MITIGATION OF SALINITY INTRUSTION DUE TO TIDAL PUMPING IN A TEXAS COASTAL SALT MARSH

by

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EXTENDED ABSTRACT

The Salt Bayou Marsh is a historically fresh to brackish water marsh located in Southeast Texas. It is connected to the Sabine-Neches Waterway (and thence to the Gulf of Mexico) via a dredged canal: the Keith Lake Fish Pass. The Fish Pass serves as an important migratory pathway for larval fish species that require the shelter of the marsh to mature in safety. The Fish Pass also serves as a flood-mitigation feature, since it the primary pathway for draining floodwaters resulting from local rainfall on the marsh.

The Keith Lake Fish Pass provides a continuous connection to a saltwater source, via the Sabine-Neches Waterway. This results in salinity intrusion into the marsh, via tidal pumping. The existing wetland communities in the marsh are largely freshwater wetlands, since they were established long before the Fish Pass was dredged. Hence, the salinity intrusion associated with the construction of the Fish Pass has resulted in severe degradation of the marsh substrate, and marsh loss.

In order to investigate potential mitigation solutions for this salinity intrusion problem, a multi-agency project development team (PDT) was assembled. The team proposed several potential mitigation solutions, each of which was designed to reduce the amount and duration of salinity intrusion into the marsh, while preserving the larval fish recruitment and flood mitigation functions of the Fish Pass. These proposed solutions were evaluated with appropriate modeling technologies, to determine which of them was most suitable for selection and implementation.

The Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory (CHL) was tasked by the Galveston District (SWG) of the US Army Corps of Engineers (USACE) to perform the modeling needed to evaluate the proposed salinity mitigation solutions. The CHL team worked closely with the PDT to screen and evaluate the proposed mitigation alternatives.

The proposed mitigation options consisted of 4 separate configurations of flow obstructions placed in the Fish Pass. These were all designed to reduce the tidal exchange through the Fish Pass by reducing the conveyance of the Fish Pass, and/or increasing the energy loss associated with flow separation around the obstructions.

Each of the proposed options was first evaluated for its efficacy with respect to salinity mitigation. A target reduction of salinity was selected by the PDT, and the options were screened to determine which, if any, could be shown to mitigate the salinity intrusion to below the target value.

The model used to evaluate the salinity and flooding criteria was the Adaptive Hydraulics model. Adaptive Hydraulics is a finite-element numerical model developed and maintained at CHL (Berger et. al. 1999). There are multiple physics modules attached to AdH, but the module used for this study was the shallow water, depth-averaged module.

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With respect to salinity intrusion, each of the mitigation alternatives performed similarly,. The degree of salinity mitigation was shown to be directly proportional to the degree damping of the tidal flux. Since each of the proposed alternative configurations induced similar degrees of tidal damping, they consequently induced similar degrees of salinity intrusion mitigation. The proposed mitigation alternatives essentially increased the residence time of the Salt Bayou Marsh, by limiting the tidal exchange. This means that salinity in the Sabine-Neches Waterway required more time to propagate into the system from the Fish Pass. Notably, however, it follows that, if the Fish Pass was fresher than the water within the Salt Bayou Marsh (as can often happen during in the initial days of a spring flood), then the mitigation measures were shown to impound the salt water longer, thereby elevating the salinity over the existing condition.

The flooding analysis showed that any constriction in the Fish Pass tended to increase the duration and extent of the impoundment of flood waters associated with rainfall. This increased inundation was observed in the model even though the mitigation structures were designed to overtop during flooded conditions. However, other overflow outlets to the Sabine-Neches Waterway could be implemented to mitigate this inundation.

In order to analyze the effects of the proposed structures on larval fish recruitment, a Lagrangean particle tracking model was used, (PTM) (Neil et al, 2006). The particles in the model were equipped with each of six different simple larval fish behaviors, which were selected and designed by the PDT. For each simulation, the particles were equipped with only one of the behaviors, so the effects of the structure on each of the behaviors could be analyzed independently.

The results of the PTM analysis indicated that each of the proposed mitigation alternatives resulted in less recruitment of larval fish than the existing condition configuration. However, the alternative that consisted of a single constriction of the Fish Pass resulted in the least reduction in larval recruitment. This was because the single constriction alternative generated the fewest number of flow separation eddies (recirculation zones) of all the proposed alternatives. The larval fish tended to get trapped in these recirculation zones, which inhibited their ability to enter the marsh.

The PTM results also showed that the difference in larval fish recruitment associated with each of the simple larval fish behaviors was far less than the difference in larval fish recruitment associated with each of the proposed mitigation options. This demonstrated that the recirculation associated with flow separation around the proposed mitigation features was the dominant factor in determining the recruitment success of the larval fish.

Based on the results of the salinity, inundation, and larval fish recruitment analyses, it was determined that the single constriction alternative demonstrated the most salinity mitigation benefit with the least impact to larval fish recruitment. Therefore, the single constriction alternative was selected as the proposed mitigation measure for the Keith Lake Fish Pass.

This feature was constructed in 2015, and is currently being evaluated for performance. Early indications are that the feature is performing satisfactorily, but it will require more time to determine the long-term impacts of this salinity mitigation on the prospects for recovery of the marsh. Also, there are other mitigation needs associated with the Salt Bayou Marsh, and these must be addressed as well before the conditions exist for robust marsh restoration to commence.

REFERENCES

Berger, R. C. and Stockstill, R.L. *A Finite Element System for Flows*. Proceedings of the 1999 Water Resources Engineering Conference, Seattle, WA, American Society of Civil Engineers, August 1999.

Neil J. MacDonald, Michael H. Davies, Alan K. Zundel, John D. Howlett, Zeki Demirbilek, Joseph Z. Gailani,Tahirih C. Lackey, and Jarrell Smith (2006) “PTM: Particle Tracking Model Report 1: Model

Theory, Implementation, and Example Applications" Coastal and Hydraulics Laboratory Technical report ERDC CHL TR 06/20.

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