SOAH DOCKET NO. 582-20-1895
TCEQ DOCKET NO. 2019-1156-IWD

IN THE MATTER OF THE	§	**BEFORE THE STATE OFFICE**
APPLICATION OF PORT OF	§	
CORPUS CHRISTI AUTHORITY OF	§	**OF**
NUECES COUNTY FOR TPDES	§	
PERMIT NO. WQ0005253000	§	**ADMINISTRATIVE HEARINGS**

EXHIBIT PAC-51R

SOAH DOCKET NO. 582-20-1895
TCEQ DOCKET NO. 2019-1156-IWD

IN THE MATTER OF THE	§	BEFORE THE STATE OFFICE
APPLICATION OF PORT OF	§	
CORPUS CHRISTI AUTHORITY OF	§	OF
NUECES COUNTY FOR TPDES	§	
PERMIT NO. WQ0005253000	§	ADMINISTRATIVE HEARINGS

REMAND PREFILED TESTIMONY

OF

SCOTT SOCOLOFSKY

ON BEHALF OF

PORT ARANSAS CONSERVANCY

SUBMITTED ON FEBRUARY 2, 2022

SOAH DOCKET NO. 582-20-1895
TCEQ DOCKET NO. 2019-1156-IWD

IN THE MATTER OF THE	**§**	**BEFORE THE STATE OFFICE**
APPLICATION OF PORT OF	**§**	
CORPUS CHRISTI AUTHORITY OF	**§**	**OF**
NUECES COUNTY FOR TPDES	**§**	
PERMIT NO. WQ0005253000	**§**	**ADMINISTRATIVE HEARINGS**

REMAND PREFILED TESTIMONY OF SCOTT SOCOLOFSKY

TABLE OF CONTENTS

LIST OF EXHIBITS

Exhibit PAC-51R SS-1	Curriculum Vitae of Scott A. Socolofsky, Ph.D.
Exhibit PAC-51R SS-2	Field Images
Exhibit PAC-51R SS-3	Figure 1 Diffuser Location from Updated Application
Exhibit PAC-51R SS-4	Satellite Images
Exhibit PAC-51R SS-5	CORMIX_CASES – Socolofsky
Exhibit PAC-51R SS-6	Channel Cross Sections PowerPoint
Exhibit PAC-51R SS-7	Brine Module Results PowerPoint
Exhibit PAC-51R SS-8	Conservative Module Results PowerPoint
Exhibit PAC-51R SS-9	Stratification
Exhibit PAC-51R SS-10	Port Brine Discharge Mixing Analysis 2018

I. SUMMARY OF EDUCATION AND EXPERIENCE.

Q. PLEASE STATE YOUR NAME, EMPLOYER, TITLE AND BUSINESS ADDRESS.

A. Scott A. Socolofsky, Professor, Zachry Department of Civil and Environmental Engineering, Texas A&M University, College Station, Texas.

Q. DO YOU RECOGNIZE THE DOCUMENT MARKED AS EXHIBIT PAC-51R SS-1?

A. Yes. This is a copy of my curriculum vitae.

Q. DOES YOUR CURRICULUM VITAE ACCURATELY DESCRIBE YOUR EDUCATION AND EXPERIENCE?

A. Yes, but it is a summary and does not show all of my work experience.

PAC offers Exhibit PAC-51R SS-1.

Q. PLEASE OUTLINE YOUR EDUCATIONAL BACKGROUND.

A. I received a bachelor's degree in Civil and Environmental Engineering from the University of Colorado, Boulder, in 1994. I received a Master's degree in 1997 and a Ph.D. in 2001, both in Civil and Environmental Engineering from Massachusetts Institute of Technology. From January 2000 to December 2001, I was a post-doctoral scholar under Professor Gerhard Jirka at the Institute for Hydromechanics, University of Karlsruhe, Germany.

Q. PLEASE DESCRIBE BRIEFLY YOUR CURRENT ROLE WITH THE TEXAS A&M UNIVERSITY'S DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING AND THE TYPE OF WORK IN WHICH YOU ARE CURRENTLY ENGAGED THAT IS RELATED TO OR A BASIS FOR YOUR OPINIONS HERE.

A. I am the J. Walter "Deak" Porter '22 and James W. "Bud" Porter '51 Chair professor in the Zachary Department of Civil and Environmental Engineering at Texas A&M University. I teach courses in the Environmental, Water Resources, and Coastal Engineering Division, which is within the department. I teach courses in environmental fluid mechanics at the undergraduate and graduate level and other areas of my working experience. I conduct research through the Texas A&M Engineering Experiment Station.

I am the developer of the Texas A&M Oil Spill/Outfall Calculator (TAMOC), which is an open-source programming suite of numerical models for near-filed analysis of oil spills and outfall discharges. This was developed through funding from the Gulf of Mexico Research Initiative (GoMRI), the Bureau of Safety and Environmental Enforcement (BSEE) through the National Oceanographic and Atmosphere Administration (NOAA), and the Department of Homeland Security (DHS) through the Arctic Domain Awareness Center (ADAC) at the University of Alaska, Anchorage.

I have applied this program to study oil spills, including the Deepwater Horizon oil spill, and for planning purposes for oil production and exploration. This suite of models is being used by industry and federal agencies in the U.S. and Canada to study the nearfield dynamics of marine oil spills. In other research funded through the Texas Sea Grant College Program and from a grant related to Hurricane Harvey from the National Science Foundation, I have studied mixing and transport through inlets on the Texas coast, including conducting idealized laboratory studies and field work at Galveston ship channel and Aransas Pass. I have also been funded by the Texas General Land Office's Oil Spill and Prevention Program to study the potential for oil transport through Galveston and Corpus Christi bays using numerical models and, most recently, field observation using unmanned aerial systems (UAS).

Q. DO YOU CURRENTLY HAVE A COPY OF THE CORMIX MODEL?

A. Yes.

Q. WHICH VERSION DO YOU HAVE?'

A. CORMIX 12.0GTH, Version 12.0.0.0.

Q. ARE YOU ABLE TO EVALUATE THE USE OF THE CORMIX MODEL IN THIS CASE BASED ON YOUR EDUCATION AND EXPERIENCE WITH IT AND OTHER MODELS?

A. Yes. My experience with this model is described in more detail below.

Q. DO THE RESULTS OF YOUR MODELING AGREE WITH THOSE OF THE PORT OR ED?

A. Yes, generally, but with some differences. I have a different version of the model. It is part of the most recent upgrades, and apparently has been revised since the version used by the Port and ED. When using the same input files as the Port, I obtain somewhat different computed results. I can tell that the model has been updated, because it also has slightly different output text messages than the version used by the Port and ED.

Q. WHAT DIFFERENCE DOES IT MAKE?

A. For the modeling that results in the critical conditions, the difference between predictions for the version of the model I use and the Port's and ED's modeling is about a 5% difference for the effluent percentages. For example, for the boundary of the aquatic life mixing zone my version predicts 8.5% of the effluent while the ED's results is 8.9%. The results using my version generally show this somewhat better mixing.

This difference is, however, not significant given other differences in our results. For example, my results for the modeling at the ZID boundary predict effluent percentages up to 55%, versus the 14.6% figure for the remaining effluent for the modeling done by the ED with the same conditions.

Q. DO YOU CURRENTLY HAVE A COPY OF THE SUNTANS MODEL?

A. No.

Q. HAVE YOU BEEN INVOLVED IN ANY USE OF THE SUNTANS MODEL FOR CONDITIONS IN ANY TEXAS BAY?

A. Yes, in both the Corpus Christi and Galveston Bay systems.

Q. ARE YOU ABLE TO EVALUATE THE USE OF THE SUNTANS MODEL IN THIS CASE BASED ON YOUR EDUCATION AND EXPERIENCE WITH IT AND OTHER MODELS?

A. Yes. My experience with this model is described in more detail below.

II. INVOLVEMENT IN THIS PROCEEDING AND KEY OPINIONS

Q. ON WHOSE BEHALF ARE YOU SUBMITTING THIS TESTIMONY?

A. Port Aransas Conservancy ("PAC").

Q. WAS THIS TESTIMONY PREPARED BY YOU OR UNDER YOUR DIRECT SUPERVISION AND CONTROL?

A. Yes.

Q. WHAT WERE YOU ASKED TO DO FOR PAC?

A. Ultimately, I was asked to evaluate the conditions in the area of the proposed discharge, the use of the CORMIX and SUNTANS models for the discharge location and diffuser design proposed here.

I had some discussions with Scott Holt in July 2020, after being introduced to him by Professor Ben Hodges at the University of Texas, Austin. That was before I was contacted by counsel for PAC. Mr. Holt had some questions about the modeling, and he asked me to review the report on the SUNTANS and the CORMIX modeling that was being used in the Port's application. I did a brief review and provided Mr. Holt with some of my thoughts. I suggested to him or someone at that time that the faster velocities in the channel might lead to worse mixing at the mixing zone boundaries than the conditions used for the CORMIX modeling shown in the documents he sent me.

It was after that exchange that I was contacted by counsel for PAC, who asked if I would agree to consult and possibly agree to be a witness in this hearing. I agreed to consult but explained my full schedule. When Mr. Lowerre asked me in August or September if I could participate by preparing written testimony, I had to decline because of my schedule. At that time, I had not run the CORMIX model for the proposed discharge.

I was again contacted mid-October 2020, and asked if it was possible to provide some testimony as a rebuttal witness in the forthcoming hearing. I began work on testimony as a rebuttal witness in November 2020. I was, however, not asked to testify.

Q. PLEASE EXPLAIN WHAT YOU WERE ASKED TO DO FOR THE AMENDED APPLICATION.

A. I was contacted again in late May or early June of 2021, and I agreed to consult and, if appropriate, testify on my opinions. The scope of the work was similar to what I had been asked to do in 2020, such as review the modeling by the Port and the Executive Director, but also perform my own modeling and assist with evaluating the conditions in the Corpus Christi Ship Channel and associated bay systems. I developed opinions with regard to the mixing that will occur at the location of the discharge as identified in the Port's amended application and at other location nearby.

Q. PLEASE STATE BRIEFLY YOUR MOST SIGNIFICANT OPINIONS WITH REGARD TO THE LOCATION OF THE DISCHARGE AS IDENTIFIED IN THE APPLICATION.

A. The location of the discharge will cause boundary interaction of the discharge plume with the local bathymetry. The CORMIX model cannot directly consider this complex bathymetry, but I have conducted a sensitivity study with different channel profiles to estimate the effect. My analysis shows that all cases with more realistic channel profiles have worse mixing than predicted by the Port and ED. This sensitivity study shows that early boundary attachment of the plume results in the percentage of effluent as high as 50% at the boundary of the ZID for this location, while the ED's figure is 14.6%.

Second, the CORMIX model predicts and it is my opinion that there will be concentrated salinity along the bottom of the Corpus Christi Ship Channel in the far field that the SUNTANS modeling here cannot identify. This concentrated salinity would also flow into the hole immediately offshore of the discharge, though CORMIX cannot directly consider this depression.

With regard to my opinion on CORMIX here, I do want to add that I would not expect the discharge to be at the location the application indicates, i.e. in the bank or right at the bank. If the discharge location were to be moved, any significant distance, I would need the site-specific data of the new location to perform modeling with CORMIX.

III. WORK PERFORMED TO DEVELOP OPINIONS

Q. HAVE YOU MADE ANY TRIPS TO THE AREA OF THE PROPOSED DISCHARGE?

A. Yes. I visited the area July 14 and 15, 2021, with Mr. Trungale and some of the client representatives.

Q. WHAT WERE YOU ABLE TO SEE FROM THAT VISIT?

A. I was able to see the general surface flow conditions in the area of the discharge during different tidal conditions. I also was able to see and understand the proximity and possible impacts of the points of land coming out from Harbor Island that are related to some of my opinions.

Q. CAN YOU IDENTIFY EXHIBIT PAC-51R SS -2?

A. Yes. These are some of the pictures that I and Mr. Trungale took on that site visit. Mr. Trungale's photograph is the one aligned vertically and labeled IMG_1107.

Q. DO THESE PICTURES ACCURATELY DEPICT THE CONDITIONS YOU SAW AT THE TIME OF THE SITE VISIT?

A. Yes.

PAC offers Exhibit PAC-51R SS-2.

Q. CAN YOU IDENTIFY EXHIBIT PAC-51R SS-3?

A. Yes, this is Figure 1 from the Updated Application, at page 32. It shows the two points of land I mentioned. They form a kind of cove that extends into the channel below the water to and beyond the discharge location at the depth of the discharge. You can also see coming off from the point on the right a few small circles in the water. It appears from the site visit that the last of those circles the sign shown in the third photograph in Exhibit PAC-51R SS-2 saying "Danger Submerged Objects."

*PAC offers Exhibit PAC-51R SS-*3 *for the limited purpose of showing the area, but not the bathymetry, discharge location, or the distance to the discharge location from the shore.*

Q. ARE THESE CONDITIONS, THE COVE, AND POINTS OF LAND SIGNIFICANT TO YOUR OPINIONS?

A. Yes. The location of the discharge, within the confines of the lateral extensions of the cove, which extended underwater to the discharge depth, will reduce the mixing of the effluent, as I will explain below.

Q. DID YOU OBSERVE ANY OTHER CONDITIONS THAT RELATE TO YOUR OPINIONS?

A. Yes. I observed water backing up on the Gulf side of the what appears to be a groin or a man-made structure extending out from the point of land on the Gulf side of the discharge location during flood tide conditions. That can be seen in the first three photographs in Exhibit PAC-51R SS -2. I also observed surface foam which indicates a recirculation zone in the area of the discharge. I observed variation in surface flow velocity between the discharge location and the ship channel. If similar flow separation and recirculation occur at the depth of the discharge, this may contribute to boundary interaction of the plume, which my modeling has shown reduces mixing.

Q. WHAT ARE THE RESOURCES THAT YOU HAVE RELIED UPON IN PERFORMING YOUR WORK AND ANALYSIS?

A. I have relied largely on my own education and experience with modeling and my ability to interpret modeling results and validation. I have also relied upon the CORMIX User's Manual. I reviewed a number of journal articles on the use of the CORMIX model, behavior of desalinization brine plumes, and channel flow over stratified depressions.

I have conducted modeling with CORMIX to evaluate the modeling done by the Port and ED and to determine if there are conditions at the new location for the proposed discharge that would affect the modeling or the mixing of the effluent.

I have also relied on my education and experience developing a model similar to CORMIX and working with the SUNTANS model results for the Corpus Christi and Galveston Bays systems. I have also relied on studies of coastal waters, including evaluations of the hydrodynamics of passes, channels and related bays and estuaries. I have relied on work done by other experts who are working or have worked for PAC in this matter.

Q. WHAT DOCUMENTS DID YOU REVIEW IN PERFORMING YOUR ANALYSIS?

A. I reviewed the modeling in the Port's amended application, and that of the ED of the TCEQ, and several journal articles. I have reviewed the results of runs using the CORMIX model for the new location performed by the ED, the Port, and some of the runs by Mr. Osting. I also reviewed sections of the Port's original and amended applications, and prefiled testimony from the prior hearing and this present hearing. I reviewed the SUNTANS report by Dr. Furnans dated October 21, 2019. I reviewed work by other experts engaged by PAC on modeling and conditions near the discharge location.

Q. HAVE YOU DISCUSSED YOUR OPINIONS OR BASIS FOR THEM WITH OTHER MODELERS?

A. Yes. Joe Trungale, Bruce Wiland, Tim Osting, and Dr. Robert Doneker.

Q. HAVE YOU RELIED ON ANY OF THEIR WORK OR OPINIONS IN DEVELOPING YOUR OPINIONS?

A. Although I developed my opinions independently, I used the discussions to provide confirmation of my opinions. My discussion with Dr. Doneker is a good example of that since he is the owner of the model.

I have relied on evaluations of the discharge location identified in the application and the bathymetric and flow conditions near that location that were prepared or presented to me orally or in writing by Mr. Wiland, Mr. Osting, and Mr. Austin.

Q. HAVE YOU DONE ANY OTHER WORK TO EVALUATE THE FLOW CONDITIONS IN THE AREA OF THE DISCHARGE?

A. Yes. I obtained several satellite photographs from Google Earth of the area which are in Exhibit PAC-51R SS-4. I have identified some of the conditions that I saw on those photographs, such as locations of eddies or eddy structures and the mixing layer boundaries. I will explain the significance of eddy structures and mixing layer boundaries later in this testimony.

Q. ARE THE SATELLITE PHOTOGRAPHS THE TYPE OF INFORMATION YOU AND OTHERS IN YOUR FIELD COMMONLY RELY UPON FOR OBTAINING INFORMATION ON THE CONDITIONS IN CHANNELS AND BAYS SUCH AS FOR EDDY STRUCTURES AND MIXING LAYERS?

A. Yes. I and others with similar expertise often rely upon such photographs to help understand conditions in areas such as the location of the proposed discharge.

PAC offers Exhibit PAC-51R SS-4.

IV. SUMMARY OF OPINIONS

A. OPINIONS REGARDING THE USE OF THE CORMIX MODEL

Q. EXPLAIN YOUR OPINIONS REGARDING THE USE OF THE CORMIX MODEL IN THE PRESENT CASE?

A. Because of the location selected by the Port, the predictions derived by the Port and the ED from the CORMIX model for mixing and salinity levels will not directly represent the conditions resulting from the discharge of the effluent within the scales of the mixing zones. It is my opinion that the predictions from the modeling done by the Port and the ED result in concentrations of salinities at the mixing zone boundaries lower than what will occur upon discharge of the effluent at the requested 95.6 mgd rate.

Q. WHY IS THAT TRUE?

A. In their modeling, the Port and ED used a schematized channel that ignores the slope and side walls of the bank and cove I described above. The channel cross-section they used does not let CORMIX predict the type of contact and interaction the plume will, under most tidal conditions, have with the bank and cove. CORMIX is designed to address boundary interaction and plume attachment, and this is a major topic of Section 2.1 in the CORMIX User's Manual. When using channel profiles more similar to the site, CORMIX predicts early plume attachment, which reduces the mixing. However, because CORMIX can only consider a straight channel, it cannot also evaluate the side slopes of the cove walls, and a sensitivity study is appropriate to assess boundary interaction effects.

Q. WHAT DO YOUR MODELING RESULTS SHOW?

A. Table 1 below shows my results and those of the ED for one set of density conditions that the ED and Port modeled. The ED assumed a distance between the bank and the discharge location of 229 feet, the distance from the shoreline of Harbor Island at the water surface, where the bank begins to slope down to the discharge location and hole.

Table 1:

Modeling results using the "Conservative" Option for CORMIX with ambient concentration of 40.57 ppt and effluent concentration of 68.7 (ppt) and a velocity of 0.8 meters per second in the channel

ED results assuming a distance of 229 feet from the bank to the discharge location are in black. My results using five different distances are in brown.

Distance to bank in meters	Percent Effluent at the ZID	Percent Effluent at the MZ	Percent Effluent at the HHMZ boundaries in %	Resulting Salinity at the ZID	Resulting Salinity at the MZ	Resulting Salinity at the HHMZ boundaries in ppt	Change in salinity at the ZID	Change in salinity at the MZ	Change in salinity at the HHMZ boundaries in ppt/%
69.8	14.6	8.9	5.1	44.68	43.07	42.00	4.11/10%	2.50/6%	1.43/4%
0	55.02	41.37	24.47	56.06	52.22	47.48	15.46/38%	11.62/29%	6.88/17%
3	55.02	41.37	24.47	56.06	52.22	47.48	15.46/38%	11.62/29%	6.88/17%
5	30.81	20.38	9.25	49.26	46.33	43.2	8.66/21%	5.73/14%	2.6/6%
10	20.61	12.9	6.22	46.39	44.22	42.35	5.79/14%	3.62/9%	1.75/4%
15	20.61	10.8	5.25	45.44	43.63	42.07	5.79/12%	3.62/7%	1.75/4%

Note the figures are the same for 0 and 3 meters away from the bank, because the model predicts the plume immediately contacts the bank in both those cases. It is this attachment to the bank that reduces mixing.

Q. DOES THIS TABLE ACCURATELY SHOW THE RESULTS REPORTED BY THE ED FOR ITS MODELING AS SHOWN IN ITS DIFFUSER REPORT OF AUGUST 10, 2021 AND YOUR MODELING?

A. Yes.

Q. IS THE MIXING PREDICTED BY YOUR FIGURES AFFECTED BY ANY OTHER CONDITIONS IN THE AREA OF THE DISCHARGE?

A. Yes. There are several conditions that could change the actual mixing, for the better or worse. The location of the underwater extensions of the points of land out from Harbor Island may be the most significant condition resulting from locating the discharge at the bank. This was the result of the decision of the Port to move the discharge away from near the center of the offshore hole and to the bank. At the new location, the CORMIX plume trajectories impact the side-walls of the bank so that it is clear to me that boundary interaction is important.

There are other conditions that in my opinion could affect the mixing; the non-uniform flow in the area of the discharge that I have seen and expect and stratification which I also believe occurs at times in the Corpus Christi Ship Channel and, presumably, in the hole.

Q. ARE THERE LOCATIONS IN THIS AREA OF THE SHIP CHANNEL OR NEARBY WHERE SUCH PLUME ATTACHMENT OR AFFECT OF THE BATHYMETRY WOULD NOT AFFECT THE TYPE OF ASSUMPTIONS THAT THE PORT AND ED MADE FOR THEIR MODELING?

A. Yes. The CORMIX simulations can provide reliable predictions throughout the mixing zones, without plume attachment or other bathymetric issues, if the Port had moved the discharge to a location in this ship channel where the banks or side walls that are reasonably similar in shape throughout the mixing zones or do not encroach on the mixing zones. The Port could have moved the outfall to locations with uniform flow conditions and where there would be no contact between the plume and the banks of Harbor Island. Other factors, such as stratification and non-uniform flow could affect the reliability of the predictions, but that would depend upon the conditions at the new location

From my review of the area, it is my opinion that there are such appropriate locations in the Corpus Christi Ship Channel and in the Gulf of Mexico. The CORMIX model could simulate the bathymetry and flow conditions in such locations and provide reliable results at the boundaries of the mixing zones and within the mixing zones.

A. B. OPINIONS REGARDING THE USE OF THE SUNTANS MODEL

Q. EXPLAIN YOUR OPINION OR OPINIONS REGARDING THE USE OF THE SUNTANS MODEL.

A. Because of the resolution used in the SUNTANS modeling, the formation and propagation of a dense plume of effluent on the channel bottom that, in my opinion will occur, cannot be accurately evaluated. Such a density current is predicted by CORMIX.

In addition, it is my opinion that to answer this question, the CORMIX model needs to be coupled with a far-field model with much higher resolution than in the SUNTANS modeling here. That higher resolution is needed for the far-field model to be capable of tracking the discharged brine as long as it represents a dense plume of water flowing along the channel bottom. Again, that far-field model is not the SUNTANS model as developed for the Port's applications.

As developed here, the predictions from the SUNTANS model provide no relevant information on mixing at the scale of the channel width near the discharge, including any areas within the mixing zones, or in the region beyond the mixing zones and into the shipping channel. I cannot provide an opinion on the far field impacts more than a mile or so from the discharge location. The predictions there from the SUNTANS model may be correct. But it is my opinion that the predictions in the area from where the near field ends and a mile or so into the far field, there will be a density current moving along the bottom of the ship channel. The modeling here with SUNTANS may provide insight on salt transport into the Corpus Christi Bay system, however, the SUNTANS model running at the resolution used here cannot predict whether a density current will form from this discharge in exiting the mixing zones and flowing into the shipping channel.

To make such predictions, the model would need a much finer grid, at least near the discharge. With only two model grid cells over this width in the present SUNTANS model, the model cannot resolve such a density current nor predict its presence or absence.

The CORMIX model includes a far-field simulation module. It is my opinion that it correctly predictions the existence of a density current, which under most conditions forms in the HHMZ as the concentrated plume falls to the bottom of the channel. CORMIX also predicts that this bottom density current will remain separated from the overlying channel flow throughout the domain of the simulations, which normally extends out at least 1.5 kilometers (nearly 1 mile). This distance is great enough that it is reasonable to expect that a density current may cross the channel between Harbor Island and Mustang Island and move in and out some distance in the Corpus Christi Ship Channel.

V. BASIS FOR OPINIONS ON CORMIX

A. EXPERIENCE WITH CORMIX

Q. PLEASE DESCRIBE YOUR PROFESSIONAL TRAINING AND EXPERIENCE RELATED TO THE USE OF THE CORMIX MODEL.

A. I first used the CORMIX model in the 1990s in my work for my Ph.D. to predict the trajectories of jets and plumes in cross flow conditions, conditions like we have here. When I completed my Ph.D., I took a post-doctoral position with Professor Gerhard Jirka at the University of Karlsruhe and worked for him for two years. Professor Jirka led the development of the CORMIX model for EPA when he was a Professor at Cornell University. I gained significant experience with the inner workings of the CORMIX model and the theories of jets and plumes during this period, as I worked on and attended various projects, seminars, and workshops related to the submodels and modules within CORMIX. I have also attended CORMIX training conducted by Dr. Doneker in the early 2000s.

Q. DO YOU KNOW DR. ROBERT DONEKER?

A. Yes. He is the person who has taken the EPA CORMIX model and made it available to universities, government agencies, industries and the public through his company MixZon, Inc.

Q. HAVE YOU WORKED WITH HIM OR CONSULTED HIM BEFORE YOUR WORK IN THIS CASE?

A. Yes, I have had numerous discussions with Dr. Doneker before this case, but I have not worked with him on any specific project. When I was a postdoctoral scholar at the University of Karlsruhe, Dr. Doneker was working with some of Professor Jirka's students, who were developing both the internal hydraulics and brine modules of CORMIX at the time. I had numerous discussions with those students and also discussed the model with Dr. Doneker at the time. Since 2002, my main consultation with him was through a CORMIX training workshop he held in Austin, Texas, that I attended in 2007. I have also kept in touch personally whenever I met him at professional conferences.

Through my discussions with Dr. Doneker and reading the literature related to CORMIX over the last several decades, I stayed up-to-date with the CORMIX model and its development. I have not studied all of the uses of the model and not read every detail of the current CORMIX manual, but I understand what is inside CORMIX, how it works, and the data validation process for the model. I understand the limitations and approach it takes.

Q. HAVE YOU WORKED WITH OTHER SIMILAR MODELS?

A. Yes, I have also developed my own integral models to study plumes in the marine environment. My modeling suite (the Texas A&M Oil spill / outfall Calculator, or TAMOC) is based on one of the inner core modules of CORMIX, CorJet. CorJet models the buoyant jet dynamics of entrainment and dilution of a discharge in the marine environment.

A similar model is the JetLag model by Professor Lee at the Hong Kong University of Science and Technology (formerly, he was at the University of Hong Kong). My model uses the theoretical aspects of these two models to simulate the trajectory and dilution of oil and gas plumes from sub-marine oil spills. I have validated my model to much of the data used to validate the CORMIX single-port discharge model, following the paper by Jirka in 2004 in Environmental Fluid Mechanics. In that paper, Professor Jirka included more than 20 data sets used to validate CORMIX under different conditions, including cases with a negatively-buoyant discharge, like the brine plume here. A good summary of my modeling system is in Dissanayake et al. (2018), which I also published in Environmental Fluid Mechanics. I also developed a line-diffuser version of the model for a reservoir bubble plume, published in Dissanayake et al. (2021). Through this work, I have a fundamental understanding of the validity and limitations of the CorJet model and its usage in CORMIX.

Q. HAVE YOU SPOKEN WITH DR. DONEKER REGARDING YOUR WORK ON THIS DISCHARGE APPLICATION?

A. Yes, I have. Twice.

Q. WHAT WERE THE DISCUSSIONS ABOUT IN THE FIRST CONVERSATION?

A. Last year, the lease PAC had for use of the CORMIX model had expired. The plan was to lease the model again. There are options with the CORMIX model, and I wanted to confirm with Dr. Doneker the contents of the different versions of the licenses.

Dr. Doneker joined the conversation late as I recall, and from an automobile, I believe. So the call was short. We did have some discussions regarding the proposed discharge. We mostly discussed the need to couple the CORMIX results with a high-resolution far-field model, if one hoped to credibly extend the end of the CORMIX simulation to determine the path and evolution of the dense bottom current resulting from the brine discharge such as the one here well into the far field, beyond what the CORMIX model can predict. He agreed with my position that the model would have to have high resolution, capable of capturing a density current.

Q. WHAT ABOUT THE SECOND CONVERSATION?

A. The second conversation occurred in November 2021. Dr. Doneker had apparently declined to be engaged by PAC as an expert witness, but was willing to discuss the model's use and some related matters. It was clear in the way he answered the questions, and in many cases avoided answering, that he was trying to avoid being pulled into the hearing process. So, the conversation was quite limited.

Much of the discussion was led by Dr. Doneker and focused more on the suitability of the site for a discharge than the appropriate uses of the CORMIX model. He strongly indicated his support for moving to an offshore discharge location.

We again discussed the need to couple a separate far-field model to the CORMIX simulations and the time and cost that would be involved. He, like me, expressed the opinion that he expected a significant bottom density current moving across the channel and into the ship channel, which was the type of density current predicted by the CORMIX model. He confirmed my opinion that a significant far-field modeling study would be required to assess plume interactions along the ship channel beyond what the CORMIX model predicted.

B. CORMIX MODULES USED

Q. PLEASE EXPLAIN THE OPTIONS FOR USING THE CORMIX MODEL TO EVALUATE THE PROPOSED DISCHARGE.

A. CORMIX can consider a number of site-specific conditions: It allows consideration of boundary interactions that I have discussed above, tidal conditions, and stratification. It also has two ways to handle the negatively-buoyant brine: the conservative tracer module and the brine module.

Q. DID YOU RUN THE MODEL FOR ALL SUCH CONSIDERATIONS?

A. Yes. However, my opinions are based on the option to evaluate boundary interactions using both the conservative tracer and brine modules.

Q. PLEASE EXPLAIN YOUR OPINION REGARDING YOUR USE OF THE BRINE MODELING OPTION.

A. The brine option is provided in CORMIX for negatively buoyant plumes, which could be ones with concentrated salinity or suspended solids. As with the conservative tracer option, it considers boundary interactions, and it provides reliable predictions for this discharge until the plume contacts the side slope of the hole. It has to be set up with different inputs, differently from the conservative tracer option, as it can have a sloping bottom. Like the conservative tracer option, it cannot directly consider a curved channel side wall. It does, in my opinion provide results that should be considered.

Q. DID THE PORT OR THE ED RUN THE BRINE OPTION.

A. I do not recall seeing any runs with the brine option by the ED for the amended application; the Port conducted one run that I have seen. The ED used the brine option for developing the critical conditions for the original application, but not with the amended application apparently.

The Port did use the brine option and it appears the results were similar to mine. However, Dr. Tischler indicated in his deposition that the brine option could not or possibly should not be used for the amended application.

I disagree, and my modeling with that option shows it can be used and provides the type of results I would expect, including those results that assist with the overall evaluation of the mixing that results from the design of the diffuser for the location proposed here. In fact, the simulation summary file that can be generated for each conservative tracer run warns the user to check the results using the brine module.

For example, I ran it for the summer conditions with 50% effluent recovery assuming 1.5 meter high (4.9 ft) risers and 0.8 m/s currents. Under this configuration, the effluent concentrations of salinity predicted were about 7% higher at the ZID and ALMZ than those for the equivalent case run using the conservative option by the ED. That is because the brine module predicts that the plume will contact the side slopes of the channel sooner than the conservative model does. As a result, the plume will not mix as quickly. The resulting higher concentrations at the points of interaction will result in higher concentrations of salinity moving into the hole, though this module also cannot model the hole or side slopes of the cove surrounding the discharge.

In all of my runs with the brine option, the predicted mixing was worse at the ZID than the equivalent results from using the conservative model option as schematized by the ED.

C. SCHEMATIZATION

Q. PLEASE EXPLAIN YOUR UNDERSTANDING OF THE USE OF SCHEMATIZATION FOR CORMIX MODELING

A. The CORMIX User's Manual defines schematization at page xxiii. See Exhibit ED-KC-3

> Schematization: the process of describing a receiving water body's actual geometry with a rectangular cross section.

The CORMIX model does have to assume such uniform channel shape and uniform flow in the channel. It cannot include or model the bathymetric conditions such as the hole or side slopes of the cove surrounding the diffuser. Thus, the results of the modeling need to be evaluated considering the factors that might increase or decrease the mixing performance predicted.

The conservative module and brine module schematize the channel differently. In the conservative module, the nearest bank is a vertical wall, and the channel bottom is flat.

In the brine module, the nearest bank has a uniform slope away from the discharge, and the channel bottom can be modeled by a slope-break offshore of the discharge. Both modules consider boundary interaction of the plume, but both modules also assume uniform conditions upstream and downstream of the discharge.

The advantage of the conservative module is that the distance to the closest bank can be set independently of the diffuser depth. This distance can be adjusted to evaluate different distances to attachment of the brine plume with the channel walls.

In the brine module, the riser height is specified as a height above the sloping bottom so that only one side-bank distance can be considered for a given riser height and bottom slope. This would be fully appropriate if the channel side walls were uniform or curving away from the discharge. Here, the walls curve in, intercepting the plume trajectory. Hence, plume attachment may be earlier in the field than predicted by the brine module.

The modeling conducted by the Port and the ED primarily used the conservative module of CORMIX. Their simulations did not predict contact of the plume with the bank or side slope within the mixing zones. This is because they schematized the channel with a side-wall distance of 200 feet or more. Hence, the Port and the ED's use of the CORMIX model ignored what in my opinion is among the most important actual conditions at the proposed discharge location in the amended application. I conducted sensitivity runs with bank distances ranging from zero to 68 ft based on my analysis of the bathymetry at the site.

Boundary interaction is an important aspect of any CORMIX application. In the Author's Note, on page v. of the User's Manual (see Exhibit ED-KC-3)

> CORMIX is broadly accepted as an easy-to-use yet powerful tool for accurate and reliable point source mixing analysis. . . . . Because of its ability to simulate details of plume boundary interaction, important for ecological and human health risk assessment, CORMIX is recognized by regulatory authorities in all continents for environmental impact assessment.

"Boundary Interaction" as defined on page xix of the Manual, "occurs when the plume encounters a vertical (i.e. water surface, bottom, pycnocline, or terminal stratified level) **or lateral (bank) boundary." (**ED-KC-3)

As I explain in other sections, running the conservative model option to evaluate the interaction of the plume with the bank, results in predictions of much poorer mixing.

D. RESULTS OF THE MODELING

Q. EXPLAIN THE RESULTS OF YOUR MODELING.

A. I have prepared a few exhibits to do so.

Q. PLEASE IDENTIFY PAC-51R SS-5.

A. This exhibit provides summary of all the runs I performed and a graph of those results. It includes all runs I performed to compare the results of my modeling with those of the Port. It also allows me to compare my results to those of the ED. It also includes all of the runs I performed using options or set ups to evaluate plume interactions with the bank, the results for the options to evaluate a brine discharge, tidal impacts, and stratification.

I did not perform many runs with the tidal option because the tidal module cannot make predictions at the HHMZ and the tidal module only considers minor re-entrainment of effluent on the reverse tide, slightly increasing the effluent concentrations. I did not perform many runs with the stratification option, as I have not evaluated data for stratification at this site and the ED had concluded that stratification was not a critical parameter for analyzing this diffuser.

PAC offers Exhibit PAC-51R SS-5.

Q. PLEASE IDENTIFY PAC-51R SS-6.

A. This exhibit shows the cross sections for the channel that I considered. It provides cross sections that show the contours of the cove at different distances from the location of the discharge as identified in the application. The colored lines are the same for all slides, and represent different schematizations for the model.

PAC offers Exhibit PAC-51R SS-6.

Q. PLEASE IDENTIFY PAC-51R SS-7.

A. This exhibit shows my representations of the plume at a number of different velocities in the ship channel using the brine option. The maps show the plume only when it is in the water, above the local bathymetry. It does not show the plume where the CORMIX model predicts the location of the plume would put in the ground, the sides of the cove or other areas where the bathymetry shows the side of the hole higher in elevation than the plume. Boundary interaction may be important anywhere the predicted trajectory significantly impacts the real local bathymetry. The plume naturally cannot travel through the ground.

For each velocity it also shows the shape of the plume viewed from the side. These plots also include the local bathymetry. Thus, it shows the height to which the plume rises, and where it collapses and forms a density current, a plume moving along the bottom of the schematized channel.

As one moves from one set of velocities to the next, the predictions for the full tidal cycle are presented, though one must keep in mind that CORMIX makes predictions assuming the currents are uniform and not changing with time.

PAC offers Exhibit PAC-51R SS-7.

Q. PLEASE IDENTIFY PAC-51R SS-8.

A. This exhibit provides the same type of information as PAC-51 R SS-7 but with the conservative modeling.

PAC offers Exhibit PAC-51R SS-8.

E. IMPACT OF THE EXISTENCE OF THE 90+ FOOT HOLE

Q. EXPLAIN YOUR OPINION REGARDING THE IMPACT OF THE HOLE ON THE MIXING.

A. It is my opinion that the effluent plume will fall into the hole and fill it up. It is also my opinion that the denser water in the hole will not be flushed out by the currents. While some of the effluent that drops into the hole will be removed as the less dense ambient water in the channel flows over the denser water in the hole, at the same time, more effluent will be moving into the hole, causing dense water to overflow the edges of the hole. The centerline trajectories of the CORMIX simulations continually contact the side slopes of the hole, below the top of the hole, under essentially all conditions, from slack tide to the highest velocity currents. Hence, I expect the effluent plume to always be cycled through the hole.

Comparing the CORMIX trajectories for the plume as the tides rise and fall and change direction to the bathymetry in the mixing zones shows that, for most conditions, the plume will hit some part of the side slope of the hole below about 65 ft depth, which means the plume will not avoid the hole; hence, the constant continuation of a dense plume coming from the discharge will flow into the hole.

There are no conditions that I considered with either the conservative tracer or brine model option in CORMIX that predict the plume centerline will flow in a way that avoids contacting the hole. It is my opinion that this prediction of the model is correct.

Figure 1 below provides a representation of what happens to the dense effluent plume water in the hole as newer effluent continues to flow into it.

025106-3 Shear driven purging of negatively buoyant fluid Phys. Fluids **24**, 025106 (2012)

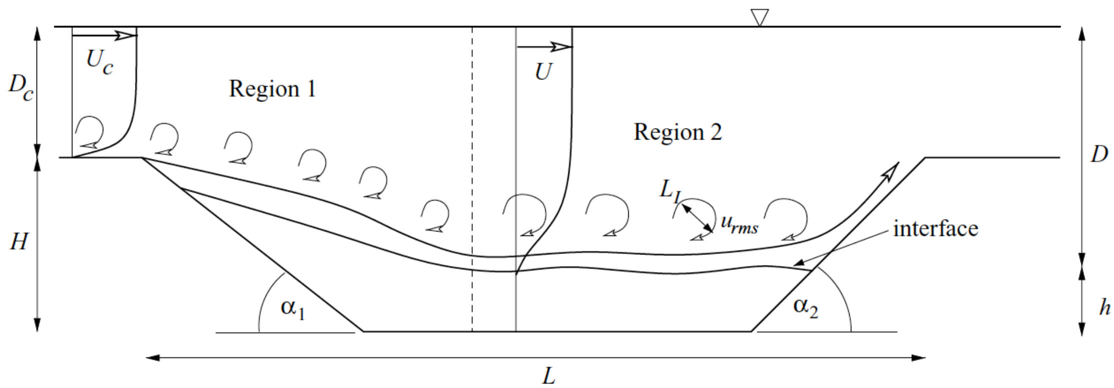

FIG. 1. Schematic of purging flow in a cavity of general shape.

This is a figure I took from a paper by Kirkpatrick et al. in the journal Physics of Fluids, published in 2012. It provides a good representation of how the less dense ambient water mixes with the top of the denser water in the hole, mixing with some and moving on to the ship channel with the entrained effluent. This figure depicts a situation where the channel currents have eroded a significant amount of dense fluid from the depression. At slower currents, the depression would be filled to a greater depth, and the entrainment less.

It is my opinion that for the brine discharge considered here, the hole will continually receive the effluent from the plume. It is my opinion that at times, the hole will fill up with effluent and spill over into the channel with the concentration that it had in the hole. At that point, the denser water from the hole creates the plume on the bottom, the density current that I have discussed before, which will move along the bottom toward lower areas of the ship channel. As CORMIX predicts for such density currents, I believe they will not simply mix, but rather will flow on the bottom for some significant distance, up to a mile as predicted in CORMIX without the hole.

Since the bottom of the ship channel away from the hole is not uniform, the plume will move to lower areas, possibly creating pools of the effluent plume in low spots. It would require a detailed far-field model with resolved bathymetry to determine the path the plume might take as conditions in the channel change.

Q. WHAT IS THE BASIS FOR THESE OPINIONS?

A. My expertise in plume movements, my review of several studies of such behavior, and the calculations that I performed. The predictions from the CORMIX model confirm my opinions as to these results in general. Without a far-field model with the resolution needed to identify these types of density currents, the best estimate of the concentrations in these density currents are those from the CORMIX model within the aquatic life mixing zone, the region containing the hole. Those predictions range between values at the end of the ZID and the edge of the ALMZ, as high as 8 ppt above the ambient salinity.

Q. WHAT SALINITY CONCENTRATION LEVELS ARE NEEDED TO FORM A DENSITY CURRENT?

A. It does not take much of a difference between the salinity concentrations in the bottom plume, or density current, and the overlying ambient water to form a density current. The CORMIX model would not predict such bottom plumes if they were not expected here. In many CORMIX simulations, the effluent concentrations in the far field are below 2%. So, at 1 ppt over ambient and even less, CORMIX predicts such stratification and propagating density currents can exist.

It is also clear that if the current velocities in the channel were strong enough to destabilize and mix such denser plume, CORMIX would have predicted that condition. It predicts, instead, the opposite: a persistent and significant density current propagating out in the HHMZ and throughout far-field simulations in CORMIX.

F. OTHER POTENTIAL MIXING ISSUES

1. EDDY OR NON-UNIFORM FLOW AND EFFECTS

Q. WHAT IS YOUR OPINION WITH REGARD TO THE PRESENCE OR ABSENCE OF EDDIES IN THE AREA OF THE DISCHARGE?

I have not seen evidence of a stationary eddy that might reside over the 90 foot hole. I also have not studied what might have created the hole.

However, with all of the infrastructure, docks, and other structures that have historically been in the water near the hole, it is possible that flow separation in the past, including formation of large eddies, could have created or contributed to the development of the hole at the location of the discharge. If so, one might refer to the hole as a scour hole. I do not have an opinion whether conditions have changed at the site, nor have I been asked to research the history of the hole.

There certainly are eddies in the area, and not just the small centimeter-scale "micro eddies" that are associated with three-dimensional turbulence – certainly these are present as well. I have seen evidence of a special class of eddies common in shallow systems that are referred to as "Large coherent structures" or "two-dimensional, large coherent structures." As an example, refer to my paper by Socolofsky and Jirka (2004).

I have seen evidence of such large eddies during my site visit and on aerial and satellite photographs. Some are shown where I have marked them on the satellite photographs in PAC-51R SS 3. While mixing within these eddies may be enhanced, my observations have been that their edges are barriers to transport. See, for example, my paper by Whilden et al. (2014) regarding eddies offshore of Aransas Pass on my CV.

It is my opinion, from what I have seen, that it is the impacts from the interaction of the brine plume with the bank and the underwater extensions of the points of land that form the cove that have the greatest negative impacts on the mixing for the amended application. Those conditions have been the focus of my evaluation. I have not spent the time that would be required to do a detailed analysis of the impacts of the eddies that I have observed in person or on photographs or any other eddies that may be present from time to time. Were the discharge to be located further out in the channel, eddies might play a more important role.

Q. WHAT IS YOUR OPINION WITH REGARD TO THE PRESENCE OR ABSENCE OF NON-UNIFORM FLOW IN THE AREA OF THE DISCHARGE?

A. Eddies are one cause of non-uniform flow. There are others, including the type of changes in velocity over the mixing zones that I have seen in person and in photographs.

But I have a similar opinion about the effects of such flow conditions on the mixing of the plume at the location of the discharge as I discussed above for eddies.

2. STRATIFICATION

Q. WHAT IS YOUR OPINION WITH STRATIFICATION AND ITS IMPACT ON THE MIXING?

A. It is my opinion that there likely is stratification in the hole and in the ship channel at times. The one or two days of data collection earlier this year by the Port cannot rule out stratification at other times and conditions. Likewise, the data available in the area, data from the Lydia Ann Channel, for example, may not be complete either. There, the study of stratification was done in an area of the channel only 10 or 20 feet deep.

I have worked on two studies in the Corpus Christi Bay system that involved stratification, and I found it in both cases. There has been, and in my opinion there will continue to be, stratification at Aransas Pass and into the ship channel, despite the large amounts of water that move through these channels.

A graduate student of mine did her thesis under my guidance that collected the data on the stratification shown in exhibit PAC-51R SS-9. Those data show significant stratification in the Pass and in the start of the Corpus Christi ship channel. Those locations were more representative of the deeper conditions at the location of the discharge than the Lydia Ann Channel, the area the Port relies upon to state that there is no stratification in the area on the whole.

I have also participated in a study that identified stratification in the middle of Corpus Christi Bay. There, we identified salty water moving along the ship channel and less salty water in the bay, moving laterally across the ship channel. Unfortunately, I no longer have any access to data documenting the stratification profiles we observed there.

I have not been asked to analyze the available stratification data in the area and do not have plans to do so. It is simply my experience that saltwater entering from the Gulf can remain concentrated in the ship channel far into Corpus Christi Bay, separated by stratification from the overlying bay water.

PAC offers Exhibit PAC-51R SS-9.

G. PREDICTION FOR DISCHARGE RATES OF LESS THAN 95.6 MGD

Q. HAVE YOU SEEN THE MODELING DONE IN THE ORIGINAL APPLICATION, AND IN PARTICULAR THE BRINE DISCHARGE MIXING ANALYSIS STARTING AT PAGE S APP S-APPLICATION 000347?

A. Yes.

Q. CAN YOU IDENTIFY PAC-51R SS-10?

A. It is that analysis from the original application.

PAC offers Exhibit PAC-51R SS-10. This is not offered for truth of the matters stated there but is to show what the Port filed in its original application.

Q. DOES THAT REPORT INCLUDE RESULTS OF MODELING FOR SOME DIFFERENT DESIGNS FOR DIFFUSERS.

A. Yes, on page S-Application 000358 there are five different design alternatives. The result of CORMIX modeling on such alternatives is provided starting on page S-Application 000358.

Q. WAS THERE ANY MODELING DONE FOR THOSE OR OTHER DESIGNS FOR DISCHARGE RATES BELOW 95.6 MGD?

A. Yes, there are several charts of results starting on page S-Application 000361.

Q. DID YOU REVIEW THOSE RESULTS WITH ANY INSIGHTS ON OPERATIONS OF THE DESALINATION FACILITIES WITH DISCHARGES AT LESS THAN 95.6 MGD?

A. Yes. Table 7 that starts on page S-Application 000361 summarizes a series of CORMIX runs for diffuser design alternative 3 for progressively lower discharges rates. Three ranges of mixing performance at the ZID, MZ, and HH mixing zone are observed. Modest mixing with about 8% effluent at the ZID occurs for flow rates 67 MGD and above, strong mixing with about 2% effluent at the ZID occurs for flow rates at 54 MGD and below, and weak mixing with 25% effluent at the ZID occurs for the test case at 57 MGD.

Q. DOES THAT SURPRISE YOU?

A. No. The CORMIX model does not contain a signal computational module that may smoothly transition from case to case. Instead, it includes a complex rules base that was formulated through laboratory experiments and expert input. This rules base may predict a different flow classification for different inputs. The modelers who created this table understood this, and they report the flow class in the last column. We can see in the table that the poor mixing results from a situation with flow class MNU9; whereas, the other cases are classified as MNU8 (for the higher discharge rates) and MNU3 (for the lower discharge rates). Each flow class may result in CORMIX running a different computational module to predict the mixing.

Q. DOES THIS HAVE ANY SIGNIFICANCE FOR EVALUATING THE POTENTIAL PRODUCTION LEVELS AND RESULTING DISCHARGE RATES FOR THE DIFFUSER PROPOSED BY THE PORT IN THE AMENDED APPLICATION?

A. Yes, the original application did the type of sensitivity analysis that should be done for the Port's diffuser. It is not possible to say that the mixing will always be better or worse based on one or two runs at different discharge rates or operational conditions. The original application did seven scenarios.

Q. DID YOU PERFORM A SIMILAR TYPE OF SENSITIVITY ANALYSIS HERE FOR DIFFERENT CONDITIONS?

A. Yes. For example, I did such sensitivity analysis for the issue of plume attachment and boundary interaction. Mr. Trungale did a similar analysis for velocities in the channel and showed that an assumption that mixing is worse at low channel velocities for a dense discharge is completely wrong. Instead, higher current velocities result in lower mixing at the mixing zone boundaries.

It appears clear to me from my experience with the CORMIX model and reviewing the CORMIX User's Manual that it is prudent for the person designing a diffuser to do detailed sensitivity analysis for the range of inputs that could affect mixing.

H. VALIDATION AND MONITORING

Q. ARE THERE ANY OTHER CONSIDERATIONS THAT SHOULD BE MADE WHEN APPLYING THE CORMIX MODEL FOR THIS LOCATION?

A. Yes. Given the complexity of the bathymetry in the area of the proposed discharge, the model predictions should be validated. Since there are no other nearfield models that could be used for validation that I am aware of, monitoring of the resulting mixing in the channel should be considered if any permit is issued for the proposed discharge location based on the CORMIX predictions.

Q. PLEASE EXPLAIN WHY.

A. As demonstrated above, the plume-bank interactions can increase the predictions for the concentrations of salinity significantly. Because the CORMIX model cannot consider the lateral banks of the submerged parts of the cove and offshore hole, we can only estimate their effect through sensitivity studies. To identify the correct predictions of the model, some validation is required.

To my knowledge, the type of brine discharge here, at a location in a cove with an offshore hole, creates unique conditions that have not been validated. Neither the Port nor the ED has presented evidence of such validation that I have seen.

Since the model cannot consider the complexity at this site, within the mixing zones, a monitoring plan to evaluate the predictions from the model, for validation or for compliance with limits in a permit, is critical, and a proper scientific approach.

For example, when Dr. Furnans determined that the SUNTANS model had not been validated for this type of use, he made an effort to do so. He looked to the literature for data with which to validate. It is my opinion that the limited data he could find is not sufficient to validate the model as he used it, but the point here is that he recognized the need for validation.

Also, an Advisory Panel report by Jenkins et al. (2012) to the State Water Resources Control Board of California identifies processes that near-field models cannot account for. One of these is the Coanda effect, a similar boundary interaction of merging jets from a diffuser. The report states in Appendix F, "…entrainment models cannot predict the Coanda effect, which reduces jet rise height and dilution. For these cases, physical modeling will be more reliable." Hence, validation is needed when a model cannot directly consider an important aspect of its application at a given site.

Again, I want to emphasize, it is not the model but the location that is the problem. It is a location, that in my opinion, is worse for use of the CORMIX model than the original location of the discharge.

Thus, it is my opinion that a monitoring or validation plan is necessary.

Q. WOULD YOU BE ABLE TO EVALUATE A MONITORING OR VALIDATION PLAN FOR THE DISCHARGE HERE IF THERE WERE ONE IN THE APPLICATION OR PERMT?

A. It would depend. I have worked on validating many models, including models similar to CORMIX. As I stated above, I have developed a similar near-field model for multiphase plumes. Though these models are similar to those in CORMIX, bubble and droplet plumes have different mixing levels and follow different, more complex, trajectories than brine discharges. I have conducted the experiments that have been used to calibrate and validate both the mixing and trajectory predictions of bubble plumes and oil and gas plumes. Much of this work is summarized in the paper I highlighted earlier by Dissanayake et al. (2012). I have also been funded by the National Science Foundation to conduct field studies on mixing by bubble plumes in lakes and by the Texas Sea Grant College Program to study mixing at Aransas Pass, among other projects.

VI. BASIS FOR YOUR OPINIONS ON THE USE OF THE SUNTANS MODEL

A. RELEVANT EXPERIENCE

Q. PLEASE DESCRIBE YOUR EXPERIENCE WITH USE OF THE SUNTANS MODEL INCLUDING ANY INTERACTIONS YOU HAVE HAD WITH BEN HODGES OR OTHERS THAT ARE RELEVANT TO YOUR EVALUATION OF THE MODELING WITH THAT MODEL HERE.

A. I have known Dr. Hodges since at least 2000, when he was hired at the University of Texas at Austin. After our correspondence about the modeling of the Port’s discharge here and introducing me to Scott Holt in the summer of 2020, I have not had any discussions with him regarding this case.

Prior to that time, I have had a number of other conversations with him and been involved with evaluating the SUNTANS model, its use and predictions for several bays in Texas. Dr. Hodges and I have been co-Principal Investigators (PIs) on three projects funded by the Texas General Land Office (GLO). He was a co-PI on the Gulf Integrated Spill Research (GISR) consortium, for which I was the chief scientist. Dr. Hodges also hosted me during my faculty development leave (similar to sabbatical) in 2014-2015.

Q. WHAT WAS INVOLVED IN HIS HOSTING YOU FOR YOUR FACULTY DEVELOPMENT LEAVE BETWEEN 2014-2015?

A. I visited him in Austin several times for extended discussions. He is developer of a Matlab model for estuarine circulation modeling called FREHD (Fine Resolution Environmental Hydro-Dynamics model). Though significantly different, this model is designed with similar purposes to the SUNTANS model. I wanted to learn to run these types of models, and he agreed to work with me on this. We discussed modeling in general, numerical techniques and problems, and issues related to setting up large-scale models. I started working with his FREHD model using bathymetry from the Texas Water Development Board for Corpus Christi Bay. Unfortunately, because I was still chief scientist of the GISR consortium at the time, I did not have the time to develop that model to a fully operational and validated state for use in the Corpus Christi Bay.

Q. DID YOU EVER PRODUCE OUTPUT FROM THE FREHD MODEL THAT WAS PUBLISHED IN A PEER-REVIEWED JOURNAL?

A. Yes. My Master's student, Katie Hutschenreuter, used the model under my direction to simulate laboratory experiments we had conducted on starting-jet vortices at tidal inlets. This is the Hutschenreuter et al. (2019) paper on my CV.

Q. HAVE YOU EVER DISCUSSED SUNTANS OR WORKED WITH IT WITH DR. HODGES?

A. Yes, multiple times. For example, during the GISR consortium, I had invited Oliver Fringer, the developer of SUNTANS, to join the team and to develop a model of Galveston Bay. I was leading the proposal and also invited Dr. Hodges to serve the role on that project of collecting field data to validate the use of SUNTANS model in Galveston Bay. This work resulted in a set of papers on Galveston Bay by Dr. Fringer's postdoctoral scholar, Dr. Matthew Rayson. Though I led the larger effort of GISR, I was not a contributing author to those papers.

After my development leave, Dr. Hodges and I wrote a proposal to GLO to use the SUNTANS model developed by Drs. Fringer and Rayson for Galveston Bay. In that first proposal, my role was to use laboratory data that I had collected previously to help validate the model's predictions of tidal starting-jet vortices. This is also the work that funded Ms. Hutschenreuter and her work with the FREHD model.

After that project concluded, Dr. Hodges and I wrote a second proposal to GLO to develop a new SUNTANS model of the Corpus Christi Bay System and to conduct new laboratory experiments. This resulted in the SUNTANS model that has been used in this permitting process.

Dr. Hodges led the SUNTANS modeling, and I conducted new laboratory experiments. So far, this collaboration has resulted in a paper by Dr. Hodges' former postdoctoral scholar, Dongyu Feng, for which I am a contributing author (see Feng et al., 2019 on my CV).

Q. DID YOU KNOW ABOUT THE WORK BY DR. HODGES TO HELP ADAPT THE SUNTANS MODEL FOR USE WITH THIS PROPOSED DISCHARGE BEFORE YOU WERE INVOLVED IN THIS CURRENT PROCESS?

A. No. I was not aware that he and Dr. Feng were involved. I was not involved in any way. I first became aware of the work when Scott Holt asked me to review it.

Q. WHAT OTHER EXPERIENCE DO YOU HAVE WITH NUMERICAL MODELS LIKE SUNTANS?

A. During my work at MIT on my Ph.D., my adviser was Dr. E. Eric Adams, who was primarily a numerical modeler. Although my work was in the laboratory and contributing to plume integral models, his other students worked on models similar to SUNTANS. Over the six and one-half years I studied with him, I attended weekly research meetings in which his other students applied models similar to the SUNTANS model. Several of these students also worked on near-field and far-field coupling that I have discussed above as being needed here.

After completing my Ph.D., I did my post-doc with Professor Gerhard Jirka at the University of Karlsruhe in the Institute for Hydromechanics. This is the same institute where Professor Wolfgang Rodi worked. He is a major pioneer in turbulence closure for numerical models like SUNTANS and other models. During my time there, I saw seminar presentations by his students and by other invited speakers on related subjects. I also collaborated with some of his students and over my time working with Dr. Jirka, I gained a strong understanding of how these models work. Though I have not become a numerical modeler myself, much of my work has focused on laboratory and field observation to validate numerical models, in particular their predictions of tracer transport.

Q. DO YOU HAVE ANY PEER-REVIEWED JOURNAL PAPERS THAT RESULTED FROM COLLABORATIONS WITH NUMERICAL MODELERS?

A. Yes. Aside from those listed above, I have at least nine such papers published since 2009. These articles involve computational fluid dynamics models where I either contributed to the numerical modeling or integrated experimental observations with the validation. The focus in such papers is often on computational models that solve versions of the Navier-

Stokes equations, as SUNTANS does. I have a number of other papers on integral jet modeling, such as those used in CORMIX.

B. OPINION ON THE USE OF THE SUNTANS MODEL HERE

Q. PLEASE STATE YOUR OPINIONS WITH REGARD TO THE USE OF THE SUNTANS MODEL TO PREDICT THE IMPACTS OF THE DISCHARGE IN THE FAR-FIELD

A. I have summarized it above. I have not run the model or attempted to determine how well it predicts conditions to the west in the Corpus Christi Bay, so I do not have an opinion on that.

However, it is my opinion that the model, as set up by Dr. Furnans, does not have the resolution needed to predict whether or not there will be plumes of higher concentrations of salinity than the ambient water as the CORMIX model can predict, and has predicted, for this discharge location.

It is my opinion that these limited far field predictions from the CORMIX model are valid with regard to their prediction of plumes of effluent moving along the bottom of the channel for some significant distance. It is also my opinion that such plumes will consist of salinity concentrations at least as high as the model predicts.

VII. RESPONSES TO TESTIMONY OF DR. JONES AND DR. TISCHLER

A. CRITICISMS BY DR. JONES

Q. HAVE YOUR READ THE PREFILED DIRECT TESTIMONY OF DR. CRAIG JONES, APP-CJ -R?

A. Yes, most of it.

Q. HAVE YOU READ THE QUESTIONS AND ANSWERS STARTING ON PAGE 13 LINE 10 THROUGH PAGE 14 LINE 14 REGARDING STATEMENTS BY PAC EXPERTS AND THE CORMIX MODELING?

A. Yes.

Q. DO THOSE STATEMENTS, WHICH THE QUESTIONS ATTRIBUTE TO PAC WITNESSES AND START ON LINE 10 AND ON LINE 27 OF PAGE 13 ABOUT CORMIX NOT BEING RELIABLE, REFLECT YOUR OPINIONS?

A. No.

Q. PLEASE SUMMARIZE YOUR POSITION WITH REGARD TO WHAT THE PORT'S QUESTION SUGGESTS.

A. I have relied on the CORMIX modeling for a number of my opinions. The model provides accurate predictions and information about how the plume will behave close to the discharge location and for a limited distance in the far field. It will accurately predict mixing if the attachment point of the boundary interaction is accurately calibrated, which, here, requires validation. I have relied on sensitivity analysis conducted with the CORMIX model to support these opinions.

Q. HAVE YOU READ THE QUESTIONS AND ANSWERS STARTING ON PAGE 14 LINES 24 THROUGH PAGE 15 LINE 7 OF DR. JONES TESTIMONY?

A. Yes.

Q. DO THE STATEMENTS, WHICH THE QUESTIONS ATTRIBUTE TO PAC WITNESSES REGARDING THE 90 FOOT BOTTOM DEPTH, REFLECT YOUR OPINIONS OR YOUR DECISION TO USE A BOTTOM DEPTH FOR THE CORMIX MODEL?

A. No. Again, I have consistently used depth to the bottom of around 90 feet for my model when it is appropriate to use, for example, in all of my brine model runs. I have used shallower depths in other simulations, matching the average channel depth at the site, but have not criticized simulations with 90 foot depth. Moreover, the depth of the hole is not a critical issue for most of my modeling, since the plume hits the side slopes of the hole well above 90 feet and it is the interaction after contact that is the prime reason the predictions beyond the distance to the side slope contact are not reliable.

A. B. CRITICISMS BY DR. TISCHLER

Q. HAVE YOUR READ THE PREFILED DIRECT TESTIMONY OF DR. TISCHLER, APP-LT – R?

A. Yes, parts of it.

Q. HAVE YOU READ THE QUESTIONS AND ANSWERS STARTING ON PAGE 52 LINE 3 THROUGH PAGE 54 LINE 2?

A. Yes.

Q. DO THOSE STATEMENTS THAT THE THREE QUESTIONS ON THOSE PAGES ATTRIBUTE TO PAC WITNESSES, ABOUT CORMIX NOT BEING RELIABLE, REFLECT YOUR OPINIONS?

A. No. Those questions, like those of Dr. Jones, may be addressing someone's statements but not mine. I am not aware of any person with experience with CORMIX taking the positions the Port attributes to PAC's witnesses.

VIII. CONCLUSION

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes.