Exhibit 3

Starkist Samoa Co. August 15, 2019
Comments on Public Notice Draft Permit NPDES No. AS0000019

Starkist Samoa Co.
August 15, 2019 Comments
Public Notice Draft Permit
NPDES AS000019

Starkist Samoa Co. ("Starkist") is providing these comments on the July 3, 2019 public notice draft National Pollutant Discharge Elimination System ("NPDES") permit ("draft Permit") published by the U.S. Environmental Protection Agency ("US EPA") for its tuna processing facility in Pago Pago, American Samoa.[1] Starkist recognizes the hard work of US EPA staff, along with the American Samoa Environmental Protection Agency ("AS EPA"), to develop the draft Permit. Starkist looks forward to working with US EPA to address the issues and concerns identified in the following comments, and to work toward issuance of a final NPDES permit for the facility that is fair, scientifically-based, protective of the environment, accommodating of Starkist's business, and maintains and supports the economic and social needs of American Samoa.

EXECUTIVE SUMMARY

Based on the reasons set forth in these comments and supporting documents, and as otherwise supported in the Administrative Record, the following revisions should be made to the proposed draft Permit before it is issued in final:

1. The effluent limits for Total Nitrogen ("TN") and Total Phosphorous ("TP") should be revised. Current receiving water quality data demonstrates that American Samoa Water Quality Standards ("AS WQS") are being achieved with the current pollutant loadings from Starkist. This data also confirms the mixing zone modeling submitted in support of the NPDES permit application that supports use of a greater dilution rate factor than applied by US EPA. The computer model used by US EPA is not well suited to this permitting effort because it ignores important differences in density in the water column. Further, Starkist and Samoa Tuna Processors, Inc. ("STP") have agreed to reallocate the allowable Joint Cannery Outfall ("JCO") discharge[2], and this agreement has not been fully recognized or implemented in the draft Permit.

Overall, the proposed effluent limits in the draft Permit represent unnecessary and overly stringent limits. Instead, the receiving water monitoring data and the most updated mixing zone modeling, using a computer model that is capable of accounting for the density gradient at the discharge location, supports alternate TN and TP limits. *See* Section III and Attachment A.

[1] Under separate cover dated August 14, 2019, Starkist submitted supplemental documents for the Administrative Record. The supplemental documents date from the term of the current NPDES permit (issued in 2008) and should have been part of the official Administrative Record. The supplemental documents were submitted under separate cover solely for the convenience of US EPA in incorporating the documents into the Administrative Record. All supplemental documents are incorporated into these comments by reference, whether or not specifically cited herein, and should be considered as supporting documents for these comments even if US EPA were to otherwise refuse to include any such documents in the Administrative Record.

[2] The JCO also conveys the wastewater discharge from the adjacent STP tuna cannery. The wastewater from the two canneries is co-mingled in the JCO. STP has ceased production, with only minor discharges through the JCO, and is under lease to Starkist for a period that extends well past the next permit term.

2. The final Permit should clearly state that mixing zones are being authorized for Starkist's discharge. The draft Permit makes passing references to mixing zones in its receiving water quality monitoring requirements, but otherwise the draft permit does not clearly state whether mixing zones are authorized. This is despite the fact that the prior NPDES permit authorized mixing zones, and AS EPA has stated its approval of the mixing zone analysis submitted by Starkist.

3. The receiving water monitoring requirements should be revised to remove unnecessary stations, to provide for a safe sampling approach near the coral reef, and to provide alternatives for the monitoring requirement for turbidity.

4. The flow rate limit should be removed as it is unnecessary. At a minimum, the requirement should be clarified to ensure that it is understood to be a daily flow limit, and not an instantaneous flow rate limit.

5. Priority pollutant scans should not be required on an annual basis. This is overly burdensome, unprecedented, and unnecessary for a food processing facility with a relatively constant production process.

6. Receiving water quality requirements should be generally consistent between Starkist's NPDES permit and the permits issued to other dischargers into Pago Pago Harbor, to allow for coordinated receiving water quality monitoring. This should include language to provide flexibility during transition periods, such as between the issuance of Starkist permit and the issuance of a renewed NPDES permit for the STP facility.

I. General Comments

A. Introduction

This NPDES permitting process is very important to Starkist. Starkist acknowledges the struggles with permit compliance that resulted from the 2012 cessation of ocean dumping and the subsequent treatment and discharge of high strength wastewater through the JCO into Pago Pago Harbor ("the Harbor"), which occurred during the term of the NPDES permit issued in 2008. Starkist has resolved its liability for violations that occurred through the March 7, 2018 Consent Decree with the United States and the Territory of American Samoa (the "Consent Decree"), and is now subject to a compliance program under the Consent Decree. Starkist has invested significant resources in addressing compliance issues at the facility and in upgrading its wastewater treatment equipment.

The results of multiple[3] receiving water monitoring events since early 2018 have consistently, and with statistical significance, shown that limits more restrictive than the JCO's effluent pollutant

[3] Sampling events were performed in March, May, August, September, October, and December 2018, in addition to February 2019, with all results now available and submitted to US EPA. The March 2018, August 2018, and February 2019 were permit required sampling events; the remainder were supplemental voluntary sampling events done by Starkist. Complete reports for these sampling events were omitted from

loading rates, since March 2018, are unnecessary to ensure attainment of AS WQS for nutrients and dissolved oxygen. It is expected that it will not be possible to meet the proposed permit limits without significant expenditures to purchase, install, operate and maintain additional wastewater treatment equipment.[4]

To the extent a treatment system can be designed and constructed to meet the draft Permit limits, given the very limited space available at the facility, it is important to recognize that the operation of a complex treatment system in a remote location with limited local operation and maintenance resources increases the risk of future non-compliance. Contracting skilled off-island treatment operators may be possible but at a significant premium, while the local mechanical, electrical, and instrumentation and control staff are less skilled than in other parts of the United States, requiring emergency off-island support in the event of equipment failure. For example, recent repairs to wastewater treatment equipment prompted a shutdown of the production facility due to the limited ability for off-island contractors to travel to the site on one of the twice-weekly flights between Hawaii and American Samoa, even on an emergency basis.

The anticipated costs to attempt to meet the proposed effluent limits presents a serious challenge to the viability of the facility and have forced Starkist to evaluate its options to close the facility and transfer production elsewhere. Transferring production off the island would have a very negative impact on the American Samoa economy. Starkist is the largest private-sector employer in American Samoa, with approximately 2,400 direct employees approximately 16% of the American Samoa workforce; approximately the same number of people are employed indirectly in jobs that result from Starkist's operations in American Samoa. An estimated 90% of the shipping containers leaving the Port of Pago Pago are associated with Starkist's operations. Starkist is already operating at a significant cost disadvantage to its competition in the tuna canning industry as a result of the competition's exclusive use of foreign canneries in low-wage countries. According to a 2016 Government Accountability Office (GAO) report, Starkist could save at least $7.6 million annually - and as much as $22.3 million annually - by relocating its American Samoa operations to another tariff-free country with lower labor costs.[5] The cost savings associated with moving operations would grow significantly if the unnecessarily stringent limits in the draft Permit are imposed.

Starkist is not suggesting that the risks to the future viability of the Starkist facility or the American Samoa economy is a basis, in itself, to determine permit limits or sidestep environmental protection. Instead, these factors are the reasons why every care[6] should be taken to derive

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US EPA's Administrative Record, but have been submitted separately by Starkist as a supplement to the Administrative Record, and are incorporated herein by reference.

[4] Even after accounting for ocean disposal, approximately 500 lbs/day on an average monthly basis and 1,600 lbs/day on a maximum day basis would need to be removed from the wastewater. At these levels, additional treatment will be required. Due to the volumes of wastewater discharged from the Starkist facility, the footprint of the treatment system will be significant at a facility with essentially no available space. The cost of additional treatment is significant.

[5] U.S. Government Accountability Office. *American Samoa: Alternatives for Raising Minimum Wages to Keep Pace with the Cost of Living and Reach the Federal Level*. December 2016.

[6] As noted in Governor Moliga's October 1, 2018 letter, "[t]he permitting process is of the utmost importance to the American Samoa Government and the people of American Samoa."

appropriate forward-looking permit limits, and associated permit terms and conditions, which are appropriately protective of the environmental, economic and social needs of American Samoa.

B. Ocean Disposal Permitting

Simultaneously with the submittal of the most recent updated permit application for this NPDES Permit in February 2019, Starkist has been engaged in discussions with US EPA and AS EPA regarding submittal of a permit application for a resumption of ocean disposal of certain fish and fish processing wastes. Ocean disposal is authorized under 33 U.S.C. § 1412(d) and § 1414b(k)(3)(B). Ocean disposal would utilize the existing approved ocean disposal location for fish processing waste, pursuant to the approval of the location at 40 C.F.R. § 228.15(m). The February 2019 NPDES permit application accounts for, and assumes, ocean disposal of approved waste materials. *See* § 228.15(m)(1)(vi). Starkist has not attempted to seek duplicative permitting for approval of discharge of such waste streams via both the JCO outfall in the outer Harbor and through ocean disposal. In the event that an ocean disposal permit is not or cannot be issued, then the assumptions underlying this NPDES permit will need to be revisited. In such event, it is likely that revisions to the permit will be necessary.

Accordingly, Starkist's comments here on the proposed NPDES Permit otherwise assume that an ocean disposal permit will be achievable. In the event that ocean disposal permitting is not achieved for all of the waste streams currently intended to be included in an ocean disposal permit, Starkist reserves the right to seek to reopen the NPDES Permit to allow for discharge of the waste streams otherwise intended for ocean disposal, and to update, revise or otherwise change the comments made herein to account for the scenario where the waste streams currently intended for ocean disposal need to be discharged under the NPDES Permit.

C. Changed Circumstances

Starkist has a continuing concern that many aspects of the approach taken to develop the draft Permit fail to account for a number of changed circumstances, both since the current permit was issued in 2008, and over the course of the past year.

1. Starkist's Improved Effluent Quality

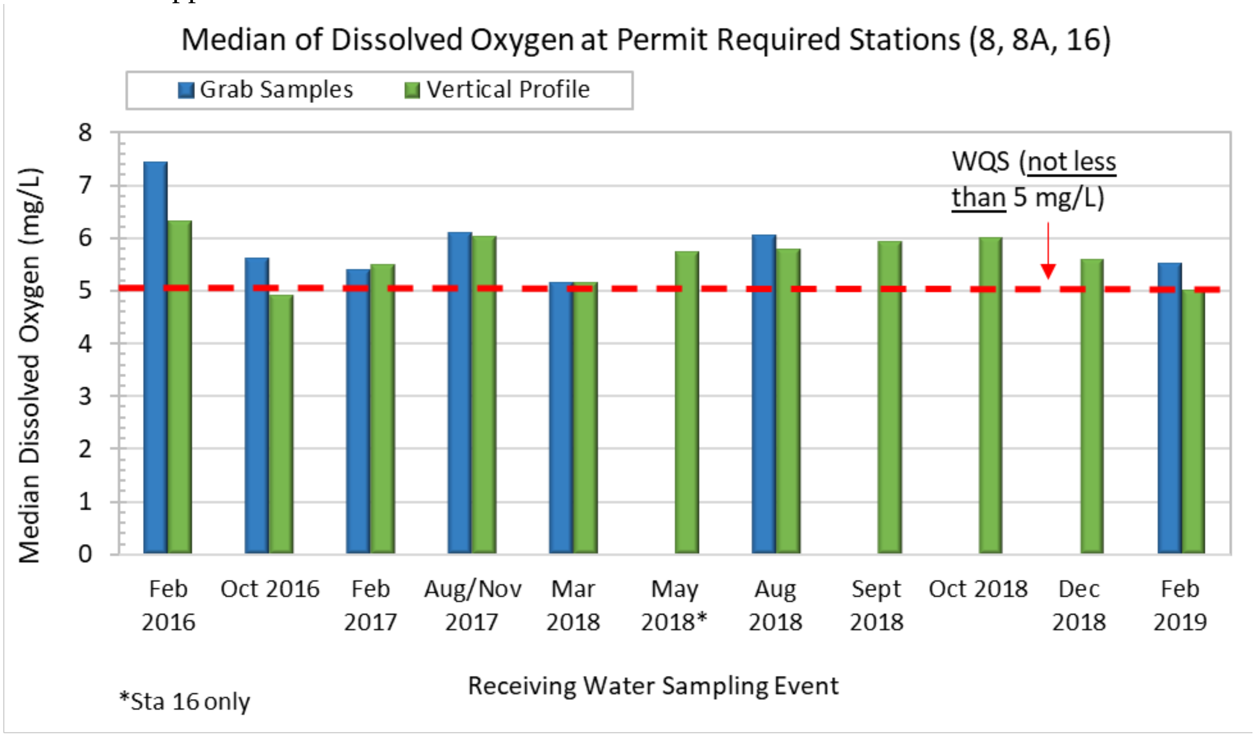
The quality of Starkist's effluent has improved dramatically with the installation of the upgraded wastewater equipment required under the Consent Decree. Effluent data from April 2018 through January 31, 2018 (the last full month in advanced of the NPDES application on February 12, 2019), is attached as Exhibit 1, and represents the operation of the upgraded wastewater treatment equipment, and is representative of the future discharge (subject to accounting for the ocean disposal of certain waste streams).[7] In contrast, some sections of the Fact Sheet describe the discharge through use of outdated and unrepresentative discharge data, and indicate that Starkist's discharge was evaluated as if the significantly higher pollutant discharge during 2012-2017 were still occurring and were planned to continue for the next permit term. For example, Table 1 of the Fact Sheet presents data from April 2008 through March 2018, thereby excluding the time period following the implementation of wastewater treatment upgrades.

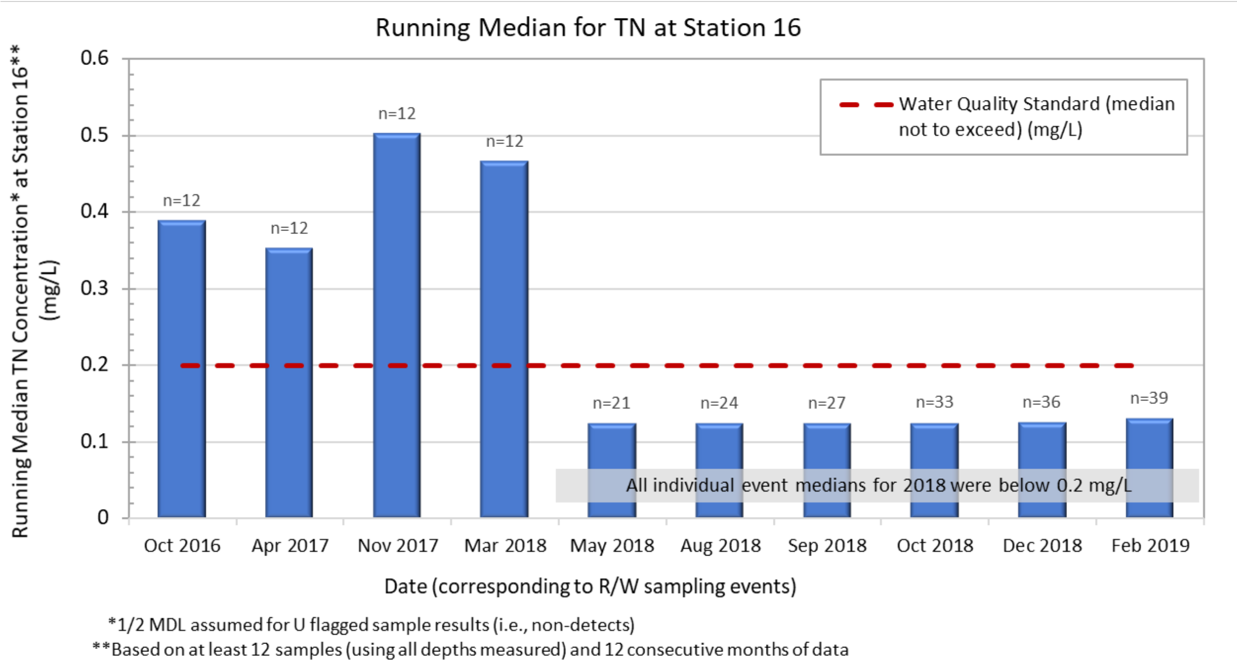
[7] *See* Exhibit 1.

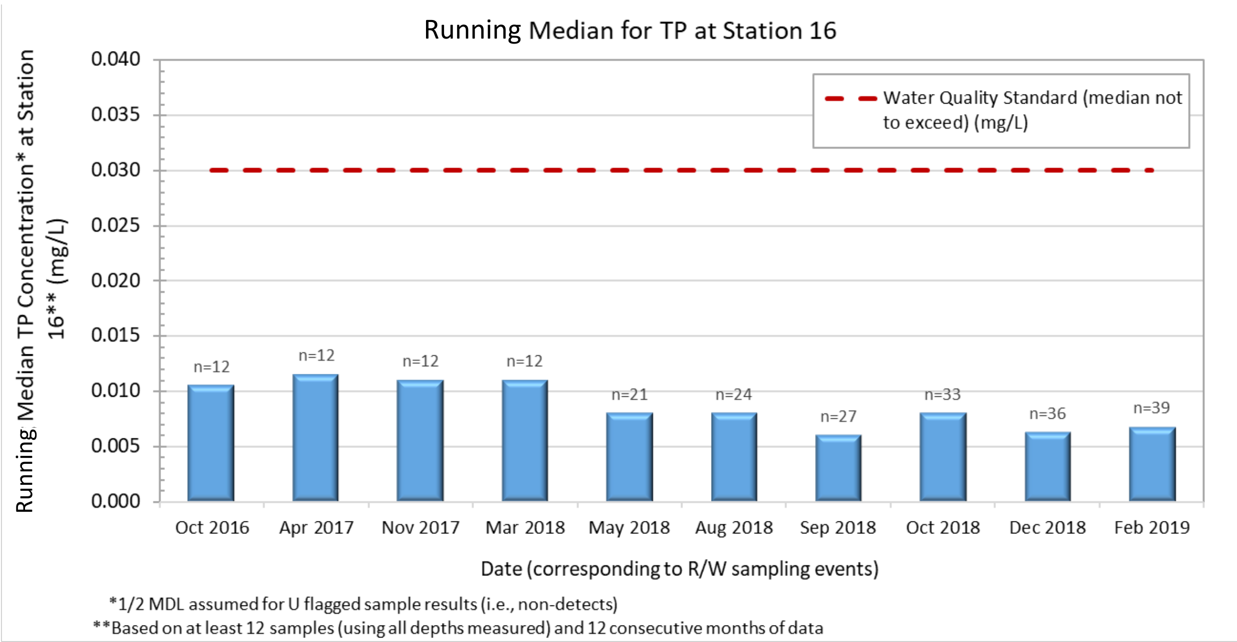
2. AS WQS are Being Met

Water quality sampling during 2018 and 2019, after the initial treatment upgrades were fully implemented, shows that the water in the Harbor is consistently meeting AS WQS. Starkist conducted the required bi-annual permit required receiving water sampling in March 2018, August 2018 and February 2019 and also conducted voluntary supplemental receiving water sampling in May, September, October and December 2018. The supplemental sampling was completed with the goal of developing a statistically significant data set for permitting purposes. The data shows water quality improvements since the 2012-2017 timeframe, and importantly shows that all applicable AS WQS are being met at the edge of the mixing zones established in the 2008 permit. This is true even before any of the waste streams are diverted from the NPDES discharge to ocean disposal. The Fact Sheet, however, indicates that the draft Permit was developed using outdated information that assumes that water quality standards cannot be met by the current discharge. US EPA's failure to recognize that water quality standards are being achieved, and assumption that they cannot be met without significant reductions from current effluent loadings, is arbitrary and capricious.

Key findings from Starkist's receiving water quality sampling events in 2018 and 2019 are summarized in the plots below. Individually and collectively, the results of the receiving water sampling demonstrate attainment of water quality standards. Copies of receiving water quality monitoring reports are included in the Administrative Record and/or have been submitted by Starkist as supplements to the Administrative Record.







3. Apportionment Between Starkist and STP Facilities

Starkist's NPDES permit application seeks apportionment of loadings for nitrogen, ammonia and phosphorous between the Starkist facility and the STP facility since Starkist and STP discharge through the common pipeline of the JCO. Derivation of effluent limits based on meeting water quality standards unavoidably must consider both the Starkist and STP discharge together. The effluent has an indivisible impact on the receiving water when it exits the JCO diffuser. Under an approach akin to a wasteload allocation, in earlier permitting cycles, beginning with the initial operation of the JCO, Starkist and the various operators of the STP facility (which have changed over time) were allowed to shift discharge allowances between the two facilities, so long as the combined discharge from the JCO did not exceed maximum allowable levels.[8] For this permit cycle, Starkist and STP reached an agreement allocating the JCO discharge for their respective NPDES permits.[9] Moreover, as US EPA is aware, Starkist has leased the STP facility for a term that will last beyond the next permit term. Continuing to allow this approach would not threaten environmental protection, would be consistent with the historical approach taken to permit the JCO discharge, and would provide the flexibility necessary for the effluent limits to be achievable by Starkist. The apportionment between the facilities has been honored in the past, and the Fact Sheet and the permit both fail to acknowledge this history and to present any rationale or reason for changing this wasteload allocation approach for this permit.[10]

II. AS EPA's Acceptance of the MZA and Section 401 Water Quality Certification.

The mixing zone request[11] ("the MZA") submitted jointly on behalf of Starkist and STP, which defined mixing zones and dilution rates, was accepted and is supported by AS EPA. *See* AS EPA letters dated August 7, 2018 and October 1, 2018.[12] To the extent that US EPA disagrees with the MZA and/or declines to accept the mixing zone modeling set forth in the MZA (using the initial dilution computer model UDKHDEN supplemented with subsequent dilution calculations as required), US EPA is overriding and disregarding the input and recommendation of AS EPA. Although US EPA is the NPDES permitting agency for the Territory of American Samoa, US EPA should not take a different approach than that supported by AS EPA absent very good cause. No such cause is present here.

Clean Water Act § 401, 33 U.S.C. 1342, exists for the very purpose of ensuring that state or territorial needs and concerns are identified, recognized and taken into consideration in the NPDES permitting process. Indeed, issuance of an NPDES permit by US EPA is prohibited until the certification process established by § 401 has been addressed. 40 C.F.R. § 124.53. For US EPA to ignore and disregard the § 401 response from American Samoa, without any explanation, is arbitrary, capricious and contrary to law.

Here, US EPA's decision to disregard AS EPA's input appears to be based primarily on a generalized preference for one computer model over another. This is despite the fact that the model used by Starkist is supported by AS EPA via its support for the MZA, and despite the fact that US

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[8] *See* Statement of Basis for 1992 NPDES Permit, at Exhibit 2.

[9] Attached to the June 1, 2018 *Wastewater Treatment System Upgrade Proposal*, in the Administrative Record.

[10] Starkist is aware that an interim letter from AS EPA during the permit development process expressed the opinion that allocation of the discharge might no longer be appropriate, but the letter was expressly qualified on the belief that all discharge from the STP facility had ceased. While Starkist disagrees that a cessation of all discharge from the STP facility is a relevant factor, in fact there is a continuing discharge from the STP facility, contrary to the underlying assumption in the AS EPA letter.

[11] *Revised Request for Water Quality Certification and Definition of Mixing Zones for the Joint Cannery Outfall*, submitted in 2017 and updated on June 19, 2018.

[12] The August 7, 2018 letter was submitted as a supplement to the Administrative Record; the October 1, 2018 letter is contained in US EPA's original Administrative Record.

EPA made no mention of any hesitation to use the UDKHDEN model during the six years from the 2012 submittal of the initial permit renewal application and the associated MZA until the first pre-public notice draft of the permit in 2018. Additionally, as described in detail here, the model used by US EPA (CORMIX) is not appropriate for use in this circumstance, thus further depriving US EPA of the good cause that should be present before US EPA disregards AS EPA's position.

US EPA's decision-making for the Permit also disregards the October 1, 2018 letter from Governor Moliga. That letter, along with the October 1, 2018 letter from the AS EPA to Governor, which was attached to the Governor's letter, demonstrates AS EPA and the American Samoa Government's acceptance and approval of the mixing zones and effluent limits proposed by Starkist. The letters both agree that the effluent limits proposed by US EPA are more stringent than necessary to protect the water quality of Pago Pago Harbor. The letters are grounded in the repeated receiving water quality monitoring events during 2018 that show water quality standards are being attained. Since these letters were written, additional receiving water quality monitoring events have continued to show attainment of water quality standards.

US EPA's decision to reject the modeling approved by AS EPA, to reject the mixing zones approved by AS EPA, and to ignore AS EPA's support for effluent limits that recognize that water quality standards are being met at the current discharge loading, is contrary to US EPA's obligation to give consideration to AS EPA, and is arbitrary, capricious, unreasonable and contrary to law.

III. <u>Effluent Limitations for Nutrients</u>

Table 1 of the draft permit provides proposed effluent limitations and monitoring requirements. Starkist has specific comments and concerns on the proposed total nitrogen (TN) and total phosphorous (TP) limitations, and seeks revision of these proposed limits.

A. <u>AS WQS for TN and TP are Currently Being Met</u>

The ultimate goal of the effluent limits is to ensure that AS WQS are met and maintained. At this time, as the ocean disposal permitting process is incomplete, actual effluent discharge from the Starkist facility exceeds the limits proposed in the draft Permit. However, despite this, AS WQS are being met.

Based on the evidence that AS WQS for TN and TP are being met despite the current pollutant discharge levels at the Starkist facility, it is clear that AS WQS can be met without restricting the effluent limits to the application of the 330:1 initial dilution that US EPA derived from its own modeling. Instead, effluent limits based on Starkist's modeling are and will be supportive of AS WQS. As such, US EPA should base TN and TP discharge limits on the modeling approach in the MZA, which has already been approved by AS EPA, and as set forth in Attachment A which sets forth updated modeling consistent with the effluent flow used in the draft Permit.

B. Application of Mixing Zone Modeling

US EPA's use of the 330:1 initial dilution from its CORMIX modeling to derive TN and TP effluent limitations is inappropriate for the following reasons, which are discussed in more detail in Section VI of these comments:

- The CORMIX modeling ignored the vertical density profile data from receiving water sampling. The model was run using an assumed constant density for the entire depth of the water column, which artificially forced the model to predict the plume would reach the surface all of the time. Actual data shows that a vertical density gradient is present.

- The results of the US EPA CORMIX modeling are not representative of observations of plume behavior. While US EPA claims there are reports of occasional plume surfacing, there are no claims that the plume continuously surfaces or even that the plume regularly surfaces. US EPA's CORMIX modeling indicates the plume surfaces all the time, which is clearly demonstrated as inaccurate by both AS EPA's observations and the ongoing permit required semi-annual Harbor receiving water monitoring program.

- A plume that occasionally surfaces is not prohibited by AS WQS. Instead, the relevant question is whether AS WQS are exceeded at the surface. US EPA's approach ignores this very important distinction.

- US EPA did not define a mixing zone size for TN or TP based on the CORMIX model results.

- The effluent limitations derived by US EPA from CORMIX results were based on dilution selected at an arbitrary depth in the water column entirely unrelated to the Starkist discharge.

As described in the discussions on modeling in Section VI, US EPA's use of the CORMIX model and its subsequent application to the derivation of limitations is flawed and not technically defensible.

Starkist further believes the original modeling and mixing zone development are more appropriate. As described in more detail below and as set forth in Attachment A, updated modeling was performed in UDKHDEN for decreased total flow from the JCO consistent with the draft Permit, increased effluent salinity related to the change in operations at STP, and at both 0 and 2 cm/s ambient current speeds based on US EPA comments in the Fact Sheet. If the updated UDKHDEN modeling results are used, even assuming use of overly conservative and unrealistic assumptions of zero ambient current speed (and updated effluent salinity and flows), the resulting median initial dilution is 550:1 and the plume remains submerged. Furthermore, the US EPA modeling that forces the plume to surface all the time eliminates use of subsequent dilution required to meet the AS WQS for TN and TP as used in the MZA.

C. Apportionment Agreement Between Starkist and STP

US EPA has historically allowed for allocation of discharges between the two facilities, and should continue to do so. Starkist and STP independently reached an allocation of loading to the JCO that allocated a certain loading to the STP facility consistent with the reduced operations at that location, and allocated the remainder of the loading to Starkist.[13] At a minimum, this agreement should be honored, as it is consistent and supportive of AS WQS as measured by recent receiving water monitoring data, and is supported by the MZA approved by AS EPA. Further, as noted in the Fact Sheet, aggregate TN and TP limits within the combined loading previously authorized at the JCO is consistent with past practice and without triggering any anti-backsliding and antidegradation concerns.

D. Water Quality Standards Used in Permit Limit Derivation

The AS WQS contains water quality standards for TN and TP as concentrations not to exceed more than 2%, 10%, and 50% (median) of the time. US EPA chose to use the median value in calculation of the monthly average permit limitation and the value not to exceed more than 10% of the time in calculation of the daily maximum limitation, as described in the Fact Sheet. US EPA noted that this was "for consistency with the other monitoring and reporting periods established under this permit".

Starkist believes that use of the water quality standard not to exceed more than 10% of the time is inappropriate for use in determining the maximum daily effluent limit. This water quality standard allows for exceedance of the water quality standard numeric value up to 10% of the time (in the receiving water). However, the permit effluent limits do not allow for any exceedances of the established values. Starkist proposes use of the water quality standard not to exceed more than 2% of the time in calculation of the maximum daily effluent limit. This value is more appropriate because it is closer to a theoretical water quality standard with no allowable exceedances (i.e., a concentration not to be exceeded at any time).

Additionally, use of the water quality standard not to exceed more than 2% of the time in calculation of the maximum daily limit is consistent with the calculation of nutrient limits in the recently proposed NPDES permit renewal for the American Samoa Power Authority's (ASPA) Utulei sewage treatment plant.[14] It is arbitrary, capricious and unreasonable for US EPA to utilize a different methodology for calculating the same type of effluent limit as between the ASPA and Starkist permits.

E. Calculation of TN and TP limits

Although Starkist believes that the dilution factor of 550:1 (based on UDKHDEN modeling with updated effluent salinity and flows, and zero ambient current speed) is an extremely conservative and unrealistic estimate of dilution based on modeling, that dilution factor was used to calculated proposed effluent limits for TN and TP as set forth below. The same calculation

[13] To the extent that the total loading to the JCO is not greater than that allowed by the 2008 permits, no anti-backsliding concerns should apply. See also the anti-backsliding discussion herein.
[14] *See* Utulei Permit Fact Sheet, at Exhibit 3.

methodology as outlined on pages 18 and 19 of the draft Permit fact Sheet was followed, with the exception that the AS WQS values not to exceed more than 2% of the time were used, instead of the AS WQS not to exceed more than 10% of the time values, for calculation of the daily max values. Accordingly, Starkist requests the following TN and TP limits:[15]

Parameter	AS WQS numeric standard for Pago Pago Harbor	Calculated effluent limit at 550:1 dilution
TN (monthly average)	0.2 mg/L	2,661.9 lb/day, rounded to 2,670 lb/day
TN (daily max)	0.5 mg/L	6,654.7 lb/day, rounded to 6,655 lb/day
TP (monthly average)	0.03 mg/L	399.3 lb/day, rounded to 400 lb/day
TP (daily max)	0.06 mg/L	1,197.9 lb/day, rounded to 1,200 lb/day

F. Key Regulatory Issues Associated with Nutrient Limit Revisions

1. Anti-Backsliding

The Clean Water Act ("CWA") generally prohibits backsliding from effluent limits contained in previously issued permits unless the proposed new effluent limitations comply with the anti-degradation provisions of CWA Section 303(d)(4), or as provided in Section 402(o).

Section 303(d)(4) of the CWA contains two categories of exemptions: 1) where applicable water quality standards are not being met, and 2) where applicable water quality standards are in attainment. *See* 33 U.S.C. 1313(d)(4). In Starkist's case, the water quality standards are being attained, and so section 303(d)(4)(B) provides that the effluent limits may be revised if such revision is subject to and consistent with applicable anti-degradation requirements. *See* anti-degradation discussion, below.

Additionally, CWA § 402(o)(2)(A) also creates an independent exemption allowing less stringent permit limits if material and substantial alterations or additions to the permitted facility occurred after permit issuance which would justify application of less stringent effluent limits. 33 U.S.C. § 1342(o)(2)(A). These regulations allow less stringent limits during reissuance of a permit when "circumstances in which the previous permit was based have materially and substantially changed since the time the permit was issued and would constitute cause for permit modification, revocation or reissuance under Section 122.62." 40 C.F.R. § 122.44(l)(1).[16] Per 40 C.F.R. § 122.62(a)(1), the same material and substantial alterations at the facility would also provide justification for permit modification. Since the 2008 issue of the existing NPDES permit, Starkist's handling of

[15] These corrected calculations produce limits that are higher than those proposed by US EPA. Starkist recognizes but does not agree with US EPA's expressed concern, which is misplaced from Starkist's perspective, regarding anti-backsliding and antidegradation being obstacles to adoption of effluent limits greater than the combined Starkist and STP effluent limits under the 2008 NPDES permits. Further discussions on this issue between Starkist and US EPA could be productive.

[16] The exemption at § 402(o)(2)(A) is modified by the requirements of CWA § 402(o)(3), which prohibit the relaxation of effluent limits in all cases if the revised effluent limits would result in a violation of applicable effluent guidelines or water quality standards. 33 U.S.C. § 1342(o)(3). This is not a prohibition when applied to Starkist's permit.

its wastewater has materially and substantially changed, including changes to tuna processing, changes to wastewater treatment equipment, and changes to the JCO diffuser. These changes provide a basis for permit modification under 40 C.F.R. §§ 122.44(l)(1) and 122.62(a)(1).

2. **Antidegradation**

Antidegradation requirements under the Clean Water Act and American Samoa regulations mandate that existing water uses be protected and that the level of water quality necessary to maintain those uses be protected. *See* AS-WQS § 24.0202. Current water quality sampling data shows the effluent limits proposed by Starkist will ensure that existing uses and designated uses are protected.

Based on receiving water quality data collected at the edge of the mixing zone in March, May, August, September, October, and December 2018, in addition to February 2019, the AS WQS are currently being met at the boundary of the mixing zone approved with the current 2008 NPDES permit. It is important to note that the AS WQS are being met even though the wastewater treatment improvements at Starkist have not achieved compliance with all current permit limits.

AS Environmental Quality Regulations, at § 24.0202, set forth AS EPA's rule on anti-degradation and require that the water quality levels can only be lowered upon a showing that it is necessary to accommodate important economic or social development. The effluent limit changes proposed by Starkist will preserve designated and existing uses, and continue of attain existing water quality standards. They are also necessary to accommodate important economic and social issues for American Samoa. *See* August 7, 2018 letter from AS EPA Director Pato and October 1, 2018 letter from Governor Moliga.

The Fact Sheet also references anecdotal information about failure to meet narrative standards. As noted elsewhere in these comments, such alleged violations are not supported with any specific information, contradict observations made during receiving water monitoring, and could well have been the result of actors and activities unrelated to Starkist and/or are conditions that have been rectified through the wastewater treatment upgrades. None of this information is specific or current enough to serve as a basis to determine that antidegradation concerns forbid the imposition of effluent limits consistent with the MZA, including as updated in Attachment A, and current discharge levels.

IV. **Receiving Water Monitoring Requirements**

Starkist, US EPA and AS EPA have had a number of discussions on receiving water quality monitoring requirements, and Starkist has previously submitted detailed comments on drafts of these requirements. The Fact Sheet is essentially silent on these concerns and considerations discussed, and fails to respond to any of the previously submitted comments. Starkist continues to assert that the monitoring requirements are in some cases technically and physically unsafe or impossible to comply with, and that certain monitoring station locations are inappropriate and unnecessary.

A. Monitoring Requirements

The draft NPDES Permit notes that all stations should be monitored for temperature, salinity, oil & grease, dissolved oxygen, pH, turbidity, TP, and TN. Additionally, the draft Permit requires sampling for mercury and ammonia at the zone of initial dilution (ZID) stations and stations 14 and R.

1. Total Nitrogen and Total Phosphorous Monitoring

Starkist requests that TP and TN only be required to be monitored at the zone of mixing (ZOM) stations, with a 1,300 ft or 981 ft radius from the diffuser (not both). These stations represent the mixing zone established in the 2008 Permit for nutrients and the requested nutrient mixing zone stated in the MZA, respectively. Assuming that US EPA intends to approve a mixing zone for the TN and TP discharges, Starkist requests that the monitoring requirements for TP and TN at the zone of initial dilution (ZID) stations and end of pipe station 14 be eliminated, as compliance is not required to be demonstrated at these stations because they are located within the ZOM where TN and TP are allowed to exceed water quality standards.

2. Turbidity Monitoring

Starkist has concerns with the technical feasibility of the requirements to monitor turbidity as vertical profiles in the receiving water because, in the past, field sensors that could reliably measure turbidity at sufficient sensitivity and reliability at the AS WQS levels were not available. During discussion with US EPA on May 8, 2019, US EPA acknowledged Starkist's concerns with measuring turbidity. But, US EPA has nevertheless continued this requirement without any acknowledgement or revision despite the fact that this requirement may be technically infeasible to meet. Therefore, Starkist requests that US EPA include alternative options in the Permit, in the event that field sensors are unsuccessful at measuring turbidity to the required standard, that allow Starkist to measure turbidity in grab samples on site (as is currently being done for ASPA's NPDES Permit Harbor monitoring program), or allow holding times to be exceeded for shipment to mainland laboratories.

B. Mixing Zones and Monitoring as Basis for Determining Compliance

The MZA requested mixing zones for a number of pollutants in the discharge. AS EPA has stated its support and approval of the proposed mixing zones. However, the draft Permit and the Fact Sheet are ambiguous on whether any mixing zones have been granted. While there are references to the mixing zones approved under the prior permit, and to the mixing zones requested in the application for the current draft Permit, there is no clear statement of an affirmative grant of any mixing zones. In the absence of defined mixing zones, there is ambiguity where AS WQS apply in the receiving water. This ambiguity should be clarified, and US EPA should make an express statement that mixing zones are being granted, and define the size and scope of the mixing zone for each pollutant receiving a mixing zone.

1. Mixing Zone Dimensions

The Fact Sheet describes the mixing zone approved with the 2008 permit as being a circle with a radius of 1,300 feet, or the 30-foot depth contour. This is only partially correct, as the 1,300 foot radius mixing zone applied only to TN and TP. Mixing zones for metals, dissolved oxygen, ammonia, and toxicity, were smaller, as they are limited to the zone of initial dilution. The Fact Sheet should be corrected to clarify this statement.

The MZA proposed a mixing zone for nutrients that is a circle with a radius of 981 feet (below 10 feet from the water surface). AS EPA approved of this mixing zone. The MZA's mixing zone contrasts with the 2008 permit, which uses a mixing zone for nutrients that is a circle with a radius of 1,300 feet. The approach taken in the MZA meets AS EPA regulations requiring that a mixing zone be as small as possible. *See* § 24.0207. In this regard, the MZA submitted by Starkist is more consistent with American Samoa regulations than re-use of the mixing zone from the 2008 permit.

2. Mixing Zone Conditions

The Fact Sheet asserts that the discharger is responsible for ensuring that the effluent plume does not reach the surface, and implies that this is a condition of approving a mixing zone. Starkist agrees that AS WQS stipulate that a zone of mixing may not include the surface of a water body (AS § 24.207(b)(9)), but otherwise notes that this is an inaccurate statement. There may be infrequent conditions that allow the plume to surface for a limited time. Instead, what is required is that plume does not reach the surface with constituent concentrations above AS WQS. This is logical, in that the mixing zone boundary defines the geographic limit where AS WQS must be met, and therefore any location outside that boundary must meet AS WQS. As such, meeting water quality standards at the mixing zone boundary is the necessary goal.

C. Monitoring Station Locations

1. Reference Site R (formerly known as Station 5)

Starkist believes that monitoring at Reference Site R (formerly Station 5) will not be useful to assess harbor-wide patterns and water quality issues because the site is too shallow and offset from the harbor mouth and does not adequately represent background concentrations of water entering or leaving the harbor. Starkist requests Station FF instead represent background concentrations. However, if a reference station for background concentrations at the mouth of the Harbor is considered necessary, a station approximately centered in the Harbor mouth would be the most appropriate based on depth and location.

Station 5 often exhibits generally higher metals and nutrients than the levels found in the Outer Harbor (particularly for mercury) for reasons not entirely clear. Higher metals may potentially related to an old Navy Dump site in the area.

Based on data collected over the term of the existing permit, and the relative shallow depth, Station 5 does not provide a good representation of reference conditions. Therefore, Starkist requests that this Station be removed from the receiving water sampling program. Station FF is a better reference station.

2. Station 14 (End of Pipe)

Starkist requests to remove monitoring requirements at the end of pipe Station 14. It is noted in the draft Permit that Station 14 would be used "to evaluate inputs to the metals mixing zones which are smaller than the zone of initial dilution." First, the draft Permit no longer contains effluent limitations for any metals except mercury (which is monitor only), since they were found to not have reasonable potential to exceed water quality standards. If the objective of monitoring at Station 14 is as stated above, then monitoring the effluent is more instructive than monitoring at Station 14. Second, Station 14 is located within all of the proposed mixing zones and cannot be used for evaluation of attainment of AS WQS. Third, it would be purely by chance whether or not a sample from Station 14 will be collected from within an individual effluent plume or collected from the dilution water between plumes. Samples at this station serve no useful regulatory purpose.

3. Coral Reef Stations

As discussed during the May 8, 2019 meeting with US EPA, Starkist raised questions as to the intent of the sampling at the coral reef stations. Starkist noted that if the intent in sampling the reef crest is to sample the water "on the reef", it must be considered that the water depth over the reef crest varies with tidal elevations from zero feet (reef is exposed at minus tides) to approximately three feet (at average high tide). Therefore, sampling at three depths is not feasible or meaningful (that is, sampling 1 meter above the bottom could be in the air and 1 meter below the surface could be below the reef substrate, only a "mid-depth" sample is possible).

Additionally, waves commonly break at the reef crest, so there is a serious health and safety issue sampling at this location. Even under flat conditions with no wind, a vessel cannot be safely operated with equipment over the side very close to the reef slope or the reef crest.

During the May 8, 2019 meeting, Starkist and US EPA agreed that health and safety during sampling was of utmost importance and further agreed to consult various external professionals on options to sample the reef area. However, US EPA has continued the reef monitoring requirement without any clarifications or apparent consideration of the health and safety issues (including both human health and the health of the coral reef).

Starkist proposes that sampling at the coral reef be addressed by a permit requirement to sample as near to the coral reef crest as can be safely accomplished, under the conditions present during the sampling attempt. Since the goal is to monitor the water quality conditions at the reef crest, the sampling should be done at 1 meter below surface, but no other depth and no vertical profile should be collected. Requiring sampling at multiple depths would increase the time necessary to complete the reef sampling, and for safety and logistical reasons would force the sampling effort to be conducted further from the reef crest to accomplish that duration of sampling. Similarly, with varying depths below the sampling boat given that it would likely be positioned over the reef slope, it would be difficult to deploy sampling equipment at depth without risk of damage to the equipment and to the reef.

4. Other monitoring stations

Starkist requests moving the zone of initial dilution (ZID) stations (Stations 8-North, 8-West and 8-South) somewhat seaward to reflect the water depth of the diffuser. This location should be consistent with 16N (previously Station 15), which also should be moved to somewhat deeper water. The draft Permit states that "sample depths should be identical for all parameters at a given sampling station, and sampling depths should also be consistent between successive sampling events at each station." However, depths may vary slightly between stations because of small scale bottom irregularities and tidal/water level variations. By adjusting the stations to all be at depths greater than the diffuser depth, these concerns can be addressed (except for Reference Station R (existing Station 5), which should be discontinued as noted above). The permit should allow initial minor adjustments of station locations (coordinates) prior to or during the first sampling event with locations to be reported to and approved by US EPA and AS EPA.

D. Proposed Special Study

Starkist requests that Stations 8-West, 16-North, 16-South, 9-North, 9-South, Coral-North, Coral-East, and Coral-South be removed from the semi-annual required monitoring and instead be monitored as part of a special study. Starkist proposes that the special study be conducted twice: once in the first and once in the fourth year of the permit term. The objective of this special study would be to collect additional water quality information within the harbor in preparation for permit renewal. The same parameters will be measured (at the same sampling depths) as the required semi-annual monitoring. However, the special study would only be required twice during the permit term.

Even if an increase in receiving water monitoring is appropriate, the number of samples and analyses is greatly increased by the draft Permit, and some of the increased sampling and analyses requirements are unnecessary and excessive. The draft Permit includes monitoring requirements for sampling at 14 receiving water stations semi-annually. The proposed special study will still provide additional information regarding water quality in the receiving water, while not drastically increasing monitoring requirements.

E. Coordinating Receiving Water Among America Samoa NPDES Permits

The obligation to monitor receiving water quality is common to several US EPA issued permits for facilities in American Samoa, including specifically Starkist, STP and ASPA's Utulei sewage treatment plant. Resources and efforts have typically been shared among these dischargers to accomplish parallel and overlapping monitoring requirements. Any changes to the Starkist's monitoring requirements should be coordinated with the other American Samoa NPDES permits. Guidance should be offered by US EPA on this coordination effort, given that the NPDES renewal for the STP facility, for example, is expected to occur later in time than the issuance of the renewed NPDES permit for the Starkist facility.

F. Additional Receiving Water Monitoring Issues

Starkist also requests the following modifications to language included in Section I.E of the draft Permit for Receiving Water Monitoring:

- Ammonia should be reported as ammonia as N rather than as NH_3 to be consistent with Appendix E as well as being consistent with past sampling and typical laboratory results/reports. Conversion between ammonia as N and NH_3 is straightforward and listed in the AS WQS for ammonia, so this will not hinder comparison with AS WQS.

- Language should be added noting "If an event arises from causes beyond Starkist's control, such as unfavorable weather conditions, that delays or prevents the monitoring from being performed, Starkist shall notify US EPA in writing within 30 days. In the event of a delay, Starkist will complete the monitoring at the earliest reasonable opportunity."

- In the event that US EPA retains, contrary to these comments, Station R and/or reef crest monitoring stations, then a footnote should be added in Section I.E.1, where the "bottom depth" is defined, stating that "Monitoring at 1 meter above the seabed if shallower than the diffuser may result in logistical issues at Station R (formerly Station 5) and potentially coral crest stations. Because there are generally multiple coral structures, rock formations, or debris that rise above the bottom at these shallow stations, which could damage sampling instruments and the coral, the shallow samples may be collected no more than 3 meters above the bottom (for stations shallower than the diffuser depth), at the discretion of the field team. An evaluation of the bottom condition can be done with the fathometer prior to sampling."

V. Additional Permit Requirements Issues

A. Flow Limitation

The imposition of a flow limit, of 2.9 million gallons per day (mgd), is a new permit term not contained in previous permits. While this limit generally provides for typical flows during normal operations, it does not allow for excess flows during heavy rain events. Some stormwater that falls on the facility is collected and treated through the wastewater treatment plant and then discharged through the JCO. Starkist requests that the maximum daily numerical limit for flow be removed and the permit instead specify that flow be monitored only, on a continuous basis. The mass-based effluent limitations accomplish what US EPA aims to achieve in terms of protecting water quality in the receiving water. There is no requirement for US EPA to include a flow limitation in the permit.

Additionally, Starkist seeks clarification on the implementation of the 2.9 MGD flow limit if it remains in the Permit. The draft Permit requires measurement of flow rate on a continuous basis. As such, this could be read to impose an instantaneous flow rate limit of 2.9 MGD. Starkist's discharge flow varies over time, and Starkist cannot discharge at a steady 2.9 MGD flow rate. As such, as an instantaneous maximum, this flow rate limit would effectively limit total daily flow through the JCO to well less than 2.9 MGD, since lower instantaneous flows could not be balanced out with higher flows. As such, this flow rate limit would unnecessarily and arbitrarily interfere with Starkist's operations since future operations may need to be reduced based on predicted rainfall amounts or will drive the need for additional equalization volume to reduce the peak flows.

Starkist requests that the flow rate limit be removed, or in the alternative that it be stated as a daily flow limit, but not as a continuous flow rate limit.

B. <u>Priority Pollutant Scan</u>

The draft Permit includes monitoring requirements for the Priority Pollutant Scan (PPS) yearly, while the current permit requires the PPS to be performed once in the permit term (in the fourth or fifth year of the term). A PPS is typically only required once per permit term (once every five years), and other recent permits in Region 9, including local permits for discharges to Pago Pago harbor, only require the PPS to be conducted once per the permit term. An annual PPS requirement is excessive and unsupported by EPA precedent and practice. The Fact Sheet offers no explanation for the imposition of an annual requirement for this permit. Starkist's tuna cannery operations are relatively consistent, in that they produce the same product, using the same process, from the same raw material, and there is no reason expect significant changes in priority pollutants from year to year. Starkist believes that it is not necessary to conduct the PPS annually and the requirement results in unnecessary cost and effort. It is requested that the monitoring frequency of the PPS is reduced to once per permit term.

VI. <u>Modeling, Mixing Zone and Dilution Rate Issues</u>[17]

Of paramount concern is the very central issue of the dilution factors and mixing zone sizes to be applied to the discharge from the JCO. Starkist and Samoa Tuna Processors, Inc. ("STP") jointly submitted a mixing zone analysis in November 2012 in support of the NPDES permit renewal applications for each facility. This was comprehensively updated and revised in March 2017 and further updated in June 2018[18], in the MZA submitted on behalf of both Starkist and STP.

The mixing zone analysis was performed using computer modeling. Starkist utilized the same computer models, UDKHDEN[19] for initial dilution and Brooks equation (CDIFF) for subsequent dilution, which was used in prior NPDES permitting of the Starkist and STP facilities, and which has been subjected to validation studies that successfully demonstrated model accuracy in the Harbor[20] (and showed that the model is conservative, that is it under-predicts dilution). US EPA has previously accepted and approved of the use of UDKHDEN not only for Starkist and STP, but for ASPA's wastewater treatment plants at Utulei and Tafuna. The modeling predicted attainment

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[17] This section of comments on the mixing zone modeling is offered in support of the request to revise the TN and TP limits set forth above.

[18] *See* June 19, 2018 gdc letter to Director Pato of the AS EPA. (Provided to US EPA as a supplement to the Administrative Record, and incorporated by reference herein.)

[19] UDKHDEN is the same model as DKHW in EPA's Visual Plumes suite of models. UDKHDEN was used in place of DKHW simply because of ease of input (DOS versus Windows interface).

[20] Dye studies were conducted during tradewind and non-tradewind seasons that demonstrated that the UDKHDEN's predictions of dilution were conservative. *See* Exhibits 4, 5 and 6.

of AS WQS at the requested JCO loading rates; receiving water sampling in 2018 and 2019 has consistently demonstrated the accuracy of this conclusion.

However, the Fact Sheet indicates that US EPA now disagrees with the use of UDKHDEN, and instead performed its own modeling using an alternate computer model that resulted in application of lower dilution rates and derivation of overly stringent effluent limits. As implemented in the Permit, there is ambiguity whether any mixing zone was granted by US EPA.

A. Mixing Zones

1. Definition of a Mixing Zone

A mixing zone, in the regulatory context of wastewater discharge, is a volume of water within which water quality standards (WQS) and associated criteria can be exceeded (i.e. not achieved). The Clean Water Act allows mixing zones as established by the states.[21,] WQS must be met, under all circumstances, at the edge of the mixing zone. Each state that allows mixing zones has its own guidelines and regulations and there is no consistent definition of application among states.

The zone of initial dilution (the ZID) is a particular type of mixing zone defined by US EPA as the point where the effluent discharge plume first passes the trapping level (that is the point in the water column where the plume density equals the ambient density) as it initially rises through the water column. In some cases (when there is no water column density stratification) the plume may surface.

2. AS WQS Mixing Zone Definition and Requirements

The AS WQS (§ 24.0207) specify that the Environmental Quality Commission ("EQC") of the American Samoa Government is authorized to grant zones of mixing. The AS WQS have territorial definitions of the ZID and zone of mixing under §24.0201 (Administrative Rule No. 001-2013) as follows (emphasis added):

> ***"zone of initial dilution"*** is that area of a plume where dilution is achieved due to the combined effects of momentum and buoyancy of the effluent discharged from an orifice. Unless otherwise approved by the EQC and USEPA, the zone of initial dilution and initial dilution ratio shall be determined using the latest version of the PLUMES model UM (EPA/600/R-93/139), assuming zero ambient current and representative ambient concentrations of the pollutant in question;
>
> ***"zone of mixing"*** means a defined portion of a water body receiving water around a point source within which specific modifications of applicable water quality standards are permitted by the EQC.

The AS WQS further limits mixing zones for toxic pollutants to the ZID. §24.0207(b)(6). The AS WQS further state that "[a] zone of mixing shall not be granted if it would include the surface

[21] In the context of the CWA territories are treated as states.

of the water body, any part of the shoreline, or any part of any barrier or fringing reef." §24.0207 (b)(9).

The Fact Sheet asserts that the discharger is responsible for ensuring that the effluent plume does not reach the surface, and implies that this is a condition of approving a mixing zone. Starkist agrees that AS WQS stipulate that a zone of mixing may not include the surface of a water body, but otherwise notes that this is an inaccurate statement. Under conditions of very weak density gradients the effluent plume may reach the surface some of the time. However, this does not mean the effluent concentration would not have been diluted to below the WQS by the time the plume reaches the surface, and thus would not be in the mixing zone. Instead, what is required is that plume does not reach the surface with constituent concentrations above AS WQS. This is logical, in that the mixing zone boundary defines the geographic limit where AS WQS must be met, and therefore any location outside that boundary must meet AS WQS. As such, meeting water quality standards at the mixing zone boundary is the necessary goal. A surfacing plume, in a marine system, is generally not the "critical" or "worst case" condition that yields the minimum dilution, and would not be used to define the mixing zone (see Section VI.B for further discussion of this point).

3. Calculation of Dilution from Modeling

The WQS must be met at the edge of the defined mixing zone. Therefore, an estimate of the dilution required and the dilution achieved by the discharge must be considered. Mixing zones are therefore based on a "worst case" scenario – that is the lowest dilution expected must be estimated. In marine environments, this requires selection of modeling parameters that result in the "worst case". Because of the dynamic nature of the marine environment this usually is based on the 10th percentile values of the various modeling parameters (Tetra Tech, 1982)[22]. However, for compliance for those parameters with median water quality criteria it is more appropriate to determine a median dilution to define the mixing zone. [23]

4. Initial Dilution and Subsequent Dilution

The Fact Sheet implies some confusion about the role of the modeling, as performed in the MZA and in the context of NPDES permitting, and the calculation of mixing zones, dilution rates and effluent limits.

The MZA modeling was performed solely for the purpose of assessing effluent plume dilution. Near-field modeling is required to evaluate initial dilution of the discharge, as presented in the MZA. Subsequent dilution modeling, which is the evaluation of mixing by advection and diffusion in receiving waters following initial dilution, requires a second model to simulate the different

[22] Tera Tech. 1982. *Revised section 301(h) technical support document*. EPA430/9-82-011. United States Environmental Protection Agency

[23] *Initial Mixing Characteristics of Municipal Ocean Discharges*, EPA/600/3-85/073a (November 1985), Section 2

mixing processes, and uses results from the initial dilution model as an input.[24] In the case of nutrients where initial dilution is insufficient to provide compliance then additional analysis (subsequent dilution) is required. Compliance with the AS WQS can be evaluated by reviewing the recent (post treatment plant upgrades) TN and TP at the receiving water quality monitoring stations. Compliance with the AS WQS has been demonstrated for the discharge since March 2018.

The modeling predicted attainment of AS WQS at the requested JCO loading rates; receiving water sampling in 2018 and 2019 has consistently demonstrated the accuracy of this conclusion.[25] It is noted that the seven recent monitoring events done between March 2018 and February 2019 clearly indicate that the AS WQS were met at the currently approved mixing zone boundaries for TN and TP at effluent concentrations well above those used to develop the mixing zone size (the model thus is quite conservative, as expected and as is desirable). Therefore, any arguments and disagreements concerning the correct initial dilution model or modeling strategy have become academic. It is noted that predictions for DO in the receiving water do not critically depend on levels of initial dilution over the range of initial dilutions being discussed in this document, but rather on decay rates of biochemical oxygen demand.

B. <u>Starkist's Mixing Zone Modeling</u>

The MZA included an updating of the pollutant-specific mixing zones applied to the discharge from the JCO used by Starkist and STP. The MZA seeks mixing zones that have been recalculated based on current circumstances, representative data available at the time of submission, updated modeling, and established methods published by US EPA. Based on receiving water quality data collected at the edge of the mixing zone since March 2018 (as described earlier in more detail), the AS WQS are currently being met at the boundary of the mixing zone approved with the current 2008 NPDES permit. It is important to note that the AS WQS are being met even though the wastewater treatment improvements at Starkist have not achieved compliance with all current permit limits, and before any ocean disposal has been implemented.

1. <u>Basis for Updated Mixing Zone Since 2008 Permit</u>

The MZA includes a model of the JCO discharges using the US EPA's UDKHDEN dilution model and the subsequent dilution model based on Brooks equation. The wasteload allocation (WLA) method, as outlined in US EPA's Technical Support Document (TSD)[26], was used to develop

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[24] Note that a simple fate and transport model (Brooks Equation, also known as CDIFF as written by John Yearsly at USEPA Region 10) was used to extend the calculation of a mixing zone for Total Nitrogen and Total Phosphorous past the point of initial dilution. The assumptions for this approach are extremely conservative (under predicts subsequent dilution). Based on the initial dilution, the subsequent dilution, and the background concentrations in the receiving water, a mixing zone for nutrients was developed in the MZA and is documented in the MZA.
[25] For example, the JCO loading rate of TN in March 2018 was just below the MZA requested load for the JCO, and the AS WQS for TN and DO were met at the permit required monitoring stations.
[26] *Technical Support Document for Water Quality Based Toxics Control*, EPA/505/2-90-001, March 1991 (Second printing July 1992).

proposed permit limits. The MZA updated the mixing zone from the 2008 permit; key inputs to the MZA model that have changed since the 2008 permit include:

a. The diffuser at the end of the JCO pipe was modified to achieve better mixing and increase hydraulic capacity. Previous modeling was based on four of the six 5-inch ports being open. The MZA accounts for use of the remaining two 5-inch ports, which were opened in 2010 to increase hydraulic capacity. A 2-inch vent was also added to the end gate in 2012.

b. Additional receiving water quality sampling data are available to characterize the current permit term. It is important to note that the results from the 2018 and 2019 receiving water quality sampling events are consistent with assumptions used in the MZA regarding receiving water quality. The receiving water data are used to evaluate compliance with the proposed mixing zones outlined in the MZA and determine the size of the extended mixing zones for nutrients.

c. Additional receiving water density profile information (vertical profiles of salinity and temperature collected during both tradewind and non-tradewind seasons) was available and was used as an input to the mixing zone modeling to determine appropriate mixing zones and dilution factors. As described below, the use of representative density profiles appears to be a point of major divergence between Starkist's modeling and that subsequently performed by US EPA.

Taken together, this significant new information required the JCO dischargers to update the inputs for the mixing zone modeling from the modeling performed for the 2008 NPDES permits, which affect determination of appropriate mixing zones and dilution factors, and also subsequent calculation of proposed effluent limitations.

2. <u>Further Updates to Mixing Zone Modeling</u>

The MZA modeled the discharge from the combined operations at both the Starkist and STP canneries. Based on the current status of the STP cannery, in that it is not conducting fish processing operations and there is no current plan for fish processing to resume there, the anticipated maximum flow through the JCO has changed from 4.0 to 3.0 MGD. The 3.0 MGD flow represents the anticipated maximum permitted flow from the Starkist facility of 2.9 MGD, plus a flow of 0.1 MGD from the STP facility. In order to assess the impact of this flow change on the modeling results, in the context of responding to the position taken by US EPA in the Fact Sheet for the Permit, updated modeling using UDKHDEN was performed.

Attached hereto as Attachment A is a Technical Memorandum that describes supplemental modeling performed using the new reduced maximum JCO flow rate. The supplemental modeling also addressed alternative ambient current speeds, using both the 2.0 cm/second flow rate used in the MZA, as well as a zero ambient current speed. Although a zero ambient current speed is unrealistic and not representative of actual site conditions, US EPA's Fact Sheet argues for use of a zero flow speed. Accordingly, and despite the fact that use of a zero ambient current speed is inappropriate, the Technical Memorandum evaluates the reduced discharge flow rate under both current speed scenarios. The Technical Memorandum also addresses modeling using an increased effluent salinity, in response to concerns that the effluent salinity has increased with the cessation of STP's operations (which used fresh water for thaw water).

The Technical Memorandum presents revised initial dilution results and mixing zone geometries. The modeling for the lower effluent flows indicates higher dilutions for a given ambient current, and dilutions for zero ambient current and increased effluent salinities are lower than for the previous conditions used, as expected. The results, incorporating recent effluent data, indicate that the effluent plume will meet AS WQS prior to reaching the closest shoreline or coral reef and will remain submerged well below the water surface under critical conditions (and for all density profiles examined in the 2017 MZA).

3. <u>The Choice of the UDKHDEN Dilution Model</u>

The discussion provided by US EPA in the Fact Sheet indicates disagreement with the use of the UDKHDEN model for use in the mixing zone analysis. Starkist believes that the mixing zone modeling performed was appropriate, as it has been in the past.

Unless otherwise approved, the AS WQS require the use of Plumes UM as the model to be used. AS § 24.0201 (definition of "zone of initial dilution"). Plumes UM is essentially the same model as UMERGE (found in EPA/600/3-85/073a). The model used by Starkist was UDKHDEN, found in the same reference as UMERGE. The difference between UMERGE and UDKHDEN is that UMERGE is a two dimensional Lagrangian model and UDKHDEN is a three dimensional Lagrangian model. ASEPA has accepted (and therefore approved) the UDKHDEN model for all past mixing zones and NPDES permits since the JCO was built, including the current 2008 permit. ASEPA has approved the current MZA and modeling per its letters of August 7, 2018 and October 1, 2018. It is noted that the AS WQS do not directly address models or approaches for subsequent dilution calculations.

EPA disregards UDKHDEN because it presumes the model has become outdated with time. However, it is notable that UDKHDEN predates CORMIX by only a few years. Moreover, the relative timing of the development of the models is irrelevant to whether they are effective tools, and whether they have been used appropriately, to evaluate Starkist's discharge. US EPA's dismissal of UDKHDEN on the basis that it is marginally older than CORMIX is arbitrary and without a reasonable basis. Furthermore, UDKHDEN is still supported by US EPA as a component of the Visual Plumes model (as DKHW), which is more recent than CORMIX.[27]

The Fact Sheet lists limitations with the chosen modeling software, and concludes on page 13 that: "More modern software packages, such as the industry-standard CORMIX, have built-in capability to account for these boundary- and re-entrainment effects." This comment appears to demonstrate some confusion between initial dilution modeling and far-field models, which are not designed or appropriate to calculate initial mixing, and which would be used in addition to, and not instead of, the near-field model. The dilution modeling presented in the MZA considers appropriate background concentrations for the parameters of concern and provides conservative predictions of

[27] The DOS version (UDKHDEN) rather than the graphical interface version (DKHW) was used by Starkist simply because of ease of input and running multiple cases.

the effects of the discharge plume, which are consistent with receiving water monitoring data from the Harbor.

UDKHDEN has been shown to be consistently conservative (that is, it under-predicts actual initial dilution).[28] It is noted that AS EPA and US EPA-Region 9 have accepted the use of UDKHDEN in the past, including for the development of the current (2008) Starkist NPDES permit and for the development of the recent diffuser modifications for the American Samoa Power Authority's (ASPA's) Utulei and Tafuna wastewater treatment plant discharges. In the face of these circumstances and this history, the use of UDKHDEN for this NPDES renewal process, which began in 2012, was a reasonable choice. AS EPA made no objection to the use of UDKHDEN in the MZA. US EPA and AS EPA made no comment on the re-use of UDKHDEN during the years between 2012 and 2018, nor any request or recommendation that any other model be used. Accordingly, the use of UDKHDEN as the initial dilution model was and remains appropriate for the prediction of initial dilution.

4. Execution of the UDKHDEN Modeling

The MZA and Starkist's UDKHDEN modeling was accepted and approved by AS EPA. In contrast, US EPA identified a list of reasons why it preferred to use its own CORMIX modeling. However, the reasons articulated by US EPA are without merit. None of the litany of issues – the age of the model, the harbor current speed, boundary concerns, re-entrainment, and anecdotal historical observations of unspecified fish wastes – are a sufficient basis, either individually or collectively, to provide a basis to entirely disregard Starkist's modeling. Starkist recognizes that the modeled discharge flow needed to be updated to match the projected future discharge from the JCO, and that has been addressed in Attachment A.

a. Representative Harbor Current Speed was Used

The Fact Sheet (page 12) asserts that a zero current must be used for the initial dilution predictions. However, the AS WQS allows for use of a realistic current number to be otherwise approved. *See* AS WQS § 24.0201 (definition of "zone of initial dilution"). In this case, through AS EPA's approval of the MZA, AS EPA has expressed its approval of use of a current speed that is greater than zero. Starkist has also provided the results of the initial dilution mode for the zero current case, see Attachment A.

As noted in the MZA, tidal marine systems seldom if ever experience zero currents and it is standard practice, and US EPA's recommendation, to use the 10th percentile current if current data are available. This was the approach used in the MZA. The initial MZA for this permit renewal was initially provided for review in 2012 prior to being updated in 2017. The modeling assumptions were discussed with USEPA at that time in 2012 and there had been no objection to employing the standard practice since the original MZA was issued. Therefore, this was the approach used, and the approach approved by AS EPA's approval of the MZA. As such, it is appropriate, reasonable, technically defensible, follows common practice for marine environments, and permissible to utilize non-zero current speed in the modeling. US EPA's

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[28] This is confirmed by confirmatory dye studies performed in both American Samoa and Puerto Rico. *See* Exhibits 4-7.

presumption that only a zero current is representative is without any factual support, appears to based on lacustrine rather than marine applications, and indeed is directly contradicted by statements in the Fact Sheet that there are complex current patterns in the Harbor in the area of the discharge.

The Fact Sheet also challenges the data on currents used to develop the minimum current as unreliable. The comment in the Fact Sheet incorrectly states the approach used in the MZA.[29] The MZA calculations did *not* use the data from the 1980s (as is clearly stated in the MZA in Section 5.4.2). The data used were from the dye studies done in the early 1990s during model verification studies. These data were conducted using reliable and accurate current meters (S4 electromagnetic current meters) placed in the vicinity of the diffuser, and provided data accurate and robust enough to define the 10th percentile current. In contrast, US EPA's apparent presumption that the passage of time has rendered this data set as invalid is unsupported speculation with no factual basis.

Additionally, a three dimensional hydrodynamic screening modeling of currents in the Harbor was performed. The model used measured wave height data, but did not include wind speed. Currents would be expected to higher than predicted by the model when wind effects are present. In all, the model predicts currents that are in the range of those observed in 1993. *See* Attachment B.

The Fact Sheet also asserts that there have been a large number of changes in the Harbor since the 1990s, with the implication that these changes have rendered the prior data unreliable. The Fact Sheet does not identify what "large number of changes" are being referenced, and provides no supporting information for this vague allegation. However, in fact, there have been virtually no changes to the Harbor morphology and hydraulics since the 1990s. At most, there have been a few minor fill, shoreline and dredging projects. There is no basis to believe or expect that there has been any change to circulation patterns or currents in the Harbor, particularly at the location of the discharge and the previous measurements of currents. The coastal area around the Harbor has only a small coastal area where development can occur, most of which was already developed many years ago. US EPA's presumption that there have been changes in the Harbor that would have affected harbor currents appears to be purely unfounded speculation. US EPA's failure to identify the specified basis for its assertion that a large number of relevant changes have occurred in the Harbor is arbitrary, capricious and unreasonable, in that it deprives Starkist of the opportunity to provide a targeted response to any facts that US EPA believes supports its assertion.

Accordingly, the harbor current speed used in Starkist's modeling was appropriate, and US EPA's disregard of the UDKHDEN modeling on the basis of the current speed used is arbitrary and unreasonable.

b. <u>Boundary Interactions were Appropriately Considered</u>

The Fact Sheet states that UDKHDEN is not appropriate because it does not account for boundary interactions and complex current patterns. Specifically, it is stated that the model is not "capable of accounting for discharges interacting with boundaries of the waterbody (e.g. the underwater

[29] This inaccuracy, also present in earlier drafts of the Fact Sheet, has been repeatedly commented on by Starkist. The current Fact Sheet not only repeats the error, but fails to acknowledge or respond to Starkist's prior comments on this point.

coral reef slope or shoreline)". In response, Starkist states that *initial dilution* modelling (i.e. UDKHDEN) is appropriate for application in the case of the JCO because the *initial dilution plume* is limited in size, as shown in the model outputs provided in the MZA, and does not approach the shoreline or coral reefs. The UDKHDEN portion of the modeling only predicts initial dilution of the effluent plume – it does not provide any information concerning concentration of effluent constituents or subsequent dilution of the plume following initial dilution. UDKHDEN is often used in confined bodies of water (lakes, reservoirs, bays and harbors) in cases where the initial dilution does not impact adjacent boundaries.

US EPA should revisit the MZA, and in particular the size of the ZID predicted by UDKHDEN. (*See* MZA Section 8.1; *see also* Attachment A). The MZA and subsequent modeling updates demonstrate that the ZID and extended mixing zones are distant from the shoreline and the edge of the reef such that boundary interactions are not a concern for initial dilution. It appears from the Fact Sheet that US EPA is confusing the role of the initial dilution modeling with the role of subsequent far-field dilution and transport modeling following initial dilution. Attachment A, which includes updated UDKHDEN modeling based on the revised maximum effluent flow of 3.0 MGD also addresses the distance between the edge of the mixing zone and the shoreline and reef. In every case, the mixing zone does not impact either the shoreline or the reef. The distance between the ZID and the shoreline and reef is even greater.

Starkist agrees that after the ZID is defined for initial dilution, and a subsequent (passive) dilution model is used to develop a mixing zones for TN and TP, this mixing zone may be affected by boundaries. This is accounted for, as described in the MZA, by considering background concentrations and current patterns. The resulting predictions are confirmed by multiple episodes of recent receiving water quality measurements since March 2018. The updated modeling results (Attachment A) indicate that the mixing zones for all constituents do not reach the adjacent reef.

c. <u>The Potential for Re-entrainment was Appropriately Addressed</u>

The Fact Sheet states that: "model outputs require additional analysis when currents drive water already containing effluent through the area of the discharge plume multiple times, because this reduces the capacity of the water to absorb and dilute additional effluent." The Fact Sheet asserts that this type of occurrence, known as "re-entrainment" was not considered in the MZA. This assertion in the Fact Sheet is inaccurate in two respects.

First, re-entrainment has little or nothing to do with an initial dilution model. As noted above, initial dilution is simply a ratio of discharged water to ambient water. This ratio is independent of the concentration of any constituent in either the discharge or in the ambient receiving water. The initial dilution models do *not* predict concentrations of effluent constituents in the plume. Instead, such predictions are made using the initial dilution, predicted maximum effluent concentrations of constituents of interest, and the observed concentrations of the same constituents in the receiving water (background concentrations).

Second, and in accordance with the foregoing, the potential for re-entrainment was addressed by the MZA. Specifically, to account for the build-up of effluent constituents in the receiving water due to re-entrainment, the maximum observed background concentration of the parameter of concern is used. Typically, one uses the worst case (highest concentration background value) of the parameter of interest and then calculates the concentration of the constituent at the desired location within the initial dilution plume using the calculations described in the MZA. This adequately accounts for "re-entrainment." This is described in Section 9.1 of the MZA, is standard practice for such calculations, and is what was done in this instance. Although an approximation, it is conservative and confirmed by receiving water monitoring results.

Further, the re-entrainment concern is ultimately focused on accurately predicting the actual resulting concentrations of constituents in the receiving water. Here, receiving water quality sampling shows that water quality standards are being met at discharge loadings in excess of those proposed in the Permit.

5. The Use of UDKHDEN Has Been Validated

The MZA's UDKHDEN modeling was focused on identifying the worst case (lowest) critical initial dilution (CID), which defines the ZID. It is recognized that the UDKHDEN modeling does not indicate that the plume will never reach the surface, but just that such circumstances will not be the conditions that lead to the CID. As such, this is an invalid reason to disregard the UDKHDEN modeling and the MZA.

A number of Fact Sheet statements express doubt about the validity of the model. It is noted that the initial dilution model UDKHDEN has been verified/validated directly by the authors[30] of the MZA in two distinct settings: in outer Pago Pago Harbor and in a number of tropical water coastal settings in Puerto Rico. These studies were conducted as dye tracer studies using fluorescent rhodamine WT dye injected into the effluent discharge (at the landside outfall entrance) and monitored in the receiving water following discharge from the outfall diffuser. Because the dye has no natural background levels, the initial dilution can be calculated from **initial** concentrations injected into the effluent and measured receiving water dye concentrations. The model was then run using the flows, currents, and hydrographic profiles collected at the time of the tracer dye injection and the results compared to actual measured dilution. Model validation studies specific to UDKHDEN include:

- Two dye tracer studies done by the canneries for the JCO in outer Pago Pago Harbor and a subsequent model verification (validation) study based on the results of these dye studies in the early 1990s. Samples were taken in the near field mixing zone around the diffuser as well as the boundary of the approved mixing zone. See Exhibits 4 and 5 for the dye studies, and Exhibit 6 for the Model Prediction Verification Study. Model predicted initial dilution and trapping depth were validated because the field measurements show higher dilution compared to the model results. Additionally, the model predicted a more conservative result for subsequent dilution between the initial dilution and the mixing zone boundary.

[30] Other studies by other investigators in additional settings (laboratory and full scale field studies) are also available.

- Eleven dye tracer studies done between approximately 2000 and 2019 for outfalls in coastal waters of Puerto Rico.[31] These studies were for marine outfalls from 30 to 400 feet deep with effluent flows at the time of the study from less than 4 mgd to greater than 120 mgd. The results of these studies show that the dilution factors predicted by the UDKHDEN models are much lower than the measured dilution factors at the end of their corresponding mixing zones as shown below. It should be noted that for these six WWTPs, shoreline interactions were not an issue because the outfalls are located a few thousand feet away from the shoreline.

Measured and Prediction Dilutions for Puerto Rico Mixing Zone Studies[32]

RWWTP	Dilution at EOMZ		
	Measured	Predicted	Ratio of Measured /Predicted
Aguadilla	3,922	999	3.9
Arecibo	4,549	550	8.3
Bayamón	3,075	354	8.7
Carolina	1,097	498	2.2
Mayagüez	4,400	305	14.4
Ponce	1,124	499	2.3
Average	3,028	534	5.7

In every case listed above the results indicate that UDKHDEN predicts initial dilutions that are less than, often much less than, measured initial dilutions, and predicts effluent concentrations that are greater than those actually measured in the field. That is, the model is consistently conservative and thus provides results that, when applied to potential impact evaluations, are protective of the environment.

6. **Anecdotal Observations are an Insufficient Basis to Disregard Starkist's Modeling**

Starkist understand that AS EPA representatives have reported observing the discharge plume on the surface of water in the Harbor on a number of occasions. We also understand that in the past residents of Aua and Onesosopo villages reported odorous and discolored water based on shore-side observations, and that AS EPA obtained photographs in November 2015. However, Starkist disagrees that these observations are representative of current conditions (with lower effluent flow

[31] The studies were done for the Puerto Rico Aqueduct and Sewer Authority with reports submitted to, and accepted by, the Puerto Rico Environmental Quality Board and the US EPA-Region 2. The studies are in the public record. *See* Exhibits 7a – 7k.
[32] The studies listed here are Exhibits 7a, 7d, 7g, 7i, 7j and 7k.

rates, lower effluent concentrations, and lower effluent buoyancy), or that they should dictate the terms of a forward-looking and appropriately crafted permit.

It is noted that essentially no information is provided in the Fact Sheet about these anecdotal accounts, which makes them particularly hard to respond to. It is incumbent on US EPA to provide some detail – basics such as who, what, when and where – to support these allegations and for Starkist to be able to appropriately respond. The timing of these observations is particularly important since the improvement to water quality associated with the treatment system improvements occurred in early 2018. Starkist has repeatedly made this comment in response to draft versions of the Fact Sheet. US EPA has decline to provide any details, evidence or other support for its statements, but has continued to use these non-specific anecdotes as a basis for decision-making on the Permit. US EPA's failure to support or detail these vague, and likely outdated, observations is arbitrary, capricious and unreasonable.

Absent necessary detail, it appears that US EPA is asserting any floating material in the Harbor must have originated from Starkist's outfall. This apparent assertion is made despite the fact there are many other users of the Harbor, and it is not unusual for materials to wash or seep into the Harbor from numerous on-shore locations, including sources ranging from septic systems and cesspools to abandoned military fuel storage tanks. Even to the extent there were identifiable fish materials in the water, it is unfortunately not uncommon for fishing boats and other vessels to deposit this and other waste materials into the Harbor.

The Starkist receiving water sampling team has been sampling in the vicinity of the JCO since the early 1990s. Only infrequently has a surfacing plume been observed in the vicinity of the discharge (1 to 3 times). The "surface expression" of the plume is seen more frequently (perhaps 3 to 6 times over the years of sampling). Such observation shows the presence of the plume because of subsurface hydrodynamic action (rising vertical currents moving uncontaminated water upwards) without actually surfacing. Similar phenomena at about the same frequency have been seen at the Utulei and Tafuna discharges in the Harbor and along the open coast, respectively. The observations of these incidents generally are short lived (on the order of an hour or less). There are other wind driven phenomena that affect surface tension of the water surface that can look like an expression of plume surfacing but are completely unrelated.

The observations mentioned in the daft Fact Sheet do not state the length of time that such occurrences persist. It is also noted that the map of supposed plume surfacing occurrences provided by AS EPA in the August 20, 2018 letter indicates physically improbable (likely impossible) plume surfacing locations well away from the discharge point. Finally, the photos of floating scum provided in the August 20, 2018 letter appear to be residue from a fishing boat and are unlikely from the cannery discharge, unless they are from a period when the outfall was not operating correctly (there have been breaks in pipeline in the past) but cannot be from Starkist if the treatment system, outfall, and diffuser are operating as designed. Regardless of any of the above discussion, this has nothing to do with the appropriateness of the predictions of initial dilution and plume dynamics by UDKHDEN (or CORMIX).

a. <u>Floating Fish Wastes</u>

The Fact Sheet alleges observations of floating wish wastes on the surface of the harbor. It is presumed that if these observations are accurate, then the observed material must have been visually identifiable as fish waste. However, the nature of the wastewater treatment processes at the Facility would not allow large fish solids to enter the JCO. The majority of the wastewater is first screened via rotary screens to remove large solids. Once screened, the wastewater passes through two equalization tanks and is then treated by a dissolved air flotation (DAF) system which floats particulate matter to the surface of the DAF tank and removes it from the wastewater stream prior to discharge. Heavier solids sink to the bottom of the DAF tank and are pumped to the rotary screens for further treatment. Any remaining solids in the wastewater are typically fine, neutrally buoyant particles of a soft pulpy nature. Due to the nature of the solids, they are more likely to readily disperse in the Harbor than collect in significant quantities on the shore or on the surface of the water. Further, the wastewater discharged from the Starkist facility since March 2018 is not opaque to the extent that it would be easily visible as a plume in the Harbor. The observations shared by US EPA are not consistent with the wastewater discharged to the JCO.

Fish processing generally produces emulsified oil as a waste product which will be removed across the DAF. DMR records for oil and grease do not indicate concentrations that should result in a floating aggregate, and trends in concentration are fairly uniform. Sighting of floating scum may be related to non-standard operations or upsets at cannery or discharges from ships (e.g. bilge water discharged from tuna boats which are often observed by the receiving water sampling team). When the cannery wastewater treatment plant is operating correctly, cannery derived surface scum or floating debris will not be seen. Furthermore, these occurrences, regardless of source issues, are not related to initial dilution modeling or the model used.

In fact, during receiving water quality sampling, observations are made and recorded of surface water conditions (floatables, odor, grease, oil, scum, foam). There have been almost no observations of plume rise to the surface,[33] and few instances of other observations during these sampling events. This has been generally true for all Harbor water sampling events over the years, as demonstrated by receiving water quality reports, and is confirmed to be the case for all Harbor water sampling events during 2018.

Ultimately, the anecdotal observations recounted in the Fact Sheet are at best outdated as they were not documented to have occurred after the full operation of the interim measures required to be implemented by Starkist. Even if one were to presume some of the observed material came from Starkist, it is likely associated with the time periods of damage to the diffuser and/or the worst discharge exceedances, during 2012 to 2017, and is not representative of current or anticipated future conditions.

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[33] It may be that the referenced observance of the "plume" on the surface reflects an effect that is seen occasionally near the discharge, where it is actually not the plume itself but a region of smooth water caused by upward water velocity of the plume (an "upwelling effect" similar to that caused by wind induced circulation near the sea surface).

b. Surface Observations do not Contradict the Modeling

The positions taken by US EPA in the Fact Sheet appear to be based on a misconception that because the UDKHDEN modeled outputs do not explain all field observations of plume behavior, the model should therefore be discounted. It must be understood that the model is not used to predict the best possible dilution, but rather is used to predict a conservative worst-case dilution. Under conditions of constant receiving water density, UDKHDEN will predict that the plume would rise to the surface (Attachment C provides a UDKHDEN model run with constant density with depth and the plume was shown go to the surface). That scenario will result in the highest dilution for that water column under the range of scenarios considered – nowhere near the desired critical condition needed to evaluate the mixing zone geometry and effluent concentrations. If an individual were on a boat near the outfall diffuser and sees the plume at the surface, it is a common misconception to believe that is the worst-case scenario, rather than what is typically the highest possible dilution scenario.

In contrast, when the water column had a density gradient with depth (high density in deeper water), the plume becomes trapped below the surface. Under this scenario, the dilution would be less; the dilution representing the lowest dilution represents the worst-case scenario. The model was used to evaluate each available water column density profile to account for subtle changes in density that affects where the plume is being trapped, and predicts a worst-case dilution (based on available data).

It is also a misconception is that any observed condition in the receiving water, for example floating material or low dissolved oxygen readings, indicates the initial dilution model predictions are inaccurate. One way to judge the accuracy of the model predictions, or more specifically the conservative nature of the model predicted dilution, is to perform a dye tracer study. If dye is injected into the effluent stream at known concentrations and measured at the edge of the model predicted mixing zone boundary, a dilution can easily be calculated. If the model required inputs (real time measurements of effluent and receiving water density, current speed, and effluent flow), are recorded and input into the model, a predicted dilution under the observed conditions can be obtained. By comparing the measured dilution to the model predicted dilution, as long as the observed dilution is higher than the model predicted dilution, the model is validated (that is the model predicts conservative results with predicted dilution equal to or lower than actual dilution). As noted, this has already been done at the JCO outfall, and elsewhere, and validated the UDKHDEN model as conservative (that is, the measured dilution was higher than the model predicted dilution).

c. Plume Surfacing and Water Quality Standards

Although the plume may surface infrequently, the AS WQS are still expected to be achieved under such circumstances based on the specification of TN and TP criteria as frequency distributions rather than a single number. *See* AS WQS §24.0206 (m). The AS WQS criteria for TN and TP include the criteria below for Pago Pago Harbor:

AS WQS Criteria for TN and TP			
Parameter	**Median (not to exceed)**	**Not to exceed more than 10% of the time**	**Not to exceed more than 2% of the time**
Total Nitrogen (TN) (µg/l as N)	200	350	500
Total Phosphorus (TP) (µg/l as P)	30	60	90

As noted previously with respect to establishment of TN and TP effluent limits, the concentration of TN can be above 500 µg/l for short periods, and the concentration of TP can be above 90 for short periods of time. Therefore, the frequency of surfacing could be considered a "secondary" critical condition and *field recorded* observations of the frequency of surfacing (< 2% of the time) have indicated AS WQS will be achieved when the plume surfaces based on the dilution predicted by the model just below the surface. Therefore, it is the submerged plume critical condition that is of primary importance. The mixing zone was sized so the median values would be met at the edge of the mixing zone under conditions of a submerged plume, which is a conservative approach.

d. Anecdotal Observations and Mixing Zones

The Fact Sheet asserts that AS WQS prohibit the surface from being part of a mixing zone. While this is correct, the Fact Sheet draws the unwarranted conclusion that any material floating the surface, even if presumed for the sake of argument to have been discharged by Starkist, proves that the MZA modeling is not representative. This is an incorrect assertion. As noted previously, the MZA's UDKHDEN modeling was focused on identifying the worst case (lowest) zone of critical initial dilution (CID). The CID will be the lowest when the plume travels the shortest distance. It is recognized that the UDKHDEN modeling does not indicate that the plume will never reach the surface, but just that such circumstances will not be the conditions that lead to the lowest CID and will not violate AS WQS for TN and/or TP. This is particularly true if the frequency of surfacing is as observed by the receiving water sampling team (<2%). As such, this is an invalid reason to disregard the UDKHDEN modeling and the MZA.

7. Dissolved Oxygen Observations do not Contradict Starkist's Modeling

The UDKHDEN model only predicts initial dilution as described above. To determine issues with DO, the assumptions used to predict subsequent DO demand ***following initial dilution*** need to be re-evaluated to assess observed conditions as described above. As noted above, initial dilution is only a minor component of DO predictions and the MZA used inputs for oxygen demand that do not reflect the current discharge. It is noted that if the CORMIX predicted dilution is used instead of the UDKHDEN predicted dilution, it does not significantly change the results of the secondary calculations for DO if the original concentration assumptions are applied to the secondary calculations for DO sag. It is also noted that the DO sag at 60 – 140 ft below the surface further validates the UDKHDEN model's prediction that the plume traps and is entirely contradictory of the CORMIX simulations. If the plume rapidly ascends to the surface as predicted by CORMIX, the DO depression would not be at the 60-140 ft trapping level but in the near surface layer.

Finally, it is noted that UDKHDEN does not predict the plume is swept out of the Harbor, the model only predicts the initial dilution occurring a few seconds to minutes following the discharge. The subsequent dilution model for DO sag accounts for plume reflux using observed background concentrations. As stated above the MZA used inputs for oxygen demand that do not reflect the existing discharge.

8. Starkist's UDKHDEN Modeling Should Have Been Accepted by US EPA

The MZA and Starkist's UDKHDEN modeling was accepted and approved by AS EPA. In contrast, US EPA identified a list of reasons why it preferred to use its own CORMIX modeling. However, the reasons articulated by US EPA are without merit, as discussed above. None of the litany of issues – the age of the model, the harbor current speed, boundary concerns, re-entrainment, and anecdotal historical observations of unspecified fish wastes – are a sufficient basis, either individually or collectively, to provide a basis to entirely disregard Starkist's modeling. Furthermore, a review of the CORMIX model run indicates that CORMIX did not address these issues either. Starkist recognizes that the modeled discharge flow needed to be updated to match the projected future discharge from the JCO, and that was addressed in Attachment A.

US EPA advocates use of its own CORMIX modeling in place of Starkist's UDKHDEN modeling. CORMIX, though, is not appropriate for the particular marine environment where the JCO discharge is located, and the CORMIX modeling is flawed and not representative, as is discussed in greater detail below.

Since UDKHDEN provides a better representation of initial dilution, and the MZA is a more appropriate basis on which to develop effluent limits for the Permit. US EPA should revise the effluent limits accordingly.

D. US EPA's CORMIX Modeling

The Fact Sheet includes a claim by US EPA that it modeled the discharge by using the CORMIX model, for which it used Starkist's own model inputs from Starkist's UDKHDEN modelling. US EPA claims that this modeling effort produced results that show that the plume rises quickly, does not reach a trapping level, and rises all the way to the surface. Based on its own CORMIX modeling, US EPA determined that a calculated dilution rate of 330:1 at a depth of 17 feet should be used to calculate effluent limits.

US EPA's use of CORMIX is addressed in detail in Attachment B. Additionally, the specific model inputs used are addressed in a Technical Memorandum comparing those inputs when used in both UDKHDEN and CORMIX. *See* Attachment C. Attachments B and C are incorporated by reference here as if fully set forth at length. By way of summary of key points in these Attachments:

1. US EPA used a constant vertical density profile in CORMIX. This is unrepresentative, as there is a variation in density from the diffuser depth to the surface. If a constant vertical density profile is used, a surfacing plume is always the result of either model; the plume cannot trap. Using UDKHDEN (or its equivalent DKHW in Visual Plumes) allows for multiple density profiles can be tested to determine the critical case (lowest initial dilution based on actual density profiles), not simplified pseudo-representative profiles.

2. Consideration of vertical density gradients is critical to modeling of a discharge in the Harbor. In a low energy environment like the Harbor, even a weak density stratification can persist and dominate the vertical mixing process. Modeling, such as that done by US EPA using CORMIX, that ignores vertical density gradients, will not accurately predict plume rise or the vertical mixing process.

3. The conclusion of the CORMIX modeling described in the Fact Sheet, that there is no trapping level and the plume will reach the surface essentially all of the time, are contradicted by actual site observations. In fact, the plume is often, almost always, trapped below the surface.[34] Even surface expressions of the plume, generated by locally induced upwelling, are rare. The fact that CORMIX predicts surfacing plumes virtually all of the time seriously calls the validity of US EPA's entire CORMIX modeling effort into question.

4. CORMIX does not have the ability to handle or model the full range of density profile variations present at the discharge location, specifically weakly stratified density profiles. As such, it is not a useful model for this situation. The use of CORMIX to model a marine discharge in an environment with density gradients that were outside of the model's ability to recognize or factor into its results, is an unreasonable and arbitrary and capricious choice.

5. If UDKHDEN is run using the same non-representative inputs (i.e. a constant vertical density) as CORMIX, it achieves the same result of a surfacing plume. As such, it is not that UDKHDEN is flawed or outdated, as claimed by US EPA, but rather that differences in the capabilities of the two models demonstrate that UDKHDEN is the better choice for this particular modeling exercise.

6. US EPA used a single model scenario as the basis for the discharge, and neglected not only the dynamics of the situation, but also ignored any uncertainty in input parameters and the sensitivity of the model. EPA should have performed a sensitivity analysis to characterize model response to small changes in input parameters.

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[34] It is also noted that the observations by Mr. Peter Peshut, as stated in the August 20, 2018 AS EPA letter to US EPA, indicate he has not seen the plume during 85-90 percent of his field visits. Using this anecdotal data, the UDKHDEN model's conservative predictions that the plume traps is validated 85-90 percent of the time and that the predictions by the CORMIX model run which indicates the plume always surfaces clearly do not represent realistic or observed conditions.

7. US EPA's selection of a depth of 5.2 meters below the water surface as the depth at which water quality standards must be met is arbitrary and without apparent basis or reasonable explanation. Further, if a set of model scenarios has been performed, a range of dilution values would have been predicted at this depth.

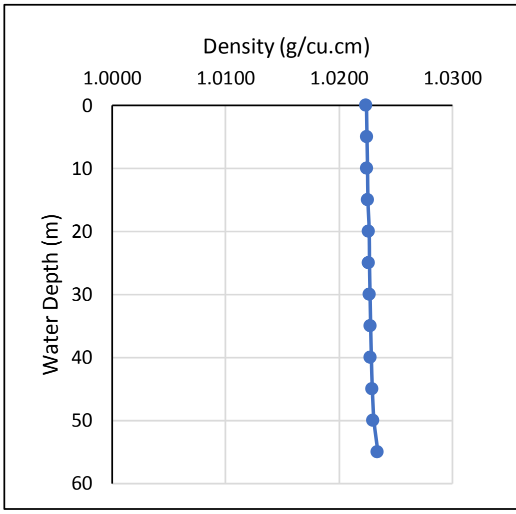
8. The Fact Sheet implies that the lack of a trapping level in US EPA's CORMIX modeling demonstrates a flaw in UDKHDEN and the MZA. This is incorrect, to the extent that the MZA's UDKHDEN modeling was focused on identifying the worst case (lowest) initial dilution (the critical initial dilution: CID). The initial dilution will be the lowest when the plume travels the shortest distance. It is recognized that the UDKHDEN modeling does not indicate that the plume will never reach the surface, but just that such circumstances will not be the conditions that lead to the critical case. As such, this is an invalid reason to disregard the UDKHDEN modeling and the MZA.

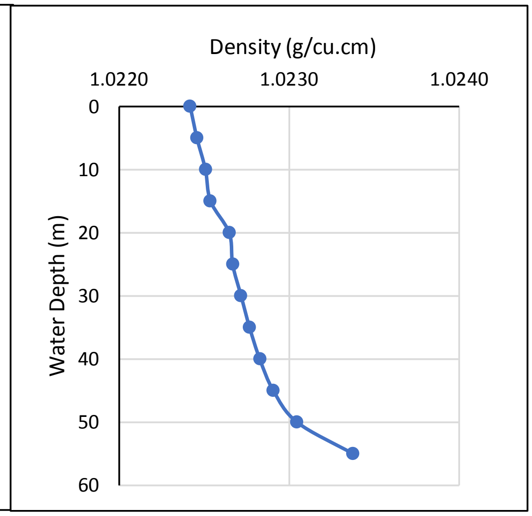
9. US EPA's claim that it ran CORMIX using Starkist's own model inputs is not entirely accurate. A number of choices need to made to set up the model and determine what inputs will be used. There is no direct one-to-one correlation of UDKHDEN inputs to CORMIX inputs that would allow US EPA to run CORMIX using the identical inputs used by Starkist.

10. The Fact Sheet states that US EPA only used Starkist's modeling inputs, and also that CORMIX was used to address boundary and re-entrainment issues. These are mutually inconsistent statements, and cannot both be accurate. As noted previously, UDKHDEN was used solely to calculate initial dilution. As such, even if the UDKHDEN inputs were appropriately and reasonably translated into CORMIX inputs, the only inputs available were for initial dilution. As such, US EPA's CORMIX output could not consider or evaluate any of the boundary and re-entrainment issues that US EPA raises as challenges to UDKHDEN, unless US EPA developed its own inputs to for these issues. It is noted that Starkist used a separate model and specific approaches to account for these factors as described above in these comments. It is noted that because CORMIX predicts a surfacing plume, boundary and re-entrainment issues would not need to be addressed.

11. CORMIX uses an equivalent slot discharge, meaning that the initial zone of flow establishment is not considered, leading to poor simulation of the plume close to the discharge and essentially ignoring the effects of near bottom density structure. Overall, CORMIX is often not considered a good choice for simulations in open coastal marine settings.

As an example, the critical density profile from the 2017 MZA is shown in the figure below. The left-hand panel shows the profile on a scale representative of fresh to highly saline water. Based on this depiction a constant density profile might be approximated and used to simulate the receiving water conditions (leading to a surfacing plume). The right-hand paned shows the profile in more detail. In particular, the change in density very close to the bottom is indicated. The depth of the discharge is at 54 meters. The sharp change near the discharge depth will have a significant effect on the plume development and lead to trapping of the plume (and lower dilutions) than if the profile were approximated as constant or, depending on the assumptions, even linear. Small changes in density can have large effects on plume behavior.





VII. Additional Issues

A. Additional items in the Permit

- In Attachment C to the draft Permit, copies of Process Flow Diagrams are attached. Attached to these comments as Exhibit 8 are updated PFDs that reflect more recent discussions with US EPA's ocean disposal permitting group.

- In Attachment E to the draft Permit (page 39) correct where "permitee" is misspelled twice

B. Additional items in the Fact Sheet

Starkist requests that US EPA provide responses that acknowledge the following issues in the Fact Sheet:

- In Section III (page 4), it is noted that "The permittee is currently conducting treatment and operational changes under a judicial consent decree to achieve current and future compliance with permit limits, including attainment of applicable water quality standards." Compliance with AS WQS has been achieved to date, and the implication that water quality standards have not yet been achieved is inaccurate.

- In Section IV (page 4), it is stated that "Data collected since the most recent (March 2018) treatment upgrades completed by the permittee suggest potential improvement of these conditions." Receiving water quality data collected and submitted to US EPA has demonstrated improvement in the receiving water.

- Table 1 in Section V (page 6) includes effluent data from Outfall 001 from April 2008 through March 2018. Starkist requests clarification that this data is not representative of current operations. Additionally, the highest monthly average reported for mercury is 0.04 lbs/day. It does not make sense for this value to be greater than the highest daily maximum value of 0.01 lbs/day. It is believed that the 0.04 lbs/day value was listed by mistake, since it is the established average monthly limit.

- Within Section VI.B.2:
  - In subsection B, it is noted that "AS-EPA has recorded examples of shoreline interaction." Based on the limited information provided, it appears that even if this is an accurate statement that has any relation to Starkist, that this has not been observed since the treatment plant upgrades were implemented. Starkist requests that the statement is clarified to note that these observations were made prior to the treatment plant upgrades. Please refer to additional comments provided in this document.
  - In subsection C, it is stated that "AS-EPA has received numerous reports from both boaters and residents on the shoreline of fish wastes floating on the harbor surface, including photographic documentation." Starkist believes that all of these observations are historical and have not been observed recently, and requests that the statement is clarified as such. Please refer to additional comments provided in this document.
  - In subsection C, it is stated that "Due to detection of ammonia levels at the ZID in excess of the applicable AS WQS, any increase in mixing and total discharge of ammonia is unlikely to be adequately protective of water quality." This statement is not accurate. Ammonia has been measured at the ZID semi-annually, and AS WQS have not been exceeded. Starkist requests that this statement is removed.

Attachment and Exhibit List

Attachments

A. Joint Cannery Outfall Revised Initial Dilution Modeling and Mixing Zone Geometry Results Technical Memorandum, by gdc, dated August 14, 2019

B. Evaluation of EPA CORMIX Modeling, Starkist Samoa Company, NPDES Permit No. AS 000019, Integral Consulting, Inc., dated August 14, 2019

C. Joint Cannery Outfall UDKHDEN – CORMIX Comparison Technical Memorandum, by gdc, dated August 13, 2019

Exhibits

1. March 2018 through January 2019 DMR data

2. 1992 Starkist NPDES Permit Statement of Basis

3. 2019 Utulei NPDES Permit Fact Sheet

4. July 1993 Joint Cannery Outfall Dye Study Report

5. October 1994 Joint Cannery Outfall Dye Study Report

6. 1995 Joint Cannery Outfall Model Prediction Verification Study

7a – 7k. Puerto Rico mixing zone validation reports

8. Updated Process Flow Diagrams

Starkist Samoa Co.
August 15, 2019 Comments
Public Notice Draft Permit
NPDES AS000019

ATTACHMENT A

TECHNICAL MEMORANDUM gdc

JOINT CANNERY OUTFALL REVISED INITIAL DILUTION MODELING AND MIXING ZONE GEOMETRY RESULTS

Prepared For: Starkist Samoa Company (NPDES Permit No. AS0000019)

Prepared By: gdc, PO. Box 1238, Trinidad, CA 95570
707-677-0123 – glatzeldacosta@suddenlink.net

Date: August 14, 2019

SUMMARY

The National Pollutant Discharge Elimination System (NPDES) permit renewal applications for Starkist Samoa Co. (SKS) and Samoa Tuna Processors, Inc. (STP) were based partially on the *Revised Request for Water Quality Certification and Definition of Mixing Zones for the Joint Cannery Outfall* and *the Amendment to the Request for Water Quality Certification and Definition of Mixing Zones for the Joint Cannery Outfall*, submitted to the American Samoa Environmental Protection Agency (ASEPA) on March 25, 2017 and June 19, 2018, respectively (the MZA). This technical memorandum (TM) represents a second addendum to the MZA and provides supplemental information and updated modeling to support StarKist's requested nutrient effluent limits in their comments on the draft SKS NPDES permit.

The dilution modeling documented in the MZA was based on the anticipated effluent flowrates from the canneries. Since then, STP has ceased production operations and is now primarily being used for non-production activities in support of the SKS operation. As a result, the current effluent flow through the Joint Cannery Outfall (JCO) is substantially lower than used in the MZA. In addition, the density of the effluent has changed because SKS uses seawater for thawing fish and STP used only freshwater that is no longer present in the combined effluent. Furthermore, in the draft SKS NPDES permit fact sheet, EPA has raised questions about the current speed used in the MZA model. Therefore, updated UDKHDEN modeling has been performed to evaluate the impact of these inputs on calculated dilution factors (which form the basis for the draft permit's water quality based effluent limits), plume surfacing, and attainment of American Samoa Water Quality Standards (ASWQS) at the shoreline and coral reef.

The initial dilution modeling presented in the MZA was conducted using a 10-percentile ambient receiving water current speed (2 cm/sec), based on the available data, as the critical condition for the modeling. The effects of using a zero ambient current was evaluated in this TM. The maximum daily effluent flow used in the MZA was also reduced, and the effluent salinity increased, to reflect the most up-to-date effluent conditions anticipated for the upcoming permit term (and consistent with the permit renewal applications). The dilution model was re-run using the critical and median dilution cases, defined by the vertical density profiles as described in the

MZA. All other model input parameters used in the MZA modeling remain as originally specified.

Based on the revised initial dilution results the mixing zone geometries and implications for the effluent concentrations were re-evaluated. The dilutions and mixing zone sizes for the range of effluent flows considered are as expected and indicate higher dilutions for lower effluent flows for a given ambient current. Dilutions for zero ambient current and increased effluent salinities are lower than for the previous conditions used, as expected.

The effluent concentrations for total nitrogen (TN) and total phosphorus (TP) presented in the MZA were also updated here to reflect recent conditions since wastewater treatment plant upgrades at SKS. Recent actual effluent concentration data were used (not lower projected effluent concentrations after resuming ocean disposal), again as an additional layer of conservatism. The results indicate that the effluent plume will meet ASWQS prior to reaching the closest shoreline or coral reef and will remain submerged well below the water surface under critical conditions (and for all density profiles examined in the MZA).

INTRODUCTION

On March 25, 2017, a *Revised Request for Water Quality Certification and Definition of Mixing Zones for the Joint Cannery Outfall* was submitted to the American Samoa Environmental Protection Agency (ASEPA). On June 19, 2018 an *Amendment to the Request for Water Quality Certification and Definition of Mixing Zones for the Joint Cannery Outfall* was submitted to ASEPA. These documents (the MZA) were submitted in support of the National Pollutant Discharge Elimination System (NPDES) permit renewals for the StarKist Samoa Company (SKS) and Samoa Tuna Processors, Inc. (STP) tuna canneries. The MZA and associated dilution modeling were based on the anticipated maximum daily effluent flows from the canneries for the upcoming NPDES permit term, at the time the MZA was developed. STP has ceased production operations and effluent flow is substantially lower than used in the MZA and is currently limited to relatively small flows from freezer and ammonia refrigeration system operations, dock wash down, tuna pouch packaging, storage, equipment maintenance, and storm water.

The dilution modeling presented in the MZA was conducted using a 10-percentile ambient receiving water current speed. In addition, the modeling presented in the MZA was based on the effluent density for the combined flows from both canneries. The effluent density has increased with the reduction of STP flows because SKS uses sea water in production process (fish thawing) and STP did not use seawater in the production process.

This Technical Memorandum (TM) presents the results of dilution modeling for the lower effluent flows associated with the current STP operations, increased effluent density, and for the (unrealistic) conservative case of zero ambient current. The anticipated maximum daily flow for SKS was modified (from the MZA) to reflect a minor increase in anticipated maximum daily production at SKS in the upcoming permit term and also removing the quantity of wastewater flow that is currently planned for ocean disposal, resulting in an overall increase compared to the MZA.

The dilution model, UDKHDEN, was re-run for lower effluent flows and the critical and median dilution cases, defined by the vertical density profiles available, as described in the MZA, increased effluent density, and zero ambient current. All other parameters used in the MZA modeling remain as originally specified. Based on the revised initial dilution results the mixing zone geometries and overall behavior of the effluent plume were re-evaluated.

DIFFUSER FLOWS AND HYDRAULICS

The MZA was based on effluent flows of 2.6 million gallons per day (mgd) for SKS and 1.4 mgd for STP for a total flow of 4.0 mgd. The current STP flow is consistently less than 0.1 mgd, and a flow of 0.1 mgd as a maximum anticipated flow for STP is assumed for the evaluations presented in this TM. This is consistent with the maximum daily flow requested in the revised STP NPDES permit renewal application submitted to U.S. EPA in February 2019. The maximum daily flow requested for SKS in the revised permit renewal application (submitted in February 2019), and subsequently included in the draft permit (issued in July 2019) as the maximum daily flow limit, is 2.9 mgd. This flow corresponds to the anticipated maximum daily production in the upcoming permit term with the quantity of wastewater flow subtracted representing the wastewater streams from SKS that were historically ocean disposed. This results in a total flow through the Joint Cannery Outfall (JCO) of 3.0 mgd. Therefore, the initial dilution model was run for a total JCO flow of 3.0 mgd at ambient current speeds of both 2.0 cm/sec and 0.0 cm/sec. The model was run for these ambient current and flow conditions using both the previous effluent density (4.95 ppt) and the revised effluent density considering the lower STP flows (10 ppt).

Available data, and professional judgement based on experience in similar systems as presented in the MZA, support the assumption of 2.0 cm/s as the ambient current speed. However, it is acknowledged that the precise critical (10th percentile) ambient current speed may be somewhat uncertain. Therefore, results for an overly conservative and unrealistic worst-case scenario current speed of 0 cm/s are also provided in this TM for comparison purposes, to allow for evaluation of the sensitivity of this input on predicted dilution.

The port flow characteristics for the lower-flow case (3.0 mgd) compared to the original MZA (4.0 mgd) case are shown in Table 1. These reduced port flows were used in the additional model runs reported in this TM.

Table 1. Port Exit Velocities and Port Flow for JCO Diffuser

Port Size	Number of Ports	Range of Port Exit Velocities (fps)	Total Flow through Port Size Group (mgd)
MZA – Maximum daily flow of 4.0 mgd			
5-inch	6	7.32 – 7.63	3.900
2-inch	1	7.32	0.100
Revised Effluent Flow – Maximum daily flow of 3.0 mgd			
5-inch	6	5.49 – 5.73	2.925
2-inch	1	5.53	0.075

fps = feet per second
mgd = millions of gallons per day

UDKHDEN Initial Dilution Results

The initial dilution model (UDKHDEN) was run for the reduced effluent flows (3.0 mgd) using the original case of 2.0 cm/sec ambient current and 0.0 cm/sec ambient current. For each case the model was also run for the previous effluent density and the increased effluent density, using a salinity of 4.95 ppt (MZA) and 10.00 ppt (this TM), respectively. The results are shown in Table 2 with the original MZA results using a combined effluent flow of 4.0 mgd and 2.0 cm/sec ambient current for reference. All other model input parameters were the same as presented in the MZA. Model input/output files are provided in Attachment 1. It is noted that receiving water profiles collected following the publication of the Revised MZA in 2017 have been examined, are consistent with the profiles used in the Revised MZA, and would not be expected to change the results and conclusions of the MZA.

Table 2. Summary of UDKHDEN Model Results for Combined SKS and STP Effluent Flows

Model Case			Plume Passing Though Trapping Level				Plume at Maximum Rise			
Model Run	**Port Diameter (inches)**	**Combined Effluent Flow (mgd)**	**Trapping Level Below Surface (m)**	**Dilution**	**Flow-weighted Trapping Level**	**Flow-weighted Dilution**	**Rise Height above Discharge (m)**	**Dilution**	**Flow-weighted Max Rise Level (m)**	**Flow-weighted Dilution**
Original MZA - 4.0 mgd and 2.0 cm/sec Ambient Current										
March 23, 2014 (AM) Density Profile – Critical Initial (10th Percentile) Dilution										
U23A40	2	4.0	49.20	225.14	42.13	**199.69**	6.38	391.02	15.83	334.81
U23B40	5		41.95	199.04			16.07	333.37		
May 1, 2008 Density Profile – Median Initial Dilution										
U11A40	2	4.0	40.39	1337.57	33.06	**535.51**	16.38	1957.66	30.21	**1,007.93**
U11B40	5		32.87	514.94			30.56	983.58		
Revised - 3.0 mgd and 0.0 cm/sec Ambient Current (previous effluent salinity)										
March 23, 2014 (AM) Density Profile – Critical Initial (10th Percentile) Dilution										
U23A030	2	3.0	46.34	180.62	37.48	**167.35**	10.42	260.13	22.60	240.44
U23B030	5		37.25	167.01			22.91	239.93		
May 1, 2008 Density Profile – Median Initial Dilution										
U11A030	2	3.0	36.8	621.75	19.97	**502.74**	22.86	891.25	39.83	**614.47**
U11B030	5		19.54	499.69			40.26	607.37		
Revised - 3.0 mgd and 2.0 cm/sec Ambient Current (previous effluent salinity)										
March 23, 2014 (AM) Density Profile – Critical Initial (10th Percentile) Dilution										
U23A230	2	3.0	49.44	238.55	42.93	**211.52**	5.99	418.26	14.55	356.30
U23B230	5		42.76	210.83			14.77	354.71		
May 1, 2008 Density Profile – Median Initial Dilution										
U11A230	2	3.0	41.06	1533.80	35.00	**562.18**	15.58	2268.35	25.88	**1,002.49**
U11B230	5		34.84	537.27			26.14	970.03		
Revised - 3.0 mgd and 0.0 cm/sec Ambient Current and Increased Effluent Salinity										
March 23, 2014 (AM) Density Profile – Critical Initial (10th Percentile) Dilution										
U23A030S	2	3.0	47.08	153.61	39.32	**137.18**	9.48	221.27	20.62	201.26
U23B030S	5		39.12	136.76			20.91	200.75		
May 1, 2008 Density Profile – Median Initial Dilution										
U11A030X	2	3.0	37.39	565.07	20.98	**452.29**	21.87	798.67	38.87	**549.56**
U11B030S	5		20.56	449.4			39.31	543.17		
Revised - 3.0 mgd and 2.0 cm/sec Ambient Current and Increased Effluent Salinity										
March 23, 2014 (AM) Density Profile – Critical Initial (10th Percentile) Dilution										
U23A230S	2	3.0	50.07	190.72	44.26	**171.60**	5.33	353.02	13.05	296.21
U23B230S	5		44.11	171.11			13.25	294.75		
May 1, 2008 Density Profile – Median Initial Dilution										
U11A230S	2	3.0	41.59	1428.62	35.94	**514.83**	15.02	2129.64	23.24	**868.99**
U11B230S	5		35.79	491.4			23.45	836.67		

The model results in Table 2 include the predicted critical initial dilution (CID) and the predicted median initial dilution (MID), and the dilution at the point of maximum plume rise. The trapping level and height of maximum plume rise are also tabulated. The results for each port size (one 2-inch port and six 5-inch ports) and the flow averaged results are presented. The model run designation is provided in Table 2 for reference to Attachment 1.

Actual dilution is expected to be greater than the model predicted results because of a number of conservative modeling assumptions, including the fact that a portion of effluent flows are planned to be diverted for ocean disposal. In addition, the model is known to be conservative (predicts lower than observed dilution) bases on numerous field verification studies.

TOXICS MIXING ZONE GEOMETRY

The American Samoa Water Quality Standards (ASWQS) require that mixing zones for toxic substances be within the zone of initial dilution (ZID), which is defined by the location of the discharge plume at the point where the CID is achieved[1]. Using the model output, the length of the mixing zone (L_{MZ}) for each port, or port group, is calculated. The dimensions of the mixing zone are typically based on the maximum value of L_{MZ}. The methodology is described in greater detail in the MZA. The results for the cases considered in this TM are provided in Table 3. As shown in Table 3, the boundary of the rectangular toxics mixing zone, based on the CID, is over 500 feet from the closest reef face[2] and over 1,100 feet from the shoreline.

Table 3. Toxicity Mixing Zone Dimensions – Centered on the JCO Diffuser

Mixing Zone	Length (feet)	Width (feet)	Area (square feet)	Depth Below Surface (feet)[a]	Distance from Shoreline (feet)	Distance from Edge of Reef (feet)
MZA Base Case - Effluent Salinity = 4.95 ppt						
4.0 mgd – Ambient Current=2.0 cm/s	335	93	31,155	138	1,154	529
Revised Flow with Effluent Salinity = 4.95 ppt						
3.0 mgd - Ambient Current=0 cm/s	317	71	22,586	123	1,143	518
3.0 mgd - Ambient Current=2 cm/s	329	81	26,674	141	1,148	523
Revised Flow with Effluent Salinity = 10 ppt						
3.0 mgd - Ambient Current=0 cm/s	302	63	19,174	129	1,139	514
3.0 mgd - Ambient Current=2 cm/s	320	76	24,440	145	1,146	521
[a] Flux average value for plume centerline						

[1] The model provides the dilutions for the plume continuously along the plume trajectory. Unless blocked by the water surface, the plume initially rises through the equilibrium or trapping level (ambient and plume water of the same density), overshooting the equilibrium level, then collapsing back to the equilibrium level. The UDKHDEN model tracks the plume to the point of maximum rise and then terminates execution. Dilution continues during the rise of the plume past the trapping level. However, to be conservative, the dilution as the plume first passes the trapping level is taken as the initial dilution for the purpose of determining the critical initial dilution.

[2] The adjacent reef is a shore attached coral reef and consists of a wide reef flat and a steep reef slope from the reef flat to the harbor bottom. Distance to the reef in this TM refers to the distance to the bottom of the reef slope in approximately 160 to 180 feet of water, not the reef crest on the seaward side of the reef flat.

MEDIAN MIXING ZONE GEOMETRY

The ASWQS regulates certain substances based on a median value. In such cases, it is appropriate to define mixing zones, if required, based on median conditions in the receiving water. An MID was defined using the vertical density profile that resulted in the median initial dilution based on all available density profiles. It is noted that critical condition ambient currents (both 0 and 2.0 cm/sec were considered) and the maximum effluent flow were used to define the MID as a conservative measure rather than using the average current and average flow rate. Therefore, the MID considered is a very conservative estimate of this condition. Table 4 shows the size of the MID based mixing zones for the same cases considered in Table 2. As shown in Table 4, the boundary of the rectangular mixing zone for ammonia, based on the MID, is over 450 feet from the closest reef face and over 1,000 feet from shoreline.

Table 4. Median Mixing Zone Dimensions – Centered on the JCO Diffuser

Mixing Zone	Length (feet)	Width (feet)	Area (square feet)	Depth Below Surface (feet)[a]	Distance from Shoreline (feet)	Distance from Edge of Reef (feet)
MZA Base Case - Effluent Salinity = 4.95 ppt						
4.0 mgd – Ambient Current=2.0 cm/s	398	139	55,418	108	1,101	476
Revised Flow with Effluent Salinity = 4.95 ppt						
3.0 mgd - Ambient Current=0 cm/s	376	104	39,493	66	1,084	459
3.0 mgd - Ambient Current=2 cm/s	383	122	46,785	115	1,093	468
Revised Flow with Effluent Salinity = 10 ppt						
3.0 mgd - Ambient Current=0 cm/s	377	108	41,008	69	1,086	461
3.0 mgd - Ambient Current=2 cm/s	380	122	46,359	118	1,093	468
[a] Flux average value for plume centerline						

EXTENDED MIXING ZONES

The ASWQS allow mixing zones beyond the ZID with specific restrictions as described in §24.0207 of the ASWQS. Parameters that may have such extended mixing zones include the nutrients total nitrogen (TN) and total phosphorus (TP), which are regulated based on a log-normal distribution with specified "not to exceed" median, 90th percentile and 98th percentile values. To develop the sizes of such mixing zones requires a stepwise procedure as described in the MZA:

- If initial dilution at the trapping level is insufficient to meet ASWQS criteria, then initial dilution past the trapping level is considered.
- Initial dilution past the trapping level continues in the effluent plume as it continues to rise through the water column up to the point of maximum rise[3].

[3] The initial dilution model terminates calculations and provides no further output at and beyond the point of maximum rise. Some initial dilution will continue as the plume collapses back to the equilibrium level beyond the point of maximum rise. The dilution

- If initial dilution at the point of maximum rise is still not sufficient then subsequent (passive) dilution is considered as the diluted plume is carried away from the point of maximum rise by ambient currents.[4]

Initial Dilution Portion of the Nutrient Mixing Zone: Based on MID at Maximum Plume Rise

The dilution at the point of maximum rise for the median conditions are shown in Table 2. The size of this portion of the mixing zone is shown in Table 5. It is noted that, in the case considered here, the size of the mixing zone in Table 5 represents only the initial part of the total nutrient mixing zone size and requires the addition of the subsequent dilution mixing zone as described in the next section.

Table 5. Extended Median Mixing Zone Dimensions – Centered on the JCO Diffuser

Mixing Zone	Length (feet)	Width (feet)	Area (square feet)	Depth Below Surface (feet)[a]	Distance from Shoreline (feet)	Distance from Edge of Reef (feet)
MZA Base Case - Effluent Salinity = 4.95 ppt						
4.0 mgd – Ambient Current=2.0 cm/s	518	148	76,487	77	1,102	477
Revised Flow with Effluent Salinity = 4.95 ppt						
3.0 mgd - Ambient Current=0 cm/s	478	157	75,108	45	1,107	482
3.0 mgd - Ambient Current=2 cm/s	473	109	51,740	91	1,083	458
Revised Flow with Effluent Salinity = 10 ppt						
3.0 mgd - Ambient Current=0 cm/s	552	196	108,051	49	1,126	501
3.0 mgd - Ambient Current=2 cm/s	453	115	52,325	100	1,086	461

[a] Flux average value for plume centerline

Subsequent Dilution Following Initial Dilution

If the initial dilution at the maximum rise height of the initial dilution plume is not sufficient to reduce the nutrient concentrations to the ASWQS criteria, then the mixing zone is extended accounting for subsequent dilution following initial dilution. This was the procedure followed in the development of the MZA. Subsequent dilution is the passive dilution following the rapid mixing that occurs during the initial dilution process and is calculated as described in the MZA.

Subsequent dilution is a much less intense process and occurs over longer time scales than initial dilution. For the case considered here, the subsequent dilution was determined based on the Brooks Equation using a conservative diffusion coefficient and the average ambient current (4 cm/sec as described in the MZA). Current direction in the area of the diffuser is governed by the

past the point of maximum rise can be estimated by post processing the model output data, however, it is relatively small and is not considered here.

[4] Although initial dilution is calculated using zero or critical ambient currents to be conservative, passive diffusion takes place over much longer time scales (hours to days rather than seconds to minutes) and the average ambient current is appropriate for these calculations.

local bathymetry, including the steep reef face which extends nearly to the surface, and trends parallel to the reef and shoreline. The subsequent dilution as a function of distance from the point of maximum plume rise is shown in Figure 1[5].

The total dilution is the product of the initial dilution (MID, Table 5) and the subsequent dilution (D_S). It is noted that this is the *potential* dilution available at any given distance. *The final size of the nutrient mixing zone depends on the dilution required.*

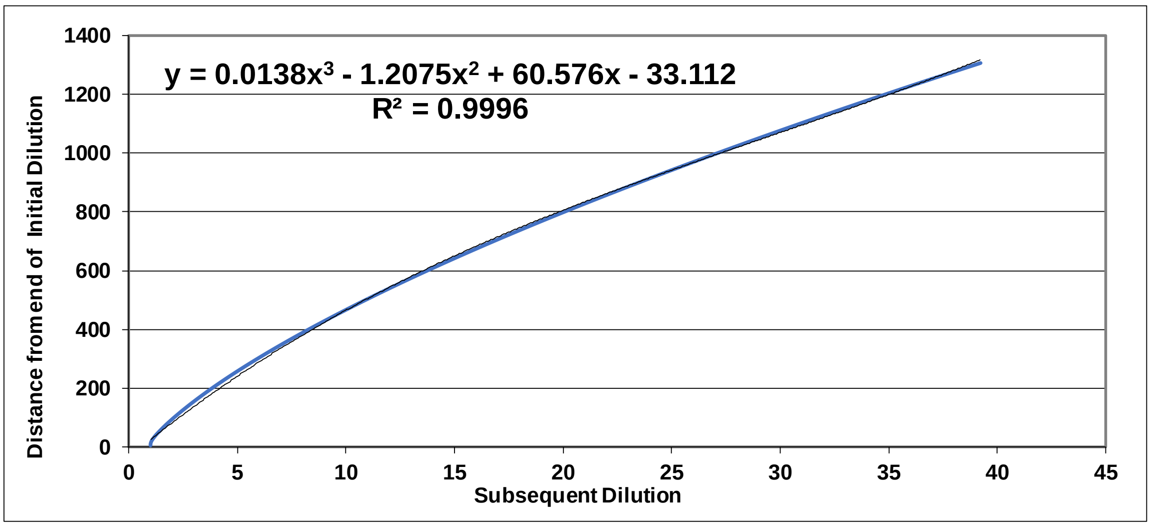


Figure 1. Subsequent Dilution as a Function of Distance from the End of Initial dilution

Figures 2, 3, and 4 provide schematic illustrations of the initial and subsequent dilution calculations presented in this TM. Figure 2 shows the initial dilution plume: the CID is defined as the plume first passes through the level where the plume density equals the surrounding ambient density (trapping level); because of momentum the plume continues to rise to the point of maximum rise; then the plume, now denser than the ambient surroundings, collapses back to a level where densities are equal. Because the model (and most initial dilution models) does not predict the rapid mixing processes resulting in initial dilution past the point of maximum rise, and additional dilution past this point is small, subsequent dilution is generally considered to start at this point (Figure 3 and 4). However, it is noted that the subsequent plume will actually be lower in the water column, slightly above the defined trapping level, than the maximum rise height because of plume collapse.

[5] The curve fit equation on Figure one is for convenience and is only applicable to the cases being considered here. The full Brooks equation for the general case is provided in the MZA

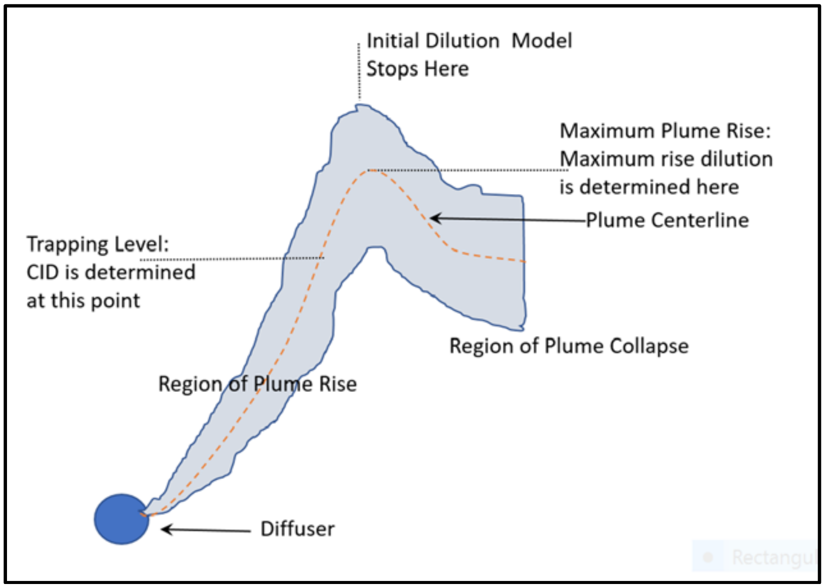


Figure 2. Elevation View Schematic of Initial Dilution Plume

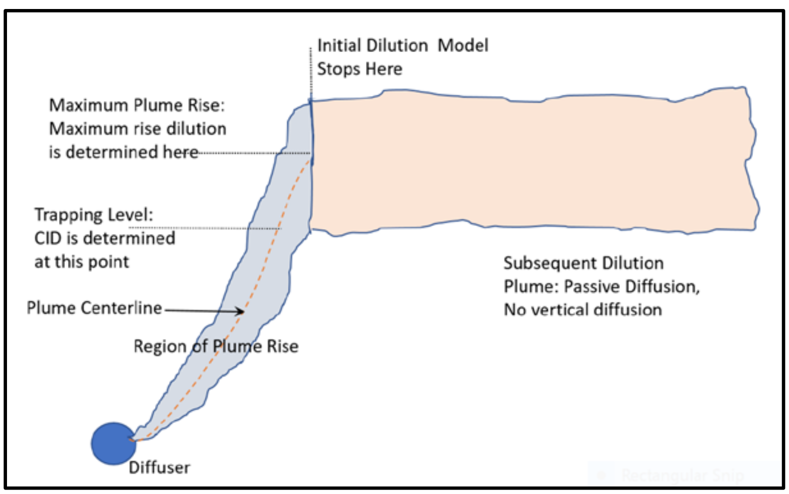


Figure 3. Elevation View Schematic of Initial and Subsequent Dilution Plumes

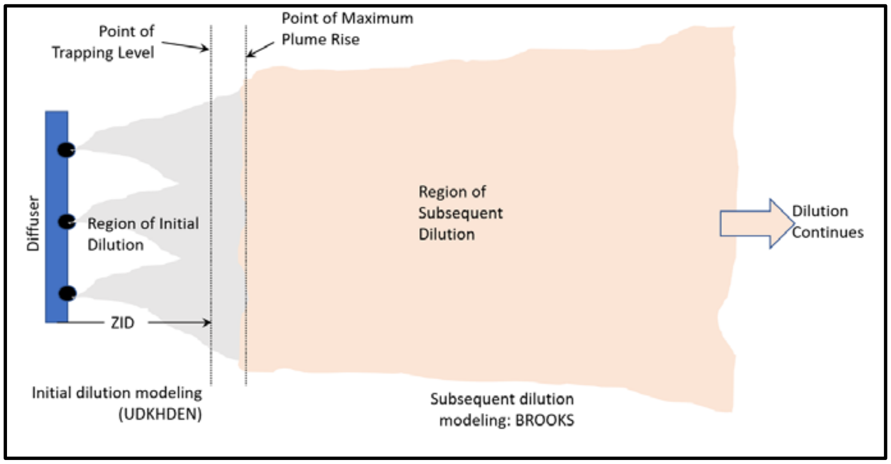


Figure 4. Plan View Schematic of Initial and Subsequent Dilution Plumes

The size of the extended mixing zones for nutrients (TN and TP) depends on the effluent concentrations and background receiving water concentrations. The *existing* nutrient mixing zone is specified as a partial circle bounded on the east by the reef slope. This was established during the design of the outfall and development of the initial NPDES permit and reflects the maximum distance that might be traveled by a discharged water parcel (but not necessarily towards the reef). The specification of the radius of the circle was conservative (larger than needed in the east-west direction) and intended to account for all potential transport paths of the discharged effluent. It is noted that the closest reef is to the east of the discharge. The circular specification (rather than an elliptical or rectangular shape) also provided a convenient way to specify receiving water quality sampling points.

Although the *existing* mixing zone appears to go east as far as the reef slope, submerged well below the surface, the original prediction when the outfall was initially permitted did not actually indicate the plume would travel that far prior to reaching concentrations of the specified water quality standards for TN or TP. For convenience and to provide ease in setting receiving water sampling points, USEPA set the mixing zone as a circle for both TN and TP, using the largest circle that accounted for both parameters. The distance was originally based on the transport model and later confirmed, in the following permit development, using initial and subsequent dilution models and further confirmed by two dye studies and a model validation study. *The same approach was used in the MZA.*

Using the recent StarKist Samoa reasonable potential effluent concentrations (April 2018 through April 2019 as presented in Attachment 2) and the receiving water concentrations presented in the MZA, the resulting mixing zone size is described in Table 6, based on currents running parallel and perpendicular to the reef. It is noted that use of the StarKist effluent data are based on the present condition of virtually no flow or loadings from the STP facility. It is noted that the plume does not reach the reef for any of the cases based on use of the 10th percentile current[6]. The dimensions of the nutrient mixing zone in Table 6 are *rectangular* and based on the shape of the initial dilution mixing zone and the potential distance travelled by the effluent plume as if the current is constant until the required subsequent dilution is achieved. *In no case is it predicted that the plume, at levels of TN and TP above the water quality standards, is transported as far as the reef slope.* Actual distances from shoreline and reef are expected to be greater than these model results due to a number of conservative modeling assumptions, including the fact that a portion of higher strength effluent flows are planned to be diverted for ocean disposal.

Table 6. Extended Nutrient Mixing Zone Dimensions – Centered on the JCO Diffuser for Updated Effluent Concentrations (April 2018 through April 2019)

Mixing Zone	Length (feet)	Width (feet)	Area (square feet)	Depth Below Surface (feet)[a]	Distance from Shoreline (feet)[b]	Distance from Edge of Reef (feet)[b]
Total Nitrogen						
Updated Effluent - Base Case - Effluent Salinity = 4.95 ppt						
4.0 mgd – Ambient Current=2.0 cm/s	656	286	187,276	77	1,058	433
Updated Effluent - Revised Flow with Effluent Salinity = 4.95 ppt						
3.0 mgd - Ambient Current=0 cm/s	715	394	281,555	45	1,004	379
3.0 mgd - Ambient Current=2 cm/s	612	248	151,435	91	1,077	452
Updated Effluent - Revised Flow with Effluent Salinity = 10 ppt						
3.0 mgd - Ambient Current=0 cm/s	817	461	376,563	49	970	345
3.0 mgd - Ambient Current=2 cm/s	616	278	171,335	100	1,061	436
Total Phosphorus						
Updated Effluent - Base Case - Effluent Salinity = 4.95 ppt						
4.0 mgd – Ambient Current=2.0 cm/s	592	222	131,627	77	1,089	464
Updated Effluent - Revised Flow with Effluent Salinity = 4.95 ppt						
3.0 mgd - Ambient Current=0 cm/s	557	263	146,559	45	1,069	444
3.0 mgd - Ambient Current=2 cm/s	535	183	97,811	95	1,109	484
Updated Effluent - Revised Flow with Effluent Salinity = 10 ppt						
3.0 mgd - Ambient Current=0 cm/s	604	299	180,412	47	1,051	426
3.0 mgd - Ambient Current=2 cm/s	570	199	113,199	89	1,110	476

[a] Flux average value for plume centerline at trapping level (after plume collapse)
[b] Shortest distance to closest shoreline and reef edge is indicated
* Plume would reach reef slope, but would not rise above depth indicated and would be directed parallel to reef by prevailing currents

IMPLICATIONS FOR EFFLUENT LIMITATIONS

Nutrients (TN and TP)

As shown in the MZA, nutrient concentrations in the effluent cannot be accommodated in the receiving water considering only initial dilution (MID or CID). Therefore, subsequent dilution with an extended mixing zone is required for these parameters, regardless of the limitation imposed, to accommodate the effluent concentrations. The size of the mixing zone is based on the concentration required expressed as an effluent limitation and any specific restrictions on an allowable mixing zone size or extent in the ASWQS. The mixing zone size can be adjusted for the required effluent concentration. The existing mixing zone (approved in the current permit) was

[6] To apply the same reasoning used to develop the *existing* mixing zone, the radius of the circle would be taken as approximately one-half of the length of the rectangular mixing zone shown in Table 6.

based on the acceptable total loading of TN and TP developed for the first JCO permit in the early 1990s.

As described above in this TM, the size of the mixing zone depends on the initial dilution plus the subsequent dilution. The size of the mixing zone for the effluent limitations requested in the MZA varies with the initial dilution considered. For nutrients, the initial dilution is taken as that for the median condition at maximum plume rise because the mixing zone must extend past this point and TN and TP compliance is based on the median concentration. The size of the mixing zone for the various cases is shown in Table 6 for the recent effluent concentrations following the treatment plant upgrades.

As discussed above, in the case of the nutrients (TN and TP) the maximum allowable concentration is not set by a fixed, limiting initial dilution. The subsequent dilution required is calculated, for the required or desired effluent concentration (as long as certain limitations are met including impact to shoreline or blocking the entire water body [to passage of organisms]). Using the more recent data representative of the treatment plant upgrades from April 2018 through April 2019 (Attachment 2), the mixing zone sizes are summarized in Table 7. As noted above, the dimensions of the nutrient mixing zone in Table 7 are rectangular and based on the shape of the initial dilution mixing zone and the potential distance travelled by the effluent plume as if the current was constant until the required subsequent dilution was achieved. The same approach was used in the MZA. To convert the rectangular mixing zone to a circular mixing zone for consistency with previous permits, the same reasoning described above and used in the MZA can be applied here. The radius of the circle would be taken as approximately one-half of the length of the rectangular mixing zone shown in Table 7.

Table 7. Total Mixing Zone Size and Shoreline Interactions for Updated Effluent Concentrations (April 2018 through April 2019)

Initial Dilution Case	Length (ft)	Width (ft)	Distance from Shoreline (ft)	Distance from Reef (ft)
TN at Updated of RPC (386 mg/l)				
4.0 mgd – Ambient Current=2.0 cm/s	656	286	1,058	433
3.0 mgd - 0 cm/sec - 4.95 ppt	715	394	1.004	379
3.0 mgd - 2 cm/sec - 4.95 ppt	612	248	1.077	452
3.0 mgd - 0 cm/sec - 10 ppt	817	461	970	345
3.0 mgd - 2 cm/sec - 10 ppt	616	278	1,061	436
TP at Updated RPC (37 mg/l)				
4.0 mgd – Ambient Current=2.0 cm/s	592	222	1,089	464
3.0 mgd - 0 cm/sec - 4.95 ppt	557	263	1,069	444
3.0 mgd - 2 cm/sec - 4.95 ppt	535	183	1,109	484
3.0 mgd - 0 cm/sec - 10 ppt	604	299	1,051	426
3.0 mgd - 2 cm/sec - 10 ppt	570	199	1,110	476

At an effluent flow of 3.0 mgd the TN and TP ASWQS criteria are predicted to be met at over 400 feet from the reef based on the more recent effluent data from April 2018 through April 2019 (Table 7).

Attachment 1

Model Runs

Attachment	Run	Port Size (inches)	Ambient Density Condition	Effluent Flow (mgd)	Ambient Current (cm/sec)
Base Case from 2017 MZA – Effluent Flow = 4.0 mgd					
1.A	U23A40	2	CID	4.0	2.0
	U23B40	5	CID		
	U11A40	2	MID		
	U11B40	5	MID		
Reduced Effluent Flow = 3.0 mgd					
1.B	U23A030	2	CID	3.0	0.0
	U23B030	5	CID		
	U11A030	2	MID		
	U11B030	5	MID		
	U23A230	2	CID		2.0
	U23B230	5	CID		
	U11A230	2	MID		
	U11B230	5	MID		
Reduced Effluent Flow = 3.0 mgd and Increased Effluent Salinity					
1.C	U23A030S	2	CID	3.0	0.0
	U23B030S	5	CID		
	U11A030X	2	MID		
	U11B030S	5	MID		
	U23A230S	2	CID		2.0
	U23B230S	5	CID		
	U11A230S	2	MID		
	U11B230S	5	MID		
CID = critical initial dilution as defined in the 2017 MZA MID = median initial dilution as defined in the 2017 MZA					

Attachment 1.A

Base Case from 2017 MZA – Effluent Flow = 4.0 mgd

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)

UNIVERSAL DATA FILE: **U23A-40**.in

CASE I.D. JCO 2012 MZA-4.0 mgd total-one 2in port at 0.10 mgd Station 16 - March 23, 2014

SINGLE PORT DISCHARGE CASE

DISCHARGE= 0.0044CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.0508
** NUMBER OF PORTS= 1 ** SPACING=1000.00-M ** DEPTH= 53.68-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.86	35.83	1.02242	0.020
5.00	29.77	35.84	1.02246	0.020
10.00	29.65	35.86	1.02251	0.020
15.00	29.56	35.86	1.02254	0.020
20.00	29.28	35.87	1.02265	0.020
25.00	29.22	35.88	1.02267	0.020
30.00	29.16	35.91	1.02272	0.020
35.00	29.07	35.94	1.02277	0.020
40.00	28.99	35.98	1.02283	0.020
45.00	28.82	36.01	1.02291	0.020
50.00	28.51	36.06	1.02305	0.020
55.00	27.80	36.19	1.02338	0.020

FROUDE NO= 19.97, PORT SPACING/PORT DIA= 19685.04
STARTING LENGTH= 0.308

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	0.00	0.05	1.000	1.000	1.000	0.00	1.00
0.00	0.31	0.00	90.00	1.19	0.14	1.000	0.999	1.000	0.14	1.96
0.00	0.71	0.02	90.00	5.39	0.42	0.323	0.319	0.322	0.52	6.30
0.00	1.11	0.09	90.00	12.87	0.69	0.193	0.180	0.192	1.26	10.84
0.00	1.50	0.21	90.00	22.13	0.95	0.133	0.103	0.133	2.32	15.94
0.00	1.86	0.39	90.00	31.42	1.21	0.097	0.042	0.097	3.67	22.01
0.00	2.19	0.63	90.00	39.44	1.50	0.072	-0.012	0.073	5.25	29.37
0.00	2.49	0.90	90.00	45.73	1.79	0.054	-0.060	0.055	7.02	38.20
0.00	2.76	1.21	90.00	50.40	2.11	0.040	-0.104	0.043	8.97	48.59
0.00	3.01	1.53	90.00	53.74	2.44	0.031	-0.144	0.034	11.07	60.57
0.00	3.25	1.86	90.00	56.05	2.80	0.023	-0.182	0.027	13.32	74.14
0.00	3.47	2.20	90.00	57.54	3.16	0.018	-0.217	0.022	15.73	89.28
0.00	3.90	2.89	90.00	58.65	3.95	0.009	-0.284	0.015	21.06	124.09
0.00	4.32	3.58	90.00	57.57	4.82	0.003	-0.351	0.010	27.17	164.49
0.00	4.78	4.26	90.00	54.54	5.74	0.001	-0.357	0.008	34.33	209.41

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	5.14	4.74	90.00	51.34	6.44	-0.001	-0.360	0.007	40.51	245.22
0.00	5.40	5.06	90.00	48.59	6.91	-0.002	-0.367	0.006	45.10	269.63
0.00	5.68	5.35	90.00	45.16	7.38	-0.002	-0.378	0.005	50.13	293.99
0.00	5.98	5.63	90.00	40.84	7.83	-0.003	-0.393	0.005	55.70	317.76
0.00	6.30	5.88	90.00	35.33	8.27	-0.004	-0.412	0.005	61.94	340.14
0.00	6.64	6.10	90.00	28.27	8.68	-0.004	-0.436	0.004	69.06	360.03
0.00	7.01	6.26	90.00	19.29	9.03	-0.005	-0.463	0.004	77.28	376.01
0.00	7.41	6.36	90.00	8.35	9.28	-0.006	-0.485	0.004	86.74	386.51
0.00	7.81	6.38	90.00	-3.67	9.36	-0.006	-0.487	0.004	96.98	391.02

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 49.20 METERS BELOW SURFACE, DILUTION= 225.14

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)

UNIVERSAL DATA FILE: **U23B-40**.in

CASE I.D. JCO 2012 MZA-4.0 mgd total-six 5in port at 3.90 mgd Station 16 - March 23, 2014
DISCHARGE= 0.1709CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.1270
** NUMBER OF PORTS= 6 ** SPACING= 30.52-M ** DEPTH= 53.68-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.86	35.83	1.02242	0.020
5.00	29.77	35.84	1.02246	0.020
10.00	29.65	35.86	1.02251	0.020
15.00	29.56	35.86	1.02254	0.020
20.00	29.28	35.87	1.02265	0.020
25.00	29.22	35.88	1.02267	0.020
30.00	29.16	35.91	1.02272	0.020
35.00	29.07	35.94	1.02277	0.020
40.00	28.99	35.98	1.02283	0.020
45.00	28.82	36.01	1.02291	0.020
50.00	28.51	36.06	1.02305	0.020
55.00	27.80	36.19	1.02338	0.020

FROUDE NO= 13.08, PORT SPACING/PORT DIA= 240.31
STARTING LENGTH= 0.749

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.72	0.21	90.00	17.47	0.35	0.978	0.958	0.978	0.34	1.98
0.00	1.67	0.57	90.00	25.62	1.09	0.299	0.245	0.298	1.24	6.69
0.00	2.54	1.10	90.00	37.73	1.80	0.164	0.053	0.165	2.98	12.24
0.00	3.27	1.80	90.00	48.39	2.50	0.102	-0.080	0.105	5.32	19.15
0.00	3.89	2.60	90.00	55.88	3.23	0.066	-0.191	0.071	8.10	27.68
0.00	4.42	3.47	90.00	60.71	3.99	0.044	-0.288	0.051	11.24	37.91
0.00	4.90	4.37	90.00	63.80	4.79	0.031	-0.298	0.038	14.70	49.82
0.00	5.33	5.29	90.00	65.82	5.63	0.023	-0.306	0.029	18.49	63.39
0.00	5.73	6.22	90.00	67.07	6.52	0.016	-0.320	0.023	22.58	78.60
0.00	6.12	7.16	90.00	67.70	7.45	0.011	-0.339	0.018	27.01	95.41
0.00	6.51	8.10	90.00	67.79	8.44	0.007	-0.362	0.015	31.80	113.78
0.00	7.29	9.97	90.00	66.60	10.61	0.003	-0.368	0.010	42.69	154.95

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	8.14	11.82	90.00	63.69	13.05	0.000	-0.372	0.008	55.75	201.46
0.00	8.61	12.72	90.00	61.19	14.40	-0.001	-0.382	0.006	63.35	226.35
0.00	9.12	13.60	90.00	57.46	15.84	-0.003	-0.398	0.006	71.95	251.91
0.00	9.71	14.43	90.00	51.80	17.37	-0.003	-0.402	0.005	81.90	277.44
0.00	10.39	15.18	90.00	42.98	18.91	-0.004	-0.416	0.004	93.84	301.67
0.00	11.21	15.78	90.00	28.29	20.37	-0.005	-0.450	0.004	108.96	321.96
0.00	12.17	16.07	90.00	4.60	21.35	-0.006	-0.489	0.004	128.98	333.37

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 41.95 METERS BELOW SURFACE, DILUTION= 199.04

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)

UNIVERSAL DATA FILE: **U11A-40**.in

CASE I.D. JCO 2012 MZA-4.0 mgd total-one 2in port at 0.10 mgd Station 16 - May 3, 2008

SINGLE PORT DISCHARGE CASE

DISCHARGE= 0.0044CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.0508
** NUMBER OF PORTS= 1 ** SPACING=1000.00-M ** DEPTH= 53.64-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.09	35.29	1.02228	0.020
5.00	29.06	35.29	1.02229	0.020
10.00	29.05	35.34	1.02233	0.020
15.00	29.02	35.40	1.02238	0.020
20.00	29.03	35.47	1.02243	0.020
25.00	29.02	35.48	1.02244	0.020
30.00	29.02	35.48	1.02244	0.020
35.00	29.00	35.50	1.02246	0.020
40.00	28.99	35.55	1.02250	0.020
45.00	28.98	35.58	1.02253	0.020
50.00	28.98	35.58	1.02253	0.020
55.00	28.98	35.58	1.02253	0.020

FROUDE NO= 20.30, PORT SPACING/PORT DIA= 19685.04 STARTING LENGTH= 0.308

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	0.00	0.05	1.000	1.000	1.000	0.00	1.00
0.00	0.31	0.00	90.00	1.15	0.14	1.000	1.000	1.000	0.14	1.96
0.00	0.71	0.02	90.00	5.22	0.42	0.323	0.322	0.322	0.52	6.30
0.00	1.12	0.08	90.00	12.48	0.69	0.194	0.193	0.193	1.26	10.82
0.00	1.50	0.20	90.00	21.52	0.95	0.135	0.134	0.134	2.32	15.89
0.00	1.87	0.38	90.00	30.74	1.21	0.099	0.098	0.098	3.67	21.91
0.00	2.20	0.61	90.00	38.88	1.49	0.074	0.074	0.074	5.26	29.19
0.00	2.50	0.89	90.00	45.42	1.79	0.057	0.057	0.057	7.04	37.95
0.00	2.77	1.19	90.00	50.44	2.10	0.045	0.045	0.045	8.98	48.30
0.00	3.02	1.51	90.00	54.20	2.43	0.036	0.036	0.036	11.06	60.29
0.00	3.25	1.85	90.00	57.01	2.77	0.029	0.029	0.029	13.27	73.94
0.00	3.46	2.19	90.00	59.10	3.12	0.024	0.024	0.024	15.60	89.27
0.00	3.86	2.90	90.00	61.85	3.85	0.017	0.017	0.017	20.60	124.97
0.00	4.24	3.62	90.00	63.36	4.62	0.013	0.013	0.013	26.01	167.40
0.00	4.60	4.35	90.00	64.15	5.41	0.010	0.010	0.010	31.80	216.52
0.00	4.95	5.08	90.00	64.49	6.22	0.008	0.008	0.008	37.95	272.30
0.00	5.30	5.82	90.00	64.55	7.04	0.007	0.006	0.006	44.43	334.67
0.00	5.65	6.55	90.00	64.42	7.87	0.005	0.005	0.005	51.22	403.54
0.00	6.00	7.28	90.00	64.17	8.71	0.005	0.005	0.005	58.30	478.85
0.00	6.36	8.01	90.00	63.84	9.55	0.004	0.004	0.004	65.67	560.50
0.00	6.72	8.74	90.00	63.44	10.40	0.003	0.002	0.003	73.29	648.39
0.00	7.08	9.47	90.00	62.85	11.27	0.003	-0.005	0.003	81.19	742.37
0.00	7.85	10.90	90.00	60.89	13.08	0.001	-0.016	0.002	97.99	947.25
0.00	8.67	12.30	90.00	57.86	14.96	0.001	-0.027	0.001	116.48	1171.44
PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT										
0.00	9.41	13.40	90.00	54.39	16.54	0.000	-0.035	0.000	133.18	1363.74
0.00	9.65	13.73	90.00	53.07	17.03	0.000	-0.037	0.000	138.70	1423.92
0.00	9.90	14.05	90.00	51.53	17.53	-0.001	-0.039	0.000	144.44	1484.22
0.00	10.15	14.36	90.00	49.73	18.03	-0.001	-0.042	-0.001	150.44	1544.27
0.00	10.42	14.67	90.00	47.60	18.54	-0.001	-0.045	-0.001	156.75	1603.67
0.00	10.70	14.96	90.00	45.09	19.05	-0.001	-0.047	-0.001	163.43	1661.87
0.00	11.00	15.24	90.00	42.11	19.56	-0.002	-0.050	-0.001	170.57	1718.21
0.00	11.31	15.51	90.00	38.57	20.08	-0.002	-0.054	-0.002	178.27	1771.84
0.00	11.63	15.75	90.00	34.33	20.59	-0.002	-0.057	-0.002	186.69	1821.69
0.00	11.98	15.96	90.00	29.24	21.09	-0.002	-0.061	-0.002	196.05	1866.37
0.00	12.34	16.14	90.00	23.11	21.58	-0.003	-0.066	-0.002	206.64	1904.20
0.00	12.72	16.28	90.00	15.81	22.03	-0.003	-0.070	-0.003	218.80	1933.17
0.00	13.12	16.36	90.00	7.38	22.36	-0.003	-0.074	-0.003	232.68	1951.27
0.00	13.53	16.38	90.00	-1.73	22.46	-0.003	-0.075	-0.003	247.74	1957.66

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 40.39 METERS BELOW SURFACE, DILUTION=1337.57

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)

UNIVERSAL DATA FILE: **U11B-40**.in

CASE I.D. JCO 2012 MZA-4.0 mgd total-six 5in port at 3.90 mgd Station 16 - May 3, 2008
DISCHARGE= 0.1709CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.1270
** NUMBER OF PORTS= 6 ** SPACING= 30.48-M ** DEPTH= 53.64-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.09	35.29	1.02228	0.020
5.00	29.06	35.29	1.02229	0.020
10.00	29.05	35.34	1.02233	0.020
15.00	29.02	35.40	1.02238	0.020
20.00	29.03	35.47	1.02243	0.020
25.00	29.02	35.48	1.02244	0.020
30.00	29.02	35.48	1.02244	0.020
35.00	29.00	35.50	1.02246	0.020
40.00	28.99	35.55	1.02250	0.020
45.00	28.98	35.58	1.02253	0.020
50.00	28.98	35.58	1.02253	0.020
55.00	28.98	35.58	1.02253	0.020

FROUDE NO= 13.30, PORT SPACING/PORT DIA= 240.00
STARTING LENGTH= 0.751
ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.72	0.21	90.00	17.39	0.35	0.987	0.987	0.987	0.34	1.98
0.00	1.67	0.57	90.00	25.38	1.09	0.303	0.301	0.301	1.24	6.69
0.00	2.54	1.10	90.00	37.43	1.80	0.168	0.167	0.167	2.98	12.22
0.00	3.28	1.79	90.00	48.30	2.50	0.108	0.107	0.107	5.33	19.10
0.00	3.90	2.59	90.00	56.20	3.21	0.074	0.074	0.074	8.10	27.64
0.00	4.42	3.47	90.00	61.57	3.95	0.054	0.054	0.054	11.18	37.94
0.00	4.87	4.37	90.00	65.20	4.71	0.041	0.041	0.041	14.53	50.00
0.00	5.28	5.31	90.00	67.71	5.49	0.032	0.032	0.032	18.10	63.82
0.00	5.65	6.25	90.00	69.47	6.30	0.026	0.025	0.025	21.88	79.40
0.00	5.99	7.21	90.00	70.72	7.12	0.021	0.021	0.021	25.85	96.73
0.00	6.32	8.17	90.00	71.61	7.96	0.018	0.017	0.017	30.00	115.78
0.00	6.94	10.10	90.00	72.64	9.70	0.012	0.000	0.012	38.84	159.05
0.00	7.54	12.05	90.00	72.93	11.53	0.009	-0.015	0.009	48.39	209.06
0.00	8.14	13.99	90.00	72.71	13.47	0.006	-0.027	0.006	58.70	265.68
0.00	8.76	15.92	90.00	71.95	15.55	0.003	-0.038	0.004	69.90	328.70
0.00	9.41	17.85	90.00	70.54	17.85	0.002	-0.047	0.002	82.19	397.81
0.00	10.12	19.75	90.00	68.34	20.38	0.000	-0.066	0.001	95.93	472.53
PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT										
0.00	10.81	21.39	90.00	65.78	22.74	0.000	-0.088	0.000	109.46	541.95
0.00	11.24	22.31	90.00	63.95	24.15	-0.001	-0.100	0.000	117.93	583.03
0.00	11.71	23.21	90.00	61.74	25.60	-0.001	-0.112	0.000	127.06	624.88
0.00	12.21	24.10	90.00	59.07	27.09	-0.001	-0.113	0.000	136.95	667.17
0.00	12.75	24.96	90.00	56.18	28.55	-0.001	-0.109	0.000	147.70	709.56
0.00	13.34	25.78	90.00	53.07	29.95	-0.001	-0.106	0.000	159.39	751.71
PLUMES MERGING										
0.00	13.97	26.58	90.00	49.31	31.29	-0.001	-0.103	0.000	172.08	792.45
0.00	14.66	27.32	90.00	45.21	32.60	-0.001	-0.101	0.000	185.90	829.35
0.00	15.40	28.02	90.00	41.05	33.90	-0.001	-0.099	0.000	200.97	862.95
0.00	16.19	28.66	90.00	36.78	35.18	-0.001	-0.099	0.000	217.43	893.34
0.00	17.03	29.23	90.00	32.05	36.47	-0.001	-0.105	0.000	235.46	920.37
0.00	17.92	29.73	90.00	26.50	37.79	-0.001	-0.110	0.000	255.41	943.58
0.00	18.85	30.13	90.00	19.99	39.08	-0.001	-0.115	-0.001	277.66	962.31
0.00	19.82	30.42	90.00	12.46	40.18	-0.001	-0.118	-0.001	302.41	975.85
0.00	20.83	30.56	90.00	4.11	40.88	-0.001	-0.120	-0.001	329.30	983.58

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 32.87 METERS BELOW SURFACE, DILUTION= 514.94

Attachment 1.B

Reduced Effluent Flow = 3.0 mgd

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u23a030**.in
CASE I.D. JCO-3.0 mgd total-one 2in port at 0.075 mgd Station 16 - March 23, 2014 AM -zero

SINGLE PORT DISCHARGE CASE
DISCHARGE= 0.0033CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.0508
** NUMBER OF PORTS= 1 ** SPACING=1000.00-M ** DEPTH= 53.68-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.86	35.83	1.02242	0.000
5.00	29.77	35.84	1.02246	0.000
10.00	29.65	35.86	1.02251	0.000
15.00	29.56	35.86	1.02254	0.000
20.00	29.28	35.87	1.02265	0.000
25.00	29.22	35.88	1.02267	0.000
30.00	29.16	35.91	1.02272	0.000
35.00	29.07	35.94	1.02277	0.000
40.00	28.99	35.98	1.02283	0.000
45.00	28.82	36.01	1.02291	0.000
50.00	28.51	36.06	1.02305	0.000
55.00	27.80	36.19	1.02338	0.000

FROUDE NO= 14.98, PORT SPACING/PORT DIA= 19685.04
STARTING LENGTH= 0.294

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	0.00	0.05	1.000	1.000	1.000	0.00	1.00
0.00	0.29	0.00	90.00	2.05	0.14	0.999	0.999	0.999	0.18	1.93
0.00	0.70	0.04	90.00	10.40	0.45	0.306	0.299	0.305	0.70	6.32
0.00	1.08	0.17	90.00	25.47	0.74	0.179	0.156	0.178	1.75	10.81
0.00	1.42	0.39	90.00	41.02	0.98	0.123	0.072	0.123	3.16	15.61
0.00	1.70	0.69	90.00	52.65	1.18	0.090	0.005	0.091	4.76	20.93
0.00	1.92	1.03	90.00	60.52	1.36	0.069	-0.053	0.071	6.45	26.84
0.00	2.10	1.39	90.00	65.86	1.55	0.054	-0.104	0.056	8.20	33.36
0.00	2.26	1.77	90.00	69.63	1.73	0.042	-0.151	0.046	10.01	40.47
0.00	2.39	2.15	90.00	72.39	1.92	0.034	-0.193	0.038	11.89	48.12
0.00	2.50	2.54	90.00	74.45	2.12	0.027	-0.233	0.032	13.83	56.28
0.00	2.61	2.93	90.00	76.04	2.32	0.021	-0.271	0.027	15.85	64.91
0.00	2.79	3.73	90.00	78.22	2.74	0.013	-0.340	0.020	20.14	83.41
0.00	2.94	4.52	90.00	79.66	3.19	0.009	-0.332	0.016	24.82	103.29
0.00	3.08	5.32	90.00	80.66	3.65	0.006	-0.336	0.013	29.92	124.34
0.00	3.21	6.13	90.00	81.33	4.14	0.003	-0.347	0.010	35.48	146.31
0.00	3.33	6.93	90.00	81.68	4.68	0.001	-0.362	0.008	41.61	168.92

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	3.43	7.64	90.00	81.70	5.23	-0.001	-0.379	0.007	47.56	188.91
0.00	3.49	8.04	90.00	81.56	5.59	-0.002	-0.389	0.006	51.30	200.29
0.00	3.55	8.44	90.00	81.25	6.01	-0.002	-0.401	0.006	55.35	211.52
0.00	3.61	8.84	90.00	80.71	6.51	-0.003	-0.407	0.005	59.82	222.49
0.00	3.68	9.24	90.00	79.85	7.12	-0.003	-0.407	0.005	64.88	233.08
0.00	3.76	9.64	90.00	78.38	7.94	-0.004	-0.408	0.005	70.76	243.10
0.00	3.85	10.04	90.00	75.38	9.21	-0.004	-0.410	0.004	78.05	252.31
0.00	3.98	10.42	90.00	64.99	12.26	-0.004	-0.415	0.004	88.64	260.13

JCO-2.7 mgd total-one 2in port at 0.075 mgd Station 16 - March 23, 2014 AM -zero

X Y Z TH1 TH2 WIDTH DRHO DTCL DSCL TIME DILUTION

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 46.34 METERS BELOW SURFACE, DILUTION= 180.62

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u23b030**.in
CASE I.D. JCO-3.0 mgd total-six 5in port at 2.925 mgd Station 16 - March 23, 2014 AM zero
DISCHARGE= 0.1282CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.1270
** NUMBER OF PORTS= 6 ** SPACING= 30.52-M ** DEPTH= 53.68-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.86	35.83	1.02242	0.000
5.00	29.77	35.84	1.02246	0.000
10.00	29.65	35.86	1.02251	0.000
15.00	29.56	35.86	1.02254	0.000
20.00	29.28	35.87	1.02265	0.000
25.00	29.22	35.88	1.02267	0.000
30.00	29.16	35.91	1.02272	0.000
35.00	29.07	35.94	1.02277	0.000
40.00	28.99	35.98	1.02283	0.000
45.00	28.82	36.01	1.02291	0.000
50.00	28.51	36.06	1.02305	0.000
55.00	27.80	36.19	1.02338	0.000

FROUDE NO= 9.81, PORT SPACING/PORT DIA= 240.31
STARTING LENGTH= 0.723

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.70	0.21	90.00	19.48	0.35	0.967	0.947	0.967	0.43	1.97
0.00	1.61	0.66	90.00	34.48	1.09	0.293	0.230	0.293	1.62	6.51
0.00	2.34	1.36	90.00	51.49	1.68	0.162	0.026	0.164	3.70	11.56
0.00	2.89	2.21	90.00	62.53	2.18	0.104	-0.116	0.108	6.19	17.41
0.00	3.30	3.14	90.00	69.10	2.66	0.071	-0.234	0.077	8.90	24.11
0.00	3.63	4.10	90.00	73.21	3.14	0.051	-0.299	0.057	11.81	31.63
0.00	3.89	5.08	90.00	76.01	3.62	0.038	-0.311	0.045	14.88	39.89
0.00	4.12	6.07	90.00	78.02	4.12	0.029	-0.328	0.036	18.13	48.84
0.00	4.32	7.07	90.00	79.49	4.62	0.022	-0.349	0.030	21.54	58.43
0.00	4.49	8.07	90.00	80.59	5.13	0.017	-0.374	0.025	25.14	68.58
0.00	4.65	9.07	90.00	81.43	5.67	0.013	-0.386	0.021	28.93	79.24
0.00	4.93	11.08	90.00	82.61	6.77	0.008	-0.381	0.016	37.13	101.84
0.00	5.18	13.10	90.00	83.33	7.95	0.004	-0.391	0.012	46.25	125.82
0.00	5.41	15.12	90.00	83.70	9.26	0.001	-0.379	0.009	56.51	150.66

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	5.60	16.89	90.00	83.76	10.56	0.000	-0.365	0.007	66.68	172.68
0.00	5.72	17.90	90.00	83.66	11.42	-0.001	-0.361	0.006	73.15	185.19
0.00	5.83	18.91	90.00	83.41	12.41	-0.002	-0.360	0.005	80.26	197.51
0.00	5.95	19.92	90.00	82.93	13.62	-0.003	-0.363	0.005	88.23	209.47
0.00	6.08	20.92	90.00	82.02	15.25	-0.004	-0.368	0.004	97.47	220.86
0.00	6.24	21.93	90.00	79.97	17.86	-0.004	-0.374	0.004	108.93	231.29
0.00	6.47	22.91	90.00	70.91	25.31	-0.005	-0.384	0.003	126.39	239.93

PLUMES MERGING

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 37.25 METERS BELOW SURFACE, DILUTION= 167.01

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)

UNIVERSAL DATA FILE: **u11a030**.in

CASE I.D. JCO 2012 MZA-3.0 mgd total-one 2in port at 0.075 mgd Station 16 - May 3, 2008 -
SINGLE PORT DISCHARGE CASE

DISCHARGE= 0.0033CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.0508
** NUMBER OF PORTS= 1 ** SPACING=1000.00-M ** DEPTH= 53.64-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.09	35.29	1.02228	0.000
5.00	29.06	35.29	1.02229	0.000
10.00	29.05	35.34	1.02233	0.000
15.00	29.02	35.40	1.02238	0.000
20.00	29.03	35.47	1.02243	0.000
25.00	29.02	35.48	1.02244	0.000
30.00	29.02	35.48	1.02244	0.000
35.00	29.00	35.50	1.02246	0.000
40.00	28.99	35.55	1.02250	0.000
45.00	28.98	35.58	1.02253	0.000
50.00	28.98	35.58	1.02253	0.000
55.00	28.98	35.58	1.02253	0.000

FROUDE NO= 15.22, PORT SPACING/PORT DIA= 19685.04

STARTING LENGTH= 0.294

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	0.00	0.05	1.000	1.000	1.000	0.00	1.00
0.00	0.29	0.00	90.00	1.98	0.14	0.999	0.999	0.999	0.18	1.93
0.00	0.70	0.04	90.00	10.07	0.45	0.306	0.305	0.305	0.70	6.32
0.00	1.09	0.16	90.00	24.80	0.74	0.179	0.178	0.178	1.75	10.80
0.00	1.43	0.38	90.00	40.30	0.98	0.124	0.124	0.124	3.17	15.58
0.00	1.71	0.68	90.00	52.14	1.18	0.093	0.092	0.092	4.79	20.87
0.00	1.93	1.01	90.00	60.25	1.36	0.073	0.072	0.072	6.49	26.75
0.00	2.11	1.38	90.00	65.84	1.54	0.058	0.058	0.058	8.24	33.26
0.00	2.27	1.75	90.00	69.82	1.72	0.048	0.048	0.048	10.04	40.38
0.00	2.40	2.14	90.00	72.78	1.90	0.040	0.040	0.040	11.89	48.09
0.00	2.51	2.53	90.00	75.05	2.08	0.034	0.034	0.034	13.78	56.37
0.00	2.61	2.92	90.00	76.83	2.26	0.030	0.030	0.030	15.71	65.21
0.00	2.77	3.72	90.00	79.45	2.63	0.023	0.023	0.023	19.70	84.48
0.00	2.91	4.52	90.00	81.27	3.00	0.018	0.018	0.018	23.85	105.78
0.00	3.02	5.32	90.00	82.61	3.37	0.015	0.015	0.015	28.16	129.01
0.00	3.12	6.13	90.00	83.62	3.75	0.013	0.012	0.012	32.62	154.10
0.00	3.20	6.94	90.00	84.41	4.12	0.011	0.011	0.011	37.22	180.97
0.00	3.28	7.75	90.00	85.04	4.50	0.009	0.009	0.009	41.96	209.57
0.00	3.34	8.56	90.00	85.56	4.88	0.008	0.008	0.008	46.83	239.83
0.00	3.40	9.37	90.00	85.98	5.26	0.007	0.001	0.007	51.82	271.71
0.00	3.46	10.18	90.00	86.32	5.65	0.006	-0.005	0.006	56.95	305.12
0.00	3.51	10.99	90.00	86.60	6.05	0.005	-0.011	0.005	62.23	339.93
0.00	3.60	12.62	90.00	87.03	6.89	0.003	-0.022	0.003	73.30	413.40
0.00	3.68	14.24	90.00	87.31	7.79	0.002	-0.031	0.002	85.14	491.23
0.00	3.75	15.86	90.00	87.47	8.81	0.001	-0.039	0.001	98.00	572.25
PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT										
0.00	3.81	17.18	90.00	87.49	9.80	0.000	-0.045	0.000	109.52	639.15
0.00	3.83	17.59	90.00	87.47	10.14	-0.001	-0.047	0.000	113.33	659.73
0.00	3.85	17.99	90.00	87.45	10.51	-0.001	-0.049	0.000	117.29	680.22
0.00	3.86	18.40	90.00	87.41	10.92	-0.001	-0.051	-0.001	121.42	700.57
0.00	3.88	18.81	90.00	87.35	11.36	-0.001	-0.054	-0.001	125.76	720.73
0.00	3.90	19.21	90.00	87.27	11.84	-0.001	-0.060	-0.001	130.34	740.63
0.00	3.92	19.62	90.00	87.17	12.36	-0.001	-0.065	-0.001	135.19	760.22
0.00	3.94	20.02	90.00	87.05	12.95	-0.002	-0.070	-0.001	140.36	779.44
0.00	3.96	20.43	90.00	86.89	13.62	-0.002	-0.075	-0.001	145.91	798.20
0.00	3.99	20.84	90.00	86.67	14.40	-0.002	-0.080	-0.001	151.95	816.42
0.00	4.01	21.24	90.00	86.37	15.35	-0.002	-0.085	-0.001	158.60	833.97
0.00	4.04	21.65	90.00	85.92	16.59	-0.002	-0.090	-0.001	166.10	850.66
0.00	4.07	22.05	90.00	85.16	18.38	-0.002	-0.095	-0.001	174.90	866.22
0.00	4.11	22.46	90.00	83.52	21.56	-0.002	-0.100	-0.002	186.06	880.18
0.00	4.18	22.86	90.00	73.68	34.23	-0.002	-0.106	-0.002	204.81	891.25

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 36.80 METERS BELOW SURFACE, DILUTION= 621.75

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u11b030**.in
CASE I.D. JCO 2012 MZA-3.0 mgd total-six 5in port at 2.925 mgd Station 16 - May 3, 2008n -
DISCHARGE= 0.1282CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.1270
** NUMBER OF PORTS=   6 ** SPACING= 30.48-M   ** DEPTH= 53.64-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.09	35.29	1.02228	0.000
5.00	29.06	35.29	1.02229	0.000
10.00	29.05	35.34	1.02233	0.000
15.00	29.02	35.40	1.02238	0.000
20.00	29.03	35.47	1.02243	0.000
25.00	29.02	35.48	1.02244	0.000
30.00	29.02	35.48	1.02244	0.000
35.00	29.00	35.50	1.02246	0.000
40.00	28.99	35.55	1.02250	0.000
45.00	28.98	35.58	1.02253	0.000
50.00	28.98	35.58	1.02253	0.000
55.00	28.98	35.58	1.02253	0.000

FROUDE NO= 9.98, PORT SPACING/PORT DIA=   240.00
STARTING LENGTH=   0.726

ALL LENGTHS ARE IN METERS-TIME IN SEC.   FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.70	0.21	90.00	19.35	0.35	0.977	0.977	0.977	0.43	1.97
0.00	1.61	0.66	90.00	34.13	1.09	0.297	0.296	0.296	1.62	6.51
0.00	2.35	1.35	90.00	51.20	1.68	0.168	0.167	0.167	3.71	11.54
0.00	2.90	2.20	90.00	62.52	2.17	0.112	0.111	0.111	6.20	17.37
0.00	3.31	3.13	90.00	69.38	2.64	0.080	0.080	0.080	8.90	24.10
0.00	3.63	4.09	90.00	73.77	3.10	0.061	0.061	0.061	11.74	31.70
0.00	3.88	5.08	90.00	76.75	3.55	0.048	0.048	0.048	14.70	40.14
0.00	4.10	6.07	90.00	78.88	4.01	0.039	0.039	0.039	17.78	49.38
0.00	4.28	7.07	90.00	80.48	4.47	0.033	0.032	0.032	20.96	59.39
0.00	4.43	8.07	90.00	81.71	4.93	0.028	0.027	0.027	24.24	70.13
0.00	4.57	9.08	90.00	82.69	5.39	0.024	0.020	0.023	27.61	81.57
0.00	4.80	11.10	90.00	84.11	6.33	0.017	0.001	0.017	34.65	106.45
0.00	5.00	13.12	90.00	85.07	7.28	0.013	-0.015	0.013	42.07	133.78
0.00	5.16	15.15	90.00	85.74	8.27	0.010	-0.027	0.010	49.89	163.32
0.00	5.30	17.17	90.00	86.22	9.30	0.007	-0.038	0.007	58.16	194.77
0.00	5.43	19.20	90.00	86.55	10.39	0.005	-0.054	0.005	66.97	227.81
0.00	5.54	21.23	90.00	86.80	11.51	0.003	-0.079	0.004	76.37	262.14
0.00	5.65	23.26	90.00	86.99	12.68	0.002	-0.101	0.003	86.41	297.54
0.00	5.76	25.29	90.00	87.14	13.88	0.002	-0.096	0.003	97.15	333.77
0.00	5.86	27.32	90.00	87.28	15.04	0.002	-0.086	0.002	108.56	370.79
0.00	5.95	29.35	90.00	87.41	16.17	0.001	-0.083	0.002	120.57	408.63
0.00	6.13	33.41	90.00	87.58	18.61	0.001	-0.101	0.001	146.47	486.32

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	6.20	35.18	90.00	87.57	19.98	-0.001	-0.082	0.000	158.85	520.67
0.00	6.25	36.20	90.00	87.49	21.05	-0.002	-0.071	-0.001	166.45	540.02
0.00	6.29	37.21	90.00	87.33	22.44	-0.002	-0.060	-0.002	174.69	558.89
0.00	6.34	38.23	90.00	87.05	24.38	-0.003	-0.050	-0.003	183.91	576.95
0.00	6.40	39.24	90.00	86.45	27.48	-0.004	-0.061	-0.004	194.82	593.72

PLUMES MERGING

0.00	6.48	40.26	90.00	84.56	34.71	-0.005	-0.085	-0.004	209.66	607.37

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 19.54 METERS BELOW SURFACE,   DILUTION= 499.69

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u23a230**.in
CASE I.D. JCO-3.0 mgd total-one 2in port at 0.075 mgd Station 16 - March 23, 2014 AM -2 CM

SINGLE PORT DISCHARGE CASE
DISCHARGE= 0.0033CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.0508
** NUMBER OF PORTS= 1 ** SPACING=1000.00-M ** DEPTH= 53.68-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.86	35.83	1.02242	0.020
5.00	29.77	35.84	1.02246	0.020
10.00	29.65	35.86	1.02251	0.020
15.00	29.56	35.86	1.02254	0.020
20.00	29.28	35.87	1.02265	0.020
25.00	29.22	35.88	1.02267	0.020
30.00	29.16	35.91	1.02272	0.020
35.00	29.07	35.94	1.02277	0.020
40.00	28.99	35.98	1.02283	0.020
45.00	28.82	36.01	1.02291	0.020
50.00	28.51	36.06	1.02305	0.020
55.00	27.80	36.19	1.02338	0.020

FROUDE NO= 14.98, PORT SPACING/PORT DIA= 19685.04
STARTING LENGTH= 0.312

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	0.00	0.05	1.000	1.000	1.000	0.00	1.00
0.00	0.31	0.01	90.00	2.14	0.14	0.999	0.998	0.999	0.19	1.97
0.00	0.72	0.04	90.00	9.27	0.41	0.325	0.318	0.323	0.68	6.36
0.00	1.11	0.15	90.00	20.94	0.68	0.189	0.168	0.188	1.64	11.26
0.00	1.47	0.33	90.00	33.23	0.95	0.123	0.078	0.123	2.98	17.36
0.00	1.79	0.58	90.00	43.19	1.23	0.084	0.009	0.085	4.63	25.24
0.00	2.06	0.88	90.00	50.20	1.54	0.059	-0.047	0.060	6.51	35.16
0.00	2.31	1.20	90.00	54.84	1.87	0.042	-0.094	0.044	8.60	47.24
0.00	2.54	1.54	90.00	57.81	2.23	0.030	-0.135	0.033	10.87	61.48
0.00	2.75	1.89	90.00	59.60	2.60	0.022	-0.172	0.026	13.33	77.88
0.00	2.95	2.24	90.00	60.53	2.99	0.016	-0.207	0.020	15.97	96.40
0.00	3.15	2.60	90.00	60.78	3.40	0.011	-0.240	0.016	18.82	116.97
0.00	3.55	3.30	90.00	59.54	4.27	0.005	-0.307	0.011	25.21	163.91
0.00	3.98	3.99	90.00	55.86	5.21	0.001	-0.341	0.008	32.76	217.32

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	4.34	4.48	90.00	51.93	5.93	-0.001	-0.342	0.006	39.41	260.27
0.00	4.60	4.80	90.00	48.64	6.40	-0.001	-0.349	0.006	44.41	289.54
0.00	4.88	5.09	90.00	44.58	6.86	-0.002	-0.360	0.005	49.96	318.64
0.00	5.18	5.36	90.00	39.48	7.31	-0.003	-0.376	0.005	56.19	346.70
0.00	5.51	5.61	90.00	32.98	7.74	-0.004	-0.398	0.004	63.30	372.52
0.00	5.86	5.80	90.00	24.63	8.12	-0.004	-0.425	0.004	71.59	394.44
0.00	6.24	5.94	90.00	14.06	8.44	-0.005	-0.454	0.004	81.41	410.36
0.00	6.65	5.99	90.00	1.62	8.60	-0.005	-0.469	0.004	92.70	418.26

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 49.44 METERS BELOW SURFACE, DILUTION= 238.55

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u23b230**.in
CASE I.D. JCO-3.0 mgd total-six 5in port at 2.925 mgd Station 16 - March 23, 2014 AM 2 cm/
DISCHARGE= 0.1282CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.1270
** NUMBER OF PORTS= 6 ** SPACING= 30.52-M ** DEPTH= 53.68-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.86	35.83	1.02242	0.020
5.00	29.77	35.84	1.02246	0.020
10.00	29.65	35.86	1.02251	0.020
15.00	29.56	35.86	1.02254	0.020
20.00	29.28	35.87	1.02265	0.020
25.00	29.22	35.88	1.02267	0.020
30.00	29.16	35.91	1.02272	0.020
35.00	29.07	35.94	1.02277	0.020
40.00	28.99	35.98	1.02283	0.020
45.00	28.82	36.01	1.02291	0.020
50.00	28.51	36.06	1.02305	0.020
55.00	27.80	36.19	1.02338	0.020

FROUDE NO= 9.81, PORT SPACING/PORT DIA= 240.31
STARTING LENGTH= 0.749

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.72	0.22	90.00	19.40	0.35	0.965	0.945	0.966	0.45	2.02
0.00	1.64	0.65	90.00	32.35	1.08	0.288	0.225	0.288	1.63	6.99
0.00	2.42	1.31	90.00	47.38	1.79	0.148	0.018	0.150	3.77	13.45
0.00	3.03	2.11	90.00	57.43	2.51	0.086	-0.118	0.090	6.53	22.06
0.00	3.53	3.00	90.00	63.21	3.28	0.054	-0.225	0.059	9.74	32.97
0.00	3.96	3.92	90.00	66.42	4.10	0.035	-0.278	0.041	13.33	46.16
0.00	4.35	4.86	90.00	68.27	4.96	0.024	-0.281	0.030	17.31	61.59
0.00	4.71	5.80	90.00	69.26	5.86	0.017	-0.292	0.023	21.67	79.25
0.00	5.07	6.76	90.00	69.60	6.82	0.011	-0.310	0.018	26.42	99.08
0.00	5.43	7.71	90.00	69.38	7.85	0.007	-0.331	0.014	31.60	121.02
0.00	5.79	8.66	90.00	68.59	8.95	0.004	-0.356	0.011	37.28	145.01
0.00	6.58	10.53	90.00	65.46	11.38	0.001	-0.352	0.008	50.53	198.59

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	7.14	11.67	90.00	62.13	13.06	-0.001	-0.360	0.006	60.43	235.33
0.00	7.64	12.55	90.00	58.03	14.51	-0.002	-0.374	0.005	69.59	265.88
0.00	8.22	13.38	90.00	51.58	16.04	-0.003	-0.398	0.005	80.35	296.45
0.00	8.92	14.12	90.00	40.56	17.60	-0.004	-0.427	0.004	93.67	324.93
0.00	9.78	14.65	90.00	21.21	19.01	-0.005	-0.475	0.004	111.59	346.63
0.00	10.78	14.77	90.00	-8.30	19.54	-0.006	-0.495	0.004	135.67	354.71

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 42.76 METERS BELOW SURFACE, DILUTION= 210.83

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u11a230**.in
CASE I.D. JCO 2012 MZA-3.0 mgd total-one 2in port at 0.075 mgd Station 16 - May 3, 2008 -

SINGLE PORT DISCHARGE CASE
DISCHARGE= 0.0033CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.0508
** NUMBER OF PORTS= 1 ** SPACING=1000.00-M ** DEPTH= 53.64-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.09	35.29	1.02228	0.020
5.00	29.06	35.29	1.02229	0.020
10.00	29.05	35.34	1.02233	0.020
15.00	29.02	35.40	1.02238	0.020
20.00	29.03	35.47	1.02243	0.020
25.00	29.02	35.48	1.02244	0.020
30.00	29.02	35.48	1.02244	0.020
35.00	29.00	35.50	1.02246	0.020
40.00	28.99	35.55	1.02250	0.020
45.00	28.98	35.58	1.02253	0.020
50.00	28.98	35.58	1.02253	0.020
55.00	28.98	35.58	1.02253	0.020

FROUDE NO= 15.22, PORT SPACING/PORT DIA= 19685.04
STARTING LENGTH= 0.312

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	0.00	0.05	1.000	1.000	1.000	0.00	1.00
0.00	0.31	0.01	90.00	2.07	0.14	0.999	0.999	0.999	0.19	1.97
0.00	0.72	0.04	90.00	8.97	0.41	0.325	0.324	0.324	0.68	6.35
0.00	1.11	0.14	90.00	20.35	0.68	0.190	0.189	0.189	1.64	11.23
0.00	1.47	0.32	90.00	32.50	0.94	0.125	0.124	0.124	2.99	17.27
0.00	1.79	0.57	90.00	42.58	1.23	0.087	0.086	0.086	4.64	25.06
0.00	2.07	0.87	90.00	49.86	1.54	0.062	0.062	0.062	6.53	34.90
0.00	2.32	1.19	90.00	54.84	1.86	0.046	0.046	0.046	8.61	46.91
0.00	2.54	1.53	90.00	58.22	2.21	0.035	0.035	0.035	10.86	61.15
0.00	2.75	1.88	90.00	60.51	2.57	0.028	0.028	0.028	13.27	77.62
0.00	2.95	2.23	90.00	62.06	2.94	0.022	0.022	0.022	15.83	96.34
0.00	3.13	2.59	90.00	63.11	3.32	0.018	0.018	0.018	18.52	117.30
0.00	3.49	3.32	90.00	64.22	4.11	0.013	0.013	0.013	24.28	165.92
0.00	3.84	4.06	90.00	64.57	4.92	0.010	0.010	0.010	30.51	223.41
0.00	4.19	4.79	90.00	64.49	5.75	0.008	0.008	0.008	37.17	289.64
0.00	4.54	5.52	90.00	64.16	6.59	0.006	0.006	0.006	44.24	364.47
0.00	4.90	6.25	90.00	63.69	7.43	0.005	0.005	0.005	51.67	447.75
0.00	5.26	6.98	90.00	63.14	8.28	0.004	0.004	0.004	59.45	539.30
0.00	5.64	7.70	90.00	62.54	9.14	0.004	0.004	0.004	67.55	638.96
0.00	6.01	8.42	90.00	61.92	9.99	0.003	0.003	0.003	75.96	746.56
0.00	6.40	9.14	90.00	61.21	10.85	0.002	-0.002	0.002	84.66	861.89
0.00	6.80	9.85	90.00	60.20	11.73	0.002	-0.008	0.002	93.70	984.53
0.00	7.64	11.24	90.00	57.28	13.56	0.001	-0.020	0.001	113.06	1248.86
0.00	8.57	12.57	90.00	52.92	15.43	0.000	-0.030	0.000	134.72	1531.83
PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT										
0.00	9.01	13.13	90.00	50.41	16.26	0.000	-0.034	0.000	145.18	1658.41
0.00	9.27	13.44	90.00	48.76	16.73	0.000	-0.037	0.000	151.49	1730.66
0.00	9.54	13.74	90.00	46.92	17.20	-0.001	-0.039	0.000	158.09	1802.39
0.00	9.83	14.03	90.00	44.76	17.67	-0.001	-0.042	-0.001	165.03	1873.10
0.00	10.12	14.31	90.00	42.20	18.14	-0.001	-0.045	-0.001	172.37	1942.07
0.00	10.43	14.58	90.00	39.16	18.62	-0.001	-0.048	-0.001	180.23	2008.41
0.00	10.75	14.83	90.00	35.55	19.09	-0.002	-0.051	-0.001	188.72	2071.00
0.00	11.09	15.05	90.00	31.24	19.56	-0.002	-0.055	-0.002	198.04	2128.46
0.00	11.45	15.24	90.00	26.10	20.03	-0.002	-0.058	-0.002	208.42	2179.07
0.00	11.82	15.40	90.00	19.98	20.47	-0.002	-0.063	-0.002	220.19	2220.76
0.00	12.21	15.52	90.00	12.81	20.85	-0.003	-0.066	-0.002	233.67	2251.21
0.00	12.61	15.58	90.00	4.71	21.10	-0.003	-0.069	-0.002	248.86	2268.35

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 41.06 METERS BELOW SURFACE, DILUTION=1533.80
PROGRAM UDKHDEN

SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)

UNIVERSAL DATA FILE: **u11b230**.in

CASE I.D. JCO 2012 MZA-3.0 mgd total-six 5in port at 2.925 mgd Station 16 - May 3, 2008n -
DISCHARGE= 0.1282CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 4.950-PPT ** DIAMETER= 0.1270
** NUMBER OF PORTS=   6 ** SPACING= 30.48-M   ** DEPTH= 53.64-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.09	35.29	1.02228	0.020
5.00	29.06	35.29	1.02229	0.020
10.00	29.05	35.34	1.02233	0.020
15.00	29.02	35.40	1.02238	0.020
20.00	29.03	35.47	1.02243	0.020
25.00	29.02	35.48	1.02244	0.020
30.00	29.02	35.48	1.02244	0.020
35.00	29.00	35.50	1.02246	0.020
40.00	28.99	35.55	1.02250	0.020
45.00	28.98	35.58	1.02253	0.020
50.00	28.98	35.58	1.02253	0.020
55.00	28.98	35.58	1.02253	0.020

FROUDE NO= 9.98, PORT SPACING/PORT DIA=   240.00
STARTING LENGTH=   0.752

ALL LENGTHS ARE IN METERS-TIME IN SEC.   FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.73	0.22	90.00	19.27	0.35	0.976	0.976	0.976	0.45	2.02
0.00	1.64	0.65	90.00	32.01	1.08	0.293	0.291	0.291	1.63	6.98
0.00	2.42	1.30	90.00	47.09	1.79	0.154	0.153	0.153	3.78	13.42
0.00	3.04	2.10	90.00	57.47	2.51	0.093	0.093	0.093	6.54	22.00
0.00	3.53	2.99	90.00	63.70	3.25	0.062	0.062	0.062	9.72	32.93
0.00	3.95	3.92	90.00	67.45	4.03	0.044	0.044	0.044	13.21	46.22
0.00	4.32	4.86	90.00	69.79	4.84	0.033	0.033	0.033	17.00	61.87
0.00	4.66	5.82	90.00	71.28	5.67	0.026	0.025	0.025	21.04	79.85
0.00	4.97	6.79	90.00	72.23	6.53	0.020	0.020	0.020	25.32	100.16
0.00	5.28	7.75	90.00	72.85	7.40	0.017	0.016	0.016	29.82	122.77
0.00	5.57	8.73	90.00	73.22	8.29	0.014	0.013	0.014	34.54	147.68
0.00	6.16	10.67	90.00	73.38	10.14	0.009	-0.006	0.009	44.59	204.30
0.00	6.74	12.62	90.00	72.96	12.10	0.006	-0.019	0.006	55.53	269.82
0.00	7.35	14.56	90.00	72.08	14.17	0.004	-0.031	0.004	67.43	343.99
0.00	8.00	16.48	90.00	70.52	16.45	0.002	-0.041	0.002	80.51	426.44
0.00	8.72	18.38	90.00	68.01	18.99	0.000	-0.051	0.001	95.17	516.50

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	9.22	19.55	90.00	65.75	20.71	0.000	-0.064	0.000	105.41	576.10
0.00	9.65	20.47	90.00	63.58	22.14	-0.001	-0.077	0.000	114.34	625.26
0.00	10.12	21.37	90.00	60.96	23.61	-0.001	-0.090	0.000	124.05	675.36
0.00	10.64	22.24	90.00	57.70	25.11	-0.001	-0.103	-0.001	134.69	725.90
0.00	11.21	23.08	90.00	53.54	26.64	-0.002	-0.117	-0.001	146.49	776.10
0.00	11.85	23.87	90.00	48.11	28.17	-0.002	-0.126	-0.001	159.81	824.74
0.00	12.57	24.59	90.00	41.50	29.62	-0.002	-0.126	-0.001	175.12	870.17

PLUMES MERGING

0.00	13.38	25.21	90.00	33.43	30.97	-0.002	-0.129	-0.001	192.98	910.26
0.00	14.27	25.70	90.00	23.81	32.29	-0.002	-0.132	-0.001	214.22	940.99
0.00	15.23	26.02	90.00	12.84	33.42	-0.002	-0.136	-0.001	239.56	961.19
0.00	16.23	26.14	90.00	0.81	33.97	-0.002	-0.138	-0.001	268.39	970.03

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 34.84 METERS BELOW SURFACE,   DILUTION= 537.27

Attachment 1.C

Reduced Effluent Flow = 3.0 mgd and Increased Effluent Salinity

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u23a030s**.in
CASE I.D. JCO-2.7 mgd total-one 2in port at 0.075 mgd Station 16 - March 23, 2014 AM -zero

SINGLE PORT DISCHARGE CASE
DISCHARGE= 0.0033CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY=10.000-PPT ** DIAMETER= 0.0508
** NUMBER OF PORTS= 1 ** SPACING=1000.00-M ** DEPTH= 53.68-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.86	35.83	1.02242	0.000
5.00	29.77	35.84	1.02246	0.000
10.00	29.65	35.86	1.02251	0.000
15.00	29.56	35.86	1.02254	0.000
20.00	29.28	35.87	1.02265	0.000
25.00	29.22	35.88	1.02267	0.000
30.00	29.16	35.91	1.02272	0.000
35.00	29.07	35.94	1.02277	0.000
40.00	28.99	35.98	1.02283	0.000
45.00	28.82	36.01	1.02291	0.000
50.00	28.51	36.06	1.02305	0.000
55.00	27.80	36.19	1.02338	0.000

FROUDE NO= 16.36, PORT SPACING/PORT DIA= 19685.04
STARTING LENGTH= 0.294

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	0.00	0.05	1.000	1.000	1.000	0.00	1.00
0.00	0.29	0.00	90.00	1.72	0.14	0.999	0.999	0.999	0.18	1.93
0.00	0.70	0.04	90.00	8.76	0.45	0.306	0.300	0.305	0.70	6.31
0.00	1.09	0.14	90.00	21.94	0.75	0.179	0.160	0.179	1.76	10.77
0.00	1.44	0.34	90.00	36.70	1.00	0.124	0.079	0.124	3.23	15.47
0.00	1.74	0.62	90.00	48.68	1.21	0.092	0.014	0.093	4.93	20.59
0.00	1.98	0.94	90.00	57.14	1.40	0.070	-0.044	0.072	6.74	26.25
0.00	2.19	1.29	90.00	63.01	1.58	0.055	-0.096	0.058	8.63	32.45
0.00	2.36	1.66	90.00	67.18	1.77	0.043	-0.143	0.047	10.59	39.19
0.00	2.50	2.04	90.00	70.22	1.96	0.034	-0.186	0.039	12.61	46.43
0.00	2.63	2.43	90.00	72.49	2.16	0.027	-0.227	0.033	14.70	54.15
0.00	2.75	2.82	90.00	74.23	2.36	0.021	-0.266	0.028	16.88	62.29
0.00	2.95	3.60	90.00	76.58	2.79	0.012	-0.339	0.020	21.53	79.70
0.00	3.13	4.40	90.00	78.04	3.25	0.008	-0.338	0.016	26.63	98.28
0.00	3.29	5.19	90.00	79.03	3.74	0.004	-0.342	0.013	32.25	117.81
0.00	3.44	5.99	90.00	79.61	4.27	0.002	-0.353	0.010	38.47	138.02

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	3.59	6.79	90.00	79.73	4.87	-0.001	-0.369	0.009	45.45	158.57
0.00	3.66	7.19	90.00	79.58	5.22	-0.002	-0.378	0.008	49.31	168.82
0.00	3.73	7.59	90.00	79.23	5.63	-0.003	-0.389	0.007	53.52	178.96
0.00	3.81	7.99	90.00	78.56	6.12	-0.003	-0.400	0.006	58.17	188.87
0.00	3.90	8.39	90.00	77.34	6.75	-0.004	-0.413	0.006	63.46	198.40
0.00	3.99	8.78	90.00	74.91	7.68	-0.005	-0.421	0.005	69.79	207.34
0.00	4.12	9.17	90.00	68.79	9.39	-0.005	-0.423	0.005	78.16	215.28
0.00	4.35	9.48	90.00	4.99	15.96	-0.006	-0.426	0.005	94.10	221.27

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 47.08 METERS BELOW SURFACE, DILUTION= 153.61

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)

UNIVERSAL DATA FILE: **u23b030s**.in

CASE I.D. JCO-2.7 mgd total-six 5in port at 2.925 mgd Station 16 - March 23, 2014 AM zero

DISCHARGE= 0.1282CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY=10.000-PPT ** DIAMETER= 0.1270

** NUMBER OF PORTS= 6 ** SPACING= 30.52-M ** DEPTH= 53.68-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.86	35.83	1.02242	0.000
5.00	29.77	35.84	1.02246	0.000
10.00	29.65	35.86	1.02251	0.000
15.00	29.56	35.86	1.02254	0.000
20.00	29.28	35.87	1.02265	0.000
25.00	29.22	35.88	1.02267	0.000
30.00	29.16	35.91	1.02272	0.000
35.00	29.07	35.94	1.02277	0.000
40.00	28.99	35.98	1.02283	0.000
45.00	28.82	36.01	1.02291	0.000
50.00	28.51	36.06	1.02305	0.000
55.00	27.80	36.19	1.02338	0.000

FROUDE NO= 10.72, PORT SPACING/PORT DIA= 240.31

STARTING LENGTH= 0.725

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.70	0.21	90.00	18.77	0.35	0.971	0.952	0.972	0.43	1.96
0.00	1.62	0.63	90.00	31.90	1.10	0.295	0.235	0.294	1.63	6.47
0.00	2.39	1.29	90.00	48.21	1.71	0.164	0.036	0.166	3.80	11.40
0.00	2.99	2.11	90.00	59.68	2.23	0.106	-0.106	0.110	6.44	17.01
0.00	3.44	3.02	90.00	66.75	2.71	0.072	-0.224	0.078	9.35	23.41
0.00	3.80	3.97	90.00	71.22	3.20	0.051	-0.291	0.059	12.47	30.54
0.00	4.10	4.94	90.00	74.28	3.69	0.038	-0.305	0.046	15.78	38.35
0.00	4.36	5.92	90.00	76.47	4.18	0.029	-0.323	0.037	19.28	46.80
0.00	4.58	6.91	90.00	78.08	4.69	0.022	-0.346	0.031	22.97	55.82
0.00	4.78	7.91	90.00	79.27	5.22	0.016	-0.371	0.025	26.86	65.36
0.00	4.96	8.91	90.00	80.15	5.77	0.012	-0.396	0.021	30.97	75.33
0.00	5.28	10.91	90.00	81.36	6.91	0.006	-0.389	0.016	39.97	96.35
0.00	5.58	12.93	90.00	82.02	8.17	0.002	-0.398	0.012	50.12	118.42

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	5.85	14.94	90.00	82.18	9.64	0.000	-0.392	0.009	61.80	140.95
0.00	5.99	15.94	90.00	82.05	10.48	-0.001	-0.384	0.008	68.42	152.18
0.00	6.14	16.95	90.00	81.74	11.46	-0.002	-0.379	0.007	75.73	163.23
0.00	6.29	17.96	90.00	81.11	12.66	-0.003	-0.376	0.006	83.98	173.96
0.00	6.45	18.96	90.00	79.86	14.30	-0.004	-0.377	0.005	93.65	184.14
0.00	6.66	19.95	90.00	76.84	17.05	-0.005	-0.382	0.004	105.92	193.38
0.00	6.98	20.91	90.00	57.63	27.00	-0.006	-0.391	0.004	126.42	200.75

PLUMES MERGING

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 39.12 METERS BELOW SURFACE, DILUTION= 136.76

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u11a030x**.in
CASE I.D. JCO 2012 MZA-3.0 mgd total-one 2in port at 0.075 mgd Station 16 - May 3, 2008 -
SINGLE PORT DISCHARGE CASE
DISCHARGE= 0.0033CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY= 9.990-PPT ** DIAMETER= 0.0508
** NUMBER OF PORTS= 1 ** SPACING=1000.00-M ** DEPTH= 53.64-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.09	35.29	1.02228	0.000
5.00	29.06	35.29	1.02229	0.000
10.00	29.05	35.34	1.02233	0.000
15.00	29.02	35.40	1.02238	0.000
20.00	29.03	35.47	1.02243	0.000
25.00	29.02	35.48	1.02244	0.000
30.00	29.02	35.48	1.02244	0.000
35.00	29.00	35.50	1.02246	0.000
40.00	28.99	35.55	1.02250	0.000
45.00	28.98	35.58	1.02253	0.000
50.00	28.98	35.58	1.02253	0.000
55.00	28.98	35.58	1.02253	0.000

FROUDE NO= 16.67, PORT SPACING/PORT DIA= 19685.04
STARTING LENGTH= 0.294
ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	0.00	0.05	1.000	1.000	1.000	0.00	1.00
0.00	0.29	0.00	90.00	1.65	0.14	1.000	1.000	1.000	0.18	1.93
0.00	0.70	0.04	90.00	8.44	0.45	0.306	0.305	0.305	0.70	6.31
0.00	1.09	0.14	90.00	21.23	0.75	0.180	0.179	0.179	1.76	10.77
0.00	1.45	0.33	90.00	35.85	1.00	0.126	0.125	0.125	3.24	15.45
0.00	1.75	0.60	90.00	48.01	1.21	0.094	0.094	0.094	4.96	20.54
0.00	1.99	0.93	90.00	56.77	1.40	0.074	0.074	0.074	6.79	26.16
0.00	2.20	1.28	90.00	62.94	1.58	0.060	0.060	0.060	8.68	32.34
0.00	2.37	1.65	90.00	67.38	1.76	0.050	0.049	0.049	10.63	39.09
0.00	2.51	2.03	90.00	70.68	1.94	0.042	0.042	0.042	12.62	46.39
0.00	2.64	2.41	90.00	73.22	2.12	0.036	0.036	0.036	14.65	54.23
0.00	2.75	2.80	90.00	75.22	2.30	0.031	0.031	0.031	16.72	62.58
0.00	2.93	3.60	90.00	78.16	2.66	0.024	0.024	0.024	21.00	80.80
0.00	3.09	4.39	90.00	80.20	3.03	0.019	0.019	0.019	25.44	100.92
0.00	3.21	5.20	90.00	81.69	3.40	0.016	0.016	0.016	30.05	122.87
0.00	3.32	6.00	90.00	82.83	3.78	0.013	0.013	0.013	34.81	146.55
0.00	3.42	6.81	90.00	83.71	4.15	0.011	0.011	0.011	39.72	171.91
0.00	3.50	7.62	90.00	84.42	4.52	0.010	0.010	0.010	44.77	198.90
0.00	3.58	8.43	90.00	85.00	4.90	0.009	0.008	0.008	49.96	227.46
0.00	3.64	9.24	90.00	85.48	5.28	0.007	0.003	0.007	55.28	257.54
0.00	3.70	10.05	90.00	85.87	5.67	0.006	-0.004	0.006	60.74	289.06
0.00	3.76	10.86	90.00	86.18	6.08	0.005	-0.010	0.005	66.36	321.91
0.00	3.86	12.48	90.00	86.64	6.92	0.003	-0.020	0.004	78.14	391.16
0.00	3.95	14.10	90.00	86.95	7.84	0.002	-0.030	0.002	90.80	464.38
0.00	4.04	15.73	90.00	87.10	8.90	0.000	-0.038	0.001	104.62	540.34
PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT										
0.00	4.09	16.74	90.00	87.10	9.69	0.000	-0.043	0.000	114.12	588.34
0.00	4.11	17.15	90.00	87.07	10.05	-0.001	-0.045	0.000	118.17	607.48
0.00	4.13	17.55	90.00	87.03	10.43	-0.001	-0.047	-0.001	122.39	626.51
0.00	4.15	17.96	90.00	86.97	10.86	-0.001	-0.049	-0.001	126.82	645.39
0.00	4.17	18.37	90.00	86.88	11.33	-0.002	-0.051	-0.001	131.49	664.04
0.00	4.19	18.77	90.00	86.76	11.87	-0.002	-0.054	-0.001	136.45	682.38
0.00	4.22	19.18	90.00	86.60	12.47	-0.002	-0.060	-0.001	141.78	700.33
0.00	4.24	19.58	90.00	86.39	13.17	-0.002	-0.065	-0.002	147.54	717.80
0.00	4.27	19.99	90.00	86.10	14.01	-0.002	-0.070	-0.002	153.85	734.70
0.00	4.30	20.39	90.00	85.68	15.05	-0.002	-0.075	-0.002	160.90	750.87
0.00	4.33	20.80	90.00	85.02	16.48	-0.002	-0.081	-0.002	169.01	766.11
0.00	4.37	21.20	90.00	83.78	18.72	-0.003	-0.086	-0.002	178.86	780.08
0.00	4.42	21.61	90.00	80.14	23.86	-0.003	-0.091	-0.002	192.61	792.06
0.00	4.44	21.87	90.00	267.80	49.99	-0.003	-0.095	-0.002	226.31	798.62

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 37.39 METERS BELOW SURFACE, DILUTION= 565.07

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)

UNIVERSAL DATA FILE: **u11b030s**.in

CASE I.D. JCO 2012 MZA-2.7 mgd total-six 5in port at 2.925 mgd Station 16 - May 3, 2008n -
DISCHARGE= 0.1282CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY=10.000-PPT ** DIAMETER= 0.1270
** NUMBER OF PORTS= 6 ** SPACING= 30.48-M ** DEPTH= 53.64-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.09	35.29	1.02228	0.000
5.00	29.06	35.29	1.02229	0.000
10.00	29.05	35.34	1.02233	0.000
15.00	29.02	35.40	1.02238	0.000
20.00	29.03	35.47	1.02243	0.000
25.00	29.02	35.48	1.02244	0.000
30.00	29.02	35.48	1.02244	0.000
35.00	29.00	35.50	1.02246	0.000
40.00	28.99	35.55	1.02250	0.000
45.00	28.98	35.58	1.02253	0.000
50.00	28.98	35.58	1.02253	0.000
55.00	28.98	35.58	1.02253	0.000

FROUDE NO= 10.93, PORT SPACING/PORT DIA= 240.00
STARTING LENGTH= 0.727

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.70	0.21	90.00	18.64	0.35	0.981	0.981	0.981	0.43	1.96
0.00	1.63	0.63	90.00	31.50	1.10	0.299	0.298	0.298	1.64	6.47
0.00	2.40	1.28	90.00	47.83	1.71	0.170	0.169	0.169	3.81	11.37
0.00	3.00	2.10	90.00	59.61	2.22	0.114	0.113	0.113	6.46	16.98
0.00	3.45	3.01	90.00	67.05	2.69	0.083	0.082	0.082	9.36	23.38
0.00	3.80	3.96	90.00	71.88	3.15	0.063	0.063	0.063	12.40	30.60
0.00	4.09	4.93	90.00	75.18	3.61	0.050	0.050	0.050	15.58	38.60
0.00	4.33	5.92	90.00	77.56	4.06	0.041	0.041	0.041	18.87	47.35
0.00	4.53	6.92	90.00	79.34	4.52	0.034	0.034	0.034	22.27	56.81
0.00	4.70	7.92	90.00	80.71	4.98	0.029	0.029	0.029	25.78	66.96
0.00	4.86	8.92	90.00	81.80	5.44	0.025	0.021	0.025	29.39	77.78
0.00	5.12	10.94	90.00	83.38	6.38	0.018	0.002	0.018	36.90	101.27
0.00	5.33	12.96	90.00	84.44	7.34	0.013	-0.014	0.014	44.82	127.06
0.00	5.52	14.98	90.00	85.19	8.33	0.010	-0.027	0.010	53.18	154.89
0.00	5.68	17.01	90.00	85.71	9.37	0.007	-0.038	0.007	62.04	184.47
0.00	5.82	19.03	90.00	86.06	10.49	0.004	-0.052	0.005	71.51	215.45
0.00	5.96	21.06	90.00	86.31	11.67	0.003	-0.077	0.004	81.70	247.50
0.00	6.08	23.09	90.00	86.49	12.90	0.002	-0.100	0.003	92.67	280.38
0.00	6.21	25.12	90.00	86.61	14.18	0.001	-0.099	0.002	104.52	313.82
0.00	6.32	27.15	90.00	86.73	15.44	0.001	-0.089	0.002	117.27	347.73
0.00	6.44	29.17	90.00	86.85	16.67	0.001	-0.086	0.002	130.84	382.13

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	6.66	33.23	90.00	86.95	19.40	0.000	-0.104	0.001	160.65	451.94
0.00	6.71	34.25	90.00	86.93	20.21	-0.001	-0.098	0.000	168.81	469.38
0.00	6.77	35.26	90.00	86.83	21.30	-0.002	-0.086	-0.001	177.45	486.62
0.00	6.82	36.28	90.00	86.60	22.80	-0.003	-0.075	-0.002	186.84	503.38
0.00	6.89	37.29	90.00	86.14	25.04	-0.004	-0.064	-0.003	197.51	519.29
0.00	6.96	38.30	90.00	85.05	29.11	-0.004	-0.054	-0.004	210.65	533.75

PLUMES MERGING

0.00	7.09	39.31	90.00	78.18	46.04	-0.005	-0.063	-0.005	232.10	543.17

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 20.56 METERS BELOW SURFACE, DILUTION= 449.40

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u23a230s**.in
CASE I.D. JCO-2.7 mgd total-one 2in port at 0.075 mgd Station 16 - March 23, 2014 AM -2 CM

SINGLE PORT DISCHARGE CASE
DISCHARGE= 0.0033CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY=10.000-PPT ** DIAMETER= 0.0508
** NUMBER OF PORTS= 1 ** SPACING=1000.00-M ** DEPTH= 53.68-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.86	35.83	1.02242	0.020
5.00	29.77	35.84	1.02246	0.020
10.00	29.65	35.86	1.02251	0.020
15.00	29.56	35.86	1.02254	0.020
20.00	29.28	35.87	1.02265	0.020
25.00	29.22	35.88	1.02267	0.020
30.00	29.16	35.91	1.02272	0.020
35.00	29.07	35.94	1.02277	0.020
40.00	28.99	35.98	1.02283	0.020
45.00	28.82	36.01	1.02291	0.020
50.00	28.51	36.06	1.02305	0.020
55.00	27.80	36.19	1.02338	0.020

FROUDE NO= 16.36, PORT SPACING/PORT DIA= 19685.04
STARTING LENGTH= 0.312

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	0.00	0.05	1.000	1.000	1.000	0.00	1.00
0.00	0.31	0.00	90.00	1.79	0.14	0.999	0.999	0.999	0.19	1.97
0.00	0.72	0.04	90.00	7.79	0.41	0.326	0.320	0.325	0.68	6.34
0.00	1.11	0.12	90.00	17.84	0.67	0.192	0.174	0.191	1.64	11.11
0.00	1.49	0.29	90.00	29.02	0.94	0.128	0.088	0.128	3.00	16.89
0.00	1.82	0.51	90.00	38.77	1.22	0.088	0.020	0.089	4.69	24.23
0.00	2.12	0.79	90.00	46.06	1.52	0.062	-0.036	0.064	6.65	33.47
0.00	2.39	1.09	90.00	51.09	1.85	0.045	-0.083	0.047	8.83	44.73
0.00	2.63	1.42	90.00	54.39	2.20	0.032	-0.125	0.036	11.22	58.07
0.00	2.86	1.75	90.00	56.42	2.56	0.023	-0.163	0.028	13.82	73.48
0.00	3.09	2.09	90.00	57.50	2.95	0.017	-0.199	0.022	16.62	90.91
0.00	3.30	2.44	90.00	57.80	3.35	0.012	-0.233	0.018	19.64	110.30
0.00	3.74	3.12	90.00	56.37	4.21	0.004	-0.300	0.012	26.44	154.44

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	4.15	3.70	90.00	52.58	5.02	-0.001	-0.360	0.008	33.46	197.77
0.00	4.41	4.02	90.00	49.38	5.49	-0.001	-0.358	0.007	38.07	223.63
0.00	4.68	4.32	90.00	45.56	5.95	-0.002	-0.363	0.006	43.21	249.65
0.00	4.98	4.59	90.00	40.89	6.39	-0.003	-0.373	0.006	48.97	275.15
0.00	5.30	4.85	90.00	35.11	6.81	-0.004	-0.389	0.005	55.51	299.19
0.00	5.64	5.06	90.00	27.86	7.19	-0.005	-0.410	0.005	63.03	320.53
0.00	6.02	5.22	90.00	18.80	7.52	-0.006	-0.434	0.005	71.80	337.55
0.00	6.41	5.31	90.00	7.90	7.75	-0.006	-0.454	0.005	81.97	348.49
0.00	6.82	5.33	90.00	-3.97	7.82	-0.006	-0.454	0.005	93.01	353.02

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 50.07 METERS BELOW SURFACE, DILUTION= 190.72

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u23b230s**.in
CASE I.D. JCO-2.7 mgd total-six 5in port at 2.925 mgd Station 16 - March 23, 2014 AM 2 cm/
DISCHARGE= 0.1282CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY=10.000-PPT ** DIAMETER= 0.1270
** NUMBER OF PORTS= 6 ** SPACING= 30.52-M ** DEPTH= 53.68-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.86	35.83	1.02242	0.020
5.00	29.77	35.84	1.02246	0.020
10.00	29.65	35.86	1.02251	0.020
15.00	29.56	35.86	1.02254	0.020
20.00	29.28	35.87	1.02265	0.020
25.00	29.22	35.88	1.02267	0.020
30.00	29.16	35.91	1.02272	0.020
35.00	29.07	35.94	1.02277	0.020
40.00	28.99	35.98	1.02283	0.020
45.00	28.82	36.01	1.02291	0.020
50.00	28.51	36.06	1.02305	0.020
55.00	27.80	36.19	1.02338	0.020

FROUDE NO= 10.72, PORT SPACING/PORT DIA= 240.31
STARTING LENGTH= 0.751

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.73	0.22	90.00	18.68	0.35	0.970	0.949	0.970	0.45	2.01
0.00	1.66	0.62	90.00	29.85	1.08	0.292	0.232	0.291	1.64	6.91
0.00	2.46	1.23	90.00	43.93	1.79	0.152	0.029	0.154	3.84	13.14
0.00	3.12	2.00	90.00	54.19	2.52	0.089	-0.107	0.093	6.74	21.36
0.00	3.67	2.86	90.00	60.36	3.30	0.055	-0.215	0.061	10.13	31.78
0.00	4.14	3.76	90.00	63.80	4.13	0.035	-0.299	0.042	13.98	44.42
0.00	4.57	4.68	90.00	65.74	5.01	0.024	-0.293	0.031	18.26	59.22
0.00	4.98	5.61	90.00	66.74	5.94	0.016	-0.301	0.024	22.98	76.18
0.00	5.38	6.54	90.00	66.99	6.93	0.010	-0.317	0.018	28.17	95.23
0.00	5.78	7.48	90.00	66.56	7.99	0.006	-0.337	0.015	33.87	116.30
0.00	6.19	8.41	90.00	65.40	9.13	0.003	-0.362	0.012	40.18	139.28

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	6.99	10.00	90.00	61.32	11.35	-0.001	-0.369	0.008	53.15	183.43
0.00	7.50	10.87	90.00	57.54	12.71	-0.002	-0.376	0.007	62.00	210.33
0.00	8.08	11.71	90.00	51.80	14.13	-0.003	-0.393	0.006	72.33	237.56
0.00	8.77	12.45	90.00	42.40	15.57	-0.005	-0.425	0.006	84.87	263.55
0.00	9.60	13.03	90.00	25.74	16.93	-0.006	-0.481	0.005	101.19	284.81
0.00	10.58	13.25	90.00	-1.72	17.68	-0.007	-0.525	0.006	123.40	294.75

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 44.11 METERS BELOW SURFACE, DILUTION= 171.11

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u11a230s**.in
CASE I.D. JCO 2012 MZA-2.7 mgd total-one 2in port at 0.075 mgd Station 16 - May 3, 2008 -

SINGLE PORT DISCHARGE CASE
DISCHARGE= 0.0033CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY=10.000-PPT ** DIAMETER= 0.0508
** NUMBER OF PORTS= 1 ** SPACING=1000.00-M ** DEPTH= 53.64-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.09	35.29	1.02228	0.020
5.00	29.06	35.29	1.02229	0.020
10.00	29.05	35.34	1.02233	0.020
15.00	29.02	35.40	1.02238	0.020
20.00	29.03	35.47	1.02243	0.020
25.00	29.02	35.48	1.02244	0.020
30.00	29.02	35.48	1.02244	0.020
35.00	29.00	35.50	1.02246	0.020
40.00	28.99	35.55	1.02250	0.020
45.00	28.98	35.58	1.02253	0.020
50.00	28.98	35.58	1.02253	0.020
55.00	28.98	35.58	1.02253	0.020

FROUDE NO= 16.68, PORT SPACING/PORT DIA= 19685.04
STARTING LENGTH= 0.312
ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	0.00	0.05	1.000	1.000	1.000	0.00	1.00
0.00	0.31	0.00	90.00	1.72	0.14	1.000	1.000	1.000	0.19	1.97
0.00	0.72	0.03	90.00	7.50	0.41	0.327	0.325	0.325	0.68	6.33
0.00	1.11	0.12	90.00	17.22	0.67	0.193	0.192	0.192	1.64	11.08
0.00	1.49	0.28	90.00	28.19	0.93	0.130	0.129	0.129	3.01	16.80
0.00	1.83	0.50	90.00	38.00	1.21	0.091	0.091	0.091	4.70	24.04
0.00	2.13	0.77	90.00	45.55	1.52	0.066	0.066	0.066	6.67	33.17
0.00	2.40	1.07	90.00	50.97	1.84	0.049	0.049	0.049	8.85	44.35
0.00	2.64	1.40	90.00	54.76	2.18	0.038	0.038	0.038	11.22	57.66
0.00	2.87	1.74	90.00	57.38	2.54	0.030	0.030	0.030	13.76	73.13
0.00	3.08	2.08	90.00	59.19	2.90	0.024	0.024	0.024	16.47	90.78
0.00	3.29	2.43	90.00	60.43	3.29	0.020	0.020	0.020	19.32	110.61
0.00	3.68	3.15	90.00	61.80	4.07	0.014	0.014	0.014	25.44	156.77
0.00	4.06	3.86	90.00	62.29	4.88	0.010	0.010	0.010	32.07	211.52
0.00	4.44	4.58	90.00	62.28	5.71	0.008	0.008	0.008	39.17	274.73
0.00	4.82	5.30	90.00	61.99	6.54	0.007	0.006	0.006	46.70	346.24
0.00	5.20	6.02	90.00	61.53	7.38	0.005	0.005	0.005	54.63	425.86
0.00	5.59	6.73	90.00	60.98	8.23	0.004	0.004	0.004	62.92	513.40
0.00	5.99	7.44	90.00	60.37	9.07	0.004	0.004	0.004	71.57	608.67
0.00	6.40	8.14	90.00	59.74	9.92	0.003	0.003	0.003	80.54	711.48
0.00	6.81	8.84	90.00	59.08	10.76	0.003	0.001	0.003	89.82	821.63
0.00	7.23	9.54	90.00	58.11	11.63	0.002	-0.006	0.002	99.43	938.76
0.00	8.12	10.90	90.00	55.11	13.41	0.001	-0.018	0.001	119.97	1190.73
PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT										
0.00	9.10	12.19	90.00	50.47	15.23	0.000	-0.028	0.000	142.99	1458.67
0.00	9.37	12.50	90.00	48.99	15.68	0.000	-0.031	0.000	149.27	1526.63
0.00	9.64	12.81	90.00	47.35	16.14	-0.001	-0.033	0.000	155.80	1594.40
0.00	9.92	13.10	90.00	45.52	16.59	-0.001	-0.036	0.000	162.63	1661.63
0.00	10.21	13.39	90.00	43.48	17.04	-0.001	-0.038	-0.001	169.80	1727.88
0.00	10.51	13.66	90.00	41.21	17.48	-0.001	-0.041	-0.001	177.35	1792.65
0.00	10.82	13.92	90.00	38.56	17.93	-0.001	-0.044	-0.001	185.36	1855.31
0.00	11.14	14.16	90.00	35.41	18.37	-0.002	-0.047	-0.001	193.93	1914.95
0.00	11.48	14.39	90.00	31.67	18.81	-0.002	-0.050	-0.002	203.23	1970.42
0.00	11.84	14.59	90.00	27.24	19.25	-0.002	-0.054	-0.002	213.46	2020.34
0.00	12.21	14.76	90.00	22.00	19.67	-0.003	-0.057	-0.002	224.86	2063.05
0.00	12.59	14.89	90.00	15.87	20.05	-0.003	-0.061	-0.002	237.74	2096.67
0.00	12.99	14.98	90.00	8.87	20.35	-0.003	-0.064	-0.003	252.26	2119.32
0.00	13.39	15.02	90.00	1.24	20.49	-0.003	-0.065	-0.003	268.09	2129.64

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 41.59 METERS BELOW SURFACE, DILUTION=1428.62

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UDKHDEN CH2MHILL Version 2.2 (1-24-89)
UNIVERSAL DATA FILE: **u11b230s**.in
CASE I.D. JCO 2012 MZA-2.7 mgd total-six 5in port at 2.925 mgd Station 16 - May 3, 2008n -
DISCHARGE= 0.1282CU-M/S ** TEMPERATURE= 29.44-C ** SALINITY=10.000-PPT ** DIAMETER= 0.1270
** NUMBER OF PORTS= 6 ** SPACING= 30.48-M ** DEPTH= 53.64-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	TEMP (C)	SALINITY (PPT)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	29.09	35.29	1.02228	0.020
5.00	29.06	35.29	1.02229	0.020
10.00	29.05	35.34	1.02233	0.020
15.00	29.02	35.40	1.02238	0.020
20.00	29.03	35.47	1.02243	0.020
25.00	29.02	35.48	1.02244	0.020
30.00	29.02	35.48	1.02244	0.020
35.00	29.00	35.50	1.02246	0.020
40.00	28.99	35.55	1.02250	0.020
45.00	28.98	35.58	1.02253	0.020
50.00	28.98	35.58	1.02253	0.020
55.00	28.98	35.58	1.02253	0.020

FROUDE NO= 10.93, PORT SPACING/PORT DIA= 240.00
STARTING LENGTH= 0.754

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.73	0.22	90.00	18.55	0.35	0.980	0.980	0.980	0.45	2.01
0.00	1.66	0.62	90.00	29.46	1.08	0.297	0.295	0.295	1.64	6.90
0.00	2.47	1.22	90.00	43.55	1.79	0.158	0.157	0.157	3.85	13.10
0.00	3.13	1.99	90.00	54.16	2.52	0.097	0.097	0.097	6.75	21.29
0.00	3.68	2.85	90.00	60.88	3.27	0.065	0.065	0.065	10.12	31.72
0.00	4.14	3.76	90.00	65.04	4.06	0.046	0.046	0.046	13.85	44.47
0.00	4.54	4.69	90.00	67.67	4.88	0.035	0.034	0.034	17.90	59.52
0.00	4.91	5.63	90.00	69.36	5.73	0.027	0.027	0.027	22.23	76.88
0.00	5.26	6.59	90.00	70.46	6.60	0.021	0.021	0.021	26.83	96.52
0.00	5.59	7.55	90.00	71.17	7.49	0.017	0.017	0.017	31.67	118.44
0.00	5.92	8.51	90.00	71.60	8.39	0.014	0.014	0.014	36.75	142.63
0.00	6.55	10.44	90.00	71.82	10.28	0.010	-0.004	0.010	47.57	197.72
0.00	7.19	12.37	90.00	71.35	12.28	0.006	-0.018	0.007	59.35	261.57
0.00	7.86	14.29	90.00	70.34	14.40	0.004	-0.030	0.004	72.22	333.90
0.00	8.57	16.19	90.00	68.48	16.73	0.002	-0.040	0.002	86.42	414.24

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	9.36	18.06	90.00	65.35	19.33	0.000	-0.050	0.000	102.47	501.64
0.00	9.81	18.98	90.00	63.06	20.75	-0.001	-0.059	0.000	111.45	547.45
0.00	10.29	19.87	90.00	60.23	22.21	-0.001	-0.072	-0.001	121.27	594.16
0.00	10.82	20.74	90.00	56.73	23.69	-0.002	-0.086	-0.001	132.10	641.23
0.00	11.41	21.57	90.00	52.27	25.19	-0.002	-0.100	-0.001	144.17	687.85
0.00	12.07	22.34	90.00	46.36	26.69	-0.002	-0.116	-0.002	157.88	732.73
0.00	12.81	23.02	90.00	38.26	28.15	-0.003	-0.133	-0.002	173.92	773.81
0.00	13.67	23.57	90.00	26.82	29.55	-0.003	-0.154	-0.002	193.49	807.68

PLUMES MERGING

0.00	14.62	23.91	90.00	11.30	30.67	-0.004	-0.165	-0.002	218.31	829.35

JCO 2012 MZA-2.7 mgd total-six 5in port at 2.925 mgd Station 16 - May 3, 2008n -

X	Y	Z	TH1	TH2	WIDTH	DRHO	DTCL	DSCL	TIME	DILUTION
0.00	15.63	23.95	90.00	-6.55	30.96	-0.004	-0.166	-0.002	247.29	836.67

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT

TRAPPING LEVEL= 35.79 METERS BELOW SURFACE, DILUTION= 491.40

Attachment 2
TN and TP Data for StarKist Samoa
April 2018 through April 2019

Starkist Samoa April 2018 through April 2019 Nutrient Data

	Date	Monthly Maximum			Monthly Average		
		Flow	TP	TN	Flow	TP	TN
		mgd	mg/l	mg/l	mgd	mg/l	mg/l
Data for Period of Record	Apr-18	2.36	19.77	242	1.66	11.74	172.47
	May-18	2.74	19.5	297.4	1.77	7.28	152.98
	Jun-18	2.08	17.76	248	1.54	8.04	164.50
	Jul-18	2.54	17.43	215	1.94	9.54	150.64
	Aug-18	2.36	24.8	226	2.06	9.25	149.16
	Sep-18	2.37	21.13	241	1.70	9.92	150.38
	Oct-18	2.48	26.67	211	1.86	7.94	138.26
	Nov-18	2.66	17.8	274	1.75	6.88	133.82
	Dec-18	2.7	16.86	194	1.81	9.16	145.47
	Jan-19	2.56	25.68	270	1.89	11.16	171.75
	Feb-19	2.6	20.1	281	2.02	11.30	181.86
	Mar-19	2.34	18.59	302.5	1.86	5.70	146.56
	Apr-19	2.41	14	277.5	2.00	6.96	159.23
Statistics for Period of Record	Violation if > permit limitation	Pending	Pending	Pending	Pending	Pending	Pending
	Water Quality Standard	NA	>30	>200	NA	>30	>200
	Total Samples in Database	13	13	13	13	13	13
	Number of Numeric Samples	13	13	13	13	13	13
	Number of Removed Samples	0	0	0	0	0	0
	Number of Samples Assessed	13	13	13	13	13	13
	Number of Exceedances	0	0	0	0	0	0
	Percent Exceedances	0%	0%	0%	0%	0%	0%
	Maximum	2.74	26.67	302.5	2.06	11.74	181.86
	Average	2.48	20.01	252.26	1.83	8.84	155.16
	Minimum	2.08	14	194	1.54	5.70	133.82
	Standard Deviation	0.18	3.72	34.44	0.15	1.89	14.10
	Rejection Criterion (Low)	1.93	8.86	148.93	1.38	3.16	112.87
	Rejection Criterion (High)	3.02	31.15	355.59	2.29	14.51	197.45
Data with Outliers Removed	Apr-18	2.36	19.77	242	1.66	11.74	172.47
	May-18	2.74	19.5	297.4	1.77	7.28	152.98
	Jun-18	2.08	17.76	248	1.54	8.04	164.50
	Jul-18	2.54	17.43	215	1.94	9.54	150.64
	Aug-18	2.36	24.8	226	2.06	9.25	149.16
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	Nov-18	2.66	17.8	274	1.75	6.88	133.82
	Dec-18	2.7	16.86	194	1.81	9.16	145.47
	Jan-19	2.56	25.68	270	1.89	11.16	171.75
	Feb-19	2.6	20.1	281	2.02	11.30	181.86
	Mar-19	2.34	18.59	302.5	1.86	5.70	146.56
	Apr-19	2.41	14	277.5	2.00	6.96	159.23
Statistics without Outliers and RPA Calculations	Permit Limitation	Pending	Pending	Pending	Pending	Pending	Pending
	Number Rejected by Criterion	0	0	0	0	0	0
	Number of Samples	13	13	13	13	13	13
	Maximum	**2.74**	**26.67**	**302.5**	**2.06**	**11.74**	**181.86**
	Average	2.48	20.01	252.26	1.83	8.84	155.16
	Minimum	2.08	14	194	1.54	5.70	134
	Standard Deviation	0.18	3.72	34.44	0.15	1.89	14.10
	Coefficient of Variation	0.07	0.19	0.14	0.08	0.21	0.09
	Confidence Level	0.99	0.99	0.99	0.99	0.99	0.99
	Probability Level (Pl)	0.99	0.99	0.99	0.99	0.99	0.99
	Probability of Maximum (Pn)	0.70	0.70	0.70	0.70	0.70	0.70
	Z of Pn	0.53	0.53	0.53	0.53	0.53	0.53
	Z of Pl	2.33	2.33	2.33	2.33	2.33	2.33
	Standard Deviation (log normal)	0.07	0.18	0.14	0.08	0.21	0.09
	Reasonable Potential Multiplier	1.14	1.39	1.28	1.16	1.46	1.18
	Reasonable Potential (PL=.99)	3.13	37.13	386	2.39	17.17	214

Starkist Samoa Co.
August 15, 2019 Comments
Public Notice Draft Permit
NPDES AS000019

ATTACHMENT B

Evaluation of EPA CORMIX Modeling

Starkist Samoa Company, NPDES Permit No. AS000019

Prepared by

integral consulting inc.

285 Century Place
Suite 190
Louisville, CO 80027

August 14, 2019

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FIGURE LIST

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ACRONYMS AND ABBREVIATIONS

ASWQS	American Samoa Water Quality Standards
EPA	U.S. Environmental Protection Agency
Integral	Integral Consulting Inc.
JCO	Joint Cannery Outfall
MZA	Mixing Zone Analysis
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System

1 BACKGROUND

A draft National Pollutant Discharge Elimination System (NPDES) permit and supporting draft Fact Sheet were issued by U.S. Environmental Protection Agency (EPA) on July 3, 2019, for the Starkist Samoa Company, NPDES Permit No. AS000019. Starkist discharges wastewater from its tuna canning facility through the Joint Cannery Outfall (JCO), located in Pago Pago Harbor, at a water depth of 53 m. The draft permit specifies limits for several parameters discharged by Starkist; this review is focused on the evaluations performed to support the proposed nutrient limits.

The American Samoa Water Quality Standards (ASWQS) specify receiving water quality limits, and allow for zones of mixing for discharges in specific circumstances. A mixing zone is an area within which exceedances of water quality standards from an effluent plume are allowed, and the boundaries of which are the compliance location where water quality standards are to be met. ASWQS specify that a mixing zone shall not include the water surface, any part of the shoreline, or any part of any barrier or fringing reef.

The draft permit specifies an allowable load of nutrients discharged by Starkist through the JCO. The allowable load is based on application of a numerical model by EPA, which was applied to a single model scenario and included simplifying assumptions that limit the application of the results to develop a permit limit. In support of the permit renewal application, Starkist performed an extensive evaluation of the discharge mixing into Pago Pago Harbor (gdc 2017, 2018a; referred to as the Mixing Zone Analysis [MZA]), which was criticized and largely disregarded by EPA in the development of the permit. The draft Fact Sheet and permit include unsupported statements, an inconsistent approach, and an inadequate modeling evaluation. This report discusses the major limitations of the draft permit.

2 HYDRODYNAMICS IN PAGO PAGO HARBOR

Pago Pago Harbor, along the southern coast of American Samoa, is its largest natural harbor and a mixed use water body that supports industrial and recreational use as well as a number of wildlife species. Several small streams discharge to the harbor, draining from watersheds across the mountainous topography. Circulation in the harbor is mainly driven by wind, waves, and tides. The topography surrounding the harbor provides sheltering from the dominant wind direction, which limits locally generated waves. Currents within the harbor are generally low due to the small tidal range and deep water. The weak vertical density stratification and the low currents in the harbor are important processes controlling the mixing of discharge plumes.

2.1 TIDES

The average tide range in Pago Pago Harbor is approximately 0.8 m, with a semidiurnal cycle (i.e., two high and two low tides each day). This small tidal range in this sheltered harbor results in small tidal current velocities.

2.2 WATER CURRENTS

There are limited current measurements in Pago Pago Harbor. The most recent were collected in 1993 and 1994, as part of a dye study to characterize plume behavior (CH2M HILL 1993, 1994). During this study, current meters were deployed in the water column on two separate deployments, October 9 to 12, 1993 (tradewind season), and February 16 to 19, 1994 (non-tradewind season). These current measurements were supplemented with drogue measurements. The results of these studies showed that currents near the bottom of the harbor averaged 2 cm/s, and mid-depth current averaged approximately 18 cm/s for non-tradewind conditions and approximately 22 cm/s during tradewind conditions. The higher mid-depth current velocities are likely forced primarily by wind blowing over the harbor as well as wind waves that enter the harbor.

To explore currents over a longer time frame than the dye study deployments, Integral Consulting Inc. (Integral) developed a screening-level hydrodynamic model to simulate currents in Pago Pago Harbor. The objective of the current modeling was to characterize the range of currents that are expected to occur in the harbor under typical conditions. A 3-dimensional, time-varying, hydrodynamic model was set up using Delft3D-FLOW (Deltares 2018) and Delft3D-WAVE. The Delft3D-FLOW model is an open source, state-of-the-science, numerical model. The model solves the Navier-Stokes equation of motion, the continuity equation, and conservative tracer transport equations to simulate non-steady flow and transport on a rectangular or curvilinear boundary-fitted grid (Deltares 2018). Delft3D-WAVE uses SWAN (Simulating Waves Nearshore) as the wave model. SWAN is fully spectral, based on the discrete spectral action balance equation, and a proven nearshore wave modeling system (Holthuijsen et al. 1993). Delft3D-FLOW and Delft3D-WAVE have been used in numerous studies of coastal and estuarine environments and are well accepted in the scientific community.

The hydrodynamic model was set up using recent, publicly available data to establish initial and boundary conditions (Table 1). The model grid was developed with bathymetry collected by National Oceanic and Atmospheric Administration (NOAA) in 2004 and 2006. Model boundary conditions include tides and waves. The tides were defined by harmonic constituents from a NOAA tide station in Pago Pago Harbor. A constant wave height, period, and direction were input at the mouth of the harbor, consistent with 2018 average observations collected offshore of the easternmost point of American Samoa at NOAA Pacific Islands Ocean Observing System Station #51209. These wave data, while collected off the eastern tip of the island, are representative of the yearly average wave conditions that would reach the harbor mouth given the dominant wave direction of east-south-east that was observed in the data. Wind was not included as a boundary condition in this screening-level model, with the purpose to provide a conservative prediction of typical conditions. The inclusion of wind in the model would primarily affect surface and mid-depth currents, and it is anticipated that the exclusion of wind generally under-predicts currents.

Table 1. Hydrodynamic Model Initial and Boundary Condition Sources

Parameter	Source	Date
Bathymetry	NOAA gridded 5 m bathymetry data of American Samoa https://catalog.data.gov/dataset/gridded-bathymetry-of-tutuila-island-american-samoa-south-pacific	January–March 2004 and February–March 2006
Tides	Harmonic tidal constituents based on NOAA Station Pago Pago, American Samoa https://tidesandcurrents.noaa.gov/harcon.html?id=1770000	1983–2001 epoch, Model input uses tides from January 18, 2019 to January 31, 2019.
Waves	NOAA NDBC Station 51209 https://www.ndbc.noaa.gov/station_page.php?station=51209	2018 annual average

The model simulated 14 days of currents, and model-predicted currents at the JCO were recorded at 10-minute intervals (Figure 1). The predicted mean current speed ranged from approximately 20 cm/s at the surface to approximately 14 cm/s at the bottom of the water column (Table 2). The 10th percentile flows were approximately 5.5 to 6.5 cm/s throughout the water column. The minimum predicted current was 0.2 cm/s for all depths. To characterize the duration of low currents, the number of reported model results (reported at 10-minute intervals, for a total of 2,016 reported results in the 14-day model simulation period) below 1 cm/s and the number of consecutive low currents were tallied. Within the modeled time period, the model only simulated a few instances of low currents, and the maximum predicted duration of currents below 1 cm/s was 40 minutes out of the 20,160 minutes in the 14-day model simulation period. The results of the screening-level model are consistent with the current measurements reported in the 1993 and 1994 dye studies, and suggest that the selection of 2 cm/s used in the MZA to represent the 10th percentile flow is likely conservative.[1]

[1] The 10th percentile current speed is often used as a representative low ambient current in tidally-influenced systems, and was used to select the ambient current in the MZA.

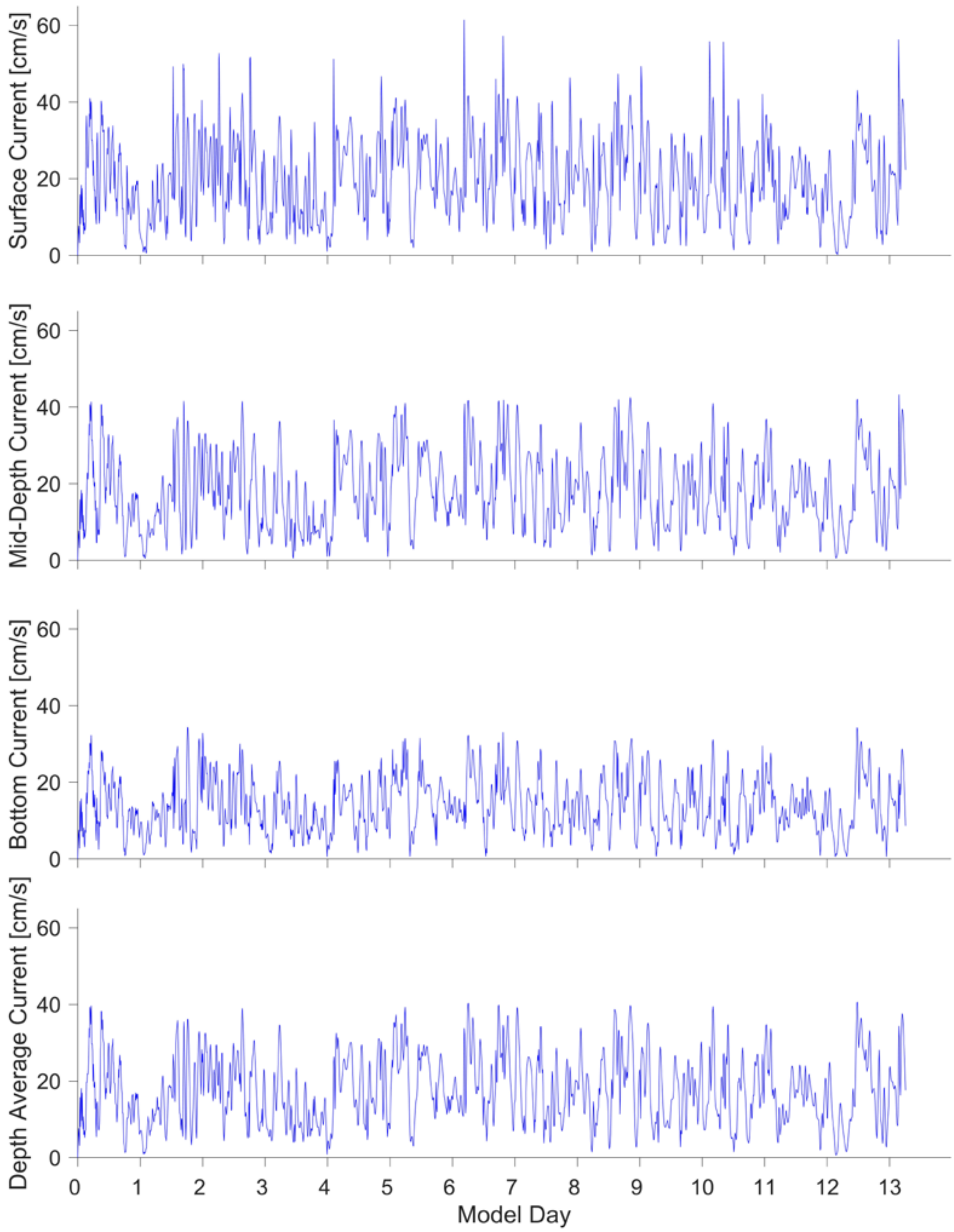

Figure 1. Hydrodynamic Model Surface, Mid-Depth, Bottom, and Depth-Averaged Currents Predicted at the JCO in Pago Pago Harbor

Table 2. Summary of Hydrodynamic Model Currents Predicted at the JCO in Pago Pago Harbor

Statistic	Surface	Mid-depth	Bottom	Depth-Averaged
Mean (cm/s)	19.9	18.1	14.1	17.7
Median (cm/s)	19.0	17.3	13.4	17.0
Minimum (cm/s)	0.2	0.5	0.5	0.7
10th percentile (cm/s)	6.5	5.9	5.5	6.7
Number of results <1 cm/s[a]	11	13	10	5
Maximum duration of currents <1 cm/s[a, b]	40 min	30 min	20 min	30 min

Noted: [a]The model results are recorded every 10 minutes over the 14-day model period, for a total of 2,016 reported results.

[b]The total duration of the 14-day model period is 20,160 minutes.

2.3 DENSITY STRATIFICATION

Vertical gradients of temperature and salinity can develop in a water column and create density stratification or a density gradient, defined as a change in density over some fraction of the total water column. A density gradient in the water column can prevent the upward (positive buoyant force) or downward (negative buoyant force) transport of a discharged effluent as well as suspended material and planktonic organisms. EPA guidance documents for mixing evaluations in estuaries and oceans emphasize the importance of density stratification on the mixing process. Jirka et al. (1992) stated that estuaries with weak tidal energy usually have a well-defined density gradient with fresh water on top and salt water beneath, and that the ambient stratification in the water column will counteract the vertical advection of a buoyant discharge plume and trap the plume at a certain level. Furthermore, Muellenhoff et al. (1985) stated that for typical municipal ocean discharges, buoyancy is likely the dominant initial mixing process.

In a low energy estuary or harbor, weak density stratification can persist and dominate vertical mixing processes. Multiple peer-reviewed studies support that density stratification will inhibit the mixing between upper and lower water columns and limit the vertical transport of suspended material. Gibbs et al. (2002) found in their research in Beatrix Bay, Pelorus Sound, New Zealand, that nutrient generation within the sediment bed, specifically nitrogen, was decoupled from the upper water column by a density gradient generated from temperature and salinity differences between the bay and ocean water. Murphy et al. (2011) found that density stratification in the Chesapeake Bay was correlated with hypoxia, depleted oxygen, in the lower water column as a result of nutrients being trapped in the lower water column. The nutrients generated in the lower water column and sediment bed were unable to be transported to the upper water column where they could be consumed by planktonic organisms. Song et al. (2013)

found that density stratification can develop in small, shallow urban ponds as a result of heating of the surface water while the lower water column remains colder.

Density stratification was observed in all vertical profiles collected within Pago Pago Harbor from 2008 to 2018 (gdc 2017, 2018b,c,d). Stratification in the outer harbor (the best representation of background stratification for use in the model, as measured at Station 16) had changes in density from the surface to the bottom of the water column ranging from approximately 0.07 to 1.4 kg/m^3.[2, 3] The variations in vertical density profiles are likely influenced by wind speed and direction across the harbor. Although comparatively weak density gradients (i.e., less than 0.1 kg/m^3 difference between the surface and bottom of the water column) were observed in approximately 10 percent of the all of the profiles collected around the harbor (and in 1 of the 32 profiles observed at Station 16), this stratification is still an important limit to vertical mixing processes, given the relatively low tidal range and currents within Pago Pago Harbor in the vicinity of the JCO.

[2] No interannual changes in stratification are evident in these data
[3] There are multiple methods for calculation of density from temperature and salinity, which can result in slight variations in density among the methods.

3 DRAFT NPDES PERMIT MODELING

The draft Fact Sheet supporting the Starkist Samoa draft NPDES permit discusses dilution in the receiving water, including a critique of the MZA modeling used to support the Starkist permit application and a presentation of modeling performed by EPA that is ultimately used to establish allowable nutrient dilution and loading in the draft permit. The discussion in the draft Fact Sheet raises several concerns about the information and evaluations presented, and the validity of the results to support establishment of permit limits.

The draft Fact Sheet states that the Pago Pago Harbor currents used as an input in the mixing modeling presented in the MZA are unreliable. The draft Fact Sheet contends that the currents were collected in the mid-1980s using instrumentation with limited precision, supplemented by current data collected during a dye study in 1993. The 2017 MZA relies on the most recently available current data collected in 1993 and 1994 from two fixed current meters and drogue trajectories (CH2M HILL 1993, 1994). The draft Fact Sheet also states that there have been a large number of changes in Pago Pago Harbor since the 1990s, and, therefore, older currents measurements may not reliably represent the full range of currents. This statement is unsupported, because there is no discussion of changes in the harbor since the 1990s that have allegedly impacted currents and no new data showing that currents have changed since 1993. Available aerial photos from 1966, 2003, and 2016 were evaluated for changes that may have occurred along the shoreline that could have impacted currents. There is evidence of some construction and alternation to docks and berthing structures over time, which could alter local current patterns (i.e., in the immediate vicinity of the in-water structure). However, none of these alterations were in the vicinity of the JCO, and none would impact currents harborwide given the size and cross-sectional area (based on the width and depth) of the harbor, and the insignificant relative area that a structure such as a dock within the harbor occupies within the harbor cross-section.

The draft Fact Sheet presents results from a mixing model performed by EPA with the CORMIX model. CORMIX is a mixing model that is commonly used to support mixing zone evaluations in support of NPDES applications; however, it is one of several mixing models that can be used for a mixing evaluation. CORMIX was previously distributed and supported by EPA,[4] but now is only available commercially through a private vendor. The draft Fact Sheet presents a modeling evaluation performed by EPA using a single set of inputs, purportedly the same inputs used in one of the model scenarios presented in the MZA. However, the model inputs used in the CORMIX model scenario differ from those used in the MZA.

Importantly, a uniform vertical density profile is used in the EPA model, compared with a weakly stratified density profile in the MZA modeling. This deviation has significant impact on

[4] https://www.epa.gov/ceam/cormix

model predictions of initial mixing. In the absence of density stratification, or vertical variation in water column density, a plume will always be predicted to rise to the water surface, regardless of model selection or other model input parameters (e.g., effluent characteristics, ambient velocity).

The MZA model scenario that EPA allegedly replicated with CORMIX represented a weakly stratified vertical density profile (approximately 0.07 kg/m^3 difference between surface and bottom water density). CORMIX does not have the capability to represent small variations in vertical density profiles.[5] EPA assumed a uniform density profile, possibly because of this model limitation, to allow the CORMIX model to perform calculations. This simplification neglects the observed density stratification found in Pago Pago Harbor. The absence of the density gradient in the water column will inaccurately represent the initial plume dynamics of the discharge, and thus CORMIX is an inappropriate choice of model to represent the observed conditions.

EPA used this single model scenario for the basis of the permit limits, selected from the set of model scenarios performed in the MZA, because it resulted in the maximum predicted plume rise. EPA criticized the MZA modeling for its inability to capture observed conditions, and yet relied on the MZA results as the basis for its modeling evaluation (specifically, to identify the condition of interest, or critical condition). A valid modeling evaluation should include model results that characterize the range of predicted responses of the model to observed conditions such that the model behavior is well understood and the condition(s) of interest are appropriately identified.

To establish permit limits, EPA arbitrarily selected a depth of 5.2 m below the water surface as the location where water quality standards must be met, and selected the CORMIX-predicted dilution at this depth as the allowable dilution and the basis for the load limits. There is no justification for selection of this water depth, because there is no definition of "water surface" in the ASWQS. Further, if a set of model scenarios had been performed, as discussed above, a range of dilution values would be predicted at this depth.

It is unclear what the allowable size of the mixing zone is in the draft permit. The required monitoring program specifies water quality sampling at both 1,300 ft (the 2007 mixing zone boundary) and 981 ft (the MZA requested mixing zone boundary). The CORMIX results indicate that the water quality standards are not met at the previous or requested mixing zone, which is inconsistent with the recent water quality data collected over the past 2 years, where observed concentrations at those locations were below the water quality standards (gdc 2018b, c, d). The fact that the CORMIX model results are not consistent with the observed data

[5] One of the simplifying assumptions in the CORMIX model is the representation of density profiles; the model includes three options to represent density profiles, and for all options, the minimum density difference that can be specified between the surface and bottom of the water column is 0.1 kg/m^3.
http://www.cormix.info/ambdensityprofiles.php

indicates that the model is not validated, and should not be relied upon for establishment of permit limits.

4 STARKIST MODELING

In support of the permit renewal application, Starkist performed an extensive evaluation of the discharge mixing into Pago Pago Harbor (gdc 2017, 2018a). This evaluation includes review of available data describing the effluent, the discharge configuration, and ambient receiving waters. A modeling evaluation was performed using UDKHDEN, a mixing model included in an EPA modeling suite for mixing evaluations (Muellenhoff et al. 1985).[6] The UDKHDEN model was applied successfully to support the approved Starkist NPDES application in 2006, and was applied in a similar manner in the MZA. The UDKHDEN model predicts initial mixing and critical initial dilution. Model output includes trapping level (i.e., the depth below the water surface that the plume rises to), maximum plume rise, and dilution at these locations.

In the 2017 MZA, UDKHDEN was applied to a set of 22 UDKHDEN model scenarios developed to represent the range of observed ambient water column temperatures and salinity in data collected from 2008 to 2015. These vertical profiles were collected at Station 16, located in the outer harbor and selected to provide the best background data for density profiles (gdc 2017). Observed ambient profiles at this location had surface to bottom density differences ranging from 0.06 to 1.3 kg/m^3. All UDKHDEN model scenarios included a uniform ambient current of 2 cm/s (representative of the 10th percentile current, based on the data collected in the 1993 and 1994 dye studies). The model predicted trapping depths ranging from 9.5 to 43 m below the water surface, and predicted dilution at the trapping depth location ranging from 1822 (at trapping depth of 9.5 m) to 170 (at trapping depth of 43 m) (gdc 2017, Exhibit 7-2). The shallowest trapping depth is predicted for the density profile with the smallest difference between surface and bottom densities, and the deepest trapping depth is predicted for the density profile with one of the largest differences between surface and bottom densities.

4.1 COMPARISON OF EPA CORMIX AND 2017 MZA UDKHDEN MODEL RESULTS

The draft Fact Sheet criticizes the MZA modeling for failure to reproduce “observed” plume surfacing, and presents an alternative modeling approach using the CORMIX model that does predict plume surfacing, as discussed above. A comparison of CORMIX and UDKHDEN was performed to compare model behavior (gdc 2019). This model comparison shows that, when the uniform density profile used by EPA in CORMIX is input in UDKHDEN, the UDKHDEN model predicts the plume surfacing, consistent with the EPA CORMIX predictions. In other words, both models predict a plume that reaches the water surface when a uniform ambient

[6] ASWQS specify the use of the PLUMES model UM for evaluation of initial mixing. This model is no longer included in the most recent version of EPA’s Visual Plumes model system (an update to PLUMES), and was replaced by the UM3 model. The model system includes DKHW, which is based on UDKHDEN. CORMIX is not included in the EPA Visual Plumes model system.

density profile is assumed. This result can be compared to the set of UDKHDEN model scenarios presented in the MZA, where all scenarios represent the observed stratification, and all scenarios predict plume trapping. To evaluate the CORMIX model predictions for stratified water column conditions, Integral ran the CORMIX model with the input parameters used in the MZA, and with a density stratification representative of typical profiles presented in the MZA.[7] The results showed that the plume was trapped below the water surface. These comparisons demonstrate that the two models result in consistent prediction when the inputs are consistent.

The importance of using a model capable of capturing observed conditions is paramount to develop representative and reliable model predictions. UDKHDEN has the capability to represent the observed, weakly stratified ambient density profile, while CORMIX does not have this capability. Accurately representing the ambient density stratification is necessary to represent the initial mixing processes of a discharged effluent when buoyancy is the dominant force.

[7] The vertical density profile used in CORMIX had a density variation greater than 0.1 kg/m3 to overcome the model limitations, which was representative of the majority of the observed profiles.

5 CONCLUSION

Hydrodynamics in Pago Pago Harbor are characterized by a small tidal range and low currents, predominantly driven by wind (at and near the surface) and wind waves. Multiple measurements of water column salinity and temperature over more than 10 years show the presence of density stratification in all conditions. Data collected in the outer harbor (representative of background conditions, appropriate for consideration of mixing) showed weak stratification (assumed to be less than 0.1 kg/mg^3) in one of 32 measurements, and all of the other measurements showed stronger stratification. A screening-level, 3-dimensional, time-varying hydrodynamic model was developed to characterize typical currents in Pago Pago Harbor. This model shows that currents are variable, decreasing with depth, and are in the range of those observed in the 1993 and 1994 dye studies, validating the characterization of ambient currents used in the MZA (and suggesting that the MZA may have used a conservative representation of ambient currents). An accurate characterization of the ambient conditions and their accurate representation in a numerical model is essential for valid model results.

The model used by EPA to establish nutrient load limits specified in the draft Starkist NPDES permit includes simplifying and erroneous assumptions and does not provide a valid basis for the permit limits for the following reasons:

- The CORMIX model evaluation is based on a single model result from the MZA, identified as the condition of interest (specifically, the result showing the highest plume rise), yet EPA alleges that the MZA model is flawed. The EPA model evaluation did not include a set of model scenarios to characterize how the CORMIX model represents the plume behavior in response to varied observed conditions, an important element of a thorough model evaluation, particularly given the differing results from different mixing models.
- The model results are not consistent with the observed data. The EPA model predicts that water quality standards are not met at the potential mixing zone boundaries, but water quality data collected in multiple recent surveys showed that water column concentrations were below water quality standards at these locations.
- EPA disregards the vertical density stratification consistently observed in Pago Pago Harbor, which is a significant driving force controlling initial mixing of the discharge plume. The CORMIX model is not capable of representing the weak density gradients observed in the harbor. The model inputs used in CORMIX are not characteristic of the observed conditions they were attempting to capture, and result in model predictions that are not representative of expected plume behavior.
- The permit limits are established to ensure that the plume does not rise to the water surface, and are based on an arbitrary water depth as the location where the water quality standards must be achieved.

The UDKHDEN model presented in the MZA provides a more realistic representation of initial plume mixing and dilution because of its ability to account for weak density gradients. The MZA modeling was performed for a range of conditions to characterize the range of responses. The UDKHDEN model results show that the plume is routinely trapped below the water surface in the modeled scenarios presented in the MZA, even in weakly stratified conditions. This detailed evaluation of initial mixing using a large set of available data provides a stronger basis for development of permit limits than the single, simplified model run performed by EPA.

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Starkist Samoa Co.
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ATTACHMENT C

JOINT CANNERY OUTFALL UDKHDEN-CORMIX COMPARISON

Prepared For: Starkist Samoa Company (NPDES Permit No. AS0000019)

Prepared By: gdc, PO. Box 1238, Trinidad, CA 95570
707-677-0123 – glatzeldacosta@suddenlink.net

Date: August 13, 2019

SUMMARY

The National Pollutant Discharge Elimination System (NPDES) permit renewal applications for Starkist Samoa Co. (SKS) and Samoa Tuna Processors, Inc. (STP) were based partially on the *Revised Request for Water Quality Certification and Definition of Mixing Zones for the Joint Cannery Outfall* and *the Amendment to the Request for Water Quality Certification and Definition of Mixing Zones for the Joint Cannery Outfall*, submitted to the American Samoa Environmental Protection Agency (ASEPA) on March 25, 2017 and June 19, 2018, respectively (the MZA). The initial dilution model used to predict the effluent plume behavior on which the MZA was based was the United States Environmental Protection Agency's (USEPA's) model UDKHDEN. During the permit renewal process and the development of draft NPDES permits USEPA used another model (CORMIX) to evaluate the discharge plume behavior as reported in an USEPA Inter-office Memorandum. According to USEPA, the CORMIX modeling purportedly used the same input values as the original UDKHDEN model and predicted significantly different plume behavior. However, upon review of information provided by USEPA, USEPA did not use the same input values as the MZA UDKHDEN model. The differences between the CORMIX model run and a UDKHDEN model run using USEPA's CORMIX input values are compared and described in this Technical Memorandum.

The primary purpose of the USEPA CORMIX modeling appears to be in support of, largely unsupported, reports of "numerous" possible effluent plume surfacing in Pago Pago Harbor. Such frequent surfacing was not observed over many decades of receiving water quality sampling in the Harbor by CH2M HILL (now Jacobs Engineering Group) and gdc, including personal observations by the author of this Technical Memorandum and as documented in receiving water quality monitoring reports. The input used in the CORMIX model was structured in a manner that ensures that surfacing was predicted (a constant water column density). When the same inputs including a constant density profile are used in UDKHDEN, surfacing is also predicted. However, when actual field data for vertical density structure is used in UDKHDEN, the plume remains submerged with lower predicted initial dilution. The purpose of the MZA, as with any mixing zone analysis, was to identify the most critical condition (lowest initial dilution, used to define the mixing zone geometry) under the range of known ambient and discharge conditions), which is generally *not* a condition that is predicted to result in a surfacing plume condition. In fact, the USEPA CORMIX modeling indicates significantly higher initial dilution than the MZA UDKHDEN modeling for

the critical case. Furthermore, USEPA only used a single density profile and made no effort to determine the critical case nor justify that a surfacing plume would be the critical case.

INTRODUCTION

A *Revised Request for Water Quality Certification and Definition of Mixing Zones for the Joint Cannery Outfall* and *the Amendment to the Request for Water Quality Certification and Definition of Mixing Zones for the Joint Cannery Outfall* (the MZA) were submitted to the American Samoa Environmental Protection Agency (ASEPA) on March 25, 2017 and June 19, 2019, respectively in support of The National Pollutant Discharge Elimination System (NPDES) permit renewal applications for StarKist Samoa Co. (SKS) and Samoa Tuna Processors, Inc. (STP). The United States Environmental Protection Agency's (USEPA's) initial dilution model UDKHDEN was the basis of the mixing zone definitions developed in the MZA.

In evaluating a discharge's effect on water quality, the appropriate conditions to consider are those that result in the lowest dilution, this results in the "worst case" or, as referenced here, the "critical case". Such conditions result in the highest concentrations of effluent constituents in the receiving water after the effluent is diluted.[1] The MZA presents the initial dilution modeling for a range of observed vertical density profiles to select the conditions that provided the lowest dilution and thus highest effluent concentration at the plume trapping level (critical condition)[2]. The critical condition must be defined to be able to develop the geometry (size and dimensions) of the appropriate mixing zones. This was Case U23a and U23b for the 2-inch and 5-inch ports on the diffuser, respectively[3]. The lowest dilution combined with the background concentration of a particular constituent (in this case total nitrogen and/or total phosphorus) is used to define a mixing zone of sufficient size that the water quality criteria will be met at the edge of the mixing zone under all scenarios, thus it is the defining or critical case. Higher dilutions would result in mixing zone definitions (geometries) for which violations could be expected at the edge of the mixing zone defined by those conditions. The case of a surfacing plume may also be considered a "critical" condition, and this is discussed in more detail below.

USEPA used another model (CORMIX) to evaluate the discharge plume behavior as reported in an USEPA Interoffice Memorandum (IM)[4]. According to the IM, the CORMIX modeling used the same input values as the original UDKHDEN model and predicted significantly different plume behavior. However, upon careful review, USEPA *did not use the same input values* as the original UDKHDEN model. The differences between the model runs and a UDKHDEN model run using USEPA's CORMIX input are described in this Technical Memorandum (TM). Furthermore, USEPA *did not compare CORMIX to UDKHDEN using the crit-*

[1] For further discussion see: *Initial Mixing Characteristics of Municipal Ocean Discharges* (Section 2). EPA/66/3-85/073a.

[2] The 10th percentile of the dilution results was selected as the critical condition rather than the absolute lowest dilution because of the large number of cases available to run.

[3] Cases referred to here are those model input/output designators defined in the initial (2017) MZA. See Section 7 of the document and/or Appendix 2.

[4] Interoffice Memorandum: to Pascal Mues, USEPA R9 from Craig Hesterlee, USEPA R4, June 14, 2019.

ical conditions (lowest predicted dilution) defined in the MZA, but rather to the UDKHDEN case that predicted the highest initial dilutions (Case U16b)[5]. Therefore, since the purpose of a mixing zone analysis is to identify the conditions that present the lowest level of dilution in order to define the mixing zone, the results of the CORMIX modeling are *not applicable to definition of mixing zones*, even if these CORMIX results were to be used. A screening level exercise using CORMIX would be required to determine the critical conditions.

According to USEPA, case U16b was selected simply because it came the closest to the surface for the UDKHDEN modeling (not because it represented the critical case of lowest predicated initial dilution). The primary purpose of the USEPA CORMIX modeling appears to be in response to reports of "numerous" potential effluent plume surfacing in Pago Pago Harbor and appears to be an attempt to "prove" such reports are justified. This is reflected in choosing the MZA model conditions that come closest to the surface. It is noted that such frequent surfacing is not documented in the field data logs over many decades of sampling in the Pago Pago Harbor by CH2M HILL (now Jacobs Engineering Group) and gdc. The physics of plume dynamics mandates that the effluent plume will surface if the ambient vertical density gradient is essentially constant because at the point of discharge the plume starts less dense than the receiving water and can never entrain surrounding receiving water that will make it denser than the surrounding receiving water. Very infrequent surfacing has been observed and documented for this discharge or the other discharge in Pago Pago Harbor from ASPA's Utulei diffuser.

Although the plume may surface infrequently, the ASWQS are expected to be achieved under such circumstances based on the specification of TN and TP criteria as frequency distributions rather than a single number [ASWQS §24.0206 (m)]. The ASWQS criteria for TN and TP include the criteria in Table 1 for Pago Pago Harbor:

Table 1. ASWQS Criteria for TN and TP

Parameter	Median (not to exceed)	Not to exceed more than 10% of the time	Not to exceed more than 2% of the time
Total Nitrogen (TN) (µg/l as N)	200	350	500
Total Phosphorus (TP) (µg/l as P)	30	60	90

The concentration of TN can be above 500 µg/l for short periods, and the concentration of TP can be above 90 for short periods of time. Therefore, the frequency of surfacing could be considered a "secondary" critical condition and *field recorded* observations of the frequency of surfacing (< 2% of the time) have indicated ASWQS will be achieved when the plume surfaces based on the dilution predicted by the model just below the surface. Therefore, it is the submerged plume critical condition that is of primary importance. The mixing zone was sized so the median values would be met at the edge of the mixing zone under conditions of a submerged plume, which is a conservative approach.

[5] The USEPA CORMIX model was run only for the 5-inch ports, which is representative of the diffuser since the single 2-inch port has little effect on the overall initial dilution.

The input used in the CORMIX model (based on MZA case 16b) was structured to ensure that surfacing was predicted, and when the same input is used in UDKHDEN, surfacing is also predicted. In fact, if a constant density profile, as used by USEPA, is considered, any initial dilution model will predict a surfacing plume regardless of the other input variables. It is noted that the MZA was based on finding the most critical condition (i.e. lowest initial dilution) which is a circumstance that is not consistent with a surfacing plume. In fact, the USEPA CORMIX modeling for Case U16b indicates significantly higher initial dilution than the 2017 MZA UDKHDEN modeling for Case U23b.

The CORMIX modeling done by USEPA also considers subsequent dilution following initial dilution. The MZA used a somewhat different approach. This TM only considers the initial dilution predictions of the two models. Consideration of subsequent dilution for the Case U16b is not meaningful at this point because, EPA terminates the consideration before initial dilution is complete and, regardless of the initial dilution model used, *Case U16b is not the critical condition* providing the lowest initial dilution and cannot be used to define the mixing zone).

MODEL INPUT

A summary of model input conditions used by USEPA is provided in Table 1. Additionally, for this TM, a UDKHDEN model run was performed using the input conditions used for the U16b-CORMIX runs done by USEPA. *Although USEPA's IM indicates the input to CORMIX was the same as used in the MZA, this is not actually the case*. The major differences in the inputs used by USEPA compared to the MZA modeling are shaded entries in Table 2. The columns in Table 2 show:

- A: The input used in the MZA modeling for Case 16b
- B: The input used by USEPA in their CORMIX simulation of Case 16b – differences from Colum A are noted
- C: The input used in this TM in UDKHDEN rather than CORMIX (identical to column B).

The most important input difference between the MZA UDKHDEN and the USEPA CORMIX model simulations is the use of a constant ambient vertical density profile described above. *This strongly biased the CORMIX results and disregards the purpose of assessing site-specific critical conditions, and in fact, prevents the determination of the critical dilution*. Based on many years of receiving water sampling, and as reflected in receiving water quality monitoring reports, site-specific data constant density gradient is not typical, and is rarely seen at the discharge site.

Table 2. Model Input Parameters

Parameter	Case and Model		
	A: U16b – UDKHDEN Used in the MZA	**B: U16b – CORMIX 2019 USEPA IM**	**C: U16bCM – UDKHDEN (This TM)**
Effluent Flow (m^3/sec)	0.1836	0.1836	0.1836
Effluent Density[a] (kg/m^3)	999.5139[b]	996.2600	996.2600
Discharge Depth (m)	53.6 m	53.6 m	53.6 m
Ambient Current (m/sec)	0.02	0.02	0.02
Ambient Density[c,d]	Profile[e]	1023 kg/m^3	1023 kg/m^3
Number of Ports	6	6	6
Port Diameter (m)	0.127	0.127	0.127
Port Angle (degrees from horizontal)	15	15	15
Port Spacing (m)	30.55	15.24	15.24

[a] The IM says the effluent density used was 999.54 kg/m^3. However, the CORMIX I/O provided shows the effluent density used was 996.2600 kg/m^3. The value used in the model is consistent with freshwater and the value indicated in the IM is consistent with the salinity of the effluent used in the MZA.
[b] The UDKHDEN input was in terms of effluent salinity and temperature, express as density in this table.
[c] Constant density throughout the water column.
[d] The average density through the water column was 1022.90 kg/m^3 or about the same as used by USEPA rounded to 1023 kg/m^3.
[e] Using a density profile as shown in Attachment A.

A primary input variable with significant effect on the dilution and plume behavior results of any dilution model *in a marine environment*, is the vertical density profile. The USEPA IM states that the CORMIX simulation of the MZA UDKHDEN Case U16b was based on a uniform density gradient of 1.023 g/cm³. However, the MZA density gradient for Case U16b was not constant but varied from 1.02311 g/cm³ at the bottom to 1.02305 g/cm³ at the surface[6]. Although this was the weakest density gradient among the data set used for the MZA, the variation is sufficient to trap the plume below the surface.

Case U16b was selected by USEPA because it rose highest in the water column. This case provided the highest dilution of the twenty-two (22) the MZA screening level model runs under UDKHDEN. For comparison, the critical case (lowest initial dilution) identified in the MZA (Case U23b) had a density gradient of 1.02338 g/cm³ at the bottom to 1.02242 g/cm³ at the surface, but the average was 1.023 g/cm³ when rounded to the same number of decimal places as used by USEPA for CORMIX model runs. In fact, 16 of the twenty-two (22) screening level model runs had average vertical densities that round to 1.023 g/cm³. If all of these profiles were used in USEPA's CORMIX setup, all of runs would have exactly the same input and yield exactly the same results – including the MZA's highest and lowest dilution predictions[7]. This demonstrates

[6] The average density gradient for this case was 1.02310 g/cm³, which was rounded to 1.023 g/cm³ for the CORMIX modeling.

[7] The remaining model runs had average density gradients (rounded as done by USEPA) of 1.022 g/cm³ (3 cases) and 1.024 g/cm³ (3 cases), and would also yield results essentially the same as the USEPA selected case.

of utilizing a model in a manner that makes use of important significant digits (as with Starkist's UDKHDEN modeling) and not rounding off prematurely (as was done for CORMIX since it cannot accommodate fine density gradient differences). The density gradients used in the MZA are provided as Attachment A.

The small differences in density described here may seem unimportant. However, *the vertical density profile controls the effluent plume behavior for a given flow and diffuser configuration*. Small differences in density with depth are important on a case specific basis for evaluation of plume trapping, initial dilution, and determining potential concentrations of parameters of concern. Selecting a model that can predict when dilution will be decreased due to plume trapping is critical and is not included in the CORMIX model as implemented by USEPA for this case.[8]

MODEL RESULTS

Model results for the USEPA CORMIX model were reviewed and compared to the UDKHDEN model run for *the same input values used by USEPA in the CORMIX model for the case considered*. As mentioned above, although USEPA indicated the CORMIX model used the same inputs as the MZA UDKHDEN model, this was not the case.

USEPA CORMIX RESULTS

The USEPA CORMIX simulation resulted in a surfacing plume with an initial dilution of 393:1 as the plume approached the water surface. The CORMIX model did not predict plumes from individual ports merging prior to encountering the surface as predicted by UDKHDEN for the same inputs. Since the vertical density gradient was constant *surfacing was inevitable*. The rapid rise through the water column and lack of plume merging is attributable, at least in part, attributable to the initial portion of the CORMIX plume being poorly simulated by the model for a marine environment. The CORMIX predicted initial dilution just after discharge assumes a line source for the diffuser discharge rather than discreet ports, which consequently does not adequately account for density variations near the point of discharge as is observed in this case. USEPA appears to have selected a depth of 17.6 feet below the surface as the point where initial dilution should be determined for use in the compliance assessments for total nitrogen and total phosphorus (see the draft NPDES permit and associated draft fact sheet). Based on a notation in the USEPA supplied CORMIX output file (contained in administrative record), the apparent rationale for this selection appears to be that it is the trapping level, predicted by UDKHDEN, for some previous modeling done for the Utulei Sewage Treatment Plant across the Harbor from the StarKist discharge, which would appear to be an arbitrary basis for selection.

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[8] CORMIX does have the ability to use a non-uniform density constant gradient (constant slope of density versus depth), but USEPA chose a uniform density (constant density throughout the water column) with depth in this case. However, even a constant gradient is not necessarily a good choice for marine systems where the gradient itself varies over distance and small changes in density near the bottom can be extremely important. It is noted that the initial dilution element of CORMIX (CORJET) can handle more complex density gradients when run outside of the CORMIX environment, and perhaps would have been a better choice for comparison to UDKHDEN for this exercise.

STARKIST UDKHDEN RESULTS

The results for the UDKHDEN case in Table 2 (U16bCM – UDKHDEN) using the USEPA CORMIX inputs (U16b – CORMIX) resulted in a surfacing plume as well, as would be expected[9]. The output file is provided in Attachment B. However, the UDKHDEN simulation predicts merging individual port plumes and a dilution as the plume approaches the surface of 1325:1 (approximately 3.5 times the CORMIX prediction). The UDKHDEN dilution is similar to, but less than, dilutions measured in Pago Pago Harbor during one of the two past dye studies under conditions when the effluent plume came close to, or was considered to be surfacing, for a short period of time during the study. During that study the plume appeared to surface based on the measurement of the injected dye and some dye tracer seen on the surface. However, the "surfacing" event was relatively short lived (from a few minutes to a few hours) and the plume was submerged both before and after that observation.

COMPARISON OF MODEL RESULTS

Dilution, horizontal distance, and vertical distance as a function of time for the USEPA CORMIX and UDKHDEN plume simulations using USEPA model inputs are shown in Figures 1 through 3. Dilution as a function of depth is shown in Figure 4. Note that plume merging was predicted at approximately 62 to 72 seconds along the plume trajectory for the UDKHDEN model run.

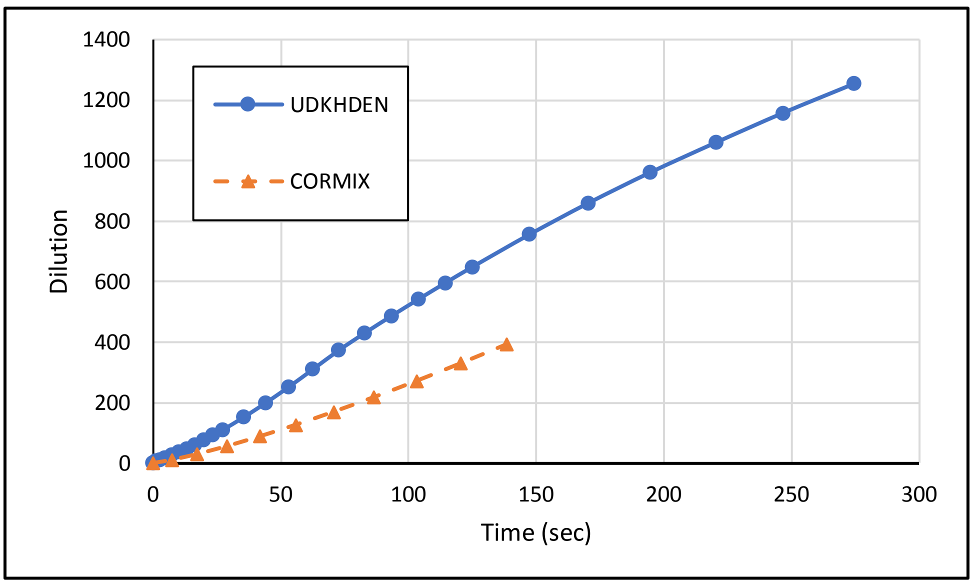

Figure 1. Dilution versus Plume Travel Time

[9] USEPA has criticized the use of UDKHDEN as predicting a non-surfacing plume. However, under a constant density profile any initial dilution model *must* predict a surfacing plume for a buoyant discharge. However, it is noted that the field sampling data does not have any recent profiles for which a surfacing plume would be predicted.

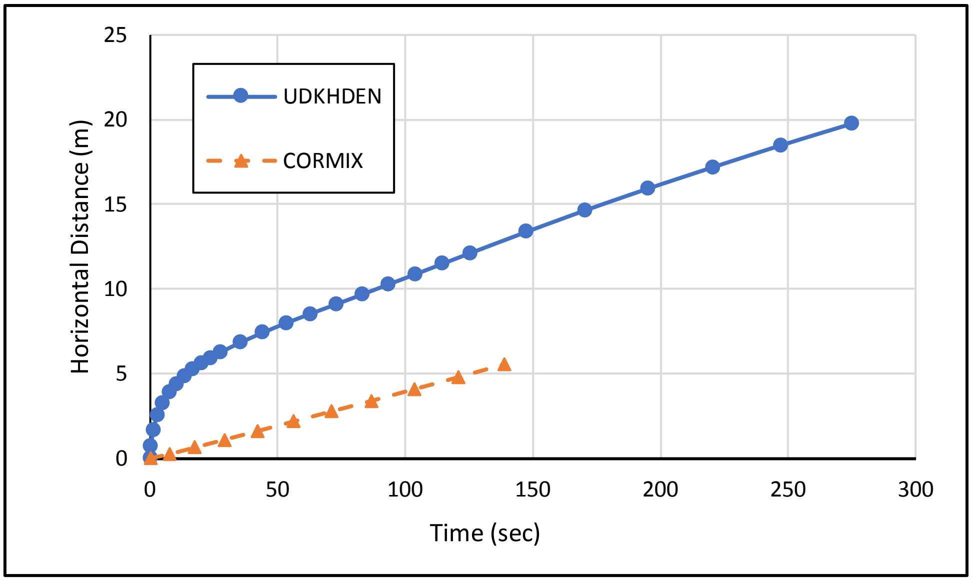

Figure 2. Horizontal Distance versus Plume Travel Time

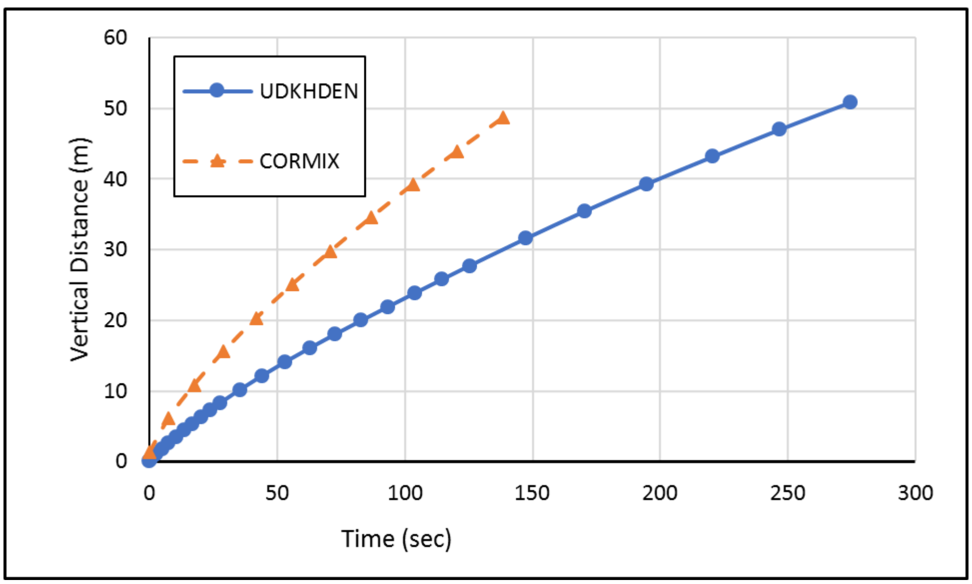

Figure 3. Vertical Distance versus Plume Travel Time

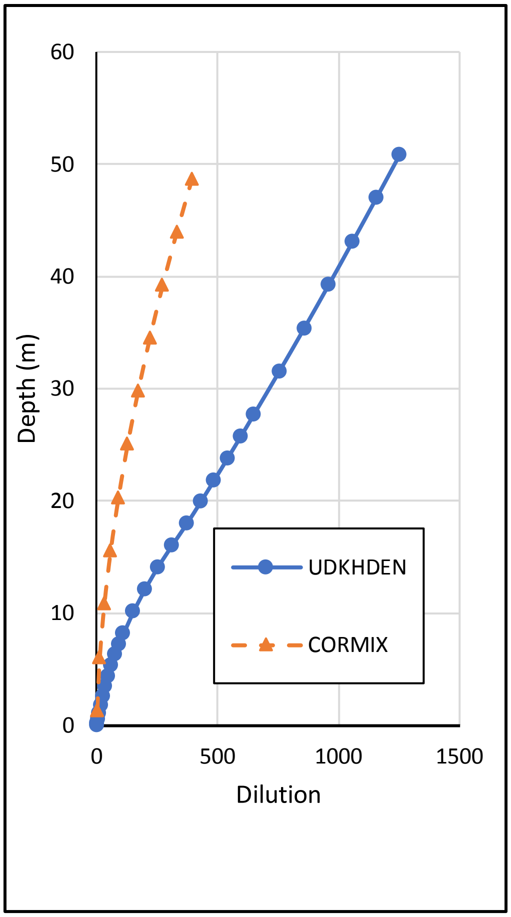

Figure 4. Dilution versus Depth

As demonstrated in these figures, the UDKHDEN simulation shows higher dilutions and extended distances and travel times compared to CORMIX for the same input conditions in Figures 1-4. This attributable to the fact that the UDKHDEN model performs more calculations immediately after discharge (in the zone of flow establishment) and much of the difference in initial dilution of the two models originates during this time. CORMIX does not perform as well as UDKHDEN in this region of plume development.[10] Therefore, UDKHDEN is a more representative model for initial dilution in marine systems even under conditions of plume surfacing. It is noted that the UDKHDEN predictions are consistent with the observations made during the dye studies and during other dye studies done over the last few years for effluent discharge from multiport diffusers in Puerto Rico

SUMMARY

The CORMIX simulation run by USEPA indicates that the plume surfaces, as it must for the input lacking any density gradient. Using the approach USEPA selected for density input into the

[10] Davis, Lorin R. Fundamentals of Environmental Discharge Modeling. CRC Press, 1999. See various descriptions of CORMIX/CORJET throughout this reference.

CORMIX model, all of the the MZA cases also would, of course, surface, and most of them (16 of 22) will give identical results for all parameters. The other six cases would very likely give similar results for dilution and plume geometry. In fact, CORMIX, as implemented by USEPA in this case, essentially predicts that the plume would surface virtually all of the time. Considering the time period and variability over which the actual density profiles have been collected and the experience of the receiving water monitoring team in the field – surfacing plumes all of the time is *not a reasonable model prediction*. An actual surfacing plume has only been noted once since 2008, and plume expressions on the surface have only been noted a few times.[11]

The UDKHDEN run using the same input as used by USEPA for the CORMIX simulation also, of course, resulted in a surfacing plume. Dilutions predicted by UDKHDEN are approximately 3.5 times higher than those predicted by CORMIX as discussed above in the absence of a density gradient.

In the the MZA UDKHDEN was run for a range of observed conditions to determine the worst case (lowest) critical initial dilution (CID), including actual density profiles from the vicinity of the discharge. The lowest CID will occur generally at the deepest trapping level of the plume because those conditions will inhibit dilution. It is not the case that UDKHDEN will not predict a surfacing plume, as shown in this TM, when a constant density profile is used. However, the advantage of UDKHDEN over CORMIX is that it will accept non-uniformly distributed weak vertical density gradient data, which is necessary to determine dilutions in a stratified environment as observed in Pago Pago Harbor. CORMIX does not have this capability, and the difference in the modeling results demonstrates that this lack of capability impacts the results, and the usefulness of the results, produced by the model. As such, the use of CORMIX was unreasonable in the face of a long-term site-specific data demonstrating the presence of a weak vertical density gradient.

CORMIX is used more often, and with success, in riverine and lacustrine environments and in rectangular channels and thermal surface discharges. CORMIX is not generally a model of choice for marine environments, for many of the reasons provided in this TM; see Dr. Davis' book referenced above for more discussion on this point. The reader is referred to the CORMIX website where reviews of CORMIX validation studies, which are typically not stratified marine environments. UDKHDEN has been validated (as conservative) in 12 studies in Pago Pago Harbor and coastal Puerto Rico.

[11] The plume can show a surface expression because of upwelling (vertical velocity) and under weak stratification conditions. The actual plume remains submerged. Such "boils" have been sampled in other locations, for example on the coast of Puerto Rico, and the results indicate uncontaminated receiving water; that is the plume remains submerged even though there is a surface signature.

Attachment A
Density Gradients Used in the the MZA Modeling

	2017 MZA Model Run Designator and Date of Density Profile Measurement							
Depth (m)	U11	U12	U13	U14	U15	U16	U17	U18
	5/3/2008	8/1/2008	2/1/2009	9/1/2009	2/1/2010	9/1/2010	3/1/2011	8/1/2011
0	1.02228	1.02351	1.02351	1.02282	1.02248	1.02305	1.02263	1.0237
5	1.02229	1.02354	1.02354	1.023	1.02275	1.02308	1.02279	1.02372
10	1.02233	1.02356	1.02356	1.02314	1.02282	1.02309	1.02286	1.02373
15	1.02238	1.02359	1.02359	1.02324	1.02284	1.0231	1.0229	1.02374
20	1.02243	1.02361	1.02361	1.02328	1.02288	1.0231	1.02294	1.02376
25	1.02244	1.02362	1.02362	1.02331	1.02291	1.0231	1.02293	1.02377
30	1.02244	1.02363	1.02363	1.02332	1.02293	1.0231	1.02295	1.02377
35	1.02246	1.02363	1.02363	1.02332	1.02296	1.02311	1.02295	1.02377
40	1.0225	1.02363	1.02363	1.02332	1.02301	1.02311	1.02297	1.02378
45	1.02253	1.02364	1.02364	1.02332	1.02318	1.02311	1.02298	1.02379
50	1.02253	1.02364	1.02364	1.02332	1.0233	1.02311	1.023	1.02379
55	1.02253	1.02364	1.02364	1.02332	1.02348	1.02311	1.02307	1.0238
Minimum	1.02253	1.02364	1.02364	1.02332	1.02348	1.02311	1.02307	1.0238
Average	1.02243	1.02360	1.02360	1.02323	1.02296	1.02310	1.02291	1.02376
Maximum	1.02228	1.02351	1.02351	1.02282	1.02248	1.02305	1.02263	1.0237
Delta	0.00025	0.00013	0.00013	0.0005	0.001	6E-05	0.00044	1E-04
Average	1022	1024	1024	1023	1023	1023	1023	1024
Depth (m)	U19	U20	U21	U22	U23	U24	U25	
	3/11/2012	3/30/2013	8/11/2012	8/25/2013	3/23/2014	3/23/2014	3/24/2014	
0	1.02287	1.02294	1.02223	1.02217	1.02242	1.02237	1.02237	
5	1.02317	1.02302	1.02235	1.02243	1.02246	1.02244	1.0225	
10	1.0232	1.02308	1.02239	1.02246	1.02251	1.02252	1.02259	
15	1.02323	1.02311	1.0224	1.02247	1.02254	1.02254	1.02264	
20	1.02325	1.02312	1.02245	1.02248	1.02265	1.02264	1.02269	
25	1.02328	1.02313	1.02252	1.02248	1.02267	1.02271	1.02272	
30	1.02329	1.02313	1.0226	1.02249	1.02272	1.02276	1.02275	
35	1.02333	1.02314	1.0227	1.02249	1.02277	1.0228	1.02278	
40	1.02342	1.02314	1.02278	1.0225	1.02283	1.02286	1.02283	
45	1.02349	1.02315	1.0229	1.02252	1.02291	1.02291	1.02286	
50	1.02364	1.02315	1.02298	1.02253	1.02305	1.02301	1.02298	
55	1.02384	1.02316	1.02309	1.02256	1.02338	1.02314	1.02303	
Minimum	1.02384	1.02316	1.02309	1.02256	1.02338	1.02314	1.02303	
Average	1.02333	1.02311	1.02262	1.02247	1.02274	1.02273	1.02273	
Maximum	1.02287	1.02294	1.02223	1.02217	1.02242	1.02237	1.02237	
Delta	0.00097	0.00022	0.00086	0.00039	0.00096	0.00077	0.00066	
Average	1023	1023	1023	1022	1023	1023	1023	
Depth (m)	U26	U27	U28	U29	U30	U31	U32	
	3/24/2014	3/25/2014	8/17/2014	8/17/2014	2/8/2015	2/8/2015	8/16/215	
0	1.0224	1.02232	1.02262	1.02251	1.02165	1.02166	1.02235	
5	1.02255	1.02246	1.02274	1.02272	1.02169	1.02173	1.02285	
10	1.02261	1.02249	1.02276	1.02279	1.02171	1.02176	1.0229	
15	1.02267	1.02252	1.02278	1.0228	1.02173	1.02177	1.02293	
20	1.02271	1.02254	1.02279	1.02281	1.02176	1.02178	1.02294	
25	1.02275	1.02259	1.0228	1.02283	1.02177	1.0218	1.02295	
30	1.02278	1.02262	1.0228	1.02284	1.02178	1.02182	1.02296	
35	1.02284	1.02266	1.02281	1.02284	1.0218	1.02187	1.02297	
40	1.02295	1.02273	1.02282	1.02284	1.02186	1.022	1.02298	
45	1.02304	1.0229	1.02283	1.02285	1.02193	1.02208	1.02298	
50	1.02311	1.02301	1.02284	1.02286	1.02204	1.02218	1.02299	
55	1.02325	1.02334	1.02287	1.02286	1.02214	1.02235	1.02299	
Minimum	1.02325	1.02334	1.02287	1.02286	1.02214	1.02235	1.02299	
Average	1.02281	1.02268	1.02279	1.02280	1.02182	1.02190	1.02290	
Maximum	1.0224	1.02232	1.02262	1.02251	1.02165	1.02166	1.02235	
Delta	0.00085	0.00102	0.00025	0.00035	0.00049	0.00069	0.00064	
Average	1023	1023	1023	1023	1022	1022	1023	

Attachment B
UDKHDEN Model Run with USEPA CORMIX Inputs

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                         PROGRAM UDKHDEN
              SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
              AMBIENT CURRENTS AND VERTICAL GRADIENTS.   AUG 1985

 UDKHDEN CH2MHILL Version 2.2 (1-24-89)
 UNIVERSAL DATA FILE: u16bcm.in
 CASE I.D. JCO the MZA with USEPA CORMIX Input -4.3 mgd total-six 5 in port at 4.19 mgd
           Station 16 – March 23, 2014
 DISCHARGE= 0.1836 CU-M/S  DENSITY=0.99626 G/CM3  ** DIAMETER= 0.1270-M
 ** NUMBER OF PORTS=   6  ** SPACING=  15.24-M  ** DEPTH    =  53.68-M

       AMBIENT STRATIFICATION PROFILE
  DEPTH (M)    DENSITY (G/CM3)   VELOCITY (M/S)
      0.00        1.02300          0.020
     55.00        1.02300          0.020

FROUDE NO= 13.22,  PORT SPACING/PORT DIA=    120.00
                                                        STARTING LENGTH=    0.750

 ALL LENGTHS ARE IN METERS-TIME IN SEC.                 FIRST LINE ARE INITIAL CONDITIONS.
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X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.72	0.21	90.00	17.43	0.35	1.000	0.987	0.987	0.31	1.98
0.00	1.67	0.57	90.00	25.58	1.09	0.326	0.302	0.302	1.15	6.66
0.00	2.54	1.10	90.00	37.79	1.79	0.213	0.168	0.168	2.77	12.13
0.00	3.27	1.80	90.00	48.76	2.49	0.172	0.108	0.108	4.94	18.89
0.00	3.88	2.61	90.00	56.70	3.18	0.152	0.075	0.075	7.50	27.21
0.00	4.40	3.49	90.00	62.10	3.90	0.139	0.055	0.055	10.34	37.17
0.00	4.84	4.40	90.00	65.76	4.63	0.130	0.041	0.041	13.40	48.78
0.00	5.24	5.34	90.00	68.30	5.39	0.123	0.033	0.033	16.67	62.03
0.00	5.60	6.29	90.00	70.09	6.16	0.117	0.026	0.026	20.11	76.91
0.00	5.93	7.25	90.00	71.37	6.95	0.112	0.022	0.022	23.73	93.38
0.00	6.25	8.21	90.00	72.30	7.75	0.107	0.018	0.018	27.51	111.43
0.00	6.84	10.15	90.00	73.45	9.39	0.100	0.013	0.013	35.52	152.23
0.00	7.41	12.10	90.00	74.02	11.07	0.094	0.010	0.010	44.08	199.19
0.00	7.97	14.06	90.00	74.24	12.79	0.089	0.008	0.008	53.16	252.19
0.00	8.52	16.01	90.00	74.24	14.53	0.084	0.007	0.007	62.72	311.12

PLUMES MERGING

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	9.08	17.97	90.00	73.70	16.18	0.081	0.005	0.005	72.71	372.88
0.00	9.66	19.92	90.00	73.12	17.54	0.080	0.005	0.005	82.97	430.48
0.00	10.26	21.86	90.00	72.73	18.77	0.078	0.004	0.004	93.38	486.46
0.00	10.86	23.80	90.00	72.45	19.91	0.078	0.004	0.004	103.91	541.49
0.00	11.48	25.73	90.00	72.25	21.02	0.077	0.003	0.003	114.55	595.82
0.00	12.10	27.67	90.00	72.10	22.10	0.076	0.003	0.003	125.33	649.57
0.00	13.36	31.53	90.00	71.89	24.27	0.073	0.002	0.002	147.42	755.41
0.00	14.63	35.39	90.00	71.77	26.50	0.069	0.002	0.002	170.47	859.03
0.00	15.90	39.25	90.00	71.70	28.82	0.065	0.002	0.002	194.79	960.37
0.00	17.18	43.11	90.00	71.65	30.91	0.062	0.001	0.001	220.56	1059.47
0.00	18.46	46.97	90.00	71.62	34.78	0.058	0.001	0.001	246.98	1157.50
0.00	19.74	50.82	90.00	71.60	37.33	0.058	0.001	0.001	274.79	1253.82

DILUTION=1325.15