First Draft- Freshwater Inflow Regime Recommendation for the Colorado River to Matagorda Bay

It is widely accepted that the Matagorda Bay system, like other Gulf Coast estuaries, is a highly dynamic environment which reacts to many drivers one of which is freshwater inflow. Other factors influencing bay conditions are gulf salinity, meteorology, physiographic modifications, harvest pressures, and large-scale Gulf of Mexico conditions that can affect species productivity in the bay. Any one or more of these factors can be of primary importance in influencing bay conditions at any point in time. Furthermore, there are significant contributors of freshwater inflow to the Matagorda Bay system from sources other than the Colorado River, which contributes approximately 40% of the total inflow into the system on an average basis.

The principal Matagorda Bay Health Evaluation (MBHE) work that has been employed to develop the criteria is the salinity, habitat, and benthic and oyster modeling for most inflow levels, and the nutrient modeling and data analyses for the longterm flow component. Also, it was determined that inflow criteria needed to be comprehensive and cover the full flow spectrum from very low flows (near drought-of-record conditions), in which species refuge becomes of primary importance, to higher flow events sufficient to provide adequate nutrient supply to the bay system.

The techniques to develop specific components of the inflow criteria suite focused on appropriate "Design Areas" where MBHE modeling and analysis tools were applied. These areas ranged from the substantial and important Delta area being formed at the mouth of the Colorado diversion channel, which was used to assess very low flow conditions, to the upper half of the Eastern Arm of Matagorda Bay (EAMB) for the inflow regime, and finally, to the entire EAMB for higher flow conditions. Keeping in mind the cautions stated above regarding our sole focus on Colorado River inflow, these Design Areas were deemed to be appropriate.

There were two parts to this assessment; the first involved describing the habitat conditions that are present in the Design Area within a range of inflows within this spectrum, using salinity as a surrogate for inflow. The second phase was to establish achievement guidelines to incorporate the frequency, timing, and duration of such conditions within the broader context of Matagorda Bay hydrology and ecology.

Habitat models were developed for shellfish (white shrimp, brown shrimp, blue crab), forage fish (Atlantic croaker, Gulf menhaden), and estuarine marsh (Spartina). The habitat suitability for each organism is the product of the physical suitability (e.g. marsh edge) and chemical suitability (salinity). Habitat quality was ranked by percentage of maximum weighted useable area for each individual organism as follows:
90-100% Selected
75-90% Good
50-75% Fair
25-50% Poor

For the habitat assessment, the highest inflow category within the Inflow Regime spectrum (MBHE 4) was chosen to support good or better habitat conditions within the Design Area for all species evaluated. This equates to at least 75% of the maximum amount of available habitat for each species being provided at all times within the Design Area. Additionally, a simultaneous goal for this criteria was to provide selected conditions for all modeled species within the Colorado River Delta.

Selected relates to 90 to 100% of the maximum amount of available habitat for a given species and the Colorado River Delta is defined as the area inside the Delta Edge transect The goal for the remaining MBHE inflow criteria in this spectrum was to stair step down in quality of habitat but maintain similar conditions to what was observed historically in the Design Area and within the Delta. As previously discussed, four MBHE inflow regime criteria were selected to promote intra-annual variability. The four inflow criteria, as established in the MBHE inflow spectrum based on habitat modeling activities, are shown below.

Inflow Category	**Modeled Species Rank within MBHE Design Area**	**Modeled Species Rank within Delta region**
MBHE 4	All species good or selected	All species selected
MBHE 3	All species fair or better	All species good or selected
MBHE 2	All species poor or better	All species fair/poor or better
MBHE 1	About half poor and half refuge	All species poor (except Atlantic croaker [refuge])

MBHE 4

The objectives of MBHE 4 inflows are to provide a condition that constitutes good to optimal conditions for the various trophic levels evaluated and creates intra-annual variability in the flow regime when coupled with the other MBHE inflow regime criteria. A salinity range of 15-18 ppt over the Design Area was selected to meet these objectives for MBHE 4. This salinity range suggests higher inflows that would in turn support a high level of primary production within the EAMB. At this salinity range, greater than 75% of the maximum habitat over the entire Design Area is provided for all trophic levels that were evaluated with the habitat model. This results in good to selected conditions for the trophic levels. The benthic analysis documents that the mean salinity at Station F (near the West Bay Tripod) during postdiversion benthic monitoring was 18.6 (Table 5, Section 2.4.4), which is higher than the MBHE 4 salinity range. Overall MBHE 4 is interpreted as maintaining good oyster health conditions.

MBHE 3

The objectives of MBHE 3 inflows are to provide a condition that constitutes fair to good conditions for the various trophic levels evaluated and supports intra-annual variability. A salinity range of 20-23 ppt over the Design Area was selected to meet these objectives for MBHE 3. This salinity range will require higher inflows than the other MBHE inflow regime criteria thus representing the highest amount of primary production during these conditions. At this salinity range, greater than 50% of the maximum habitat available across the Design Area is provided for all trophic levels that were evaluated with the habitat model. This results in fair to good conditions for the trophic levels presented under MBHE 3. The benthic analysis suggests conditions are less favorable than at MBHE 4 because as salinity conditions start to change greater than about 20% from the long-term average (this starts to happen at the upper end of the MBHE 3 salinity range), a change in benthic community structure, biomass, and diversity for both deposit feeders and suspension feeders in Matagorda Bay starts to occur.
MBHE 3 is interpreted as maintaining fair oyster health conditions.

MBHE 2

MBHE 2 inflows are recommended to provide a mid-level MBHE flow to assist inflow variability and to maintain ecological conditions similar to those historically observed at these inflow levels. A salinity range of 24-26 ppt over the MBHE Design Area was selected to meet these objectives for MBHE 2. This salinity range provides for inflows that would provide primary production levels between the other MBHE inflow categories. At this salinity range, greater than 25% of the maximum habitat available across the Design Area is provided for all trophic levels. The benthic analysis suggests conditions are less favorable than at MBHE 3 because all salinities within this range are greater than 20% from the long-term average at Station F likely resulting in a change in benthic community structure, biomass, and diversity for both deposit feeders and suspension feeders in Matagorda Bay. Overall MBHE 2 is interpreted as maintaining poor oyster health conditions with the potential for infrequent detrimental effects.

MBHE 1

The objectives of MBHE 1 inflows are to maintain ecological conditions similar to those historically observed at these inflow levels while providing another level of inflow variability. The goal is to maintain tolerable oyster reef health, benthic character, and habitat conditions to the degree practical during these conditions. A salinity range of 27-29 ppt over the Design Area was selected to meet these objectives for MBHE 1. This salinity range provides the lowest MBHE inflows thus also the lowest primary production within the system compared to the other MBHE inflow categories. At this salinity range, all trophic levels that were evaluated with the habitat model are represented by poor to refuge conditions. A shift from euhaline to marine benthic assemblages has the potential to occur at the upper end of this range, with a complete shift likely to occur above this range. Overall, MBHE 1 is interpreted as maintaining poor oyster health and the oyster model shows that dermo intensity would likely be detrimental.

Threshold

As discussed above, during Threshold conditions, the majority of the EAMB is experiencing high salinity conditions with limited nutrient input. Throughout the historical record, the reduction of inflow levels has never eliminated any of the key species addressed in this bio-statistical effort (shown by the absence of any zero values of annual-mean abundance in the data record). Also, these populations continue to exist at more-or-less historical levels, so reduction of inflow levels does not preclude the re-establishment of the population after a population reduction. Therefore, the data record does not reveal a level of inflow that is, in some sense, catastrophic for any one of these species, and which, therefore, would have to be exceeded at all times. However, future conditions will likely change, and to be conservative, the threshold recommendation is included as a criteria which would attempt to avoid experiencing a catastrophic event.

The ecological objectives during these extreme periods are to sustain live oysters, maintain estuarine benthic character, and provide refuge habitat for shellfish and forage fish to the extent possible. Thus, the Design Area of the immediate Colorado River Delta was chosen because of the direct relationship of Colorado River inflow to the Delta during these extreme drought conditions. An evaluation of the percentage of time that this condition was historically experienced or exceeded, along with the 27 ppt salinity bound (Station F mean salinity plus 1 standard deviation) from the benthic analysis were used to set the Threshold criteria. To accomplish these objectives to the degree practicable during extreme droughts, a minimum inflow is recommended to maintain salinity conditions in the Delta below 30 ppt. One goal of maintaining this level of inflow is to provide refuge areas for shellfish and forage fish outside of the main river channel. Maintaining this level should protect the estuarine benthic character in at

least portions of the Delta. The level of dermo infestation during extreme temperatures often accompanying these periods of extended low inflow may cause extensive mortality. Similar to nature, there are no guarantees, and thus oyster and dermo monitoring during these periods will be vital to guide potential adaptive management opportunities aimed at protecting live oysters within the Delta during these extreme events.

The suite of recommended inflow criteria are summarized below:

Flow Volumes (AF)				**Achievement Guideline**
Threshold Maintain 15,000 AF per month				100%
Regime	Spring	Fall	Intervening	
MBHE 1	114,000	81,000	105,000	90%*
MBHE 2	168,700	119,900	155,400	75%
MBHE 3	246,200	175,000	226,800	60%
MBHE 4	433,200	307,800	399,000	35%**

Note 1: Could allow for adaptive inflow management during Threshold conditions. For example, holdback of minimum flow during a given month or months to allow for larger pulse flow release.

* Based on historical frequency of occurrence

Note 2: For the Threshold and Regime criteria levels (MBHE 1-3), operating protocol ("triggers") are to be established to manage flows by releases from storage so as to satisfy the achievement guidelines recommended above.

** MBHE 4 criteria achievement guideline is also based on historical frequency of occurrence. However, it is recommended that Water Availability Model (WAM) results be examined to determine that this frequency is achieved by a combination of years that either 1) fully satisfy all seasonal components of the MBHE 4 criteria, or 2) are projected to have an annual flow that exceeds the volume (approximately 1.6 million acre feet [MAF]) necessary to maintain a monthly average of 15 ppt salinity at the Mad Island reef transect (the outermost transect of the Design Area), meet two of the three seasonal components of MBHE 4, and exceed the MBHE 3 criteria for the remaining seasonal component.

Long-Term Volume and Variability Average at least 1.4 to 1.5 MAF per year 100%

Recommend that WAM results be examined to determine that the projected long-term annual average flow is maintained at a level of at least 1.4 to 1.5 million AF, with a coefficient of variation (CV) value above 0.8.

Note 3: As the satisfaction of all criteria is based on a 59-year WAM simulation, an important adjunct to the Inflow Criteria is the establishment of a monitoring program, which measures key bay health and productivity indicators and verifies the projected response of the bay to flow levels in the Colorado River. Also, it will be necessary to regularly review the basic assumptions (demand, hydrology, etc.) that are fundamental to the WAM simulation upon which successful criteria achievement is projected. Regular reassessment based on new data and refined assumptions would provide the basis for an adaptive management approach to maintaining bay health and productivity.