos Point (PCT3811)	Sitka Harbor, Channel off Harbor Island (PCT4166)	Tiaya Inlet (SEA0825)	Wrangell Harbor (PCT3131)
Tidal current 10th percentile (cm/s)	June: 2.1 @ 35', 2.8 @ 133'; 2.3 (interpolated to discharge depth)	July: 5.9 @87'	August: 1.6	July: 1.7	June: 1.4 @37'	August: 4.0
Tidal current average (Ebb/Flood, cm/s)	June: 10.2/10.7 @ 35', 11.3/16.1 @ 133'; 10.5/12.6 (interpolated to discharge depth)	July: 49.2/20.1 @87'	August: 10.4/7.8	July: 10.3/8.0	June: 6.9/12.2 @37'	August: 20.8/23.5
VP current angle[7] (degrees)	90	140	120	225	350	90

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[7] Zero degrees is eastward.
[8] Names of electronic files provided by EPA Region 10 on March 31, 2021.

In the following sections, the modeling of effluent dilution in mixing zones at each site is presented and results are displayed in both tables and graphs. Text output from the VP and FARFIELD model simulations at each location are provided in an appendix to this report.

HAINES

The wastewater treated at Haines is discharged 549 m offshore in Portage Cove, Chinook Inlet (Figure 1), from a 2-port diffuser at a depth of 21.3 m (MLLW[9]). The permitted maximum flow rate is 2.9 MGD. Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. The diffuser port spacing at Haines is uncertain (somewhere in the range of 15 to 30 ft.) due to one of three ports being closed. The models predicted lower DFs for the narrowest port spacing (15 ft.), so that spacing was used for all model simulations.

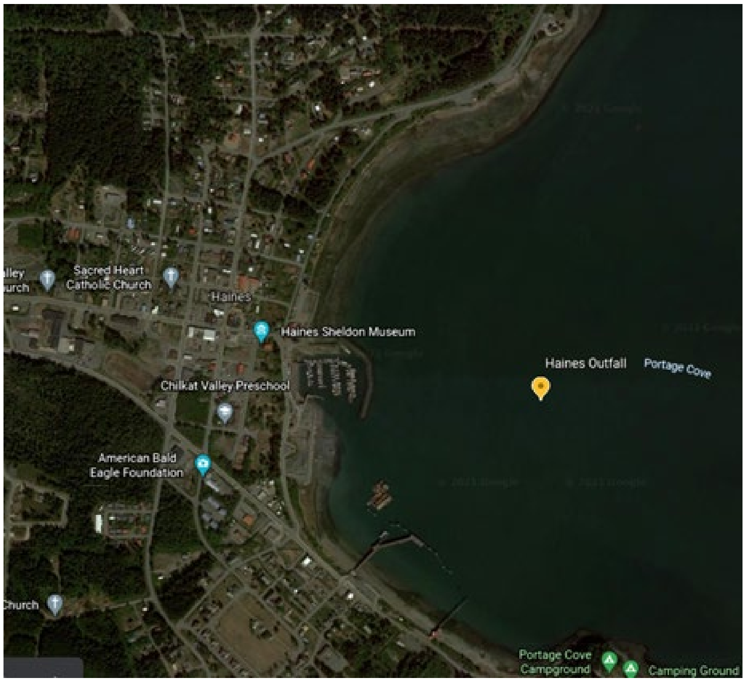

Figure 1. Aerial View of the POTW Outfall Location at Haines

According to the permit fact sheet, the circulation patterns within Portage Cove are not known. The effluent discharged by the Haines WWTP is subject to a net transport of water out of Chinook Inlet due to fresh water supplied by runoff. The period of low net circulation is expected to be December through April, during times of minimum river flow. NOAA 6-minute tidal current predictions from Battery Point, Chinook Inlet (SEA0826) were used to calculate the 10th percentile and average tidal current velocities at 35 and 133 ft. (10.7 and 40.5 m; Table 2), that were then interpolated to the discharge depth of 21.1 m. The resulting 10th percentile current velocity used for modeling was 2.3 cm/s, while the average ebb and flood tidal velocities were 10.5 and 12.6 cm/s.

No specific data were available for vertical profiles of temperature and salinity in Portage Cove or Chinook Inlet. Such data are used to calculate the density profile and define the vertical stratification that limits vertical mixing of the buoyant discharge plume. Instead, we used vertical profiles of temperature and salinity measured in Tiaya Inlet, an adjoining waterway that is also the receiving water body for Skagway's discharge. Vertical profile data were available for five locations that were sampled in October

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[9] Mean lower low water.

2002, July and August 2004, and June 2005. Preliminary initial dilution simulations made with UM3 for profiles measured at four of the locations (the fifth was excluded because it was influenced by freshwater input from a tributary near Skagway), determined that the June 2005 vertical profile from site 1 (shown in Figure 2) was limiting in terms of minimizing effluent dilution. That profile was used for all subsequent dilution modeling at Haines.

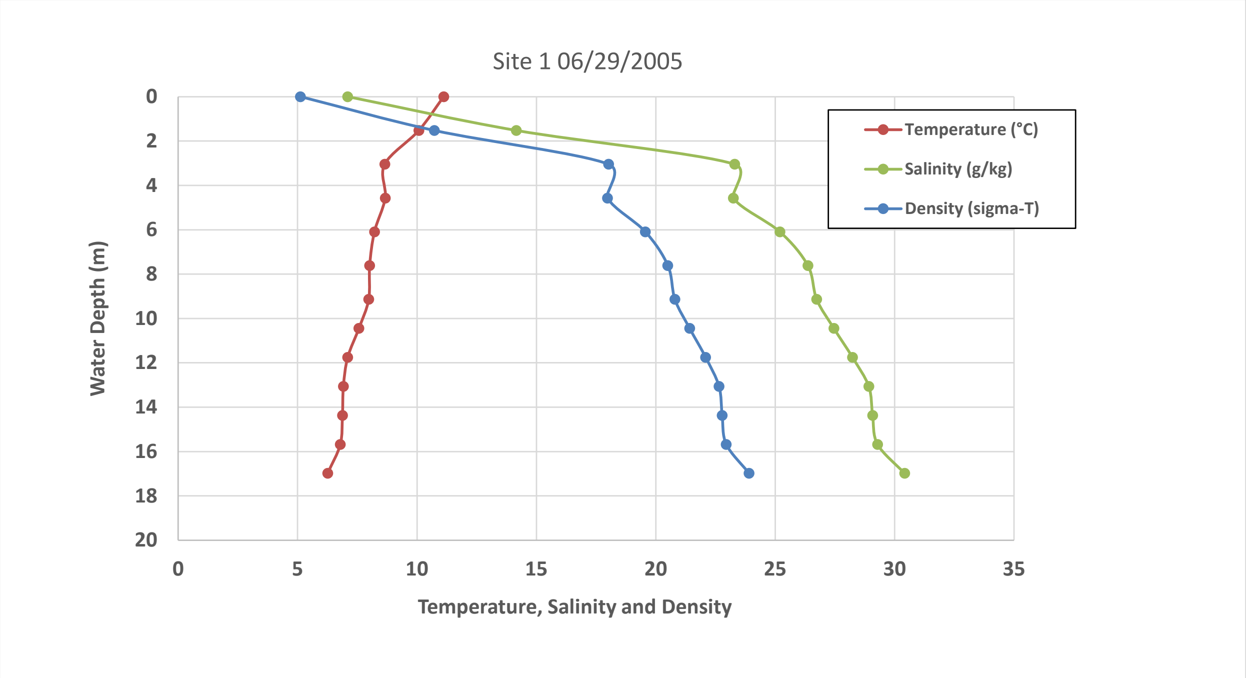

Figure 2. Vertical Ambient Profile of Temperature, Salinity and Density in Haines Mixing Zones Resulting in Least Mixing

Mixing zone dilution modeling results for Haines are summarized in Table 3. The two applicable initial mixing models, UM3 and DKHW, gave nearly identical results for dilution at a distance of 1*depth (Table 3, simulations 10 vs. 11). UM3 was selected for further analysis at Haines. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Dilution factors at distances of 1*depth to 10*depth range from 100 to 766 (Table 3, simulations 15-18); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 3 (plan view from above of the discharge plume boundary), 4 (profile view from the side of the discharge plume centerline and boundary) and 5 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 3, the plume was trapped at a depth of 20 m by the ambient density stratification, the initial mixing region extended 16 m from the outfall, and the travel time to the mixing zone boundaries ranged from 4 minutes (MZ=1*depth) to 143 minutes (MZ=10*depth). A dilution factor of 99 was predicted for the boundary of the initial mixing region and at the distance to the shore (549 m) the DF was 2770.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature[10], current velocity and direction, and discharge flow rate) is demonstrated in simulations 20-28 (Table 3). Of these

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[10] The alternative effluent temperature used for sensitivity analysis was the monthly average effluent temperature for the month found to have the most limited dilution.

parameters, DFs were most sensitive to variation in effluent flow rate (Q), with dilution increasing with greater flow. DFs were relatively insensitive to variation in ambient velocity. Sensitivity of the far-field model to bounding values of the diffusion parameter α (alpha) was also found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity (see Washington DoE, 2018 for explanation).

Table 3. Haines mixing zone dilution modeling results

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
1. MZ=1*depth	Skagway site 1 Oct. 2002	UM3	21.3	190	117	118	17	>21.3	
2. " "	Skagway site 2 Oct. 2002	UM3	" "	191	118	118	17	>21.3	
3. " "	Skagway site 4 Oct. 2002	UM3	" "	190	117	118	17	>21.3	
4. " "	Skagway site 1 Jul. 2004	UM3	" "	189	117	118	17	>21.3	
5. " "	Skagway site 2 Jul. 2004	UM3/FF	" "	185	110	113	19	20	2
6. " "	Skagway site 4 Jul. 2004	UM3/FF	" "	181	113	116	19	21	0.5
7. " "	Skagway site 1 Aug. 2004	UM3	" "	188	118	118	17	>21.3	
8. " "	Skagway site 2 Aug. 2004	UM3	" "	186	117	117	17	>21.3	
9. " "	Skagway site 4 Aug. 2004	UM3/FF	" "	181	114	117	19	21	0.2
10. " "	Skagway site 1 June 2005	UM3/FF	" "	179	99	104	20	16	5
11. " "	Skagway site 1 June 2005	DKHW/FF	" "	179	99	99	20	16	4
12. " "	Skagway site 2 June 2005	UM3/FF	" "	183	105	109	20	18	2
13. " "	Skagway site 4 June 2005	UM3	" "	185	117	117	17	>21.3	

---

[11] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	**Ambient Input**	**Model(s)**	**MZ Distance (m)**	**Froude Number**	**Dilution Factor**	**Dilution Factor w/Bacteria Decay**	**Trapping depth (m)**	**Length of Initial Mixing Region (m)**	**Travel Time to MZ Boundary (min)[11]**
Different mixing zone distances:									
14. MZ= initial mixing region	Skagway site 1 June 2005	UM3	16	179	**99**	100	20		1
15. MZ=1*depth	“ “	UM3/FF	21.3	179	**100**	100	20	16	4
16. MZ=2*depth	“ “	UM3/FF	42.6	179	**136**	137	20	16	19
17. MZ=5*depth	“ “	UM3/FF	106.5	179	**330**	331	20	16	65
18. MZ=10*depth	“ “	UM3/FF	213	179	**766**	768	20	16	143
19. MZ=distance to nearest shore	“ “	UM3/FF	549	179	**2770**	2780	20	16	386
Model sensitivity:									
20. avg. effluent T=11.975° C	Skagway site 1 June 2005	UM3/FF	21.3	181	100	100	20	16	4
21. ½*current v=1.15 cm/s	“ “	UM3/FF	“ “	178	101	101	20	16	8
22. ¼ *current v=0.575 cm/s		UM3/FF	“ “	179	120	120	20	16	16
23. 2*current v=4.6 cm/s	“ “	UM3/FF	“ “	179	105	105	20	17	2
24. average current v=12.6 cm/s	“ “	UM3/FF	“ “	179	126	126	20	19	4
25. reverse current direction=270°	“ “	UM3/FF	“ “	179	92	92	20	15	4
26. average Q=0.27 MGD	“ “	UM3/FF	“ “	17	63	63	18	5	12
27. Q/2=1.45 MGD	“ “	UM3/FF	“ “	89	87	87	20	11	7
28. 2*Q=5.8 MGD	“ “	UM3	“ “	358	111	111	20	21	0.5

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
Far-field model sensitivity to diffusion parameter:									
29. alpha=0.0001	Skagway site 1 June 2005	UM3/FF	213	178	248	249	20	16	143
30. alpha=0.000453	" "	UM3/FF	" "	178	1280	1280	20	16	143
31. Linear eddy diffusivity	" "	UM3/FF	" "	178	486	488	20	16	143

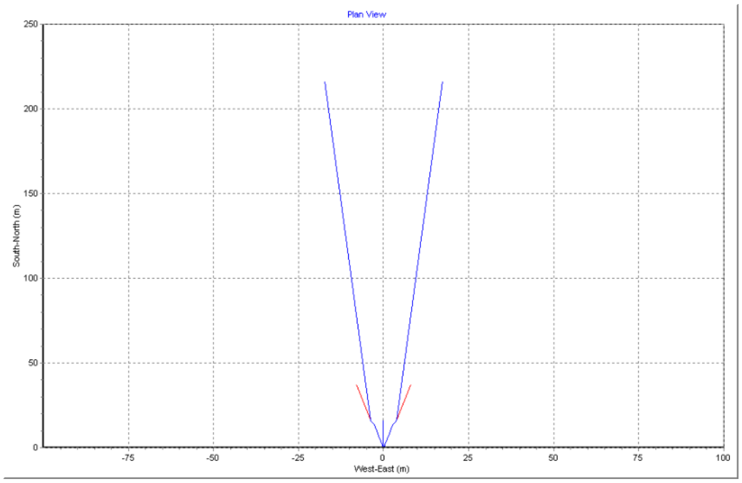

Figure 3. Haines Discharge Plume Boundary Plan View from Above

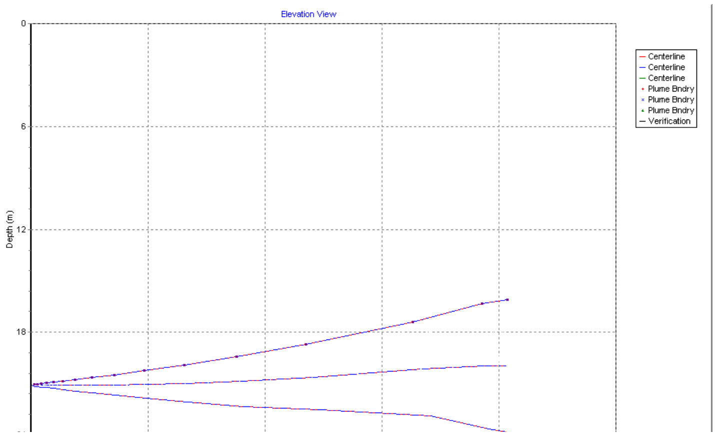

Figure 4. Haines Discharge Plume Centerline and Boundary Profile View from Side

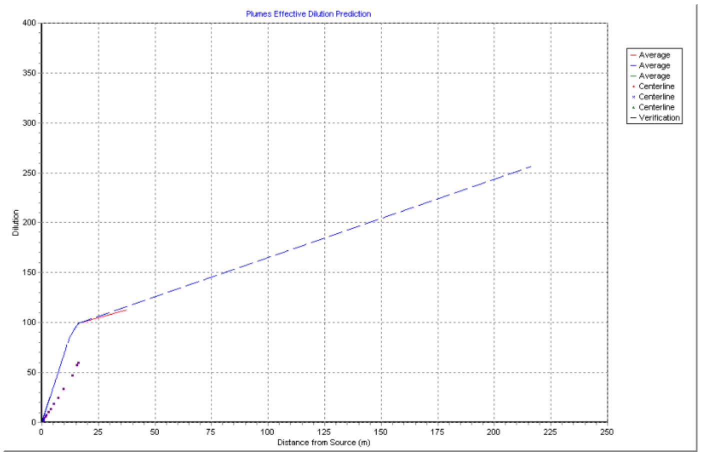

Figure 5. Haines Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

KETCHIKAN

The wastewater treated at Ketchikan is discharged 221 m offshore of Charcoal Point in the Tongass Narrows (Figure 6), at a depth of 29.9 m (MLLW). Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2.

Figure 6. Aerial View of the POTW Outfall Location at Ketchikan

Charcoal Point is at the narrowest width of the Narrows and is approximately 400 m wide and 34 m deep. According to the 2000 Permit application, the Tongass Narrows has a net northwest seaward exchange (away from the City and Pennock Island) with the Gulf of Alaska. Strong currents (that do not vary seasonally) provide vertical mixing in Tongass Narrows, minimizing the vertical density gradient and preventing stratification. Ambient tidal current data were collected with a current meter deployed near shore in December 1988 to verify published Tidal Current Table predictions. The data collected indicate that the flood tide current velocity was 34 cm/s, while the ebb tide currents was 1 cm/s in both directions. NOAA 6-minute tidal current predictions from East of Airport (SEA0711) were used to calculate the 10th percentile and average tidal current velocities at a depth of 87 ft. (26.5 m; Table 2). The 10th percentile current velocity used for modeling was 5.9 cm/s, while the average ebb and flood tidal velocities were 49.2 and 20.1 cm/s.

Preliminary initial dilution simulations made with UM3 for five available ambient profiles, determined that the July 1997 vertical profile from Site 3 (Figure 7) was limiting in terms of minimizing effluent dilution. As noted previously, the diffuser at Ketchikan was a hybrid, consisting of five 6-inch ports on a manifold and a single 12-inch port. These were modeled separately, and initial simulations with both UM3 and DKHW demonstrated that effluent dilution from the single 12-inch port was lower than from the five, 6-inch ports. UM3 gave more conservative dilution predictions (see Table 4, simulations 5 vs. 6), so that initial mixing model was selected for further analysis at Ketchikan.

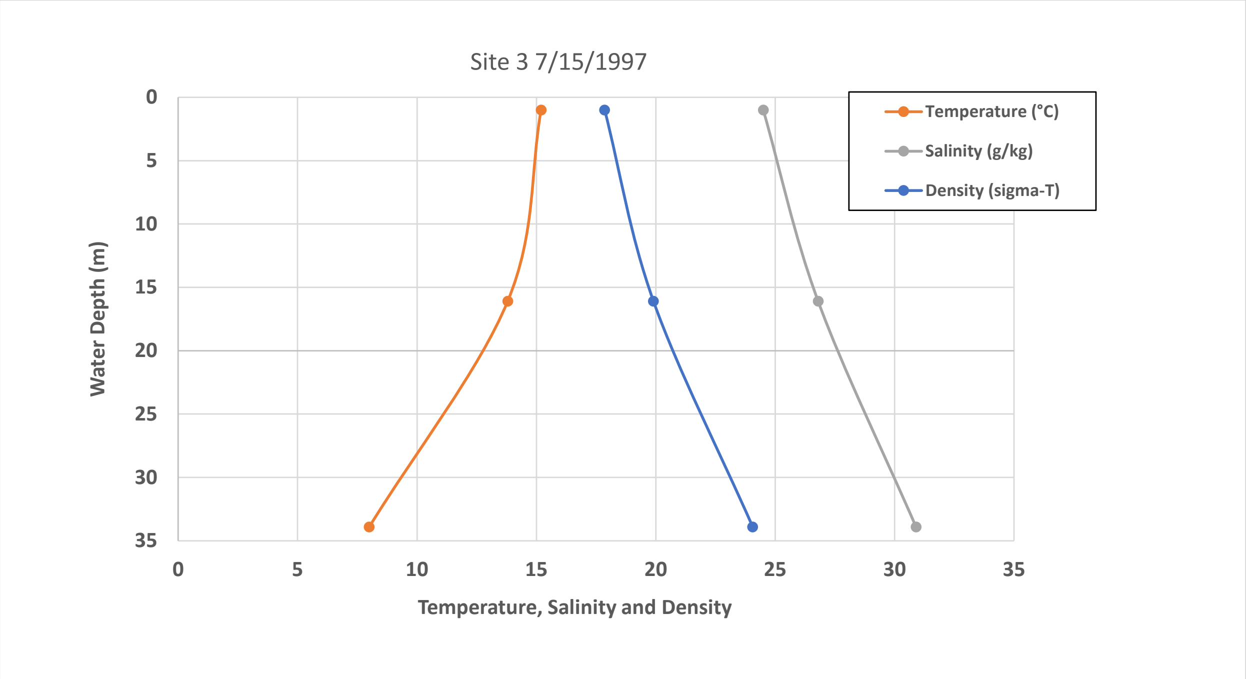

Figure 7. Vertical Ambient Profile of Temperature, Salinity and Density in Ketchikan Mixing Zone Resulting in Least Mixing.

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Ketchikan on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 4 (simulations 20 vs. 31 and 32).

Dilution factors at distances of 1*depth to 10*depth range from 52 to 179 (Table 4, simulations 17-20). It should be noted that the 10*depth distance (299 m) is greater than the distance from the diffuser to shore (221 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 8 (plan view from above of the discharge plume boundary), 9 (profile view from the side of the discharge plume centerline and boundary) and 10 (discharge plume average and centerline dilution vs. distance from the outfall). Note that these figures include dilution model predictions for both the single 12-inch port and the five 6-inch ports. As shown in Table 4, the plume was trapped at a depth of 22 m by the ambient density stratification, the initial mixing region extended 13 m from the outfall. The travel time to the mixing zone boundaries ranged from 5 minutes (MZ=1*depth) to 81 minutes (MZ=10*depth). A dilution factor of 51 was predicted for the boundary of the initial mixing region and at the distance to the shore (221 m) the DF was 141.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature[12], current velocity and direction, and discharge flow rate) is demonstrated in simulations 22-30 (Table 4). Of these parameters, DFs were most sensitive to variation in ambient velocity (simulations 23-26).

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[12] The alternative effluent temperature used for sensitivity analysis was the average of maximum monthly effluent temperatures (no monthly averages in DMR).

Table 4. Ketchikan Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
1. MZ=1*depth	Ketchikan 2000	UM3/FF	29.9	12" port	14	73	75	19	15	4
2. " "	" "	UM3(half spacing)/FF	" "	5x6" ports	18	117	123	22	12	5
3. " "	Ketchikan Pier 12/1988	UM3/FF	" "	12" port	14	158	168	7	17	4
4. " "	" "	UM3(half spacing)/FF	" "	5x6" ports	18	305	324	8	18	3
5. " "	Ketchikan site 3 7/1997	UM3/FF	" "	12" port; limiting	14	52	54	22	13	5
6. " "	" "	DKHW/FF	" "	12" port	14	79	79	24	12	5
7. " "	" "	UM3(DS only, 3 ports x7.35")/FF	" "	5x6" ports	17	60	62	23	12	5
8. " "	Ketchikan site 3 9/1997	UM3/FF	" "	12" port	14	99	104	14	15	4
9. " "	Ketchikan site 3 8/1997	UM3/FF	" "	12" port	13	106	112	12	14	4
10. " "	Ketchikan site 3 7/1996	UM3/FF	" "	12" port	13	99	104	14	15	4
11. " "	Ketchikan site 3 8/1996	UM3/FF	" "	12" port	14	79	83	18	15	4

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
12. “ “	Ketchikan site 3 9/1996	UM3/FF	“ “	12" port	14	101	106	15	16	4
13. “ “	Ketchikan site 3 7/1998	UM3/FF	“ “	12" port	14	89	93	16	6	4
14. “ “	Ketchikan site 3 8/1998	UM3/FF	“ “	12" port	13	112	118	13	17	4
15. “ “	Ketchikan site 3 9/1998	UM3/FF	“ “	12" port	14	92	97	16	16	4
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:										
16. MZ= initial mixing region	Ketchikan 3 7/1997	UM3	13	12" port	14	**51**	52	22		1
17. MZ=1*depth	Ketchikan 3 7/1997	UM3/FF-LED	29.9	“ “	14	**52**	52	22	13	5
18. MZ=2*depth	“ “	“ “	59.8	“ “	14	**62**	63	22	13	13
19. MZ=5*depth	“ “	“ “	149.5	“ “	14	**105**	106	22	13	39
20. MZ=10*depth	“ “	“ “	299[13]	“ “	14	**179**	180	22	13	81
21. MZ=distance to nearest shore	“ “	“ “	221	“ “	14	**141**	141	22	13	59
Model sensitivity:										
22. avg. effluent T=14.6° C	Ketchikan 3 7/1997	UM3/FF-LED	29.9	12" port	14	52	52	22	13	5

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[13] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
23. ½*current v=2.95 cm/s	“ “	“ “	“ “	“ “	14	54	54	20	13	10
24. ¼ *current v=1.475 cm/s	“ “	“ “	“ “	“ “	14	67	67	20	13	19
25. 2*current v=11.8 cm/s	“ “	“ “	“ “	“ “	14	88	88	24	14	2
26. average current v=49.2 cm/s	“ “	UM3	“ “	“ “	14	179	180	27	30	1
27. reverse current direction=320°	“ “	UM3/FF-LED	“ “	“ “	14	47	47	22	10	6
28. Q/4=0.864 MGD	“ “	“ “	“ “	“ “	4	72	72	22	6	7
29. Q/2=1.728 MGD	“ “	“ “	“ “	“ “	7	58	59	22	8	6
30. 2*Q=6.912 MGD	“ “	“ “	“ “	“ “	28	56	57	23	20	3
Far-field model sensitivity to diffusion parameter:										
31. alpha=0.0001	Ketchikan 3 7/1997	UM3/FF	299	12" port	14	94	94	22	13	81
32. alpha=0.000453	“ “	“ “	“ “	“ “	14	396	398	22	13	81

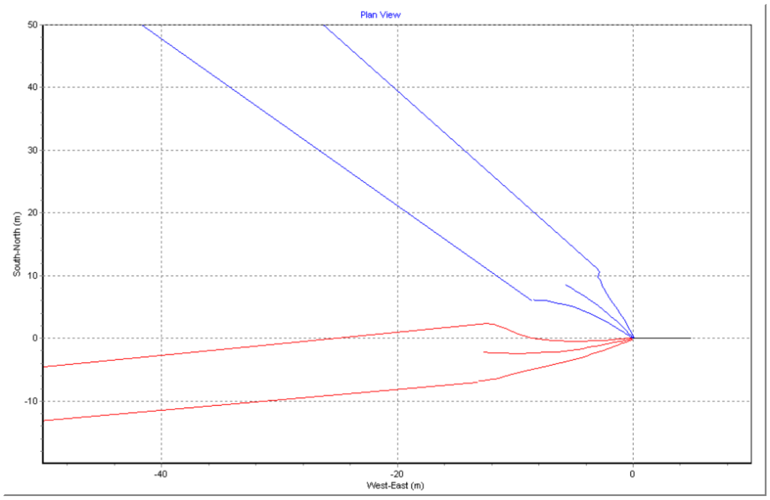

Figure 8. Ketchikan Discharge Plume Boundary Plan View from Above
(plume from 12-inch port is red; plume from five 6-inch ports is blue)

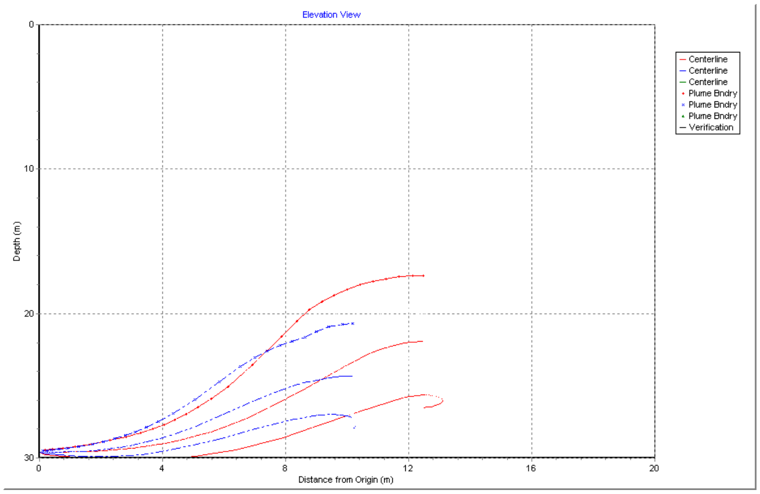

Figure 9. Ketchikan Discharge Plume Centerline and Boundary Profile View from Side

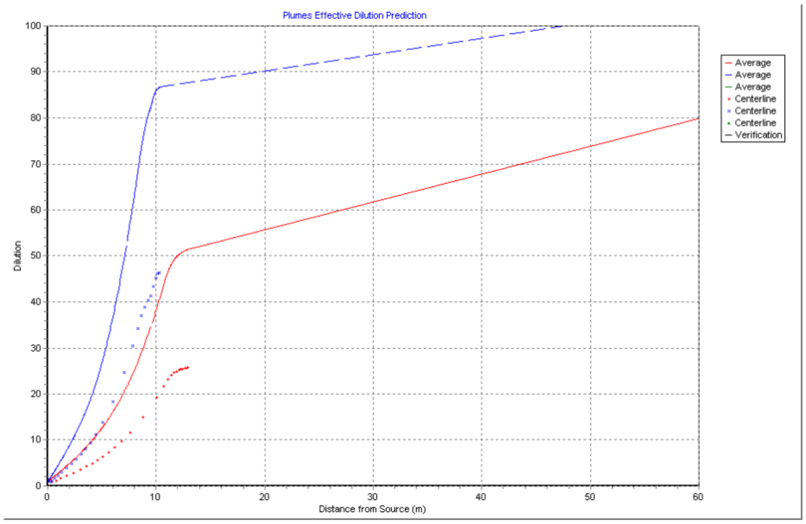

Figure 10. Ketchikan discharge plume average and centerline dilution vs. distance from outfall
Figure is based on graphic output by VP; DFs in far field (beyond 13 m for the 12-inch port) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity.

PETERSBURG

Wastewater treated at Petersburg is discharged 366 m offshore in Frederick Sound (Figure 11), from a two-port diffuser at a depth of 18.3 m (MLLW). The permitted maximum flow is 3.6 MGD. Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. The port spacing at Petersburg is uncertain (somewhere in the range of 10 to 34 ft.) due to only two of five diffuser ports being open. The models predicted lower DFs for the narrowest port spacing (10 ft.), so that spacing was used for all model simulations.

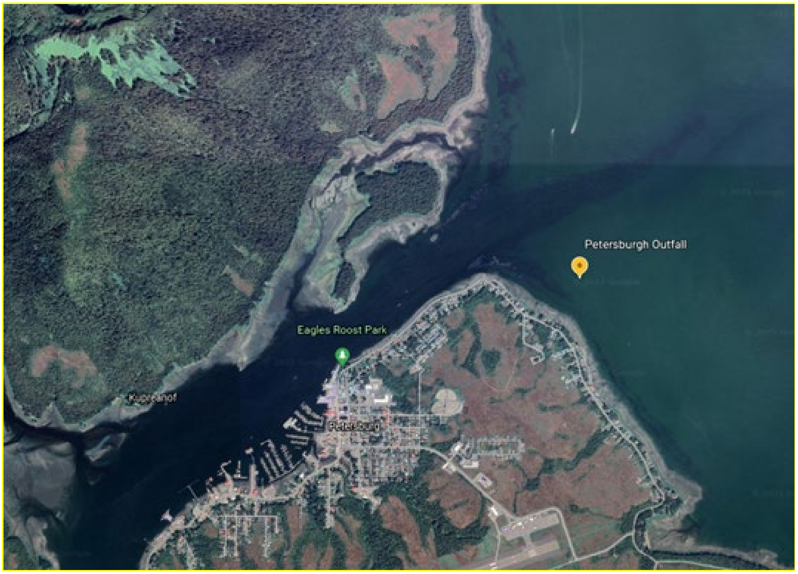

Figure 11. Aerial View of the POTW Outfall Location at Petersburg

Frederick Sound is connected to the Pacific Ocean via Chatham Strait to the northwest and Dry Strait/Sumner Strait to the southeast. According to the 1990 permit questionnaire, surface water densities near the outfall vary due to freshwater inputs from nearby streams. Maximum freshwater input to Frederick Sound occurs in summer (June or July) and minimum freshwater input occurs in March. The freshwater input is due primarily to the combined flows of the Stikine and Iskut Rivers. Currents generally flow northwestward in Frederick Sound with southwestward flows during large tides. NOAA tidal current predictions for nearby Cosmos Point (PCT3811) were used to calculate the 10th percentile current velocity used for modeling, 1.6 cm/s, and the average ebb and flood tidal velocities, 10.4 and 7.8 cm/s. According to the questionnaire, current velocities in the area are reportedly in the range of two to five knots (100 to 260 cm/s), 10 to 100 times larger than the velocities calculated from NOAA tidal current predictions and used for modeling. This discrepancy in the magnitude of ambient velocities could not be resolved given the information available, but may warrant further inquiry.

Preliminary initial dilution simulations made with UM3 for eight available ambient profiles sampled at two ZID boundary monitoring locations in January of 2002 and 2004, and August 2003 and 2005, determined that the August 2005 vertical profile from Site 1 (Figure 12) was limiting in terms of minimizing effluent dilution.

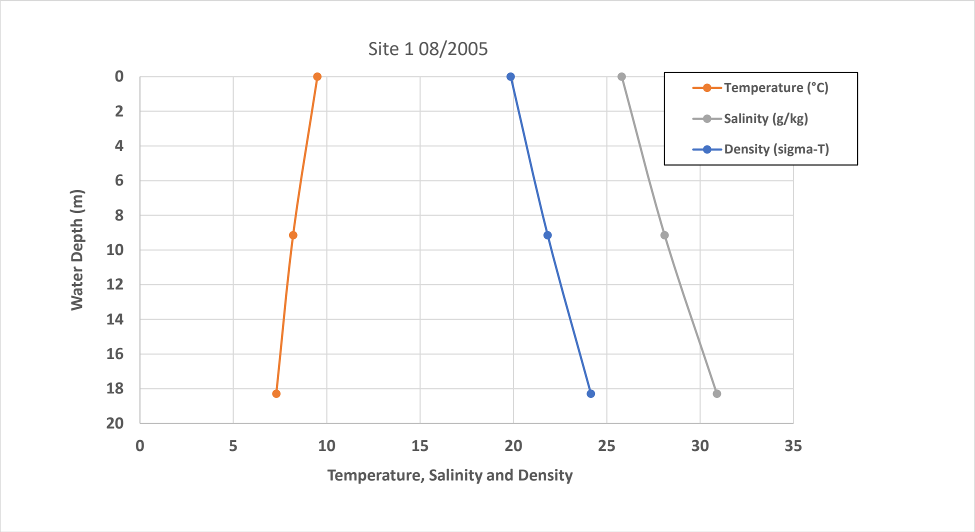

Figure 12. Vertical Ambient Profile of Temperature, Salinity and Density in Petersburg Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Petersburg are summarized in Table 5. The two applicable initial mixing models, UM3 and DKHW, gave very similar results for dilution at a distance of 1*depth (67 vs. 70). UM3 gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Petersburg. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Dilution factors at distances of 1*depth to 10*depth range from 67 to 647 (Table 5, simulations 11-14); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 13 (plan view from above of the discharge plume boundary), 14 (profile view from the side of the discharge plume centerline and boundary) and 15 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 5, the plume was trapped at a depth of 14 m by the ambient density stratification, the initial mixing region extended 23 m from the outfall, and the travel time to the mixing zone boundaries ranged from 1 minute (MZ=1*depth) to 167 minutes (MZ=10*depth). A dilution factor of 74 was predicted for the boundary of the initial mixing region and at the distance to the shore (366 m) the DF was 1720.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 5). DFs were moderately sensitive to variation in ambient velocity (DFs increase with velocity, simulations 17-19) and effluent flow rate (DFs decrease with Q, simulations 21-24). Sensitivity of the far-field model to bounding values of the diffusion parameter α (alpha) was also found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity.

Table 5. Petersburg Mixing Zone Dilution Modeling Results

Model simulation	**Ambient input**	**Model(s)**	**MZ distance (m)**	**Froude number**	**Dilution factor**	**Dilution factor w/ bacteria decay**	**Trapping depth (m)**	**Length of initial mixing region (m)**	**Travel time to MZ boundary (min)[14]**
1. MZ=1*depth	Petersburg 1 8/2005	UM3	18.3	114	67	67	15	>18.3	
2. " "	" "	DKHW	18.3	114	70	70	14	>18.3	
3. " "	Petersburg 1 8/2003	UM3	18.3	95	72	73	12	>18.3	
4. " "	Petersburg 1 1/2002	UM3	18.3	114	69	69	14	>18.3	
5. " "	Petersburg 2 1/2002	UM3	18.3	113	69	69	14	>18.3	
6. " "	Petersburg 1 1/2004	UM3	18.3	114	69	69	14	>18.3	
7. " "	Petersburg 2 1/2004	UM3	18.3	114	69	69	14	>18.3	
8. " "	Petersburg 2 8/2003	UM3	18.3	94	72	72	12	>18.3	
9. " "	Petersburg 2 8/2005	UM3	18.3	116	68	68	15	>18.3	
Dilution at different distances:									
10. MZ= initial mixing region	Petersburg 1 8/2005	UM3	23	115	**74**	75	14		1
11. MZ=1*depth	" "	UM3	18.3	115	**67**	67	15	>18.3	1
12. MZ=2*depth	" "	UM3/FF	36.6	115	**90**	90	14	23	15
13. MZ=5*depth	" "	UM3/FF	91.5	115	**256**	257	14	23	72
14. MZ=10*depth	" "	UM3/FF	183	115	**647**	650	14	23	167
15. MZ=distance to nearest shore	" "	UM3/FF	366	115	**1720**	1730	14	23	358

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[14] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[14]
Model sensitivity:									
16. avg. effluent T=13.2° C	Petersburg 1 8/2005	UM3	18.3	115	67	68	15	>18.3	
17. ½*current v=0.8 cm/s	“ “	UM3	18.3	115	66	66	15	>18.3	
18. 2*current v=3.2 cm/s	“ “	UM3	18.3	115	70	70	15	>18.3	
19. average current v=10.4 cm/s	“ “	UM3	18.3	115	80	81	16	>18.3	
20. reverse current direction=300°	“ “	UM3	18.3	115	66	66	15	>18.3	
21. average Q=0.43 MGD	“ “	UM3/FF	18.3	14	81	82	12	6	13
22. Q/4=0.9 MGD	“ “	UM3/FF	18.3	29	68	69	13	9	9
23. Q/2=1.8 MGD	“ “	UM3/FF	18.3	57	65	65	14	15	4
24. 2*Q=7.2 MGD	“ “	UM3	18.3	229	65	65	17	>18.3	
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Petersburg 1 8/2005	UM3/FF	183	114	202	203	14	23	167
26. alpha=0.000453	“ “	UM3/FF	183	114	1090	1091	14	23	167
27. Linear eddy diffusivity	“ “	UM3/FF	183	114	397	399	14	23	167

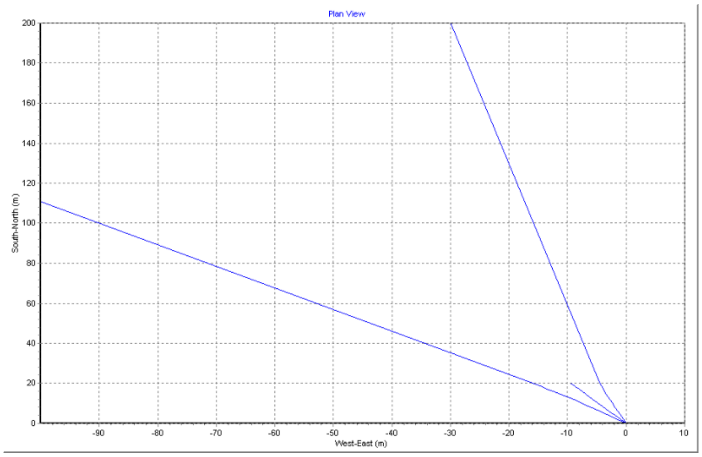

Figure 13. Petersburg Discharge Plume Boundary Plan View from Above

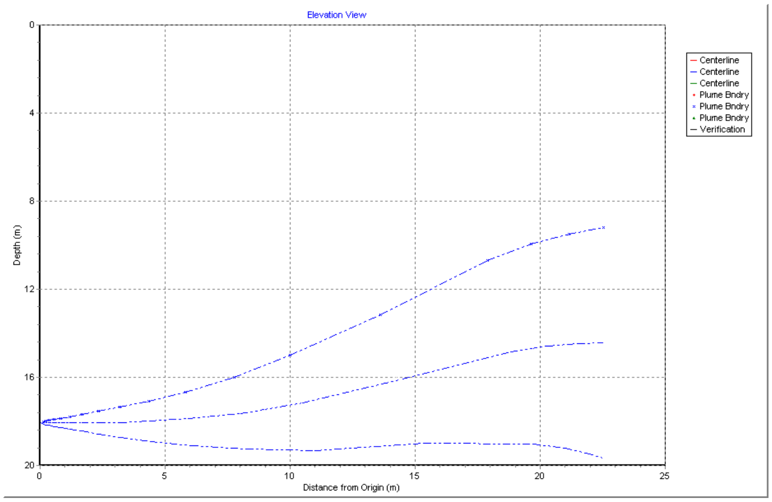

Figure 14. Petersburg Discharge Plume Centerline and Boundary Profile View from Side

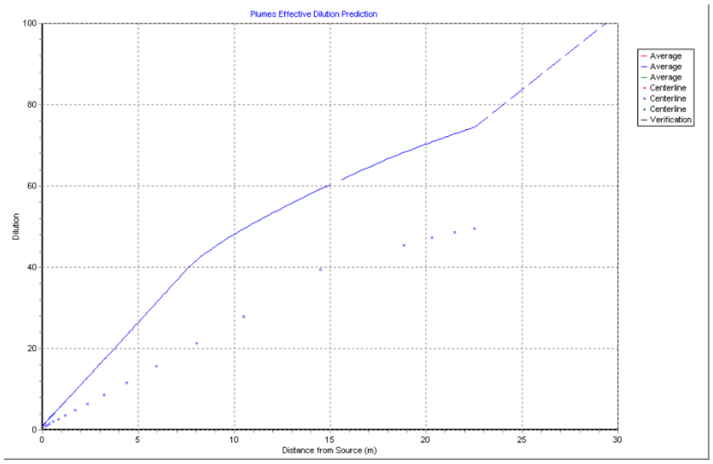

Figure 15. Petersburg Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

SITKA

The wastewater treated at Sitka is discharged 114 m offshore in the Middle Channel of Sitka Sound (Figure 16), from a 16-port diffuser at a depth of 24.4 m (MLLW). The permitted maximum flow is 5.3 MGD.

Figure 16. Aerial View of the POTW Outfall Location at Sitka

According to the permit fact sheet, the Middle Channel has relatively weak tidal currents, rotating in a clockwise pattern, which are superimposed on the seaward flow of fresh water in Sitka Sound. The net current is toward the southeast and included an easterly wind-driven component. The direction of transport of effluent from the outfall varies, depending upon the tidal stage and direction of prevailing winds. NOAA tidal current predictions for Sitka Harbor, Channel off Harbor Island (PCT4166) were used to calculate the 10th percentile current velocity used for modeling, 1.7 cm/s, and the average ebb and flood tidal velocities, 10.3 and 8.0 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Detailed vertical ambient profiles were only available for one location (Site C, a reference station west of the outfall) that was in sampled in the months of April and July in 2010 and 2015. Preliminary initial dilution simulations made with UM3 for these four available ambient profiles, determined that the July 2010 vertical profile from Site C (Figure 17) was limiting in terms of minimizing effluent dilution (Table 6, simulations 1, 2, 8 and 9).

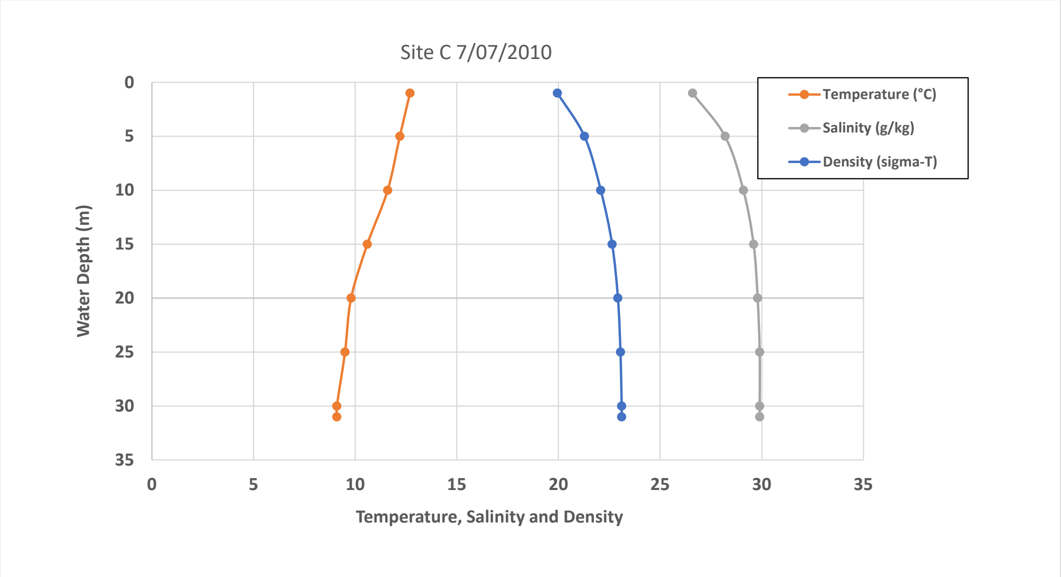

Figure 17. Vertical Ambient Profile of Temperature, Salinity and Density in Sitka Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Sitka are summarized in Table 6. The two initial mixing models, DKHW and UM3, combined with the Brooks far-field model gave similar results for dilution at a distance of 1*depth (sims. 2 and 5); simulation results for the downstream-only cross-diffuser merging approach and the third initial mixing model, NRFIELD, also fell within this range of DFs. DKHW gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Sitka.

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Sitka on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 6 (simulations 14 vs. 25 and 26).

Dilution factors at distances of 1*depth to 10*depth range from 87 to 227 (Table 6, simulations 11-14); accounting for bacterial decay had a negligible effect on dilution factors. It should be noted that the 5*depth and 10*depth distances (122 and 244 m) are greater than the distance from the diffuser to shore (114 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 18 (plan view from above of the discharge plume boundary), 19 (profile view from the side of the discharge plume centerline and boundary) and 20 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 6, the plume was trapped at a depth of 10 m by the ambient density stratification, the initial mixing region extended 6.9 m from the outfall, and the travel time to the mixing zone boundaries ranged from 17 minutes (MZ=1*depth) to 232 minutes (MZ=10*depth). A dilution factor of 86 was predicted for the boundary of the initial mixing region and at the distance to the shore (114 m) the DF was 138.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 6). DFs were moderately sensitive to variation in ambient velocity (DFs increase with velocity, simulations 17-19) and effluent flow rate (DFs decrease with Q, simulations 22-24).

Table 6. Sitka Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[15]
1. MZ=1*depth	Sitka C 7/2015	UM3(half spacing)/FF	24.4	11	131	133	9	7	17
2. “ “	Sitka C 7/2010	” “	24.4	12	118	119	12	6	18
3. “ “	Sitka C 7/2010	” “	16.0	12	113	114	12	6	10
4. “ “	Sitka C 7/2010	NRFIELD	16.0	12	89		10		
5. “ “	Sitka C 7/2010	DKHW(half spacing)/FF	24.4	12	87	87	10	7	17
6. “ “	“ “;	UM3(DS-only, 8 portsx5.3")/FF	24.4	11	109	110	11	7	17
7. “ “	“ “	DKHW(DS-only, 8 portsx5.3")/FF	24.4	11	90	90	10	8	16
8. “ “	Sitka C 4/2010	UM3(half-spacing)/FF	24.4	12	179	181	4	7	17
9. “ “	Sitka C 4/2015	” “	24.4	11	172	174	5	7	17
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:									
10. MZ= initial mixing region	Sitka C 7/2010	DKHW(half-spacing)	6.9	12	**86**	86			1
11. MZ=1*depth	“ “	DKHW(half-spacing)/FF-LED	24.4	12	**87**	87	10	7	17
12. MZ=2*depth	“ “	“ “	48.8	12	**97**	97	10	7	41
13. MZ=5*depth	“ “	“ “	122[16]	12	**143**	143	10	7	113
14. MZ=10*depth	“ “	“ “	244[16]	12	**227**	227	10	7	232

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[15] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

[16] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[15]
15. MZ=distance to nearest shore	“ “	“ “	114	12	**138**	138	10	7	105
Model sensitivity:									
16. avg. effluent T=14° C	Sitka C 7/2010	DKHW(half-spacing)/FF-LED	24.4	12	87	87	10	7	17
17. ½*current v=0.85 cm/s	“ “	“ “	“ “	12	79	79	9	7	35
18. 2*current v=3.4 cm/s	“ “	“ “	“ “	12	119	119	11	9	8
19. average current v=10.3cm/s	“ “	“ “	“ “	12	187	187	15	22	0.5
20. reverse current direction=45°	“ “	“ “	“ “	12	87	87	10	7	17
21. current dir +30°	“ “	“ “	“ “	12	131	131	12	7	17
22. average Q=0.98 MGD	“ “	“ “	“ “	2	208	208	15	4	20
23. Q/2=2.65 MGD	“ “	“ “	“ “	6	121	121	12	5	19
24. 2*Q=10.6 MGD	“ “	“ “	“ “	23	66	66	8	12	12
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Sitka C 7/2010	DKHW(half-spacing)/FF	244	12	126	126	10	7	233
26. alpha=0.000453	“ “	“ “	“ “	12	426	426	10	7	233

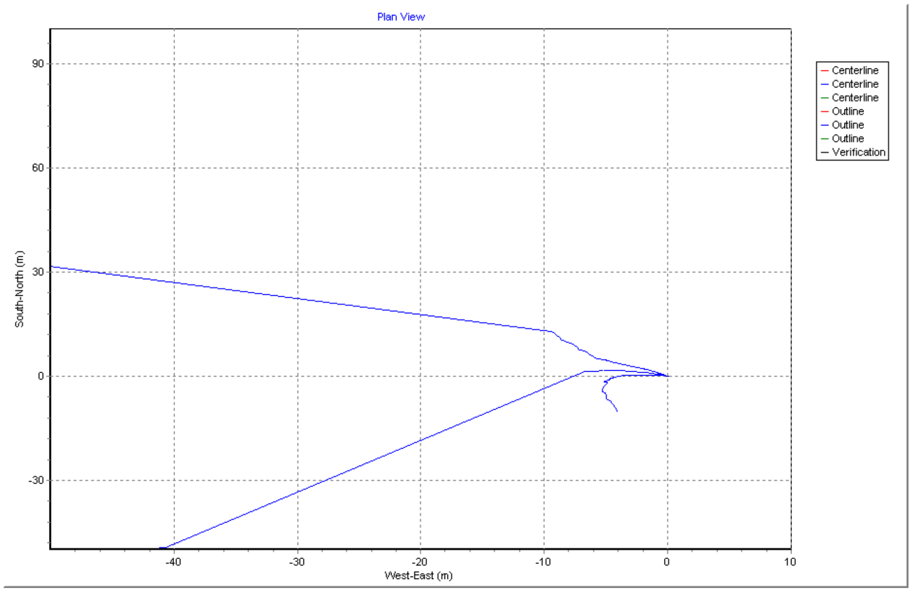

Figure 18. Sitka Discharge Plume Boundary Plan View from Above

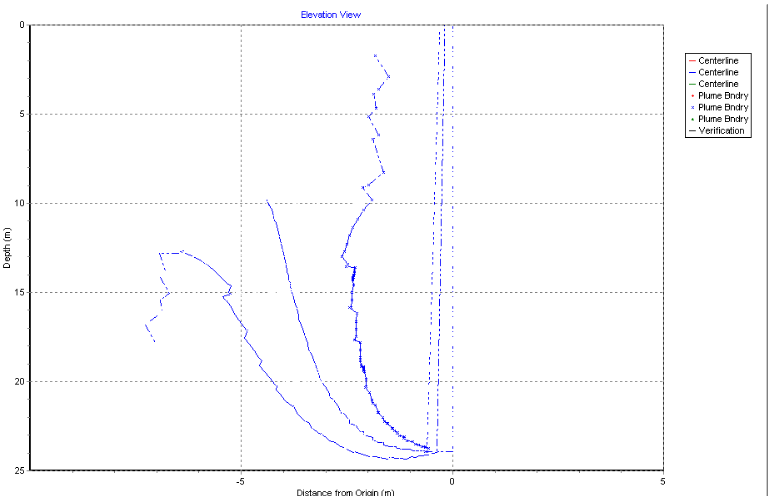

Figure 19. Sitka Discharge Plume Centerline and Boundary Profile View from Side

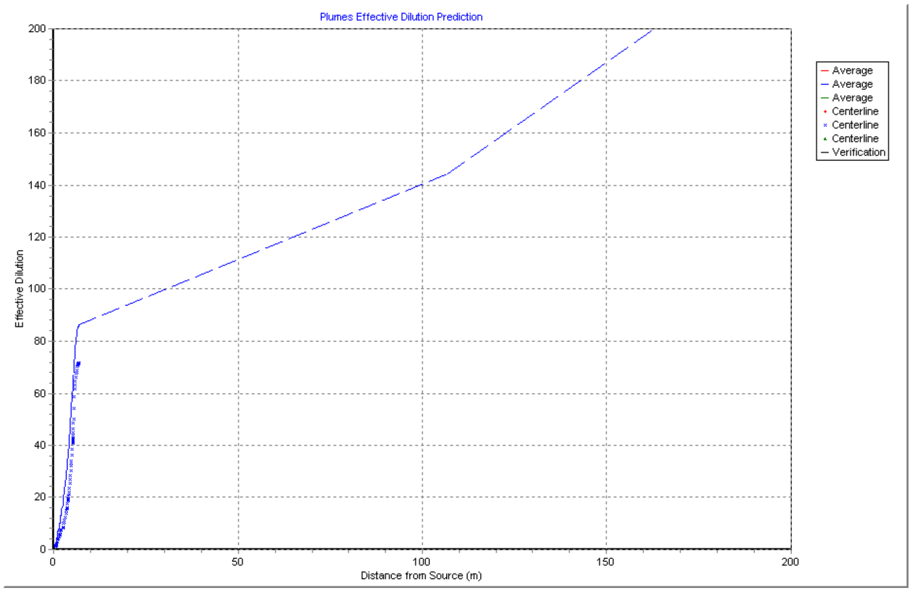

Figure 20. Sitka Discharge Plume Average and Centerline Dilution vs. Distance from Outfall (Figure is based on graphic output by VP; DFs in far field (beyond 7 m) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity).

SKAGWAY

Wastewater treated at Skagway is discharged 125 m offshore in Tiaya Inlet (Figure 21), at a depth of 18.3 m (MLLW), from an 8-port diffuser. The permitted maximum flow rate is 0.63 MGD.

Figure 21. Aerial View of the POTW Outfall Location at Skagway

According to the permit fact sheet, Taiya Inlet is a deep fjord with a 457 m average depth. Taiya Inlet supports a classic fjord-type, two-layer circulation, with a large saline lower layer and a very thin upper brackish layer. The circulation of the inlet is dependent on tides and freshwater flow into the inlet. There are no obstructions to impede circulation near the outfall. Stratification in Taiya Inlet is dependent on freshwater inflows from the Taiya and Skagway Rivers with the highest stratification typically occurs during the high runoff summer period from June through August. As noted in the 2007 permit reapplication, a small cross-current (2 cm/s) was present under stratified condition in a June 1999 temperature/salinity data set.

NOAA 6-minute tidal current predictions from Tiaya Inlet (SEA0825) were used to calculate the 10th percentile and average tidal current velocities (Table 2). The 10th percentile current velocity used for modeling was 1.4 cm/s, while the average ebb and flood tidal velocities were 6.9 and 12.2 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Vertical profiles of temperature and salinity measured in Tiaya Inlet were available for five locations that were sampled in October 2002, July and August 2004 and June 2005. Preliminary initial dilution simulations made with UM3 for all available profiles, determined that the June 2005 vertical profile measured at site 1 (shown in Figure 22) was limiting in terms of minimizing effluent dilution[17]. That profile was used for all subsequent dilution modeling at Skagway.

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[17] A different vertical profile measured in June 2005 at site 5 (a site in the cruise ship terminal harbor nearest to freshwater inflow from the Skagway River) actually produced smaller DF predictions. However, the unusually low

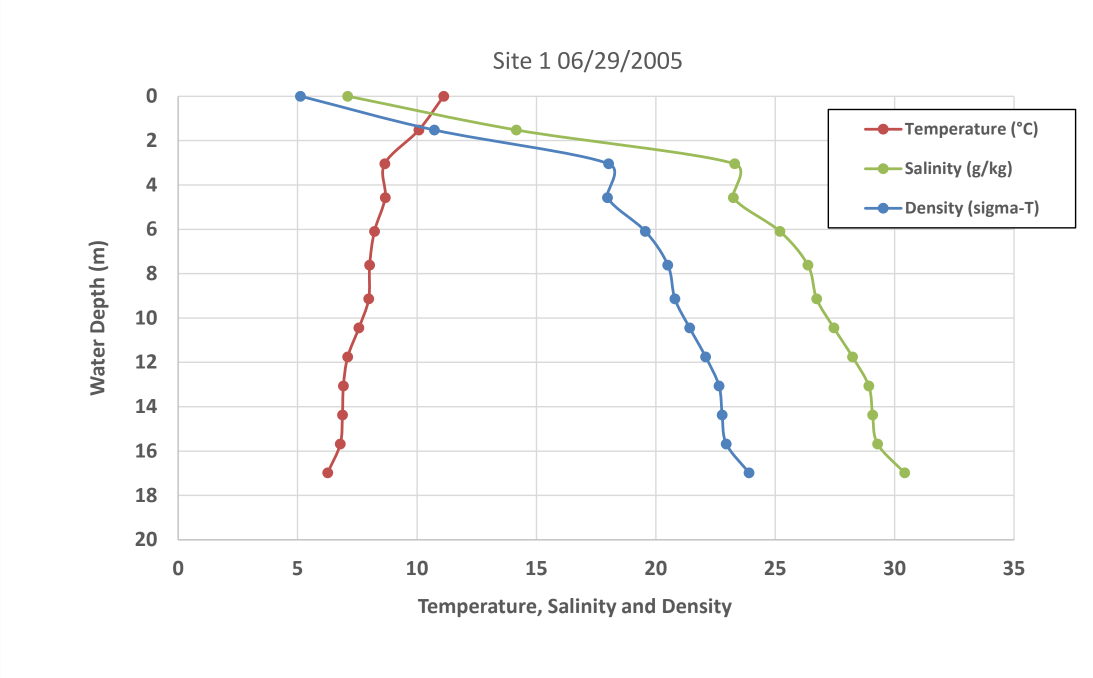

Figure 22. Vertical Ambient Profile of Temperature, Salinity and Density in Skagway Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Skagway are summarized in Table 7. Two of the applicable initial mixing models, UM3 and DKHW, gave similar results for dilution at a distance of 1*depth, for both cross-diffuser merging approaches (simulations 11-13). UM3 gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Skagway. We also applied the third initial mixing model, NRFIELD, that predicted DFs reasonably comparable to UM3 (simulations 14 vs. 15) at a distance shorter than 1*depth (5.9 m).

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Skagway on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 7 (simulations 23 vs. 33 and 34).

Dilution factors at distances of 1*depth to 10*depth range from 56 to 330 (Table 7, simulations 20-23); accounting for bacterial decay had a negligible effect on dilution factors. It should be noted that the 10*depth distance (183 m) is greater than the distance from the diffuser to shore (125 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 23 (plan view from above of the discharge plume boundary), 24

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salinity of the upper 3-4 m of that profile led to difficulties in modeling dilution over the range of parameters and conditions of interest, so the site 1 June 2005 profile (that was the next most conservative in terms of limiting DFs) was used instead.

(profile view from the side of the discharge plume centerline and boundary) and 25 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 7, the plume was trapped at a depth of 15 m by the ambient density stratification, the initial mixing region extended 3.5 m from the outfall, and the travel time to the mixing zone boundaries ranged from 18 minutes (MZ=1*depth) to 214 minutes (MZ=10*depth). A dilution factor of 42 was predicted for the boundary of the initial mixing region and at the distance to the shore (125 m) the DF was 233.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 25-32 (Table 7). DFs were moderately sensitive to variation in ambient velocity (minimum DFs at velocities near 2 cm/s, simulations 26-28) and effluent flow rate (DFs decrease with Q, simulations 30-32).

Table 7. Skagway Mixing Zone Dilution Modeling Results

Model simulation	**Ambient input**	**Model(s)**	**MZ distance (m)**	**Froude number**	**Dilution factor**	**Dilution factor w/ bacteria decay**	**Trapping depth (m)**	**Length of initial mixing region (m)**	**Travel time to MZ boundary (min)**
1. MZ=1*depth	Skagway site 1 10/02	UM3 (half spacing) /FF	18.3	10	129	130	9	4	17
2. " "	Skagway site 2 10/02	" "	18.3	10	145	147	7	5	16
3. " "	Skagway site 4 10/02	" "	18.3	10	127	128	9	4	17
4. " "	Skagway site 1 7/2004	" "	18.3	10	94	95	12	4	18
5. " "	Skagway site 2 7/2004	" "	18.3	10	97	97	12	4	17
6. " "	Skagway site 4 7/2004	" "	18.3	10	79	79	13	4	17
7. " "	Skagway site 1 8/2004	" "	18.3	10	130	131	9	4	17
8. " "	Skagway site 2 8/2004	" "	18.3	10	113	114	10	4	17
9. " "	Skagway site 4 8/2004	" "	18.3	10	82	83	13	4	17
10. " "	Skagway site 1 6/2005	" "	18.3	10	59	59	15	3	18
11. " "	" "	UM3(DS-only, 4x3.95")/FF	18.3	10	59	59	14	5	16
12. " "	" "	DKHW(half spacing)/FF	18.3	10	62	63	16	3	18
13. " "	" "	DKHW(DS-only, 4x3.95")/FF	18.3	10	66	66	15	4	17
14. " "	" "	NRFIELD	5.9	10	39		14		
15. " "	" "	UM3(half spacing) /FF	5.9	10	42	42	15	3	3
16. " "	Skagway site 2 6/2005	" "	18.3	10	80	80	13	4	17
17. " "	Skagway site 4 6/2005	" "	18.3	10	100	100	12	4	17
18. " "	Skagway site 5 6/2005	" "	18.3	9	39	39	16	2	19
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:									
19. MZ= initial mixing region	Skagway site 1 6/2005	UM3(half spacing)	3.5	10	**42**	42	15		0.7

Model simulation	**Ambient input**	**Model(s)**	**MZ distance (m)**	**Froude number**	**Dilution factor**	**Dilution factor w/ bacteria decay**	**Trapping depth (m)**	**Length of initial mixing region (m)**	**Travel time to MZ boundary (min)**
20. MZ=1*depth	“ “	UM3(half spacing) /FF-LED	18.3	10	**56**	56	15	3	18
21. MZ=2*depth	“ “	“ “	36.6	10	**86**	86	15	3	39
22. MZ=5*depth	“ “	“ “	91.5	10	**177**	178	15	3	105
23. MZ=10*depth	“ “	“ “	183[18]	10	**330**	331	15	3	214
24. MZ=distance to nearest shore	“ “	“ “	125	10	**233**	234	15	3	145
Model sensitivity:									
25. avg. effluent T=14.7° C	Skagway site 1 6/2005	UM3(half spacing) /FF-LED	18.3	10	56	56	15	3	18
26. ½*current v=0.7 cm/s	“ “	“ “	“ “	10	76	76	15	3	36
27. 2*current v=2.8 cm/s	“ “	“ “	“ “	10	52	52	15	4	9
28. average current v=12.2 cm/s	“ “	“ “	“ “	10	101	101	17	6	2
29. reverse current direction=170°	“ “	“ “	“ “	10	56	56	14	5	19
30. average Q=0.27 MGD				4	73	73	15	2	19
31. Q=0.5 MGD	“ “	“ “	“ “	8	60	60	15	3	18

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[18] Distance is greater than the distance from the diffuser to shore.

Model simulation	**Ambient input**	**Model(s)**	**MZ distance (m)**	**Froude number**	**Dilution factor**	**Dilution factor w/ bacteria decay**	**Trapping depth (m)**	**Length of initial mixing region (m)**	**Travel time to MZ boundary (min)**
32. 2*Q=1.26 MGD	“ “	“ “	“ “	20	49	49	15	5	16
Far-field model sensitivity to diffusion parameter:									
33. alpha=0.0001	Skagway site 1 6/2005	UM3(half spacing) /FF	183	10	173	174	15	3	214
34. alpha=0.000453	“ “	“ “	183	10	1100	1103	15	3	214

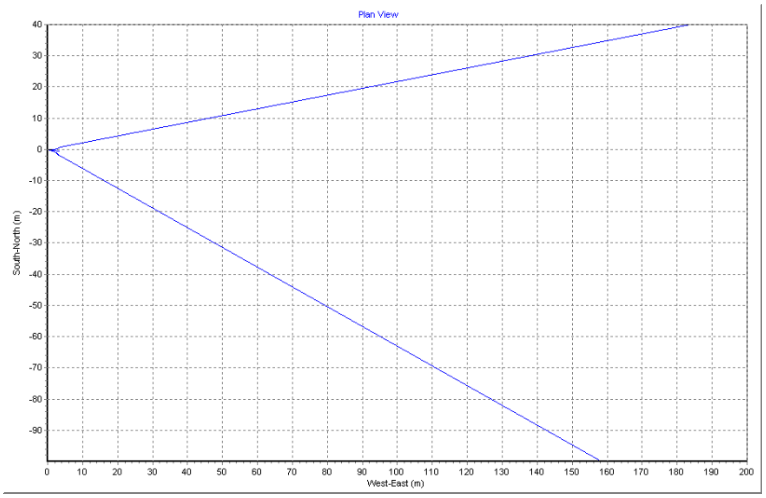

Figure 23. Skagway Discharge Plume Boundary Plan View from Above

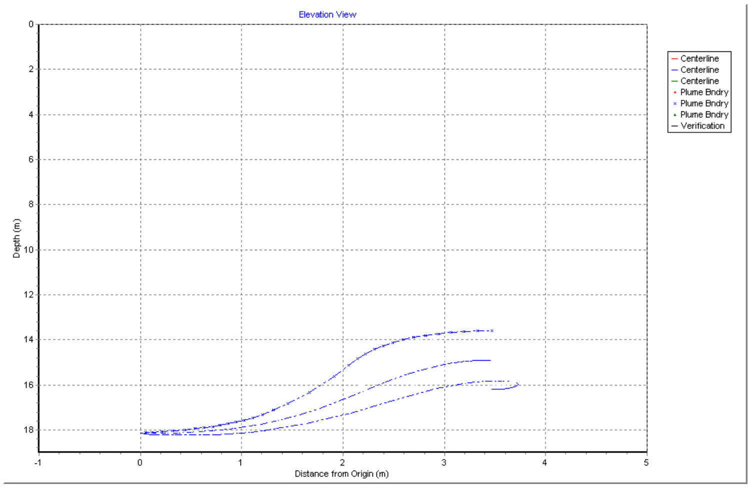

Figure 24. Skagway Discharge Plume Centerline and Boundary Profile View from Side

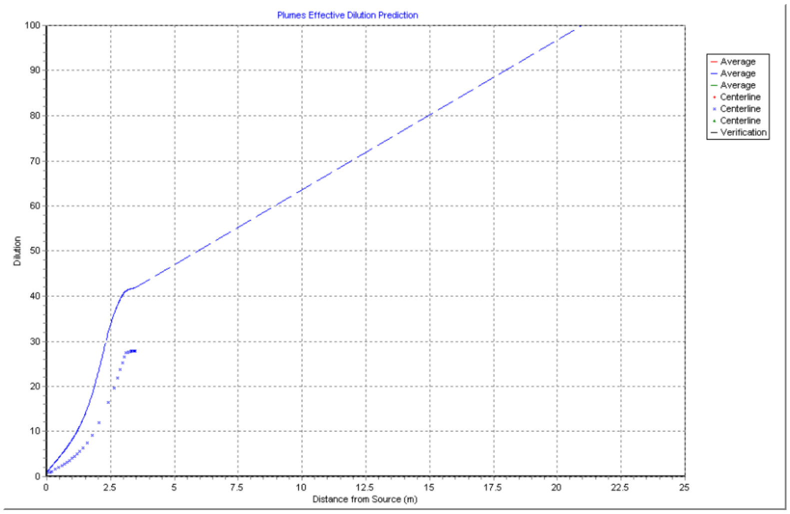

Figure 25. Skagway Discharge Plume Average and Centerline Dilution vs. Distance from Outfall (Figure is based on graphic output by VP; DFs in far field (beyond 3 m) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity)

WRANGELL

The wastewater treated at Wrangell is discharged 457 m offshore in the Zimovia Strait (Figure 26), at a depth of 30.5 m (MLLW), from a 16-port diffuser. The permitted maximum flow rate is 3.0 MGD.

Figure 26. Aerial View of the POTW Outfall Location at Wrangell

According to the permit fact sheet, Zimovia Strait has a net northwest seaward exchange with the Gulf of Alaska. The maximum current velocity is around 51.4 cm/sec (1.0 knot) and the water circulation patterns do not vary seasonally. Strong currents provide vertical mixing, minimize the vertical density gradient, and prevent stratification. Also, according to the permit fact sheet, prior dilution modeling in Zimovia Strait used a conservative current speed of 2.35 cm/sec and no stratification. NOAA tidal current predictions for Wrangell Harbor (PCT3131) were used to calculate the 10th percentile current velocity used for modeling, 4.0 cm/s, and the average ebb and flood tidal velocities, 20.8 and 23.5 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Vertical profiles of temperature and salinity measured in Zimovia strait at the ZID boundaries were available for two mixing zone locations that were sampled in August of 2015, 2016 and 2017. Preliminary initial dilution simulations made with UM3 for all profiles, determined that the vertical profile measured at station 4 in August of 2016 (shown in Figure 27) was limiting in terms of minimizing effluent dilution. That profile was used for all subsequent dilution modeling at Wrangell.

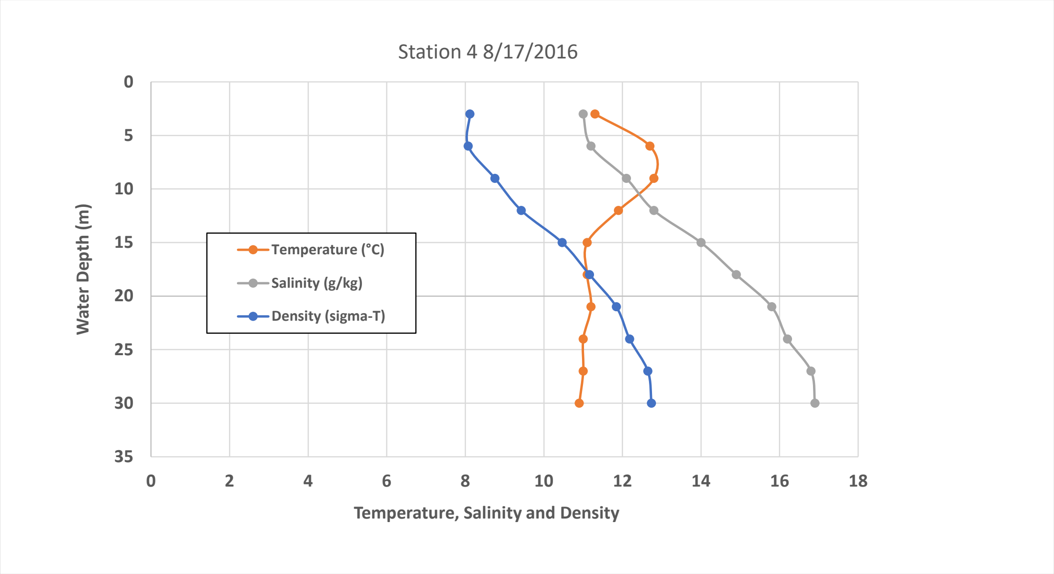

Figure 27. Vertical Ambient Profile of Temperature, Salinity and Density in Wrangell Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Wrangell are summarized in Table 8. Two of the applicable initial mixing models, UM and DKHW, gave different results for dilution at a distance of 1*depth (30.5 m; simulations 3 vs. 4). The third initial mixing model, NRFIELD, predicted a lower DF at a distance shorter than 1*depth (16.8 m; simulations 5 vs. 6). UM3 gave more conservative DF results (simulation 7) when run using the downstream-only cross-diffuser merging, so we selected this approach for further analysis at Wrangell. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Sensitivity of the far-field model to bounding values of the diffusion parameter α was found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity.

Dilution factors at distances of 1*depth to 10*depth range from 112 to 229 (Table 8, simulations 10-13); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 28 (plan view from above of the discharge plume boundary), 29 (profile view from the side of the discharge plume centerline and boundary) and 30 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 8, the plume was trapped at a depth of 24 m by the ambient density stratification, the initial mixing region extended 12 m from the outfall, and the travel time to the mixing zone boundaries ranged from 8 minutes (MZ=1*depth) to 122 minutes (MZ=10*depth). A dilution factor of 112 was predicted for the boundary of the initial mixing region and at the distance to the shore (457 m) the DF was 323.

The initial mixing model was moderately sensitive to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 8). DFs were sensitive to variation in ambient velocity (dilution increasing with velocity, simulations 17-19) and effluent flow rate (dilution decreases with Q, simulations 21-24).

Table 8. Wrangell Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[19]
1. MZ=1*depth	Wrangell station 4 8/2015	UM3(half spacing)/FF	30.5	34	262	274	23	15	7
2. “ “	Wrangell station 3 8/2016	“ “	“ “	33	232	243	23	13	8
3. “ “	Wrangell station 4 8/2016	“ “	“ “	32	153	160	25	10	8
4. “ “	“ “	DKHW(half spacing)/FF	“ “	32	228	228	26	11	8
5. “ “	“ “	UM3 (half spacing)/FF	16.8	32	153	157	25	10	3
6. “ “	“ “	NRFIELD	16.8	33	75		25		
7. “ “	“ “	UM3(DS-only, 8x3.95")/FF	30.5	33	112	117	24	12	8
8. “ “	Wrangell station 3 8/2017	UM3(half-spacing)/FF	“ “	39	494	516	17	25	2
9. “ “	Wrangell station 4 8/2017	“ “	“ “	40	743	791	6	21	4
Dilution at different distances:									
10. MZ= initial mixing region	Wrangell station 4 8/2016	UM3 (DS-only, 8x3.95")	12	33	**112**	113	24		2
11. MZ=1*depth	“ “	UM3(DS-only, 8x3.95")/FF	30.5	33	**112**	113	24	12	8
12. MZ=2*depth	“ “	“ “	61	33	**115**	115	24	12	20
13. MZ=5*depth	“ “	“ “	152.5	33	**149**	149	24	12	59
14. MZ=10*depth	“ “	“ “	305	33	**229**	230	24	12	122

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[19] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[19]
15. MZ=distance to nearest shore	" "	" "	457	33	**323**	325	24	12	185
Model sensitivity:									
16. avg. effluent T=17.3° C	Wrangell station 4 8/2016	UM3(DS-only, 8x3.95")/FF	30.5	33	112	112	24	12	8
17. ½*current v=2 cm/s	" "	" "	" "	33	86	86	24	11	16
18. 2*current v=8 cm/s	" "	" "	" "	33	198	199	25	15	3
19. ave. current v=23.5 cm/s	" "	UM3 (DS-only, 8x3.95")	" "	33	412	412	27	31	2
20. reverse current direction=270°	" "	UM3(DS-only, 8x3.95")/FF	" "	33	112	113	24	12	8
21. ave. Q=0.36 MGD	" "	" "	" "	3.9	243	244	26	5	11
22. Q/4=0.75 MGD	" "	" "	" "	8.1	161	161	25	6	10
23. Q/2=1.5 MGD	" "	" "	" "	16	125	126	25	8	9
24. 2*Q=6.0 MGD	" "	" "	" "	65	119	120	25	18	5
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Wrangell station 4 8/2016	UM3(DS-only, 8x3.95")/FF	305	33	130	131	24	12	122
26. alpha=0.000453	" "	" "	" "	33	321	323	24	12	122
27. Linear eddy diffusivity	" "	" "	" "	33	203	204	24	12	122

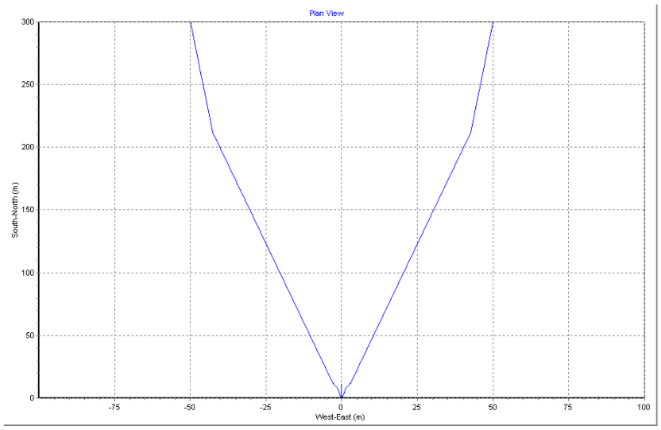

Figure 28. Wrangell Discharge Plume Boundary Plan View from Above

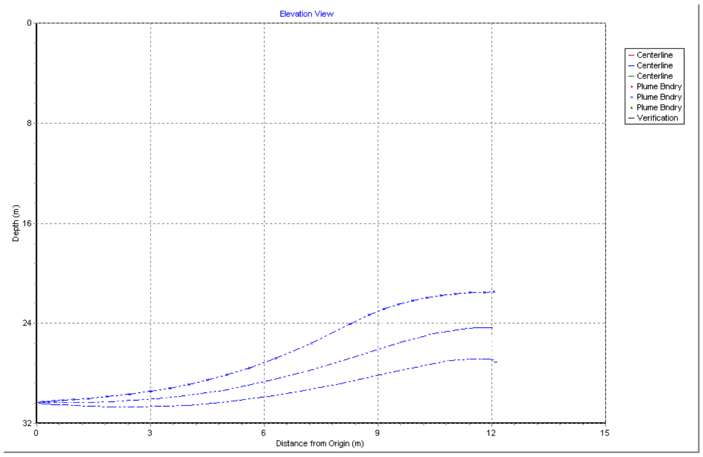

Figure 29. Wrangell Discharge Plume Centerline and Boundary Profile View from Side

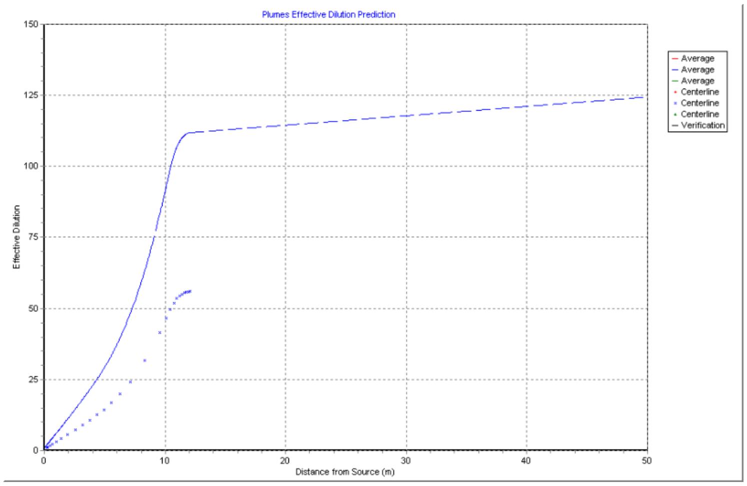

Figure 30. Wrangell Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

SUMMARY

A summary of the average dilution predictions at various distances (corresponding to 1-10 times the depth of discharge) from the discharge point at each Alaskan mixing zone location is presented in Table 9. As indicated in this table, some of the distances exceed the distance from the outfall to the nearest shore. Under some conditions the tidal currents could direct the discharge plume towards the shore and, upon reaching this boundary, further mixing would likely not occur. The distance from the outfall to nearest shore at each location and the predicted DFs and travel times for these distances are presented in Table 10. The dilution predictions are also graphed as a function of distance from the outfall (Figure 31). In this figure, DFs for Ketchikan, Sitka and Skagway have been truncated at the distance to shore.

Table 9. Average Dilution Factor Predictions at Distances from the Discharge Point Corresponding to 1-10 Times the Depth of Discharge

Location	1*depth			2*depth			5*depth			10*depth		
	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)
Haines	21.3	100	4	43	136	19	107	330	65	213	766	143
Ketchikan	29.9	52	5	60	62	13	150	105	39	299*	179	81
Petersburg	18.3	67	1	37	90	15	92	256	72	183	647	167
Sitka	24.4	87	17	49	97	41	122*	143	113	244*	227	232
Skagway	18.3	56	18	37	86	39	92	177	105	183*	330	214
Wrangell	30.5	112	8	61	115	20	153	149	59	305	229	122

* Distance greater than the distance from the outfall to shore.

Table 10. Average Dilution Factor Predictions at the Distance from the Outfall to Shore

Location	Distance from outfall to shore (m)	DF at distance from outfall to shore	Travel time to shore (min)
Haines	549	2770	386
Ketchikan	221	141	59
Petersburg	366	1720	358
Sitka	114	138	105
Skagway	125	233	145
Wrangell	457	323	185

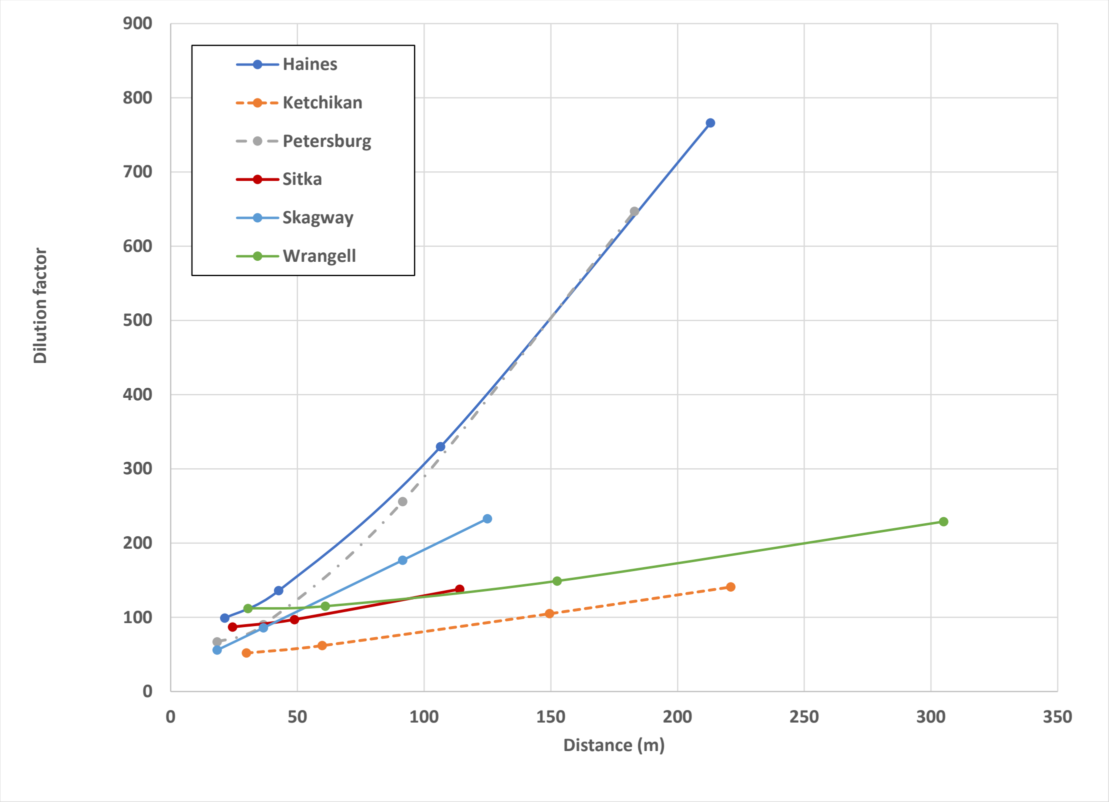

Figure 31. DF Predictions Graphed as a Function of Distance from the Outfall
(predictions are DFs for distances corresponding to 1-10 times the depth of discharge; in the cases of Ketchikan, Sitka and Skagway, DFs have been truncated at the distances to the shore)

A summary of the dilution factors predicted at the initial mixing region boundaries is presented in Table 11. For each location this table includes the distance to this boundary, the predicted DF and the travel times to the boundary. Compared to the depth-based distances in Table 9, the initial mixing region boundary distances are quite short, although the DFs at a distance of 1*depth are comparable (within 25%) of the initial mixing region dilution factors.

Table 11. Dilution Factor Predictions at Distances Equal to Initial Mixing Region Boundaries

Location	Initial Mixing Region Boundary (m)	DF	Travel Time to Boundary (min)
Haines	16	99	1
Ketchikan	13	51	1
Petersburg	23	74	1
Sitka	6.9	86	1
Skagway	3.5	42	0.7
Wrangell	12	112	2

The far-field model was also used to calculate the distances required to attain the FC criteria (i.e., the DFs in Table 1). These distances, presented in Table 11, range from 3.4 to 135 km to attain the 43/100 mL FC criterion and 7.2 to 420 km to attain the 14/100 mL FC criterion. These distances greatly exceed the mixing zone sizes certified by the state in the current wastewater discharge permits for the six POTW facilities.

Table 12. Dilution Factors and Mixing Zone Distances Required to Attain FC Criteria

Location	DF required to attain the 43/100 mL FC criterion	Distance to attain the 43/100 mL FC criterion (km)	DF required to attain the 14/100 mL FC criterion	Distance to attain the 14/100 mL FC criterion (km)
Haines	50,000	4.0	150,000	8.3
Ketchikan	67,000	135	210,000	420
Petersburg	47,000	3.4	140,000	7.2
Sitka	87,000	126	270,000	390
Skagway	60,000	36	190,000	114
Wrangell	4,400	3.9	14,000	8.9

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Frick, W. and P.J.W. Roberts. 2019. Visual Plumes (Plumes20.exe) October 2019 Update, the UM3 plume-water surface reflection approximation and mixing zone endpoints (https://ftp.waterboards.ca.gov/Surface%20reflection%20tech.docx).

MixZone Inc. 2020. CorHyd Internal Diffuser Hydraulics Model User Manual. December 15, 2020.

Reese, C., George, K. and Gerry Brown. 2021. Mixing zones 101 (PowerPoint presentation). Alaska Department of Environmental Conservation (https://dec.alaska.gov/media/16267/mixing-zones.pdf, accessed April 21, 2021).

Washington Department of Ecology (DoE). 2018. Permit Writer's Manual (Revised January 2015/ Updated September 2018). Publication no. 92-109 Part 1. Appendix C. Water Quality Program, Washington State Department of Ecology. Olympia, Washington (https://fortress.wa.gov/ecy/publications/SummaryPages/92109part1.html).

APPENDIX: VP AND FARFIELD[20] OUTPUT FOR EACH LOCATION

Haines (model output for 1*depth, 2*depth, 5*depth and 10*depth)

```
Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Haines" memo4

Model configuration items checked: Brooks far-field solution;
  Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
 Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
 Bacteria model  : Mancini (1978) coliform model
 PDS sfc. model heat transfer : Medium
 Equation of State : S, T
 Similarity Profile : Default profile (k=2.0, ...)
 Diffuser port contraction coefficient 0.61
 Light absorption coefficient 0.16
 Farfield increment (m) 200
 UM3 aspiration coefficient 0.1
  Output file: text output tab
  Output each ?? steps 100
  Maximum dilution reported 100000
 Text output format : Standard
 Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:19:37 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: --------------
--------------------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m       m/s       deg       psu        C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0   0.023     90.00   7.100     11.12       0.0  0.000192     0.023     90.00    0.0003  5.180276
   1.523     0.023     90.00     14.16     10.08       0.0  0.000194     0.023     90.00    0.0003  10.78304
   3.047     0.023     90.00     23.30     8.650       0.0  0.000193     0.023     90.00    0.0003  18.06627
   4.570     0.023     90.00     23.25     8.670       0.0  0.000193     0.023     90.00    0.0003  18.02474
   6.090     0.023     90.00     25.20     8.220       0.0  0.000193     0.023     90.00    0.0003  19.60292
   7.617     0.023     90.00     26.37     8.020       0.0  0.000193     0.023     90.00    0.0003  20.54204
   9.140     0.023     90.00     26.74     7.980       0.0  0.000193     0.023     90.00    0.0003  20.83621
   10.45     0.023     90.00     27.46     7.570       0.0  0.000193     0.023     90.00    0.0003  21.45192
   11.75     0.023     90.00     28.24     7.100       0.0  0.000193     0.023     90.00    0.0003  22.12180
   13.06     0.023     90.00     28.92     6.920       0.0  0.000193     0.023     90.00    0.0003  22.67724
   14.37     0.023     90.00     29.08     6.880       0.0  0.000192     0.023     90.00    0.0003  22.80770
   15.68     0.023     90.00     29.29     6.790       0.0  0.000192     0.023     90.00    0.0003  22.98359
   16.98     0.023     90.00     30.42     6.260       0.0  0.000192     0.023     90.00    0.0003  23.93584
```

---

[20] If required.

```
    22.00    0.023    90.00    34.78    4.213      0.0  0.000192    0.023    90.00    0.0003  27.61629

Diffuser table:
  P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)  (deg)  (deg)    (m)     (m)     ()   (ft)    (m)(concent)    (m)  (MGD)  (psu)    (C)(col/dl)
  3.0000    0.0  90.000    0.0     0.0  2.0000  15.000  21.300  200.00  21.100  2.9000    0.0  15.800
2.13E+6

Simulation:
Froude No:     178.8; Strat No: 2.20E-3; Spcg No:   76.82; k:   992.9; eff den (sigmaT) -0.960860; eff vel
22.84(m/s);
       Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn   Iso dia
Step     (m)  (cm/s)    (in) (col/dl)      ()      (m)      (m)      (m)
  0    21.10   2.300    2.343 2.130E+6    1.000      0.0      0.0      0.0;  10.68 T-90hr,
 100    21.10    2.300    23.86 208749.0    10.20    0.000    1.346    0.6058;  10.68 T-90hr,
 160    21.03    2.300    77.28  63725.7    33.42    0.000    4.775    1.9614; bottom hit;  10.65 T-90hr,
 200    20.49    2.300    166.7  28847.1    73.76    0.000    10.62    4.2261;  10.42 T-90hr,
 204    20.37    2.300    179.9  26645.8    79.84    0.000    11.48    4.5599; trap level;  10.37 T-90hr,
 205    20.34    2.300    183.3  26122.1    81.44    0.000    11.71    4.6475; merging;  10.36 T-90hr,
 232    19.97    2.300    305.7  21392.8    99.34    0.000    16.27    7.7425; local maximum rise or fall;
10.20 T-90hr,
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):   16.274
Lmz(m):   16.274
forced entrain      1   1.873    1.132    7.764    1.000
Rate sec-1   0.00019515 dy-1       16.8607  kt:  0.000062421 Amb Sal       33.0175
Const Eddy Diffusivity.  Farfield dispersion based on wastefield width of      12.34 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 21392.8   99.34   12.34   16.27 2.78E-4     0.0   16.27    2.300    90.00 3.00E-4 6.2421E-5
 20539.8   99.48   14.21   21.30   0.061      0.0   16.27    2.300    90.00 3.00E-4 6.2421E-5
 18354.2   113.1   20.80   37.57   0.258      0.0   16.27    2.300    90.00 3.00E-4 6.2421E-5
count: 1
 ;
5:19:40 AM. amb fills: 4
/ UM3. 6/23/2021 5:20:06 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: --------------
--------------------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
        m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
      0.0    0.023    90.00    7.100    11.12      0.0  0.000194    0.023    90.00    0.0003  5.180276
    1.523    0.023    90.00    14.16    10.08      0.0  0.000198    0.023    90.00    0.0003  10.78304
    3.047    0.023    90.00    23.30    8.650      0.0  0.000197    0.023    90.00    0.0003  18.06627
    4.570    0.023    90.00    23.25    8.670      0.0  0.000196    0.023    90.00    0.0003  18.02474
    6.090    0.023    90.00    25.20    8.220      0.0  0.000196    0.023    90.00    0.0003  19.60292
    7.617    0.023    90.00    26.37    8.020      0.0  0.000196    0.023    90.00    0.0003  20.54204
    9.140    0.023    90.00    26.74    7.980      0.0  0.000196    0.023    90.00    0.0003  20.83621
    10.45    0.023    90.00    27.46    7.570      0.0  0.000196    0.023    90.00    0.0003  21.45192
```

```
   11.75    0.023    90.00    28.24    7.100      0.0  0.000196    0.023    90.00    0.0003  22.12180
   13.06    0.023    90.00    28.92    6.920      0.0  0.000195    0.023    90.00    0.0003  22.67724
   14.37    0.023    90.00    29.08    6.880      0.0  0.000195    0.023    90.00    0.0003  22.80770
   15.68    0.023    90.00    29.29    6.790      0.0  0.000195    0.023    90.00    0.0003  22.98359
   16.98    0.023    90.00    30.42    6.260      0.0  0.000195    0.023    90.00    0.0003  23.93584
   22.00    0.023    90.00    34.78    4.213      0.0  0.000195    0.023    90.00    0.0003  27.61629

Diffuser table:
  P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)  (deg)  (deg)    (m)     (m)     ()   (ft)    (m)(concent)    (m)  (MGD)  (psu)    (C)(col/dl)
 3.0000    0.0  90.000    0.0     0.0  2.0000  15.000  42.600  200.00  21.100  2.9000    0.0  15.800
2.13E+6

Simulation:
Froude No:     178.8; Strat No: 2.20E-3; Spcg No:   76.82; k:   992.9; eff den (sigmaT) -0.960860; eff vel
22.84(m/s);
       Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn   Iso dia
Step     (m)   (cm/s)    (in) (col/dl)      ()      (m)      (m)       (m)
  0     21.10    2.300    2.343 2.130E+6    1.000      0.0       0.0   0.05935;  10.68 T-90hr,
 100    21.10    2.300    23.86 208749.0    10.20    0.000     1.346    0.6058;  10.68 T-90hr,
 160    21.03    2.300    77.28  63725.7    33.42    0.000     4.775    1.9614; bottom hit;  10.65 T-90hr,
 200    20.49    2.300    166.7  28847.1    73.76    0.000     10.62    4.2261;  10.42 T-90hr,
 204    20.37    2.300    179.9  26645.8    79.84    0.000     11.48    4.5599; trap level;  10.37 T-90hr,
 205    20.34    2.300    183.3  26122.1    81.44    0.000     11.71    4.6475; merging;  10.36 T-90hr,
 232    19.97    2.300    305.7  21392.8    99.34    0.000     16.27    7.7425; local maximum rise or fall;
10.20 T-90hr,
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):   16.274
Lmz(m):   16.274
forced entrain      1   1.873    1.132    7.764    1.000
Rate sec-1   0.00019515 dy-1      16.8607  kt:  0.000062421 Amb Sal       33.0175
Const Eddy Diffusivity.  Farfield dispersion based on wastefield width of       12.34 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 21392.8   99.34   12.34   16.27 2.78E-4     0.0   16.27    2.300    90.00 3.00E-4 6.2421E-5
 19386.1   118.7   23.00   42.60   0.318     0.0   16.27    2.300   90.00 3.00E-4 6.2421E-5
 15243.7   136.7   30.62   58.87   0.515     0.0   16.27    2.300   90.00 3.00E-4 6.2421E-5
count: 1
 ;
5:20:07 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT

4/3 Power Law
Eo=(alpha)*(width)$^{4/3}$
(Grace/Brooks equation 7-66)

1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	42.6	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 8.5548E-03 m^2/s
Beta = 3.6170E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.317995169	26.33	42.6	1.36E+02	1.56E+04	137

```
/ UM3. 6/23/2021 5:20:24 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: --------------
--------------------

Ambient Table:
   Depth  Amb-cur  Amb-dir  Amb-sal  Amb-tem  Amb-pol Solar rad  Far-spd  Far-dir  Disprsn
Density
      m      m/s      deg      psu       C    kg/kg      s-1       m/s      deg  m0.67/s2  sigma-T
    0.0    0.023    90.00    7.100    11.12      0.0  0.000194    0.023    90.00   0.0003  5.180276
   1.523   0.023    90.00    14.16    10.08      0.0  0.000198    0.023    90.00   0.0003  10.78304
   3.047   0.023    90.00    23.30    8.650      0.0  0.000197    0.023    90.00   0.0003  18.06627
   4.570   0.023    90.00    23.25    8.670      0.0  0.000196    0.023    90.00   0.0003  18.02474
   6.090   0.023    90.00    25.20    8.220      0.0  0.000196    0.023    90.00   0.0003  19.60292
   7.617   0.023    90.00    26.37    8.020      0.0  0.000196    0.023    90.00   0.0003  20.54204
   9.140   0.023    90.00    26.74    7.980      0.0  0.000196    0.023    90.00   0.0003  20.83621
   10.45   0.023    90.00    27.46    7.570      0.0  0.000196    0.023    90.00   0.0003  21.45192
   11.75   0.023    90.00    28.24    7.100      0.0  0.000196    0.023    90.00   0.0003  22.12180
   13.06   0.023    90.00    28.92    6.920      0.0  0.000195    0.023    90.00   0.0003  22.67724
   14.37   0.023    90.00    29.08    6.880      0.0  0.000195    0.023    90.00   0.0003  22.80770
   15.68   0.023    90.00    29.29    6.790      0.0  0.000195    0.023    90.00   0.0003  22.98359
   16.98   0.023    90.00    30.42    6.260      0.0  0.000195    0.023    90.00   0.0003  23.93584
   22.00   0.023    90.00    34.78    4.213      0.0  0.000195    0.023    90.00   0.0003  27.61629

Diffuser table:
  P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)  (deg)  (deg)    (m)     (m)     ()   (ft)    (m)(concent)    (m)  (MGD)  (psu)    (C)(col/dl)
 3.0000    0.0  90.000    0.0     0.0  2.0000  15.000  106.50  200.00  21.100  2.9000     0.0  15.800
2.13E+6

Simulation:
Froude No:     178.8; Strat No: 2.20E-3; Spcg No:   76.82; k:   992.9; eff den (sigmaT) -0.960860; eff vel
22.84(m/s);
      Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn   Iso dia
Step     (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)       (m)
  0    21.10    2.300    2.343 2.130E+6    1.000      0.0      0.0   0.05935;  10.68 T-90hr,
 100   21.10    2.300    23.86 208749.0    10.20    0.000    1.346    0.6058;  10.68 T-90hr,
 160   21.03    2.300    77.28  63725.7    33.42    0.000    4.775    1.9614; bottom hit;  10.65 T-90hr,
 200   20.49    2.300    166.7  28847.1    73.76    0.000    10.62    4.2261;  10.42 T-90hr,
 204   20.37    2.300    179.9  26645.8    79.84    0.000    11.48    4.5599; trap level;  10.37 T-90hr,
 205   20.34    2.300    183.3  26122.1    81.44    0.000    11.71    4.6475; merging;  10.36 T-90hr,
 232   19.97    2.300    305.7  21392.8    99.34    0.000    16.27    7.7425; local maximum rise or fall;
10.20 T-90hr,
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):   16.274
Lmz(m):   16.274
forced entrain      1   1.873   1.132   7.764   1.000
Rate sec-1   0.00019515 dy-1      16.8607  kt:  0.000062421 Amb Sal      33.0175
Const Eddy Diffusivity.  Farfield dispersion based on wastefield width of       12.34 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)             (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
```

```
 21392.8   99.34   12.34   16.27 2.78E-4    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
 16299.5   181.1   56.68   106.5   1.090    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
 10795.8   194.1   66.75   122.8   1.287    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
count: 1
 ;
5:20:24 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT

4/3 Power Law
Eo=(alpha)*(width)$^{4/3}$
(Grace/Brooks equation 7-66)

1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	106.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 8.5548E-03 m^2/s
Beta = 3.6170E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.0897343	90.23	106.5	3.30E+02	6.43E+03	331

```
/ UM3. 6/23/2021 5:20:41 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: --------------
--------------------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m       m/s       deg       psu       C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0     0.023     90.00     7.100     11.12       0.0  0.000194     0.023     90.00    0.0003  5.180276
   1.523     0.023     90.00     14.16     10.08       0.0  0.000198     0.023     90.00    0.0003  10.78304
   3.047     0.023     90.00     23.30     8.650       0.0  0.000197     0.023     90.00    0.0003  18.06627
   4.570     0.023     90.00     23.25     8.670       0.0  0.000196     0.023     90.00    0.0003  18.02474
   6.090     0.023     90.00     25.20     8.220       0.0  0.000196     0.023     90.00    0.0003  19.60292
   7.617     0.023     90.00     26.37     8.020       0.0  0.000196     0.023     90.00    0.0003  20.54204
   9.140     0.023     90.00     26.74     7.980       0.0  0.000196     0.023     90.00    0.0003  20.83621
   10.45     0.023     90.00     27.46     7.570       0.0  0.000196     0.023     90.00    0.0003  21.45192
   11.75     0.023     90.00     28.24     7.100       0.0  0.000196     0.023     90.00    0.0003  22.12180
   13.06     0.023     90.00     28.92     6.920       0.0  0.000195     0.023     90.00    0.0003  22.67724
   14.37     0.023     90.00     29.08     6.880       0.0  0.000195     0.023     90.00    0.0003  22.80770
   15.68     0.023     90.00     29.29     6.790       0.0  0.000195     0.023     90.00    0.0003  22.98359
   16.98     0.023     90.00     30.42     6.260       0.0  0.000195     0.023     90.00    0.0003  23.93584
   22.00     0.023     90.00     34.78     4.213       0.0  0.000195     0.023     90.00    0.0003  27.61629

Diffuser table:
   P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()    (ft)     (m)(concent)    (m)   (MGD)   (psu)     (C)(col/dl)
  3.0000     0.0  90.000     0.0     0.0  2.0000  15.000  213.00  200.00  21.100  2.9000     0.0  15.800
2.13E+6

Simulation:
Froude No:     178.8; Strat No: 2.20E-3; Spcg No:   76.82; k:   992.9; eff den (sigmaT) -0.960860; eff vel
22.84(m/s);
        Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn   Iso dia
Step      (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)       (m)
   0    21.10    2.300    2.343 2.130E+6    1.000      0.0      0.0  0.05935;  10.68 T-90hr,
 100    21.10    2.300    23.86 208749.0    10.20    0.000    1.346   0.6058;  10.68 T-90hr,
 160    21.03    2.300    77.28  63725.7    33.42    0.000    4.775   1.9614; bottom hit;  10.65 T-90hr,
 200    20.49    2.300    166.7  28847.1    73.76    0.000    10.62   4.2261;  10.42 T-90hr,
 204    20.37    2.300    179.9  26645.8    79.84    0.000    11.48   4.5599; trap level;  10.37 T-90hr,
 205    20.34    2.300    183.3  26122.1    81.44    0.000    11.71   4.6475; merging;  10.36 T-90hr,
 232    19.97    2.300    305.7  21392.8    99.34    0.000    16.27   7.7425; local maximum rise or fall;
10.20 T-90hr,
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):   16.274
Lmz(m):   16.274
forced entrain      1   1.873   1.132   7.764   1.000
Rate sec-1   0.00019515 dy-1      16.8607  kt:  0.000062421 Amb Sal      33.0175
Const Eddy Diffusivity.  Farfield dispersion based on wastefield width of       12.34 m
    conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)             (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
  21392.8   99.34   12.34   16.27 2.78E-4     0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
```

```
 12646.5   246.9   121.4   200.0   2.219    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
 8191.65   256.7   134.2   216.3   2.416    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
count: 1
 ;
5:20:41 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT

4/3 Power Law
Eo=(alpha)*(width)$^{4/3}$
(Grace/Brooks equation 7-66)

1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	213	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 8.5548E-03 m^2/s
Beta = 3.6170E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.375966184	196.73	213	7.66E+02	2.77E+03	768

Ketchikan (model output for 1*depth, 2*depth, 5*depth and 10*depth)

```
Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Ketchikan_1port" memo

Model configuration items checked: Brooks far-field solution;
  Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
 Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
 Bacteria model  : Mancini (1978) coliform model
 PDS sfc. model heat transfer : Medium
 Equation of State : S, T
 Similarity Profile : Default profile (k=2.0, ...)
 Diffuser port contraction coefficient 0.61
 Light absorption coefficient 0.16
 Farfield increment (m) 200
 UM3 aspiration coefficient 0.1
  Output file: text output tab
  Output each ?? steps 100
  Maximum dilution reported 100000
 Text output format : Standard
 Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:27:49 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: -------------------
---------------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m      m/s       deg       psu        C     kg/kg       s-1        m/s       deg  m0.67/s2  sigma-T
     0.0    0.059     140.0     24.50     15.20       0.0  0.000196     0.059     140.0    0.0003  17.89918
   1.000    0.059     140.0     24.50     15.20       0.0    0.0002     0.059     140.0    0.0003  17.89918
   16.10    0.059     140.0     26.80     13.80       0.0    0.0002     0.059     140.0    0.0003  19.93814
   33.90    0.059     140.0     30.90     8.000       0.0  0.000199     0.059     140.0    0.0003  24.08526

Diffuser table:
  P-dia VertAng H-Angle SourceX SourceY   Ports  MZ-dis Isoplth P-depth Ttl-flo Eff-sal    Temp
Polutnt
   (in)   (deg)   (deg)     (m)     (m)      ()     (m)(concent)   (m)   (MGD)   (psu)     (C)(col/dl)
 12.000     0.0  205.00     0.0     0.0  1.0000  29.900  100.00  29.600  3.4560     0.0  20.500 20000.0

Simulation:
Froude No:     14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k:   57.66; eff den (sigmaT) -1.837438; eff
vel    3.402(m/s);
       Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step     (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)       (m)
   0   29.60    5.900    9.372  20000.0    1.000      0.0      0.0      0.0   0.2374;  13.41 T-90hr,
 100   29.37    5.900    61.18   2975.1    6.722   -2.606   -1.081    3.096   1.5410;  13.32 T-90hr,
```

```
 200    27.61    5.900    135.6   1142.4    17.50   -6.017   -2.060    14.40    3.3681;  12.62 T-90hr,
 249    24.16    5.900    233.0    562.5    35.49   -9.308   -2.435    34.83    5.6507; trap level;  11.26 T-90hr,
 276    22.92    5.900    300.9    445.7    44.77   -10.56   -2.414    45.33    7.2032; begin overlap;  10.77 T-
90hr,
 300    22.48    5.900    333.7    414.4    48.13   -11.13   -2.377    50.59    7.9496;  10.60 T-90hr,
 400    21.94    5.900    383.7    388.9    51.25   -12.54   -2.254    64.07    9.1014;  10.40 T-90hr,
 417    21.94    5.900    385.5    387.6    51.42   -12.73   -2.235    65.91    9.1403; local maximum rise or
fall;  10.39 T-90hr,
Horiz plane projections in effluent direction: radius(m):   2.4839; CL(m):   12.480
Lmz(m):   14.964
forced entrain      1 1.28E+9   7.663   9.791   1.000
Rate sec-1   0.00019971 dy-1      17.2550  kt:  0.000059972 Amb Sal      28.1446
4/3 Power Law.  Farfield dispersion based on wastefield width of       9.79 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 387.592   51.42   9.799   12.92 2.78E-4     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
 372.140   52.31   12.10   29.90  0.0802     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
 346.023   56.38   13.95   42.82   0.141     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
count: 1
 ;
5:27:49 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT

Linear Eddy Diffusivity
Eo=(alpha)(width)
(Grace/Brooks equation 7-65)

1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	29.9	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.2830E-03 m^2/s
Beta = 1.3053E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	7.99E-02	16.98	29.90	5.22E+01	3.82E+02	52

```
/ UM3. 6/23/2021 5:28:05 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: -------------------
---------------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m       m/s       deg       psu        C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0     0.059     140.0     24.50     15.20       0.0  0.000195     0.059     140.0    0.0003  17.89918
   1.000     0.059     140.0     24.50     15.20       0.0    0.0002     0.059     140.0    0.0003  17.89918
   16.10     0.059     140.0     26.80     13.80       0.0    0.0002     0.059     140.0    0.0003  19.93814
   33.90     0.059     140.0     30.90     8.000       0.0  0.000199     0.059     140.0    0.0003  24.08526

Diffuser table:
   P-dia VertAng H-Angle SourceX SourceY   Ports  MZ-dis Isoplth P-depth Ttl-flo Eff-sal    Temp
Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()  (m)(concent)     (m)   (MGD)   (psu)     (C)(col/dl)
  12.000     0.0  205.00     0.0     0.0  1.0000  59.800  100.00  29.600  3.4560     0.0  20.500 20000.0

Simulation:
Froude No:    14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k:   57.66; eff den (sigmaT) -1.837438; eff
vel    3.402(m/s);
        Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)       (m)
   0    29.60    5.900    9.372  20000.0    1.000      0.0      0.0      0.0    0.2222;  13.41 T-90hr,
 100    29.37    5.900    61.18   2975.1    6.722   -2.606   -1.081    3.096    1.5410;  13.32 T-90hr,
 200    27.61    5.900    135.6   1142.4    17.50   -6.017   -2.060    14.40    3.3681;  12.62 T-90hr,
 249    24.16    5.900    233.0    562.5    35.49   -9.308   -2.435    34.83    5.6507; trap level;  11.26 T-90hr,
 276    22.92    5.900    300.9    445.7    44.77   -10.56   -2.414    45.33    7.2032; begin overlap;  10.77 T-
90hr,
 300    22.48    5.900    333.7    414.4    48.13   -11.13   -2.377    50.59    7.9496;  10.60 T-90hr,
 400    21.94    5.900    383.7    388.9    51.25   -12.54   -2.254    64.07    9.1014;  10.40 T-90hr,
 417    21.94    5.900    385.5    387.6    51.42   -12.73   -2.235    65.91    9.1403; local maximum rise or
fall;  10.39 T-90hr,
Horiz plane projections in effluent direction: radius(m):   2.4839; CL(m):   12.480
Lmz(m):   14.964
forced entrain      1 1.28E+9   7.663   9.791   1.000
Rate sec-1   0.00019971 dy-1      17.2550  kt:  0.000059972 Amb Sal      28.1446
4/3 Power Law.  Farfield dispersion based on wastefield width of       9.79 m
    conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)             (m)     (m)   (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 387.592   51.42   9.799   12.92 2.78E-4     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
 361.000   64.47   16.52   59.80   0.221     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
 273.501   71.65   18.57   72.72   0.282     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
count: 1
 ;
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT

Linear Eddy Diffusivity
Eo=(alpha)(width)
(Grace/Brooks equation 7-65)

1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	59.8	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.2830E-03 m^2/s
Beta = 1.3053E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.21E-01	46.88	59.80	6.24E+01	3.19E+02	63

```
5:28:05 AM. amb fills: 4
/ UM3. 6/23/2021 5:28:34 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: -------------------
---------------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m       m/s        deg        psu         C     kg/kg       s-1        m/s        deg  m0.67/s2   sigma-T
      0.0     0.059     140.0     24.50     15.20       0.0  0.000195     0.059     140.0    0.0003  17.89918
    1.000     0.059     140.0     24.50     15.20       0.0    0.0002     0.059     140.0    0.0003  17.89918
    16.10     0.059     140.0     26.80     13.80       0.0    0.0002     0.059     140.0    0.0003  19.93814
    33.90     0.059     140.0     30.90     8.000       0.0  0.000199     0.059     140.0    0.0003  24.08526

Diffuser table:
   P-dia VertAng H-Angle SourceX SourceY   Ports  MZ-dis Isoplth P-depth Ttl-flo Eff-sal    Temp
Polutnt
    (in)  (deg)  (deg)     (m)      (m)       ()     (m)(concent)     (m)   (MGD)   (psu)     (C)(col/dl)
  12.000     0.0  205.00     0.0     0.0  1.0000  149.50  100.00  29.600  3.4560     0.0  20.500 20000.0

Simulation:
Froude No:     14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k:   57.66; eff den (sigmaT) -1.837438; eff
vel     3.402(m/s);
          Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn      Time   Iso dia
Step       (m)   (cm/s)     (in) (col/dl)       ()       (m)       (m)       (s)       (m)
   0     29.60    5.900    9.372  20000.0    1.000       0.0       0.0       0.0    0.2222;  13.41 T-90hr,
 100     29.37    5.900    61.18   2975.1    6.722    -2.606    -1.081     3.096    1.5410;  13.32 T-90hr,
 200     27.61    5.900    135.6   1142.4    17.50    -6.017    -2.060     14.40    3.3681;  12.62 T-90hr,
 249     24.16    5.900    233.0    562.5    35.49    -9.308    -2.435     34.83    5.6507; trap level;  11.26 T-90hr,
 276     22.92    5.900    300.9    445.7    44.77    -10.56    -2.414     45.33    7.2032; begin overlap;  10.77 T-
90hr,
 300     22.48    5.900    333.7    414.4    48.13    -11.13    -2.377     50.59    7.9496;  10.60 T-90hr,
 400     21.94    5.900    383.7    388.9    51.25    -12.54    -2.254     64.07    9.1014;  10.40 T-90hr,
 417     21.94    5.900    385.5    387.6    51.42    -12.73    -2.235     65.91    9.1403; local maximum rise or
fall;  10.39 T-90hr,
Horiz plane projections in effluent direction: radius(m):   2.4839; CL(m):   12.480
Lmz(m):   14.964
forced entrain      1 1.28E+9   7.663   9.791   1.000
Rate sec-1   0.00019971 dy-1      17.2550  kt:  0.000059972 Amb Sal      28.1446
4/3 Power Law.  Farfield dispersion based on wastefield width of       9.79 m
    conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)              (m)      (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 387.592   51.42   9.799   12.92 2.78E-4     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
 329.541   122.8   32.26   149.5   0.643     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
 149.151   132.4   34.81   162.4   0.704     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
count: 1
 ;
5:28:34 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT

Linear Eddy Diffusivity
Eo=(alpha)(width)
(Grace/Brooks equation 7-65)

1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	149.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.2830E-03 m^2/s
Beta = 1.3053E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.43E-01	136.58	149.50	1.05E+02	1.89E+02	106

```
/ UM3. 6/23/2021 5:28:46 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: -------------------
---------------

Ambient Table:
   Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m       m/s       deg       psu        C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0     0.059     140.0     24.50     15.20       0.0  0.000195     0.059     140.0    0.0003  17.89918
   1.000     0.059     140.0     24.50     15.20       0.0    0.0002     0.059     140.0    0.0003  17.89918
   16.10     0.059     140.0     26.80     13.80       0.0    0.0002     0.059     140.0    0.0003  19.93814
   33.90     0.059     140.0     30.90     8.000       0.0  0.000199     0.059     140.0    0.0003  24.08526

Diffuser table:
  P-dia VertAng H-Angle SourceX SourceY   Ports  MZ-dis Isoplth P-depth Ttl-flo Eff-sal    Temp
Polutnt
   (in)   (deg)   (deg)     (m)     (m)      ()  (m)(concent)     (m)   (MGD)   (psu)     (C)(col/dl)
 12.000     0.0  205.00     0.0     0.0  1.0000  299.00  100.00  29.600  3.4560     0.0  20.500 20000.0

Simulation:
Froude No:     14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k:   57.66; eff den (sigmaT) -1.837438; eff
vel     3.402(m/s);
        Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)      (m)
   0    29.60    5.900    9.372  20000.0    1.000      0.0      0.0      0.0   0.2222;  13.41 T-90hr,
 100    29.37    5.900    61.18   2975.1    6.722   -2.606   -1.081    3.096   1.5410;  13.32 T-90hr,
 200    27.61    5.900    135.6   1142.4    17.50   -6.017   -2.060    14.40   3.3681;  12.62 T-90hr,
 249    24.16    5.900    233.0    562.5    35.49   -9.308   -2.435    34.83   5.6507; trap level;  11.26 T-90hr,
 276    22.92    5.900    300.9    445.7    44.77   -10.56   -2.414    45.33   7.2032; begin overlap;  10.77 T-
90hr,
 300    22.48    5.900    333.7    414.4    48.13   -11.13   -2.377    50.59   7.9496;  10.60 T-90hr,
 400    21.94    5.900    383.7    388.9    51.25   -12.54   -2.254    64.07   9.1014;  10.40 T-90hr,
 417    21.94    5.900    385.5    387.6    51.42   -12.73   -2.235    65.91   9.1403; local maximum rise or
fall;  10.39 T-90hr,
Horiz plane projections in effluent direction: radius(m):   2.4839; CL(m):   12.480
Lmz(m):   14.964
forced entrain      1 1.28E+9   7.663   9.791   1.000
Rate sec-1   0.00019971 dy-1      17.2550  kt:  0.000059972 Amb Sal      28.1446
4/3 Power Law.  Farfield dispersion based on wastefield width of       9.79 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)             (m)     (m)     (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 387.592   51.42   9.799   12.92 2.78E-4     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
 313.051   161.8   42.56   200.0   0.881     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
 94.9421   348.2   91.63   400.0   1.823     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
 54.9006   361.8   95.21   412.9   1.884     0.0   16.00   5.900   140.0 3.00E-4 5.9972E-5
count: 2
 ;
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT

Linear Eddy Diffusivity
Eo=(alpha)(width)
(Grace/Brooks equation 7-65)

1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	299	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.2830E-03 m^2/s
Beta = 1.3053E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.35E+00	286.08	299.00	1.79E+02	1.11E+02	180

Petersburg (model output for 1*depth, 2*depth, 5*depth and 10*depth)

```
Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Petersburg" me

Model configuration items checked: Brooks far-field solution;
  Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
 Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
 Bacteria model  : Mancini (1978) coliform model
 PDS sfc. model heat transfer : Medium
 Equation of State : S, T
 Similarity Profile : Default profile (k=2.0, ...)
 Diffuser port contraction coefficient 0.61
 Light absorption coefficient 0.16
 Farfield increment (m) 200
 UM3 aspiration coefficient 0.1
  Output file: text output tab
  Output each ?? steps 100
  Maximum dilution reported 100000
 Text output format : Standard
 Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:40:38 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ---------------------
-------------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
        m      m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2  sigma-T
      0.0    0.016     120.0     25.80     9.500       0.0  0.000195     0.016     120.0    0.0003  19.89413
    9.150    0.016     120.0     28.10     8.200       0.0  0.000196     0.016     120.0    0.0003  21.86897
    18.29    0.016     120.0     30.90     7.300       0.0  0.000196     0.016     120.0    0.0003  24.18118
    20.00    0.016     120.0     31.42     7.132       0.0  0.000195     0.016     120.0    0.0003  24.61448

Diffuser table:
   P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
    (in)  (deg)  (deg)     (m)     (m)      ()    (ft)    (m)(concent)     (m)   (MGD)   (psu)     (C)(col/dl)
  4.0000     0.0  115.00     0.0     0.0  2.0000  10.000  18.300  200.00  18.070  3.6000     0.0  14.600
2.02E+6

Simulation:
Froude No:     114.5; Strat No: 7.46E-4; Spcg No:   38.41; k:   996.7; eff den (sigmaT) -0.776899; eff vel
15.95(m/s);
       Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step     (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)      (m)
   0   18.07    1.600    3.124 2.020E+6    1.000      0.0      0.0      0.0   0.0746;  9.342 T-90hr,
```

```
 100    18.07    1.600    27.00 233103.2    8.665   -0.637    1.364    0.470    0.6855;  9.340 T-90hr,
 177    17.70    1.600    121.5  50815.2    39.73   -3.202    6.837    9.667    3.0831; merging;  9.198 T-90hr,
 200    16.92    1.600    192.0  38804.9    51.98   -4.867    10.37    20.86    4.8693;  8.895 T-90hr,
 212    15.74    1.600    258.0  32719.8    61.58   -6.629    14.10    35.23    6.5408; trap level;  8.436 T-
90hr,
 221    14.97    1.600    323.8  29956.8    67.21   -7.796    16.57    45.91    8.2053; MZ dis;  8.143 T-90hr,
forced entrain      1   1.914   3.095   8.224   0.970
Rate sec-1   0.00019604 dy-1      16.9376  kt:  0.000077955 Amb Sal      29.8950
Mixing Zone reached in near-field, no far-field calculation attempted
 ;
5:40:38 AM. amb fills: 4
/ UM3. 6/23/2021 5:40:52 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: --------------------
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Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
        m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
      0.0     0.016     120.0     25.80     9.500       0.0  0.000195     0.016     120.0    0.0003  19.89413
    9.150     0.016     120.0     28.10     8.200       0.0  0.000196     0.016     120.0    0.0003  21.86897
    18.29     0.016     120.0     30.90     7.300       0.0  0.000196     0.016     120.0    0.0003  24.18118
    20.00     0.016     120.0     31.42     7.132       0.0  0.000195     0.016     120.0    0.0003  24.61448

Diffuser table:
   P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()    (ft)     (m)(concent)    (m)   (MGD)   (psu)     (C)(col/dl)
  4.0000     0.0  115.00     0.0     0.0  2.0000  10.000  36.600  200.00  18.070  3.6000     0.0  14.600
2.02E+6

Simulation:
Froude No:     114.5; Strat No: 7.46E-4; Spcg No:   38.41; k:   996.7; eff den (sigmaT) -0.776899; eff vel
15.95(m/s);
       Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step     (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)      (m)
   0    18.07    1.600    3.124 2.020E+6    1.000      0.0      0.0      0.0   0.07918;  9.342 T-90hr,
 100    18.07    1.600    27.00 233103.2    8.665   -0.637    1.364    0.470    0.6855;  9.340 T-90hr,
 177    17.70    1.600    121.5  50815.2    39.73   -3.202    6.837    9.667    3.0831; merging;  9.198 T-90hr,
 200    16.92    1.600    192.0  38804.9    51.98   -4.867    10.37    20.86    4.8693;  8.895 T-90hr,
 212    15.74    1.600    258.0  32719.8    61.58   -6.629    14.10    35.23    6.5408; trap level;  8.436 T-
90hr,
 269    14.43    1.600    412.1  27015.9    74.42   -9.596    20.37    63.81    10.443; local maximum rise or
fall;  7.935 T-90hr,
Horiz plane projections in effluent direction: radius(m):  0.03203; CL(m):   22.520
Lmz(m):   22.552
forced entrain      1   2.252   3.642   10.47   1.000
Rate sec-1   0.00019608 dy-1      16.9412  kt:  0.000080118 Amb Sal      29.7168
4/3 Power Law.  Farfield dispersion based on wastefield width of       13.51 m
    conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)             (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
```

```
 27015.9   74.42   13.51   22.52 2.78E-4    0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
 24577.8   89.58   21.72   36.60   0.245    0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
 13316.6   149.2   37.30   59.12   0.636    0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
count: 1
 ;
5:40:52 AM. amb fills: 4
/ UM3. 6/23/2021 5:41:05 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: --------------------
-------------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
      m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0     0.016    120.0     25.80     9.500       0.0  0.000195     0.016     120.0    0.0003  19.89413
   9.150     0.016    120.0     28.10     8.200       0.0  0.000196     0.016     120.0    0.0003  21.86897
   18.29     0.016    120.0     30.90     7.300       0.0  0.000196     0.016     120.0    0.0003  24.18118
   20.00     0.016    120.0     31.42     7.132       0.0  0.000195     0.016     120.0    0.0003  24.61448

Diffuser table:
   P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()    (ft)     (m)(concent)     (m)   (MGD)   (psu)     (C)(col/dl)
  4.0000     0.0  115.00     0.0     0.0  2.0000  10.000  91.500  200.00  18.070  3.6000     0.0  14.600
2.02E+6

Simulation:
Froude No:     114.5; Strat No: 7.46E-4; Spcg No:   38.41; k:   996.7; eff den (sigmaT) -0.776899; eff vel
15.95(m/s);
        Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)       (m)
   0    18.07    1.600    3.124 2.020E+6    1.000      0.0      0.0      0.0   0.07916;  9.342 T-90hr,
 100    18.07    1.600    27.00 233103.2    8.665   -0.637    1.364    0.470    0.6855;  9.340 T-90hr,
 177    17.70    1.600    121.5  50815.2    39.73   -3.202    6.837    9.667    3.0831; merging;  9.198 T-90hr,
 200    16.92    1.600    192.0  38804.9    51.98   -4.867    10.37    20.86    4.8693;  8.895 T-90hr,
 212    15.74    1.600    258.0  32719.8    61.58   -6.629    14.10    35.23    6.5408; trap level;  8.436 T-
90hr,
 269    14.43    1.600    412.1  27015.9    74.42   -9.596    20.37    63.81    10.443; local maximum rise or
fall;  7.935 T-90hr,
Horiz plane projections in effluent direction: radius(m):  0.03203; CL(m):   22.520
Lmz(m):   22.552
forced entrain       1   2.252    3.642    10.47    1.000
Rate sec-1   0.00019608 dy-1       16.9412  kt:  0.000080118 Amb Sal       29.7168
4/3 Power Law.  Farfield dispersion based on wastefield width of       13.51 m
    conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)              (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 27015.9   74.42   13.51   22.52 2.78E-4    0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
 18670.4   255.8   64.12   91.50   1.198    0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
 5869.71   340.7   85.44   114.0   1.589    0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
count: 1
 ; 5:41:06 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
		4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	74.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	13.51	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	22.52	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	91.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.016	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.70E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.6530E-03 m^2/s
Beta = 5.3588E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.197569444	68.98	91.5	2.56E+02	7.86E+03	257

```
/ UM3. 6/23/2021 5:41:17 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: --------------------
-------------

Ambient Table:
   Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m       m/s       deg       psu        C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0     0.016     120.0     25.80     9.500       0.0  0.000195     0.016     120.0    0.0003  19.89413
   9.150     0.016     120.0     28.10     8.200       0.0  0.000196     0.016     120.0    0.0003  21.86897
   18.29     0.016     120.0     30.90     7.300       0.0  0.000196     0.016     120.0    0.0003  24.18118
   20.00     0.016     120.0     31.42     7.132       0.0  0.000195     0.016     120.0    0.0003  24.61448

Diffuser table:
  P-diaVer angl H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)  (deg)  (deg)    (m)    (m)     ()   (ft)   (m)(concent)   (m)  (MGD)  (psu)    (C)(col/dl)
 4.0000    0.0  115.00    0.0    0.0  2.0000  10.000  183.00  200.00  18.070  3.6000     0.0  14.600
2.02E+6

Simulation:
Froude No:     114.5; Strat No: 7.46E-4; Spcg No:   38.41; k:   996.7; eff den (sigmaT) -0.776899; eff vel
15.95(m/s);
      Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step     (m)  (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)      (m)
  0    18.07    1.600    3.124 2.020E+6    1.000      0.0      0.0      0.0  0.07916;  9.342 T-90hr,
 100    18.07    1.600    27.00 233103.2    8.665   -0.637    1.364    0.470   0.6855;  9.340 T-90hr,
 177    17.70    1.600    121.5  50815.2    39.73   -3.202    6.837    9.667   3.0831; merging;  9.198 T-90hr,
 200    16.92    1.600    192.0  38804.9    51.98   -4.867    10.37    20.86   4.8693;  8.895 T-90hr,
 212    15.74    1.600    258.0  32719.8    61.58   -6.629    14.10    35.23   6.5408; trap level;  8.436 T-
90hr,
 269    14.43    1.600    412.1  27015.9    74.42   -9.596    20.37    63.81   10.443; local maximum rise or
fall;  7.935 T-90hr,
Horiz plane projections in effluent direction: radius(m):  0.03203; CL(m):   22.520
Lmz(m):   22.552
forced entrain     1   2.252   3.642   10.47   1.000
Rate sec-1   0.00019608 dy-1      16.9412  kt:  0.000080118 Amb Sal      29.7168
4/3 Power Law.  Farfield dispersion based on wastefield width of      13.51 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)             (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 27015.9   74.42   13.51   22.52 2.78E-4     0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
 11807.9   646.9   162.2   183.0   2.786     0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
 2638.61   760.1   190.6   205.5   3.177     0.0   16.25   1.600   120.0 3.00E-4 8.0118E-5
count: 1
 ;
5:41:17 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
		4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	74.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	13.51	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	22.52	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	183	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.016	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.70E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.6530E-03 m^2/s
Beta = 5.3588E-01 unitless

	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	2.786111111	160.48	183	6.47E+02	3.11E+03	650

Sitka (model output for 1*depth, 2*depth, 5*depth and 10*depth)

```
Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Sitka" memo

Model configuration items checked: Brooks far-field solution; Report effective dilution; ;
  Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
 Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
 Bacteria model  : Mancini (1978) coliform model
 PDS sfc. model heat transfer : Medium
 Equation of State : S, T
 Similarity Profile : Default profile (k=2.0, ...)
 Diffuser port contraction coefficient 1
 Light absorption coefficient 0.16
 Farfield increment (m) 100
 UM3 aspiration coefficient 0.1
  Output file: text output tab
  Output each ?? steps 100
  Maximum dilution reported 100000
 Text output format : Standard
 Max vertical reversals : to max rise or fall

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ----------------------------
-----

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m      m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0    0.017     225.0     26.60     12.70       0.0  0.000196     0.017     225.0    0.0003  19.98988
   1.000    0.017     225.0     26.60     12.70       0.0  0.000198     0.017     225.0    0.0003  19.98988
   5.000    0.017     225.0     28.20     12.20       0.0  0.000198     0.017     225.0    0.0003  21.31369
   10.00    0.017     225.0     29.10     11.60       0.0  0.000198     0.017     225.0    0.0003  22.11543
   15.00    0.017     225.0     29.60     10.60       0.0  0.000197     0.017     225.0    0.0003  22.67329
   20.00    0.017     225.0     29.80     9.800       0.0  0.000197     0.017     225.0    0.0003  22.95817
   25.00    0.017     225.0     29.90     9.500       0.0  0.000196     0.017     225.0    0.0003  23.08290
   30.00    0.017     225.0     29.90     9.100       0.0  0.000196     0.017     225.0    0.0003  23.14401

Diffuser table:
   P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()    (ft)    (m)(concent)    (m)   (MGD)   (psu)    (C)(col/dl)
  4.0000     0.0  300.00     0.0     0.0  16.000  13.000  24.400  200.00  23.940  5.3000     0.0  15.000
3.74E+6

Simulation:
```

```
Froude No:    11.60; Strat No: 5.45E-4; Spcg No:   39.00; k:   105.3; eff den (sigmaT) -0.836341; eff vel
1.790(m/s);
     Depth  Amb-cur    P-dia  Polutnt  net Dil   x-posn   y-posn     Time   Iso dia
Step    (m)   (cm/s)    (in) (col/dl)      ()      (m)      (m)      (s)      (m)
   0   23.94    1.700    4.000 3.740E+6     0.0      0.0      0.0      0.0   0.1014;  11.44 T-90hr,
   1   23.94    1.700    4.000 3.740E+6    1.000     0.0      0.0      0.0   0.1016;  11.44 T-90hr,
   2   23.93    1.700    10.94 1.929E+6    1.939   -0.497    0.285    0.320   0.2780;  11.43 T-90hr,
   3   23.92    1.700    14.30 1.472E+6    2.540   -0.585    0.334    0.385   0.3632;  11.43 T-90hr,
   5   23.90    1.700    21.15 988111.0    3.785   -0.763    0.432    0.566   0.5372;  11.42 T-90hr,
   7   23.87    1.700    28.20 733621.0    5.098   -0.940    0.527    0.820   0.7162;  11.41 T-90hr,
   9   23.80    1.700    38.91 519516.6    7.199   -1.202    0.662    1.331   0.9883;  11.38 T-90hr,
  11   23.64    1.700    52.78 364415.9    10.26   -1.539    0.825    2.240   1.3405;  11.32 T-90hr,
  13   23.42    1.700    63.65 283591.1    13.19   -1.848    0.963    3.349   1.6165; merging;  11.24 T-90hr,
  17   22.83    1.700    76.78 206140.1    18.14   -2.365    1.164    5.764   1.9498;  11.01 T-90hr,
  21   22.14    1.700    87.81 163240.4    22.91   -2.776    1.297    8.271   2.2298;  10.75 T-90hr,
  27   21.03    1.700    104.8 125663.6    29.76   -3.270    1.419    12.28   2.6616;  10.33 T-90hr,
  55   19.66    1.700    131.6  99789.2    37.48   -3.747    1.497    17.53   3.3416;  9.805 T-90hr,
  67   17.85    1.700    164.7  79160.1    47.25   -4.268    1.537    24.48   4.1811;  9.113 T-90hr,
  79   15.49    1.700    218.5  62651.8    59.70   -4.873    1.525    33.78   5.5450;  8.222 T-90hr,
 133   12.24    1.700    351.2  49337.1    75.81   -5.704    1.423    48.38   8.9048;  7.033 T-90hr,
 151   9.808    1.700    947.0  43327.2    86.32   -6.744    1.206    68.20   24.008;  6.180 T-90hr,
4/3 Power Law.  Farfield dispersion based on wastefield width of      83.49 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 43327.2   86.32   83.51   6.851 2.78E-4     0.0   8.000    1.700   225.0 3.00E-4 5.5441E-5
 3.53E+6   87.12   100.3   24.40   0.287     0.0   8.000    1.700   225.0 3.00E-4 5.5441E-5
 9.94E+5   89.08   107.1   31.25   0.399     0.0   8.000    1.700   225.0 3.00E-4 5.5441E-5
count: 1
 ;
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	24.4	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.87E-01	17.549	24.40	8.70E+01	4.30E+04	87

```
/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ----------------------------
-----

Ambient Table:
   Depth  Amb-cur  Amb-dir  Amb-sal  Amb-tem  Amb-pol Solar rad  Far-spd  Far-dir  Disprsn
Density
       m      m/s      deg      psu       C    kg/kg      s-1      m/s      deg  m0.67/s2  sigma-T
     0.0    0.017    225.0    26.60    12.70      0.0  0.000196    0.017    225.0   0.0003  19.98988
   1.000    0.017    225.0    26.60    12.70      0.0  0.000198    0.017    225.0   0.0003  19.98988
   5.000    0.017    225.0    28.20    12.20      0.0  0.000198    0.017    225.0   0.0003  21.31369
   10.00    0.017    225.0    29.10    11.60      0.0  0.000198    0.017    225.0   0.0003  22.11543
   15.00    0.017    225.0    29.60    10.60      0.0  0.000197    0.017    225.0   0.0003  22.67329
   20.00    0.017    225.0    29.80    9.800      0.0  0.000197    0.017    225.0   0.0003  22.95817
   25.00    0.017    225.0    29.90    9.500      0.0  0.000196    0.017    225.0   0.0003  23.08290
   30.00    0.017    225.0    29.90    9.100      0.0  0.000196    0.017    225.0   0.0003  23.14401

Diffuser table:
  P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)  (deg)  (deg)     (m)     (m)      ()    (ft)    (m)(concent)    (m)  (MGD)   (psu)    (C)(col/dl)
 4.0000     0.0  300.00     0.0     0.0  16.000  13.000  48.800  200.00  23.940  5.3000     0.0  15.000
3.74E+6

Simulation:
Froude No:     11.60; Strat No: 5.45E-4; Spcg No:   39.00; k:   105.3; eff den (sigmaT) -0.836341; eff vel
1.790(m/s);
      Depth  Amb-cur    P-dia  Polutnt  net Dil   x-posn   y-posn     Time   Iso dia
Step     (m)   (cm/s)    (in) (col/dl)       ()      (m)      (m)      (s)       (m)
  0    23.94    1.700    4.000 3.740E+6    1.000      0.0      0.0      0.0   0.1014;  11.44 T-90hr,
  1    23.94    1.700    4.000 3.740E+6    1.000      0.0      0.0      0.0   0.1016;  11.44 T-90hr,
  2    23.93    1.700    10.94 1.929E+6    1.939   -0.497    0.285    0.320   0.2780;  11.43 T-90hr,
  3    23.92    1.700    14.30 1.472E+6    2.540   -0.585    0.334    0.385   0.3632;  11.43 T-90hr,
  5    23.90    1.700    21.15 988111.0    3.785   -0.763    0.432    0.566   0.5372;  11.42 T-90hr,
  7    23.87    1.700    28.20 733621.0    5.098   -0.940    0.527    0.820   0.7162;  11.41 T-90hr,
  9    23.80    1.700    38.91 519516.6    7.199   -1.202    0.662    1.331   0.9883;  11.38 T-90hr,
 11    23.64    1.700    52.78 364415.9    10.26   -1.539    0.825    2.240   1.3405;  11.32 T-90hr,
 13    23.42    1.700    63.65 283591.1    13.19   -1.848    0.963    3.349   1.6165; merging;  11.24 T-90hr,
 17    22.83    1.700    76.78 206140.1    18.14   -2.365    1.164    5.764   1.9498;  11.01 T-90hr,
 21    22.14    1.700    87.81 163240.4    22.91   -2.776    1.297    8.271   2.2298;  10.75 T-90hr,
 27    21.03    1.700    104.8 125663.6    29.76   -3.270    1.419    12.28   2.6616;  10.33 T-90hr,
 55    19.66    1.700    131.6  99789.2    37.48   -3.747    1.497    17.53   3.3416;  9.805 T-90hr,
 67    17.85    1.700    164.7  79160.1    47.25   -4.268    1.537    24.48   4.1811;  9.113 T-90hr,
 79    15.49    1.700    218.5  62651.8    59.70   -4.873    1.525    33.78   5.5450;  8.222 T-90hr,
133    12.24    1.700    351.2  49337.1    75.81   -5.704    1.423    48.38   8.9048;  7.033 T-90hr,
151    9.808    1.700    947.0  43327.2    86.32   -6.744    1.206    68.20   24.008;  6.180 T-90hr,
4/3 Power Law.  Farfield dispersion based on wastefield width of      83.49 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)             (m)     (m)   (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 43327.2   86.32   83.51   6.851 2.78E-4     0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
```

```
 3.26E+6   98.22   125.2   48.80   0.686    0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
 2.14E+5   102.8   132.5   55.65   0.798    0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
count: 1
 ;
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT

Linear Eddy Diffusivity
Eo=(alpha)(width)
(Grace/Brooks equation 7-65)

1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	48.8	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.85E-01	41.949	48.80	9.65E+01	3.87E+04	97

```
/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ----------------------------
-----

Ambient Table:
   Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
      m      m/s       deg       psu        C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0    0.017     225.0     26.60     12.70       0.0  0.000196     0.017     225.0    0.0003  19.98988
   1.000    0.017     225.0     26.60     12.70       0.0  0.000198     0.017     225.0    0.0003  19.98988
   5.000    0.017     225.0     28.20     12.20       0.0  0.000198     0.017     225.0    0.0003  21.31369
   10.00    0.017     225.0     29.10     11.60       0.0  0.000198     0.017     225.0    0.0003  22.11543
   15.00    0.017     225.0     29.60     10.60       0.0  0.000197     0.017     225.0    0.0003  22.67329
   20.00    0.017     225.0     29.80     9.800       0.0  0.000197     0.017     225.0    0.0003  22.95817
   25.00    0.017     225.0     29.90     9.500       0.0  0.000196     0.017     225.0    0.0003  23.08290
   30.00    0.017     225.0     29.90     9.100       0.0  0.000196     0.017     225.0    0.0003  23.14401

Diffuser table:
  P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)   (deg)   (deg)     (m)     (m)      ()    (ft)    (m)(concent)    (m)   (MGD)   (psu)     (C)(col/dl)
 4.0000     0.0  300.00     0.0     0.0  16.000  13.000  122.00  200.00  23.940  5.3000     0.0  15.000
3.74E+6

Simulation:
Froude No:     11.60; Strat No: 5.45E-4; Spcg No:   39.00; k:   105.3; eff den (sigmaT) -0.836341; eff vel
1.790(m/s);
      Depth  Amb-cur    P-dia  Polutnt  net Dil   x-posn   y-posn     Time   Iso dia
Step    (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)      (m)
   0  23.94    1.700    4.000 3.740E+6    1.000      0.0      0.0      0.0   0.1014;  11.44 T-90hr,
   1  23.94    1.700    4.000 3.740E+6    1.000      0.0      0.0      0.0   0.1016;  11.44 T-90hr,
   2  23.93    1.700    10.94 1.929E+6    1.939   -0.497    0.285    0.320   0.2780;  11.43 T-90hr,
   3  23.92    1.700    14.30 1.472E+6    2.540   -0.585    0.334    0.385   0.3632;  11.43 T-90hr,
   5  23.90    1.700    21.15 988111.0    3.785   -0.763    0.432    0.566   0.5372;  11.42 T-90hr,
   7  23.87    1.700    28.20 733621.0    5.098   -0.940    0.527    0.820   0.7162;  11.41 T-90hr,
   9  23.80    1.700    38.91 519516.6    7.199   -1.202    0.662    1.331   0.9883;  11.38 T-90hr,
  11  23.64    1.700    52.78 364415.9    10.26   -1.539    0.825    2.240   1.3405;  11.32 T-90hr,
  13  23.42    1.700    63.65 283591.1    13.19   -1.848    0.963    3.349   1.6165; merging;  11.24 T-90hr,
  17  22.83    1.700    76.78 206140.1    18.14   -2.365    1.164    5.764   1.9498;  11.01 T-90hr,
  21  22.14    1.700    87.81 163240.4    22.91   -2.776    1.297    8.271   2.2298;  10.75 T-90hr,
  27  21.03    1.700    104.8 125663.6    29.76   -3.270    1.419    12.28   2.6616;  10.33 T-90hr,
  55  19.66    1.700    131.6  99789.2    37.48   -3.747    1.497    17.53   3.3416;  9.805 T-90hr,
  67  17.85    1.700    164.7  79160.1    47.25   -4.268    1.537    24.48   4.1811;  9.113 T-90hr,
  79  15.49    1.700    218.5  62651.8    59.70   -4.873    1.525    33.78   5.5450;  8.222 T-90hr,
 133  12.24    1.700    351.2  49337.1    75.81   -5.704    1.423    48.38   8.9048;  7.033 T-90hr,
 151  9.808    1.700    947.0  43327.2    86.32   -6.744    1.206    68.20   24.008;  6.180 T-90hr,
4/3 Power Law.  Farfield dispersion based on wastefield width of      83.49 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)             (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 43327.2   86.32   83.51   6.851 2.78E-4     0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
 2.76E+6   138.1   183.2   100.0   1.522     0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
```

```
 46877.1   236.4   315.8   200.0   3.156     0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
 23592.2   243.8   325.7   206.9   3.268     0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
count: 2
 ;
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	122	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.88E+00	115.149	122.00	1.43E+02	2.61E+04	143

```
/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ----------------------------
-----

Ambient Table:
   Depth  Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
      m      m/s       deg       psu        C     kg/kg       s-1       m/s       deg  m0.67/s2  sigma-T
     0.0    0.017    225.0    26.60    12.70      0.0  0.000196    0.017    225.0   0.0003  19.98988
   1.000    0.017    225.0    26.60    12.70      0.0  0.000198    0.017    225.0   0.0003  19.98988
   5.000    0.017    225.0    28.20    12.20      0.0  0.000198    0.017    225.0   0.0003  21.31369
   10.00    0.017    225.0    29.10    11.60      0.0  0.000198    0.017    225.0   0.0003  22.11543
   15.00    0.017    225.0    29.60    10.60      0.0  0.000197    0.017    225.0   0.0003  22.67329
   20.00    0.017    225.0    29.80    9.800      0.0  0.000197    0.017    225.0   0.0003  22.95817
   25.00    0.017    225.0    29.90    9.500      0.0  0.000196    0.017    225.0   0.0003  23.08290
   30.00    0.017    225.0    29.90    9.100      0.0  0.000196    0.017    225.0   0.0003  23.14401

Diffuser table:
  P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)  (deg)  (deg)     (m)     (m)      ()    (ft)     (m)(concent)     (m)   (MGD)   (psu)     (C)(col/dl)
  4.0000     0.0  300.00     0.0     0.0  16.000  13.000  244.00  200.00  23.940  5.3000     0.0  15.000
3.74E+6

Simulation:
Froude No:     11.60; Strat No: 5.45E-4; Spcg No:   39.00; k:   105.3; eff den (sigmaT) -0.836341; eff vel
1.790(m/s);
       Depth  Amb-cur     P-dia  Polutnt  net Dil   x-posn   y-posn     Time   Iso dia
Step     (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)      (m)
   0   23.94    1.700    4.000 3.740E+6    1.000      0.0      0.0      0.0   0.1014;  11.44 T-90hr,
   1   23.94    1.700    4.000 3.740E+6    1.000      0.0      0.0      0.0   0.1016;  11.44 T-90hr,
   2   23.93    1.700    10.94 1.929E+6    1.939   -0.497    0.285    0.320   0.2780;  11.43 T-90hr,
   3   23.92    1.700    14.30 1.472E+6    2.540   -0.585    0.334    0.385   0.3632;  11.43 T-90hr,
   5   23.90    1.700    21.15 988111.0    3.785   -0.763    0.432    0.566   0.5372;  11.42 T-90hr,
   7   23.87    1.700    28.20 733621.0    5.098   -0.940    0.527    0.820   0.7162;  11.41 T-90hr,
   9   23.80    1.700    38.91 519516.6    7.199   -1.202    0.662    1.331   0.9883;  11.38 T-90hr,
  11   23.64    1.700    52.78 364415.9    10.26   -1.539    0.825    2.240   1.3405;  11.32 T-90hr,
  13   23.42    1.700    63.65 283591.1    13.19   -1.848    0.963    3.349   1.6165; merging;  11.24 T-90hr,
  17   22.83    1.700    76.78 206140.1    18.14   -2.365    1.164    5.764   1.9498;  11.01 T-90hr,
  21   22.14    1.700    87.81 163240.4    22.91   -2.776    1.297    8.271   2.2298;  10.75 T-90hr,
  27   21.03    1.700    104.8 125663.6    29.76   -3.270    1.419    12.28   2.6616;  10.33 T-90hr,
  55   19.66    1.700    131.6  99789.2    37.48   -3.747    1.497    17.53   3.3416;  9.805 T-90hr,
  67   17.85    1.700    164.7  79160.1    47.25   -4.268    1.537    24.48   4.1811;  9.113 T-90hr,
  79   15.49    1.700    218.5  62651.8    59.70   -4.873    1.525    33.78   5.5450;  8.222 T-90hr,
 133   12.24    1.700    351.2  49337.1    75.81   -5.704    1.423    48.38   8.9048;  7.033 T-90hr,
 151   9.808    1.700    947.0  43327.2    86.32   -6.744    1.206    68.20   24.008;  6.180 T-90hr,
4/3 Power Law.  Farfield dispersion based on wastefield width of      83.49 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 43327.2   86.32   83.51   6.851 2.78E-4     0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
 2.76E+6   138.1   183.2   100.0   1.522     0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
```

```
 46877.1   236.4   315.8   200.0   3.156    0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
 17411.5   352.0   470.5   300.0   4.790    0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
 13591.4   360.5   481.8   306.9   4.902    0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
count: 3
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	244	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	3.87E+00	237.149	244.00	2.27E+02	1.65E+04	227

Skagway (model output for 1*depth, 2*depth, 5*depth and 10*depth)

```
Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Skagway" memo

Model configuration items checked: Brooks far-field solution;
  Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
 Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
 Bacteria model  : Mancini (1978) coliform model
 PDS sfc. model heat transfer : Medium
 Equation of State : S, T
 Similarity Profile : Default profile (k=2.0, ...)
 Diffuser port contraction coefficient 0.61
 Light absorption coefficient 0.16
 Farfield increment (m) 200
 UM3 aspiration coefficient 0.1
  Output file: text output tab
  Output each ?? steps 100
  Maximum dilution reported 100000
 Text output format : Standard
 Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:51:09 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: -----------------------
----------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m      m/s      deg       psu       C     kg/kg      s-1       m/s       deg  m0.67/s2  sigma-T
     0.0   0.014    350.0    7.100    11.12      0.0  0.000194    0.014    350.0   0.0003  5.180276
   1.523    0.014    350.0    14.16    10.08      0.0  0.000197    0.014    350.0   0.0003  10.78304
   3.047    0.014    350.0    23.30    8.650      0.0  0.000197    0.014    350.0   0.0003  18.06627
   4.570    0.014    350.0    23.25    8.670      0.0  0.000196    0.014    350.0   0.0003  18.02474
   6.090    0.014    350.0    25.20    8.220      0.0  0.000196    0.014    350.0   0.0003  19.60292
   7.617    0.014    350.0    26.37    8.020      0.0  0.000196    0.014    350.0   0.0003  20.54204
   9.140    0.014    350.0    26.74    7.980      0.0  0.000195    0.014    350.0   0.0003  20.83621
   10.45    0.014    350.0    27.46    7.570      0.0  0.000195    0.014    350.0   0.0003  21.45192
   11.75    0.014    350.0    28.24    7.100      0.0  0.000195    0.014    350.0   0.0003  22.12180
   13.06    0.014    350.0    28.92    6.920      0.0  0.000195    0.014    350.0   0.0003  22.67724
   14.37    0.014    350.0    29.08    6.880      0.0  0.000195    0.014    350.0   0.0003  22.80770
   15.68    0.014    350.0    29.29    6.790      0.0  0.000195    0.014    350.0   0.0003  22.98359
   16.98    0.014    350.0    30.42    6.260      0.0  0.000195    0.014    350.0   0.0003  23.93584
   20.00    0.014    350.0    33.05    5.029      0.0  0.000195    0.014    350.0   0.0003  26.14924

Diffuser table:
   P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
```

```
  (in)  (deg)  (deg)    (m)    (m)    ()   (ft)   (m)(concent)   (m)  (MGD)  (psu)    (C)(col/dl)
 3.0000    0.0  350.00    0.0    0.0  8.0000  3.5000  18.300  200.00  18.150  0.6300    0.0  17.300
2.59E+6

Simulation:
Froude No:    10.06; Strat No: 2.47E-3; Spcg No:   17.93; k:   88.59; eff den (sigmaT) -1.214163; eff vel
1.240(m/s);
       Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step     (m)   (cm/s)    (in) (col/dl)       ()      (m)      (m)      (s)      (m)
   0    18.15    1.400    2.343 2.590E+6    1.000      0.0      0.0      0.0    0.0594;  9.458 T-90hr,
 100    18.07    1.400    12.32 471750.7    5.490    0.639   -0.113    1.673    0.3130;  9.424 T-90hr,
 200    17.61    1.400    21.87 219905.3    11.77    1.318   -0.232    6.056    0.5554;  9.240 T-90hr,
 267    16.05    1.400    42.65  85238.4    30.34    2.296   -0.405    19.44    1.0826; trap level, merging;
8.615 T-90hr,
 300    15.34    1.400    63.27  67833.1    38.10    2.732   -0.482    28.58    1.6057;  8.339 T-90hr,
 318    15.20    1.400    71.39  65187.4    39.64    2.853   -0.503    31.31    1.8117; begin overlap;  8.285
T-90hr,
 400    14.95    1.400    94.95  62151.2    41.55    3.192   -0.563    39.26    2.4091;  8.187 T-90hr,
 480    14.90    1.400    102.6  61721.1    41.83    3.409   -0.601    44.43    2.6036; local maximum rise or
fall;  8.170 T-90hr,
Horiz plane projections in effluent direction: radius(m):   0.0000; CL(m):   3.4620
Lmz(m):   3.4620
forced entrain      1   14.06   3.247   2.606   1.000
Rate sec-1   0.00019534 dy-1      16.8772  kt:  0.000078146 Amb Sal      29.1654
4/3 Power Law.  Farfield dispersion based on wastefield width of       10.07 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1   41.83   10.08   3.462 2.78E-4     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 55457.0   59.02   19.36   18.30   0.295     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 38485.5   66.05   21.80   21.76   0.363     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
count: 1
 ;
5:51:09 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)

This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	18.3	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	2.94E-01	14.838	18.30	5.61E+01	4.60E+04	56

```
/ UM3. 6/23/2021 5:51:23 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: -----------------------
----------

Ambient Table:
   Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
      m      m/s       deg       psu        C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0    0.014     350.0     7.100     11.12       0.0  0.000194     0.014     350.0    0.0003  5.180276
   1.523    0.014     350.0     14.16     10.08       0.0  0.000197     0.014     350.0    0.0003  10.78304
   3.047    0.014     350.0     23.30     8.650       0.0  0.000197     0.014     350.0    0.0003  18.06627
   4.570    0.014     350.0     23.25     8.670       0.0  0.000196     0.014     350.0    0.0003  18.02474
   6.090    0.014     350.0     25.20     8.220       0.0  0.000196     0.014     350.0    0.0003  19.60292
   7.617    0.014     350.0     26.37     8.020       0.0  0.000196     0.014     350.0    0.0003  20.54204
   9.140    0.014     350.0     26.74     7.980       0.0  0.000196     0.014     350.0    0.0003  20.83621
   10.45    0.014     350.0     27.46     7.570       0.0  0.000195     0.014     350.0    0.0003  21.45192
   11.75    0.014     350.0     28.24     7.100       0.0  0.000195     0.014     350.0    0.0003  22.12180
   13.06    0.014     350.0     28.92     6.920       0.0  0.000195     0.014     350.0    0.0003  22.67724
   14.37    0.014     350.0     29.08     6.880       0.0  0.000195     0.014     350.0    0.0003  22.80770
   15.68    0.014     350.0     29.29     6.790       0.0  0.000195     0.014     350.0    0.0003  22.98359
   16.98    0.014     350.0     30.42     6.260       0.0  0.000195     0.014     350.0    0.0003  23.93584
   20.00    0.014     350.0     33.05     5.029       0.0  0.000195     0.014     350.0    0.0003  26.14924

Diffuser table:
  P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)  (deg)  (deg)     (m)     (m)      ()    (ft)    (m)(concent)     (m)   (MGD)   (psu)     (C)(col/dl)
 3.0000     0.0  350.00     0.0     0.0  8.0000  3.5000  36.600  200.00  18.150  0.6300     0.0  17.300
2.59E+6

Simulation:
Froude No:     10.06; Strat No: 2.47E-3; Spcg No:    17.93; k:    88.59; eff den (sigmaT) -1.214163; eff vel
1.240(m/s);
       Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step     (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)      (m)
   0   18.15    1.400    2.343 2.590E+6    1.000      0.0      0.0      0.0  0.05945;  9.458 T-90hr,
 100   18.07    1.400    12.32 471750.7    5.490    0.639   -0.113    1.673   0.3130;  9.424 T-90hr,
 200   17.61    1.400    21.87 219905.3    11.77    1.318   -0.232    6.056   0.5554;  9.240 T-90hr,
 267   16.05    1.400    42.65  85238.4    30.34    2.296   -0.405    19.44   1.0826; trap level, merging;
8.615 T-90hr,
 300   15.34    1.400    63.27  67833.1    38.10    2.732   -0.482    28.58   1.6057;  8.339 T-90hr,
 318   15.20    1.400    71.39  65187.4    39.64    2.853   -0.503    31.31   1.8117; begin overlap;  8.285
T-90hr,
 400   14.95    1.400    94.95  62151.2    41.55    3.192   -0.563    39.26   2.4091;  8.187 T-90hr,
 480   14.90    1.400    102.6  61721.1    41.83    3.409   -0.601    44.43   2.6036; local maximum rise or
fall;  8.170 T-90hr,
Horiz plane projections in effluent direction: radius(m):   0.0000; CL(m):   3.4620
Lmz(m):   3.4620
```

```
forced entrain      1   14.06   3.247   2.606   1.000
Rate sec-1   0.00019534 dy-1      16.8772  kt:  0.000078146 Amb Sal      29.1654
4/3 Power Law.  Farfield dispersion based on wastefield width of      10.07 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)           (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1   41.83   10.08   3.462 2.78E-4     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 50071.9   100.1   33.29   36.60   0.658     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 23499.3   108.8   36.19   40.06   0.726     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
count: 1
 ;
5:51:23 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	36.6	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.58E-01	33.138	36.60	8.58E+01	3.01E+04	86

```
/ UM3. 6/23/2021 5:51:35 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ------------------------
----------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m       m/s       deg       psu        C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0     0.014     350.0     7.100     11.12       0.0  0.000194     0.014     350.0    0.0003  5.180276
   1.523     0.014     350.0     14.16     10.08       0.0  0.000197     0.014     350.0    0.0003  10.78304
   3.047     0.014     350.0     23.30     8.650       0.0  0.000197     0.014     350.0    0.0003  18.06627
   4.570     0.014     350.0     23.25     8.670       0.0  0.000196     0.014     350.0    0.0003  18.02474
   6.090     0.014     350.0     25.20     8.220       0.0  0.000196     0.014     350.0    0.0003  19.60292
   7.617     0.014     350.0     26.37     8.020       0.0  0.000196     0.014     350.0    0.0003  20.54204
   9.140     0.014     350.0     26.74     7.980       0.0  0.000196     0.014     350.0    0.0003  20.83621
   10.45     0.014     350.0     27.46     7.570       0.0  0.000195     0.014     350.0    0.0003  21.45192
   11.75     0.014     350.0     28.24     7.100       0.0  0.000195     0.014     350.0    0.0003  22.12180
   13.06     0.014     350.0     28.92     6.920       0.0  0.000195     0.014     350.0    0.0003  22.67724
   14.37     0.014     350.0     29.08     6.880       0.0  0.000195     0.014     350.0    0.0003  22.80770
   15.68     0.014     350.0     29.29     6.790       0.0  0.000195     0.014     350.0    0.0003  22.98359
   16.98     0.014     350.0     30.42     6.260       0.0  0.000195     0.014     350.0    0.0003  23.93584
   20.00     0.014     350.0     33.05     5.029       0.0  0.000195     0.014     350.0    0.0003  26.14924

Diffuser table:
   P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()    (ft)     (m)(concent)    (m)   (MGD)   (psu)     (C)(col/dl)
  3.0000     0.0  350.00     0.0     0.0  8.0000  3.5000  91.500  200.00  18.150  0.6300     0.0  17.300
2.59E+6

Simulation:
Froude No:     10.06; Strat No: 2.47E-3; Spcg No:    17.93; k:    88.59; eff den (sigmaT) -1.214163; eff vel
1.240(m/s);
        Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)       (m)
   0    18.15    1.400    2.343 2.590E+6    1.000      0.0      0.0      0.0   0.05945;  9.458 T-90hr,
 100    18.07    1.400    12.32 471750.7    5.490    0.639   -0.113    1.673    0.3130;  9.424 T-90hr,
 200    17.61    1.400    21.87 219905.3    11.77    1.318   -0.232    6.056    0.5554;  9.240 T-90hr,
 267    16.05    1.400    42.65  85238.4    30.34    2.296   -0.405    19.44    1.0826; trap level, merging;
8.615 T-90hr,
 300    15.34    1.400    63.27  67833.1    38.10    2.732   -0.482    28.58    1.6057;  8.339 T-90hr,
 318    15.20    1.400    71.39  65187.4    39.64    2.853   -0.503    31.31    1.8117; begin overlap;  8.285
T-90hr,
 400    14.95    1.400    94.95  62151.2    41.55    3.192   -0.563    39.26    2.4091;  8.187 T-90hr,
 480    14.90    1.400    102.6  61721.1    41.83    3.409   -0.601    44.43    2.6036; local maximum rise or
fall;  8.170 T-90hr,
Horiz plane projections in effluent direction: radius(m):   0.0000; CL(m):   3.4620
Lmz(m):   3.4620
forced entrain      1   14.06   3.247   2.606   1.000
Rate sec-1   0.00019534 dy-1      16.8772  kt:  0.000078146 Amb Sal      29.1654
4/3 Power Law.  Farfield dispersion based on wastefield width of       10.07 m
```

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)           (m)      (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1   41.83   10.08   3.462 2.78E-4     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 36855.9   263.9   87.83   91.50   1.747     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 9323.75   275.8   91.82   94.96   1.816     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
count: 1
 ;
5:51:35 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	91.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	1.75E+00	88.038	91.50	1.77E+02	1.46E+04	178

```
/ UM3. 6/23/2021 5:51:47 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: -----------------------
----------

Ambient Table:
   Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2  sigma-T
     0.0     0.014     350.0     7.100     11.12       0.0  0.000194     0.014     350.0    0.0003  5.180276
   1.523     0.014     350.0     14.16     10.08       0.0  0.000197     0.014     350.0    0.0003  10.78304
   3.047     0.014     350.0     23.30     8.650       0.0  0.000197     0.014     350.0    0.0003  18.06627
   4.570     0.014     350.0     23.25     8.670       0.0  0.000196     0.014     350.0    0.0003  18.02474
   6.090     0.014     350.0     25.20     8.220       0.0  0.000196     0.014     350.0    0.0003  19.60292
   7.617     0.014     350.0     26.37     8.020       0.0  0.000196     0.014     350.0    0.0003  20.54204
   9.140     0.014     350.0     26.74     7.980       0.0  0.000196     0.014     350.0    0.0003  20.83621
   10.45     0.014     350.0     27.46     7.570       0.0  0.000195     0.014     350.0    0.0003  21.45192
   11.75     0.014     350.0     28.24     7.100       0.0  0.000195     0.014     350.0    0.0003  22.12180
   13.06     0.014     350.0     28.92     6.920       0.0  0.000195     0.014     350.0    0.0003  22.67724
   14.37     0.014     350.0     29.08     6.880       0.0  0.000195     0.014     350.0    0.0003  22.80770
   15.68     0.014     350.0     29.29     6.790       0.0  0.000195     0.014     350.0    0.0003  22.98359
   16.98     0.014     350.0     30.42     6.260       0.0  0.000195     0.014     350.0    0.0003  23.93584
   20.00     0.014     350.0     33.05     5.029       0.0  0.000195     0.014     350.0    0.0003  26.14924

Diffuser table:
   P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()    (ft)     (m)(concent)    (m)   (MGD)   (psu)     (C)(col/dl)
  3.0000     0.0  350.00     0.0     0.0  8.0000  3.5000  183.00  200.00  18.150  0.6300     0.0  17.300
2.59E+6

Simulation:
Froude No:    10.06; Strat No: 2.47E-3; Spcg No:   17.93; k:   88.59; eff den (sigmaT) -1.214163; eff vel
1.240(m/s);
        Depth  Amb-cur    P-dia  Polutnt   Dilutn   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)       (m)
   0    18.15    1.400    2.343 2.590E+6    1.000      0.0      0.0      0.0   0.05945;  9.458 T-90hr,
 100    18.07    1.400    12.32 471750.7    5.490    0.639   -0.113    1.673    0.3130;  9.424 T-90hr,
 200    17.61    1.400    21.87 219905.3    11.77    1.318   -0.232    6.056    0.5554;  9.240 T-90hr,
 267    16.05    1.400    42.65  85238.4    30.34    2.296   -0.405    19.44    1.0826; trap level, merging;
8.615 T-90hr,
 300    15.34    1.400    63.27  67833.1    38.10    2.732   -0.482    28.58    1.6057;  8.339 T-90hr,
 318    15.20    1.400    71.39  65187.4    39.64    2.853   -0.503    31.31    1.8117; begin overlap;  8.285
T-90hr,
 400    14.95    1.400    94.95  62151.2    41.55    3.192   -0.563    39.26    2.4091;  8.187 T-90hr,
 480    14.90    1.400    102.6  61721.1    41.83    3.409   -0.601    44.43    2.6036; local maximum rise or
fall;  8.170 T-90hr,
Horiz plane projections in effluent direction: radius(m):   0.0000; CL(m):   3.4620
Lmz(m):   3.4620
forced entrain      1   14.06   3.247   2.606   1.000
Rate sec-1   0.00019534 dy-1      16.8772  kt:  0.000078146 Amb Sal       29.1654
4/3 Power Law.  Farfield dispersion based on wastefield width of      10.07 m
```

```
    conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)             (m)      (m)     (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1    41.83    10.08    3.462 2.78E-4     0.0    16.30    1.400    350.0 3.00E-4 7.8146E-5
 22115.3    634.0    211.0    183.0    3.563      0.0    16.30    1.400    350.0 3.00E-4 7.8146E-5
 3965.60    649.9    216.3    186.5    3.631      0.0    16.30    1.400    350.0 3.00E-4 7.8146E-5
count: 1
 ;
5:51:47 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	183	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	3.56E+00	179.538	183.00	3.30E+02	7.82E+03	331

Wrangell (model output for 1*depth, 2*depth, 5*depth and 10*depth)

```
Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Wrangell" memoQ=

Model configuration items checked: Brooks far-field solution; Report effective dilution;
  Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
 Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
 Bacteria model  : Mancini (1978) coliform model
 PDS sfc. model heat transfer : Medium
 Equation of State : S, T
 Similarity Profile : Default profile (k=2.0, ...)
 Diffuser port contraction coefficient 0.61
 Light absorption coefficient 0.16
 Farfield increment (m) 200
 UM3 aspiration coefficient 0.1
  Output file: text output tab
  Output each ?? steps 100
  Maximum dilution reported 100000
 Text output format : Standard
 Max vertical reversals : to max rise or fall

/ UM3. 8/3/2021 9:23:16 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ----------------------
-----------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
        m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2  sigma-T
      0.0     0.040     90.00     11.00     11.30       0.0  0.000194     0.040     90.00    0.0003  8.178952
    3.000     0.040     90.00     11.00     11.30       0.0  0.000194     0.040     90.00    0.0003  8.178952
    6.000     0.040     90.00     11.20     12.70       0.0  0.000194     0.040     90.00    0.0003  8.137535
    9.000     0.040     90.00     12.10     12.80       0.0  0.000194     0.040     90.00    0.0003  8.815796
    12.00     0.040     90.00     12.80     11.90       0.0  0.000194     0.040     90.00    0.0003  9.487716
    15.00     0.040     90.00     14.00     11.10       0.0  0.000194     0.040     90.00    0.0003  10.52628
    18.00     0.040     90.00     14.90     11.10       0.0  0.000194     0.040     90.00    0.0003  11.22223
    21.00     0.040     90.00     15.80     11.20       0.0  0.000194     0.040     90.00    0.0003  11.90396
    24.00     0.040     90.00     16.20     11.00       0.0  0.000194     0.040     90.00    0.0003  12.24129
    27.00     0.040     90.00     16.80     11.00       0.0  0.000194     0.040     90.00    0.0003  12.70520
    30.00     0.040     90.00     16.90     10.90       0.0  0.000194     0.040     90.00    0.0003  12.79661
    31.00     0.040     90.00     16.93     10.87       0.0  0.000194     0.040     90.00    0.0003  12.82707

Diffuser table:
   P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()    (ft)     (m)(concent)    (m)   (MGD)   (psu)     (C)(col/dl)
```

```
  3.9500    0.0  90.000    0.0     0.0  8.0000  32.000  30.500  200.00  30.350  3.0000     0.0  18.400
1.91E+5

Simulation:
Froude No:    32.56; Strat No: 8.40E-4; Spcg No:   124.5; k:   85.17; eff den (sigmaT) -1.415928; eff vel
3.407(m/s);
      Depth  Amb-cur    P-dia  Polutnt  net Dil   x-posn   y-posn     Time   Iso dia
Step    (m)   (cm/s)    (in) (col/dl)      ()      (m)      (m)      (s)      (m)
  0    30.35    4.000    3.085 191000.0    1.000     0.0      0.0      0.0      0.0;  14.06 T-90hr,
 100    30.32    4.000    21.88  25869.1    7.383    0.000    1.223    1.461    0.5546;  14.05 T-90hr,
 200    29.23    4.000    75.55   6306.8    30.29    0.000    5.127    18.85    1.9038;  13.64 T-90hr,
 265    25.85    4.000    147.1   2462.3    77.57    0.000    9.228    57.16    3.6599; trap level;  12.34 T-
90hr,
 300    24.85    4.000    191.4   1914.4    99.77    0.000    10.45    72.89    4.7344;  11.95 T-90hr,
 301    24.84    4.000    192.3   1907.0    100.2    0.000    10.47    73.16    4.7551; begin overlap;  11.95 T-
90hr,
 400    24.32    4.000    227.5   1702.3    112.2    0.000    11.88    93.03    5.6075;  11.75 T-90hr,
 415    24.32    4.000    228.3   1697.3    112.5    0.000    12.05    95.47    5.6269; local maximum rise or
fall;  11.75 T-90hr,
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):   12.046
Lmz(m):   12.046
forced entrain      1   143.3   6.034   5.800   1.000
Rate sec-1   0.00019572 dy-1      16.9100  kt:  0.000054521 Amb Sal      16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law.  Farfield dispersion based on wastefield width of      74.08 m
   conc  dilutn   width distnce    time bckgrnd    decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 1697.28   112.0   74.09   12.05 2.78E-4     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1632.35   112.0   81.17   30.50   0.128     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1668.65   112.4   85.91   42.55   0.212     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
count: 1
 ;
9:23:18 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
		4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	30.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	0.128125	18.45	30.5	1.12E+02	1697	113

```
/ UM3. 8/3/2021 9:24:14 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ----------------------
-----------

Ambient Table:
   Depth  Amb-cur  Amb-dir  Amb-sal  Amb-tem  Amb-pol Solar rad  Far-spd  Far-dir  Disprsn
Density
      m      m/s      deg      psu       C    kg/kg      s-1      m/s      deg  m0.67/s2  sigma-T
     0.0    0.040    90.00    11.00    11.30      0.0 0.000195    0.040    90.00   0.0003  8.178952
   3.000    0.040    90.00    11.00    11.30      0.0 0.000196    0.040    90.00   0.0003  8.178952
   6.000    0.040    90.00    11.20    12.70      0.0 0.000196    0.040    90.00   0.0003  8.137535
   9.000    0.040    90.00    12.10    12.80      0.0 0.000196    0.040    90.00   0.0003  8.815796
   12.00    0.040    90.00    12.80    11.90      0.0 0.000196    0.040    90.00   0.0003  9.487716
   15.00    0.040    90.00    14.00    11.10      0.0 0.000196    0.040    90.00   0.0003  10.52628
   18.00    0.040    90.00    14.90    11.10      0.0 0.000196    0.040    90.00   0.0003  11.22223
   21.00    0.040    90.00    15.80    11.20      0.0 0.000196    0.040    90.00   0.0003  11.90396
   24.00    0.040    90.00    16.20    11.00      0.0 0.000196    0.040    90.00   0.0003  12.24129
   27.00    0.040    90.00    16.80    11.00      0.0 0.000196    0.040    90.00   0.0003  12.70520
   30.00    0.040    90.00    16.90    10.90      0.0 0.000196    0.040    90.00   0.0003  12.79661
   31.00    0.040    90.00    16.93    10.87      0.0 0.000196    0.040    90.00   0.0003  12.82707

Diffuser table:
  P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)  (deg)  (deg)     (m)     (m)      ()    (ft)     (m)(concent)     (m)   (MGD)   (psu)     (C)(col/dl)
 3.9500     0.0  90.000     0.0     0.0  8.0000  32.000  61.000  200.00  30.350  3.0000     0.0  18.400
1.91E+5

Simulation:
Froude No:     32.56; Strat No: 8.40E-4; Spcg No:   124.5; k:   85.17; eff den (sigmaT) -1.415928; eff vel
3.407(m/s);
       Depth  Amb-cur    P-dia  Polutnt  net Dil   x-posn   y-posn     Time   Iso dia
Step     (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)      (m)
   0    30.35    4.000    3.085 191000.0    1.000      0.0      0.0      0.0  0.07603;  14.06 T-90hr,
 100    30.32    4.000    21.88  25869.1    7.383    0.000    1.223    1.461   0.5546;  14.05 T-90hr,
 200    29.23    4.000    75.55   6306.8    30.29    0.000    5.127    18.85   1.9038;  13.64 T-90hr,
 265    25.85    4.000    147.1   2462.3    77.57    0.000    9.228    57.16   3.6599; trap level;  12.34 T-
90hr,
 300    24.85    4.000    191.4   1914.4    99.77    0.000    10.45    72.89   4.7344;  11.95 T-90hr,
 301    24.84    4.000    192.3   1907.0    100.2    0.000    10.47    73.16   4.7551; begin overlap;  11.95 T-
90hr,
 400    24.32    4.000    227.5   1702.3    112.2    0.000    11.88    93.03   5.6075;  11.75 T-90hr,
 415    24.32    4.000    228.3   1697.3    112.5    0.000    12.05    95.47   5.6269; local maximum rise or
fall;  11.75 T-90hr,
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):   12.046
Lmz(m):   12.046
forced entrain      1   143.3   6.034   5.800   1.000
Rate sec-1   0.00019572 dy-1      16.9100  kt:  0.000054521 Amb Sal       16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law.  Farfield dispersion based on wastefield width of       74.08 m
```

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)           (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 1697.28   112.0   74.09   12.05 2.78E-4    0.0   16.34    4.000    90.00 3.00E-4 5.4521E-5
 1565.88   114.7   93.35   61.00   0.340    0.0   16.34    4.000   90.00 3.00E-4 5.4521E-5
 1596.09   117.5   98.31   73.05   0.424    0.0   16.34    4.000   90.00 3.00E-4 5.4521E-5
count: 1
 ;
9:24:14 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	61	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	0.339930556	48.95	61	1.15E+02	1657	115

```
/ UM3. 8/3/2021 9:24:33 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ----------------------
-----------

Ambient Table:
    Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
        m       m/s       deg       psu        C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
      0.0     0.040     90.00     11.00     11.30       0.0  0.000195     0.040     90.00    0.0003  8.178952
    3.000     0.040     90.00     11.00     11.30       0.0  0.000196     0.040     90.00    0.0003  8.178952
    6.000     0.040     90.00     11.20     12.70       0.0  0.000196     0.040     90.00    0.0003  8.137535
    9.000     0.040     90.00     12.10     12.80       0.0  0.000196     0.040     90.00    0.0003  8.815796
    12.00     0.040     90.00     12.80     11.90       0.0  0.000196     0.040     90.00    0.0003  9.487716
    15.00     0.040     90.00     14.00     11.10       0.0  0.000196     0.040     90.00    0.0003  10.52628
    18.00     0.040     90.00     14.90     11.10       0.0  0.000196     0.040     90.00    0.0003  11.22223
    21.00     0.040     90.00     15.80     11.20       0.0  0.000196     0.040     90.00    0.0003  11.90396
    24.00     0.040     90.00     16.20     11.00       0.0  0.000196     0.040     90.00    0.0003  12.24129
    27.00     0.040     90.00     16.80     11.00       0.0  0.000196     0.040     90.00    0.0003  12.70520
    30.00     0.040     90.00     16.90     10.90       0.0  0.000196     0.040     90.00    0.0003  12.79661
    31.00     0.040     90.00     16.93     10.87       0.0  0.000196     0.040     90.00    0.0003  12.82707

Diffuser table:
   P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
    (in)   (deg)   (deg)     (m)     (m)      ()    (ft)     (m)(concent)     (m)   (MGD)   (psu)     (C)(col/dl)
  3.9500     0.0  90.000     0.0     0.0  8.0000  32.000  152.50  200.00  30.350  3.0000     0.0  18.400
1.91E+5

Simulation:
Froude No:     32.56; Strat No: 8.40E-4; Spcg No:   124.5; k:   85.17; eff den (sigmaT) -1.415928; eff vel
3.407(m/s);
        Depth  Amb-cur    P-dia  Polutnt  net Dil   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)       (m)
   0    30.35    4.000    3.085 191000.0    1.000      0.0      0.0      0.0   0.07603;  14.06 T-90hr,
 100    30.32    4.000    21.88  25869.1    7.383    0.000    1.223    1.461    0.5546;  14.05 T-90hr,
 200    29.23    4.000    75.55   6306.8    30.29    0.000    5.127    18.85    1.9038;  13.64 T-90hr,
 265    25.85    4.000    147.1   2462.3    77.57    0.000    9.228    57.16    3.6599; trap level;  12.34 T-
90hr,
 300    24.85    4.000    191.4   1914.4    99.77    0.000    10.45    72.89    4.7344;  11.95 T-90hr,
 301    24.84    4.000    192.3   1907.0    100.2    0.000    10.47    73.16    4.7551; begin overlap;  11.95 T-
90hr,
 400    24.32    4.000    227.5   1702.3    112.2    0.000    11.88    93.03    5.6075;  11.75 T-90hr,
 415    24.32    4.000    228.3   1697.3    112.5    0.000    12.05    95.47    5.6269; local maximum rise or
fall;  11.75 T-90hr,
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):    12.046
Lmz(m):    12.046
forced entrain      1   143.3   6.034   5.800   1.000
Rate sec-1   0.00019572 dy-1      16.9100  kt:  0.000054521 Amb Sal      16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law.  Farfield dispersion based on wastefield width of      74.08 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
```

```
(col/dl)          (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 1697.28   112.0   74.09   12.05 2.78E-4     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1382.28   148.5   133.1   152.5   0.976     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1220.33   154.2   138.7   164.5   1.059     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
count: 1
 ;
9:24:33 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	152.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	0.975347222	140.45	152.5	1.49E+02	1280	149

```
/ UM3. 8/3/2021 9:24:50 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ----------------------
-----------

Ambient Table:
   Depth   Amb-cur   Amb-dir   Amb-sal   Amb-tem   Amb-pol Solar rad   Far-spd   Far-dir   Disprsn
Density
       m       m/s       deg       psu         C     kg/kg       s-1       m/s       deg  m0.67/s2   sigma-T
     0.0     0.040     90.00     11.00     11.30       0.0  0.000195     0.040     90.00    0.0003  8.178952
   3.000     0.040     90.00     11.00     11.30       0.0  0.000196     0.040     90.00    0.0003  8.178952
   6.000     0.040     90.00     11.20     12.70       0.0  0.000196     0.040     90.00    0.0003  8.137535
   9.000     0.040     90.00     12.10     12.80       0.0  0.000196     0.040     90.00    0.0003  8.815796
   12.00     0.040     90.00     12.80     11.90       0.0  0.000196     0.040     90.00    0.0003  9.487716
   15.00     0.040     90.00     14.00     11.10       0.0  0.000196     0.040     90.00    0.0003  10.52628
   18.00     0.040     90.00     14.90     11.10       0.0  0.000196     0.040     90.00    0.0003  11.22223
   21.00     0.040     90.00     15.80     11.20       0.0  0.000196     0.040     90.00    0.0003  11.90396
   24.00     0.040     90.00     16.20     11.00       0.0  0.000196     0.040     90.00    0.0003  12.24129
   27.00     0.040     90.00     16.80     11.00       0.0  0.000196     0.040     90.00    0.0003  12.70520
   30.00     0.040     90.00     16.90     10.90       0.0  0.000196     0.040     90.00    0.0003  12.79661
   31.00     0.040     90.00     16.93     10.87       0.0  0.000196     0.040     90.00    0.0003  12.82707

Diffuser table:
  P-dia VertAng H-Angle SourceX SourceY   Ports Spacing  MZ-dis Isoplth P-depth Ttl-flo Eff-sal
Temp Polutnt
   (in)   (deg)   (deg)     (m)     (m)      ()    (ft)     (m)(concent)    (m)   (MGD)   (psu)     (C)(col/dl)
 3.9500     0.0  90.000     0.0     0.0  8.0000  32.000  305.00  200.00  30.350  3.0000     0.0  18.400
1.91E+5

Simulation:
Froude No:     32.56; Strat No: 8.40E-4; Spcg No:   124.5; k:   85.17; eff den (sigmaT) -1.415928; eff vel
3.407(m/s);
        Depth  Amb-cur    P-dia  Polutnt  net Dil   x-posn   y-posn     Time   Iso dia
Step      (m)   (cm/s)     (in) (col/dl)       ()      (m)      (m)      (s)      (m)
   0    30.35    4.000    3.085 191000.0    1.000      0.0      0.0      0.0  0.07603;  14.06 T-90hr,
 100    30.32    4.000    21.88  25869.1    7.383    0.000    1.223    1.461   0.5546;  14.05 T-90hr,
 200    29.23    4.000    75.55   6306.8    30.29    0.000    5.127    18.85   1.9038;  13.64 T-90hr,
 265    25.85    4.000    147.1   2462.3    77.57    0.000    9.228    57.16   3.6599; trap level;  12.34 T-
90hr,
 300    24.85    4.000    191.4   1914.4    99.77    0.000    10.45    72.89   4.7344;  11.95 T-90hr,
 301    24.84    4.000    192.3   1907.0    100.2    0.000    10.47    73.16   4.7551; begin overlap;  11.95 T-
90hr,
 400    24.32    4.000    227.5   1702.3    112.2    0.000    11.88    93.03   5.6075;  11.75 T-90hr,
 415    24.32    4.000    228.3   1697.3    112.5    0.000    12.05    95.47   5.6269; local maximum rise or
fall;  11.75 T-90hr,
Horiz plane projections in effluent direction: radius(m):      0.0; CL(m):    12.046
Lmz(m):    12.046
forced entrain      1   143.3   6.034   5.800   1.000
Rate sec-1   0.00019572 dy-1       16.9100  kt:  0.000054521 Amb Sal        16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law.  Farfield dispersion based on wastefield width of       74.08 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
```

```
(col/dl)          (m)     (m)     (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 1697.28   112.0   74.09   12.05 2.78E-4    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1295.62   171.8   155.5   200.0   1.306    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 819.357   286.6   261.7   400.0   2.694    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 642.616   294.2   268.7   412.0   2.778    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
count: 2
 ;
9:24:50 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
		4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	305	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT						
			Eo =	9.3337E-02	m^2/s	
			Beta =	3.7799E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	2.034375	292.95	305	2.29E+02	829	230