January 01, 2011

Transmittal to Basin and Bay Area Stakeholders Committees (BBASCs) and
Basin and Bay Expert Science Teams (BBESTs)

Title: Discussion Paper – Consideration of Attainment Frequencies and Hydrologic Conditions in Developing and Implementing Instream Environmental Flow Regimes

Associating a required attainment frequency with the different components of an instream environmental flow regime recommendation has been recognized as an important consideration when implementing environmental flow requirements; however, the manner in which such attainment frequencies may be achieved or even considered during implementation and/or water rights permitting has not been fully addressed thus far and continues to be clouded with uncertainty. The Trinity-San Jacinto (T-SJ) and Sabine-Neches (S-N) BBESTs and the Texas Commission on Environmental Quality (TCEQ) in its rulemaking process for establishing environmental flow standards for these basins have all approached this issue differently. This paper discusses each of these and other approaches, and provides some insight as to the pros and cons of using different methods for addressing the issue of satisfying, or at least considering, attainment frequencies.

At this point, the SAC considers it inappropriate and possibly misleading to suggest a single recommended approach for dealing with attainment frequencies in the development of e-flow regimes and implementation of those regimes through adopted environmental flow standards. Site-specific circumstances can dictate different methodologies, and the BBESTs, through their studies and deliberations, can decide on the best course of action for their respective basins in order to meet their legislative charge of developing e-flow regime recommendations "considering all reasonably available science, without regard to the need for the water for other uses" (SB3, Sec. 11.02362m). On the other hand, the basin-bay stakeholders and the TCEQ, with their broader legislative mandates under SB 3 to develop e-flow standards while also considering human needs for water, have greater latitude with regard to the structure and implementation of e-flow regimes, including the procedures used for addressing attainment frequencies.

The SAC will continue to follow the work of the existing BBESTs and stakeholder groups, as well as the rulemaking activity at the TCEQ, as they deal with these important aspects of environmental flow development.

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DISCUSSION PAPER

Consideration of Attainment Frequencies and Hydrologic Conditions In Developing and Implementing Instream Environmental Flow Regimes

January 1, 2011

1.0 INTRODUCTION

Associating a required attainment frequency with the different components of an instream environmental flow (e-flow) regime has been recognized as an important consideration when implementing environmental flow requirements (SAC, 2010a and 2010b); however, the manner in which such attainment frequencies may be achieved or even considered during implementation and/or water rights permitting has not been fully addressed thus far and continues to be clouded with uncertainty. Certainly, the initial Basin and Bay Expert Science Teams (BBESTs) for the Trinity-San Jacinto (T-SJ) and the Sabine-Neches (S-N) basins approached the concept of attainment frequencies for their respective basins differently, and the Texas Commission on Environmental Quality (TCEQ) in its rulemaking process for establishing environmental flow standards for these basins has done so as well. This paper discusses each of these and other approaches and provides some insight as to the pros and cons of using different methods for addressing the issue of satisfying or at least considering attainment frequencies.

At this point, it is considered inappropriate and possibly misleading to suggest a single recommended approach for dealing with attainment frequencies in the development of e-flow regimes and implementation of those regimes through adopted environmental flow standards. Site-specific circumstances can dictate different methodologies, and the BBESTs, through their studies and deliberations, can decide on the best course of action for their respective basins in order to meet their legislative charge of developing e-flow regime recommendations "considering all reasonably available science, without regard to the need for the water for other uses" (SB3, Sec. 11.02362m). On the other hand, the basin-bay stakeholders and the TCEQ, with their broader legislative mandates under SB 3 to develop e-flow standards while also considering human needs for water, have greater latitude with regard to the structure and implementation of e-flow regimes, including the procedures used for addressing attainment frequencies.

2.0 HYDROLOGIC CONDITIONS COMPLIANCE APPROACH

One way for attempting to satisfy the attainment frequencies assigned to different e-flow regime components is to engage the e-flow components in accordance with certain hydrologic conditions that are set at specific frequencies such that the resulting frequencies of instream flows match the desired attainment frequencies. Since the assignment of attainment frequencies to individual instream e-flow components typically has been based on the historical occurrence of specific flow values during some specified hydrologic period, it follows that associating the individual e-flow components with certain hydrologic conditions as a means for determining when the e-flow components should be engaged should be a useful mechanism for attempting to satisfy attainment frequencies during implementation. The thinking here has been that these different hydrologic conditions could be expressed in terms of some hydrologic indicator such as upstream reservoir storage, antecedent streamflows or drought index, with different values of the hydrologic indicator, either in a model simulation or in the real world, then used as triggers to determine when the different e-flow components would be engaged. These triggers would be established, likely through an iterative process, so that as the selected trigger values of the hydrologic indicator are employed, the desired attainment frequency of a particular e-flow component would be achieved.

With the above hydrologic conditions approach, if the base-flow components of an e-flow regime are defined to include wet, average and dry values for four different seasons with an attainment frequency prescribed for each flow component, then for each season, two trigger values for the selected hydrologic indicator would need to be established to define the divisions between the wet and average hydrologic conditions and the average and dry hydrologic conditions. This would result in a total of eight different trigger values for implementing all of the seasonal base-flow components. On the other hand, if annual rather than seasonal attainment frequencies are prescribed, then only two trigger values would be required.

The extension of the hydrologic conditions concept to determine when different levels of high-flow pulses within a particular season should be engaged in order to satisfy attainment frequencies may be theoretically possible, but the required analyses are even more complicated in a technical sense and most likely would result in definitions for hydrologic conditions that are different from those established for base flows using the same hydrologic record. These complexities are likely to make consideration of this approach beyond what the BBESTs can, or even should, effectively undertake with their limited resources and schedule. If hydrologic conditions are to be considered at all for defining when different levels of high-flow pulses are to be engaged, the most effective approach may be to simply adopt the definitions for the base-flow hydrologic conditions and to factor these definitions into the development and prescription of the different high-flow pulses with regard to attainment frequencies in order to rationalize that these frequencies are being somewhat satisfied.

This process of establishing meaningful hydrologic conditions can be quite challenging when trying to relate attainment frequencies derived from historical flow records to the frequencies of highly variable future flow conditions that are likely to be changing over time as they are influenced by increased surface water usage and water supply development. By necessity, this leads to some assumption regarding future surface water usage and water supply development that must be made in order to effectively define the hydrologic conditions. Certainly considering future human needs for water is within the purview of the stakeholders and the TCEQ in their deliberations to develop e-flow standards, but how BBESTs can address this issue without compromising their mission to develop appropriate e-flow regime recommendations based solely on available science remains a challenge, but one that may have to be rationalized by the BBESTs and their respective stakeholder committee if meaningful e-flow implementation procedures are to be achieved.

It is important to note that the hydrologic conditions approach described above, whereby hydrologic condition triggers are specifically defined so that desired attainment frequencies for the e-flow components are likely to be achieved, was not employed by either of the T-SJ or S-N

BBESTs. While the S-N BBEST did associate different levels of base flow and different high flow pulses with prescribed wet, average and dry hydrologic conditions, as described in Section 4.0 below, the triggers defining these hydrologic conditions were set at the 25% and 75% exceedance frequencies (as representative high and low values) for storage in major upstream reservoirs rather than at frequencies specifically designed to achieve certain prescribed e-flow attainment frequencies.

3.0 TRINITY-SAN JACINTO BBEST APPROACH

Both of the Trinity-San Jacinto BBEST groups (Regime and Conditional) recommended multi-tiered instream e-flow regimes at multiple locations on streams within the Trinity and San Jacinto basins that included seasonal values of subsistence and base flows.[1] (T-SJ BBEST, 2009). The Regime group recommended a subsistence flow value, wet, average and dry values for base flows, and high flow pulses for each season, whereas the Conditional group recommended a subsistence flow value and only a single base flow for each season.

Each of the flow components recommended by the BBEST groups was associated with some measure of attainment frequency. Historical frequencies of occurrence based on a selected period of record were specified for the different seasonal subsistence and base flow components, and the required number of events per season was noted for each of the high-flow pulses.

Neither of the T-SJ BBEST groups presented any suggestions on how to actually achieve the recommended attainment frequencies, and there was no apparent consideration of the use of the hydrologic conditions approach as a means for associating the different subsistence and base flow values with hydrologic indicator triggers that yield frequencies of occurrence similar to the specified attainment frequencies. Certainly, this may have been deliberate to avoid any suggestion that the BBEST was addressing how to implement its e-flow recommendations for actual new water rights, which could be interpreted as reaching beyond the BBEST's mandate of "considering all reasonably available science, without regard to the need for the water for other uses".

4.0 SABINE-NECHES BBEST APPROACH

The Sabine-Neches BBEST also recommended multi-tiered instream e-flow regimes at multiple locations within the Sabine and Neches basins that included seasonal values of subsistence and base flows and high-flow pulses[2], including wet, average and dry values for the base flows for each season (S-N BBEST, 2009). Various high-flow pulses also were recommended for each season, depending on hydrologic condition.

Attainment frequencies were not specified by the S-N BBEST for the different levels of the base-flow components of the recommended e-flow regimes. However, hydrologic conditions dictating when each of the wet, average and dry base-flow values would be engaged (as pass-

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[1] Each high-flow pulse is characterized by a required peak-flow trigger that must be exceeded on at least one day and associated minimum values of either duration in days or volume in acre-feet, one of which must be satisfied.

[2] Based on standard high-flow pulse definition as previously noted.

through requirements for permits subject to these environmental flow standards) were defined in terms of the frequency of occurrence of the combined storage in major upstream reservoirs assuming full use of authorized water rights[3]. The wet hydrologic condition was associated with the combined upstream reservoir storage that would be exceeded less than 25% of the time, and the dry hydrologic condition was associated with the combined upstream reservoir storage that would be exceeded more than 75% of the time. The average hydrologic condition was defined to apply when neither the wet nor the dry conditions were in effect. The hydrologic condition was to be established based on the combined upstream reservoir storage at the beginning of the first day of a particular season, with the associated base-flow value for that season to be in effect during the entire season.

The S-N BBEST also associated different high-flow pulses with the same hydrologic conditions used for the base flows. For the wet hydrologic condition, a single (relatively large) high-flow pulse was required for each season, with different pulses defined for the different seasons. For the average hydrologic condition, two (relatively small) high-flow pulses were required each season, with different pulses defined for the different seasons but with each of the pulses the same for each season. A single (relatively small) high-flow pulse also was required for the dry hydrologic condition, but only during the spring and summer seasons; no pulse was required during the fall and winter seasons.

As noted above, the S-N BBEST did not attempt to establish triggers for the different hydrologic conditions designed to achieve specific attainment frequencies. Instead, the 25% and 75% exceedance frequencies for upstream reservoir storage were adopted as representative high and low flow triggers, and special studies and analyses involving application of the recommended e-flow regimes to an example water supply project using these triggers were undertaken by the BBEST. Based on an assessment and evaluation of the resulting streamflows at the different e-flow regime locations with regard to their hydrologic, biologic, geomorphic and water quality implications for environmental flows and the exercise of best professional judgment, the BBEST determined that the recommended e-flow regimes, when engaged using the adopted hydrologic conditions, were sufficient "to sustain native species for extended periods" and "for long-term support of a sound ecological environment".

5.0 TCEQ DRAFT RULES APPROACH

In developing its draft rules for adoption of e-flow standards and set asides for the Trinity-San Jacinto and Sabine-Neches basins[4], the TCEQ utilized information provided by the two basin-bay area stakeholder committees (T-SJ BBASC, 2010 and S-N BBASC, 2010) and their associated BBESTs. Based on this information, the TCEQ structured draft e-flow standards at multiple locations within each of the basins, with each of these standards comprised of subsistence and base flows and high-flow pulses for each season. The TCEQ then applied these e-flow standards as flow restrictions on the diversions and/or storage for actual proposed individual water supply projects in each of the basins in order to evaluate the potential water

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[3] Assuming full use of authorized water rights is consistent with conditions simulated with the Run 3 version of the TCEQ's water availability models (WAMs).

[4] http://www.tceq.state.tx.us/assets/public/legal/rules/rule_lib/proposals/07049298_pex.pdf

supply impacts of the proposed standards. For these evaluations, the TCEQ used the Run 3 versions of the respective basin WAMs with full use of all existing authorized water rights and no return flows. Results from these WAM simulations were examined by the TCEQ and used to support its determinations regarding the quantities of flow that needed to be preserved for the environment and the balancing of environmental interests with other public interests, including human needs for water.

5.1 Trinity-San Jacinto Basin – Daily Flow Compliance Approach

For the T-SJ basin, the TCEQ's draft rules include instream e-flow standards at six measurement locations, with each standard comprised of a subsistence flow and a single base-flow value for each of four seasons and a high-flow pulse for each of three seasons (spring, summer and winter, excluding the fall months of October and November). Two of the specified high-flow pulses are required to be satisfied each season, if they occur.

For purposes of implementation of the draft e-flow standards, the TCEQ did not address attainment frequencies as included in the T-SJ BBEST and stakeholder committee reports.[5] The draft rules simply state that if the flow on any given day at any one of the measurement points downstream of a water right that is subject to the new standards is:

(1) Less than or equal to the subsistence flow value, no streamflow may be diverted or stored by the water right on that day,

(2) Greater than the subsistence flow value but less than or equal to the applicable base-flow value, all streamflow in excess of the subsistence flow value may be diverted or stored by the water right on that day, or

(3) Greater than the applicable base-flow value but less than the applicable peak flow value for the high-flow pulse, all streamflow in excess of the applicable base-flow value may be diverted or stored by the water right on that day.

This daily flow compliance approach does not attempt to limit diversions or storage by a water right that is subject to the new standards based on achievement of prescribed attainment frequencies. Rather, it simply preserves the frequencies at which flows at the measurement locations either occurred historically for some period prior to implementation of the water right or are expected to occur at some time in the future[6]. For example, if the frequency of occurrence of a particular base-flow value is calculated to be 75% based on a recent historical period of record (the percentage that could have been used as the basis for prescribing an attainment frequency for the base flow), the approach used by the TCEQ would limit the diversions and/or storage of a recently issued water right so that the base-flow value would be preserved about 75% of the time with the new water right in place. On the other hand, if the frequency of occurrence of that same base-flow value is projected to be only 55% under full water rights utilization as simulated with the Run 3 version of the WAM, then the diversions and/or storage

[5] Note that TCEQ did propose a table of multiple flow magnitudes (expressed as annual volumes) and attainment frequencies for freshwater inflow standards, e.g., see the draft rules for freshwater inflows to Galveston Bay.

[6] Said another way, the daily flow compliance approach preserves the frequencies at which the specified flows at the measurement locations would occur in the absence of the permit that is subject to such conditions.

of the recently issued water right would be limited in the future so as to preserve this same base-flow value 55% of the time, assuming that all existing water rights would be fully utilized under similar hydrologic conditions. In essence, the approach used by the TCEQ assures that a certain prescribed subsistence or base-flow quantity will not be diminished by a new water right that is subject to the draft e-flow standards. Of course, this approach is not capable of achieving a desired frequency of occurrence for a prescribed base-flow amount if current or future flow conditions, influenced by increased surface water usage and water supply development authorized under existing water rights not subject to the draft e-flow standards, already have or are projected to be characterized by lower occurrence frequencies. In addition, future climate variability (changes in precipitation patterns, timing of rainfall events, temperature, etc.) may also affect the ability to achieve desired frequencies of occurrence.

With regard to the implementation of high-flow pulses, the TCEQ draft rules state that if the flow is above the applicable base-flow value and if the peak-flow value for a particular high-flow pulse is satisfied at a downstream e-flow measurement location, then no streamflow is to be diverted or stored by a water right that is subject to the new standards unless:

(1) The stipulated volume amount for the high-flow pulse event has passed the measurement location, or

(2) The stipulated duration of the high-flow pulse event in days since the peak-flow trigger occurred has been satisfied.[7]

While the draft TCEQ rules do require that two prescribed high-flow pulse events be passed each season, assuming that they actually occur, before streamflows can be diverted and/or stored by a water right subject to these standards, each season is considered independent of the preceding and subsequent seasons with respect to high-flow pulse frequency. Hence, there is no carry-over of deficit or surplus in the two-pulse per season requirement in the event of under- or over-achievement of the requirement in the previous season.

One last point to note regarding the daily flow compliance approach is that it always requires some level of flow to be passed by a water right that is subject to the e-flow standards (provided such flow actually occurs), even a high flow pulse of significant magnitude during extreme drought conditions when water supplies stored in upstream reservoirs may be substantially depleted and drought contingency plans may significantly curtail water usage. While it is recognized that such a high flow pulse would occur naturally and could provide certain benefits to downstream ecosystems, the necessity of passing such an isolated pulse during the course of a severe drought is arguable with regard to its actual contribution for maintaining the downstream ecosystem. In other words, could the ecosystem have been satisfactorily maintained without the pulse? This potential shortcoming of the daily flow compliance approach generally is not an issue with the hydrologic conditions compliance approach, since smaller pulse requirements typically are associated with dry hydrologic conditions and higher pulses are required to be

[7] It should be noted that this procedure for accounting for the volume and duration of a high-flow pulse is not consistent with the hydrograph separation techniques typically employed when applying the HEFR program to identify high-flow pulses for a given period of hydrologic record. Rather than starting a high-flow pulse event on the day the desired peak flow occurs, these techniques assume the pulse begins when the rate of change in the mean daily flow exceeds a prescribed value.

passed only during wet conditions, with the designation of these hydrologic conditions based on water supply storage in upstream reservoirs.

5.2 Sabine-Neches Basin – Hydrologic Conditions Compliance Approach

For the S-N basin, the TCEQ's draft rules include instream e-flow standards at eleven measurement locations, with each standard comprised of a subsistence flow, three levels of base flow corresponding to wet, average and dry hydrologic conditions for each of four seasons, and up to two levels of high-flow pulses varying in magnitude and frequency for the different seasons. Depending on the defined hydrologic condition, which is the same as that determined for base flows, none or one or two of the specified high-flow pulses are required to be satisfied each season, provided they occur.

For purposes of implementation of the S-N draft e-flow standards, the TCEQ has defined wet, average and dry hydrologic conditions using procedures consistent with the S-N BBEST recommendations, hence adopting a hydrologic conditions compliance approach. The volume of water in storage in designated major reservoirs upstream of each of the eleven measurement points on the last day of a season is used to determine the hydrologic condition for the subsequent season. Using the time series of all monthly storage values in these reservoirs over the 1940-1998 period of hydrologic record as simulated with the Run 3 versions of the Sabine and Neches WAMs, the TCEQ performed statistical analyses and determined the 25th and 75th percentiles of the combined storage levels for each of the eleven instream e-flow measurement locations. These storage values then were adopted as the dry and wet triggers, respectively, for establishing the wet, average and dry hydrologic conditions[8].

Once the hydrologic condition is established at a particular measurement location, then the corresponding base-flow requirement and any high-flow pulse requirements can be determined and engaged for the following season. Implementation of the subsistence flow and the base-flow requirements follow a similar framework as the three steps outlined above for the T-SJ basin, with the primary exception that diversion down to the subsistence level is only permissible during dry conditions. Likewise, the same procedures described above for implementing the high-flow pulses in the T-SJ basin also apply to high-flow pulses in the S-N basin.

6.0 OBSERVATIONS

It is clear that different approaches have been used with regard to attainment frequencies for the different components of an e-flow regime, not only by the BBESTs and the stakeholder committees, but also by the TCEQ in its analyses of the impacts of draft e-flow standards on proposed water supply projects. Basically, two fundamental approaches have evolved from the TCEQ's rulemaking process depending on whether or not the BBESTs or the stakeholders for a

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[8] While the TCEQ determined dry and wet triggers based on monthly reservoir storage values for all months of the WAM simulation period and then applied these triggers at the beginning of each season to determine the hydrologic condition for the season, seasonally-varying dry and wet triggers could have been determined using only the monthly reservoir storage values for each of the seasons. This would have resulted in four sets of dry and wet triggers for the four seasons and could have provided a better representation of the recommended seasonally-varying e-flow requirements and flow frequencies.

particular basin recommended the use of hydrologic conditions for engaging different levels of base flows and/or pulse flows, or more importantly whether the BBESTs or the stakeholders provided the TCEQ with specific direction in terms of triggers for defining these hydrologic conditions.

Without such direction, as was the case for the T-SJ basin, the TCEQ did not consider recommended attainment guidelines for base flows and employed a simple daily flow compliance approach in which the decision as to whether a water right subject to the new e-flow standards can divert or store water is made daily based on currently-existing flow conditions at each of the downstream e-flow measurement locations. Alternatively, when direction was provided as to how certain hydrologic conditions should be defined with corresponding e-flows in effect, as was the case for the S-N basin, the TCEQ utilized the hydrologic conditions compliance approach whereby specific hydrologic triggers related to upstream reservoir storage were employed to define wet, average or dry hydrologic conditions and their corresponding e-flow requirements. The only significant difference between the daily flow compliance approach and the hydrologic conditions compliance approach as employed by the TCEQ appears to relate to the manner in which the effective base flows and high-flow pulses are determined. Otherwise, the procedures for the actual engagement and application of the resulting e-flow components by the TCEQ are essentially the same.

Neither of the two approaches directly addresses satisfying prescribed attainment frequencies. The daily flow compliance approach does not consider attainment frequencies at all, whereas the hydrologic conditions compliance approach at least has the potential to consider attainment frequencies through proper definition of the hydrologic triggers. However, as described previously, this can evolve into a very complex process, particularly when trying to relate attainment frequencies derived from historical flow records to the frequencies of highly variable future flow conditions that are likely to be changing over time as they are influenced by increased surface water usage and water supply development. By necessity, this leads to some assumption regarding future surface water usage and water supply development that must be made in order to effectively define the hydrologic conditions, and this is exactly the procedure utilized by the S-N BBEST for evaluating the effectiveness of its adopted hydrologic conditions and corresponding e-flow recommendations.

One distinct advantage of the daily flow compliance approach is that it does ensure that a certain prescribed subsistence or base-flow quantity will not be diminished by a new water right that is subject to the draft e-flow standards; hence, the frequency of occurrence of the e-flow quantity also will not be diminished as a result of the new water right relative to the frequency that existed prior to the new water right being exercised. Like the hydrologic conditions compliance approach, the daily flow compliance approach is not capable of achieving a desired frequency of occurrence for a prescribed base-flow amount if future flow conditions influenced by increased surface water usage and water supply development authorized under existing water rights not subject to the draft e-flow standards are already projected to be characterized by lower occurrence frequencies.

Also, as noted above, the daily flow compliance approach always requires some level of flow to be passed by a water right that is subject to the e-flow standards (provided such flows actually occur), even a high flow pulse of significant magnitude during extreme drought conditions when water supplies stored in upstream reservoirs may be substantially depleted and drought contingency plans may significantly curtail water usage. Conversely, this approach also allows diversions to be made under extremely low-flow conditions when only the subsistence e-flow requirement would need to be passed downstream even though upstream reservoirs may be relatively full. Such potential shortcomings of the daily flow compliance approach generally is not an issue with the hydrologic conditions compliance approach, since smaller pulse requirements typically are associated with dry hydrologic conditions and higher pulses are required to be passed only during wet conditions, with the designation of these hydrologic conditions based on water supply storage in upstream reservoirs. Likewise, subsistence flows are required to be passed only during dry hydrologic conditions when storage in upstream reservoirs is relatively low.

The TCEQ staff has suggested that application of the daily flow compliance approach for implementing e-flow standards necessitates that the e-flow regime at a particular location on a stream consist of only a subsistence flow, a single base-flow component, and up to two high-flow pulses for each season. Otherwise, implementation and compliance monitoring of the e-flow standards at multiple locations in the real world has been judged to be too cumbersome for TCEQ and water right holders subject to the standards. On the other hand, the TCEQ staff has indicated that the hydrologic conditions compliance approach could be implemented in a manner that would allow multiple values of base flows and high-flow pulses for each season to be included in a prescribed e-flow standard at a particular stream location. The different degrees of difficulty in implementing the two approaches as suggested by the TCEQ are not readily apparent; however, the perceived differences on behalf of the TCEQ staff very likely could influence which approach might be considered by BBESTs and stakeholders when structuring e-flow recommendations.

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