## APPENDIX G INDICATORS

{The ideas included in this draft document are only intended as a starting point for the development of a workplan to begin the process of adaptive a management.}

As the Cypress-Flows Project (CFP) proceeds, it will need to evaluate how well implementation of the flow regimes, flow standard and set aside accomplish the goal of protecting the ecological health of lakes, rivers and streams of the Cypress Basin. Although a general objective for such protection was clearly articulated at the beginning of the Project, , and research goals set, in part, for base line data for such evaluations, a clear set of specific measures to assess ecological health were not defined. Development of indicators and an analysis of the data available or that should be collected for an appropriate set of indicator was begun in 2009.

The goal of this work is to identify specific quantifiable indicators so that the efficacy of the proposed flow regime can be evaluated through adaptive management. A sound ecological environment is one that maintains the integrity and function of the natural system. It *has the things that it should have*, richness and diversity of plants and animals, and it *does the things it should do*, maintain water quality, move sediments, and connect the riverine and riparian area and flood plains.

Review of historical data suggests that the plant and animal communities have changed partially in response to human alterations. The fish community appears to have shifted from assemblages dominated by cyprinids, percids, cyprinodontids in the 1950's to assemblages dominated by centrachids, other cyprinids, clupeids, and artherinids by the 1980's. The plant community of this wetland of international importance has developed a more homogeneous age structure likely due to the stabilization of flows by upstream impoundment. Water quality concerns related to dissolved oxygen, nutrients, bacteria and mercury have been identified. Although sediment loadings have not been measured, it is reasonable to assume that major impoundments have captured a high proportion of sediment and this may have implications for channel morphology.

The best available science on environmental flows predicts that maintaining key components of the natural flow regime is the safest and surest way to maintain and restore ecological health. Preliminary flow recommendations have identified the key components of that regime. These will be implemented via an adaptive management approach. The success of this approach will be evaluated based on the resource response. Specifically the resource should show maintenance of species richness and diversity, support of a heterogeneous age class of wetland plants, reduction of human induced water quality concerns and maintenance of in channel habitat conditions.

*Indicators*

There are multiple aspects of the structure and function of a “sound ecological environment” or a river’s ecological integrity. Measurement of an ecosystem’s condition and monitoring of restoration or management objectives should consider these aspects. In addition, due to limited resources and time, monitoring programs must be as efficient and focused as possible.

The Texas Instream Flows Program (TIFP) has proposed a system for developing objectives for meeting goals for each priority study segment and developing indicators to monitor progress. The framework is also very similar to and highly compatible with the way that The Nature Conservancy sets conservation objectives and monitors success (TNC 2001). Thus, CFP can utilize an approach based on the TIFP framework to monitor implementation of flow building blocks and to guide adaptive management.

Flow recommendations were developed based on review of existing data and in some cases model simulations of instream habitat, water quality, sediment transport, and watershed connectivity. The goal of the flow recommendations is to protect a sound ecological environment, which is defined as a condition that maintains the integrity and function of the riverine system. Although some site-specific data and analysis was available to link flows to a ecological resource response, via the intermediate steps of analysis of water quality, habitat, sediment transport and connectivity, the recommendations were in good part based on an application of the natural flow paradigm which states that a sound ecological environment is maintained by maintaining critical component of the natural flow regime. The recommendations are now being evaluated and refined within an adaptive management context and the effectiveness of the recommendation on meeting the goal will be evaluated on several levels.

*Relationship to ecological health and timeframe of ecological response*

A critical piece of the process of adaptive management is the monitoring of specific and quantifiable measures of the ecosystem response. As outlined in the TIFP, useful ecological indicators share a number of important characteristics. They may have "intrinsic importance (measure a species or process directly)," perhaps serve as an early warning or sensitive indicator or they may serve to stand in for a process (TIFP 2008). Other important considerations are cost and ease of monitoring and the availability of historical or baseline data against which comparisons can be made. Each of these issues should be considered when selecting among the many choices of available indicators. Unfortunately, the most comprehensive measures of ecosystem health are the ones that typically take the longest to see a response to changes in water management and are the most difficult to measure. Changes in species richness and diversity fall in this category. Deviation from flow recommendations are relatively easy to monitor, however the prediction of ecological response to these deviations carries more uncertainty.

A simplistic model of a general approach used to develop an instream flow recommendation is illustrated in Figure 12.

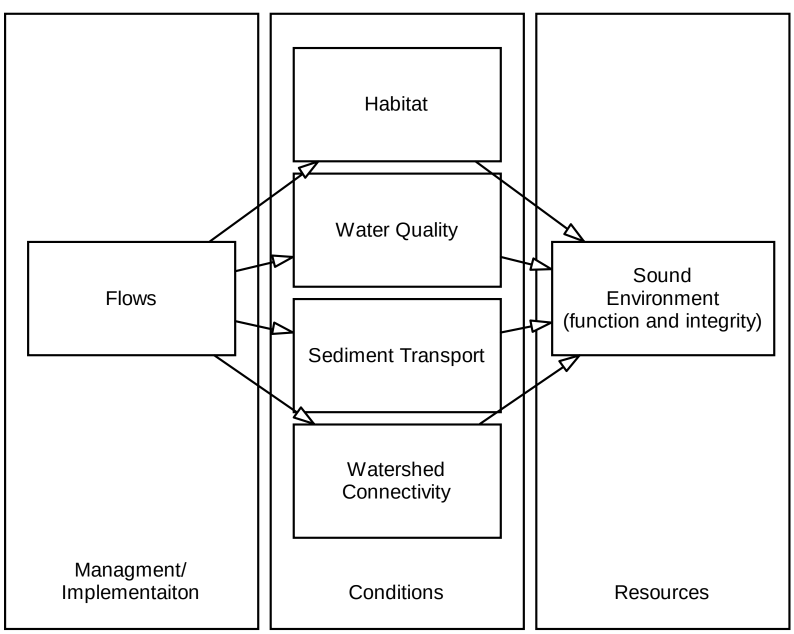



**Figure 12 Multilevel indicators of ecological health.**

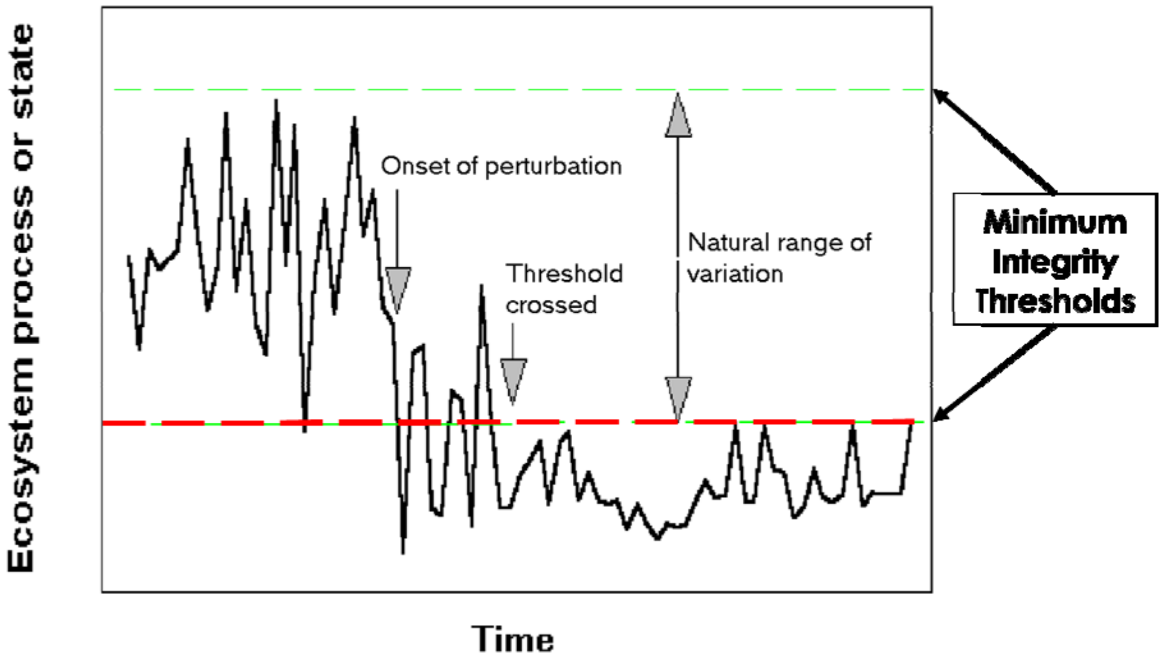
Resource level measures of ecosystem integrity and function apply to the riverine "resources" including biological measures such as species richness and diversity, and riverine functions such as the ability to assimilate wastewater and to maintain river channels. While these measures are desirable, detecting a response in these resources to a change in water management is often difficult and it may be years before this response is detected. These delayed responses can be counteracted somewhat by the selection of relatively more sensitive attributes such as early life stage responses or recruitment success, but there is no getting around the fact that detection of community level effects will require a significant level of time and resources. With the next level of indicator, mid-term/ conditions, rather than directly evaluate the "resource" response, indicators measure the response of the "conditions" that are necessary to maintain those resources (i.e. measurement of habitat, water quality, sediment transport and connectivity). These indicators might also be viewed as analysis or model verification. If a habitat model predicts that a certain flow rate will provide a specific amount of available riffle habitat these indicators can be used to verify this prediction and if necessary refine or recalibrate the model to improve these predictions. The final indicator level, short-term/management might be viewed as an indicator of the implementation success. These indicators address the question of whether the water management plan produces the prescribed flow recommendations. These include not only the various magnitudes, frequencies, durations and timing prescribed in the building blocks but also the desired attainment frequencies at which these recommendations should be achieved. As such, development of these indicators is integrated with the development of various triggers that will be necessary to allow operators to implement these recommendations and a consideration of other factors related to water supply, operational constraints and values associated with other water uses. These indicators may also take different forms when considering real time operations and long term planning or water rights permitting.

While monitoring of these various types of indicators can take place concurrently, there is a logical progression from the short-term/management to the mid-term/conditions and finally the long-term/resource level measures. If the water management implementation plan is not achieving the desired flow conditions, it is impossible to evaluate the resource response to the flow recommendations. The process of adaptive management addresses this issue by providing for evaluation of response to specific flow conditions. However, even these evaluations will likely be limited to mid-tem intermediate indicators.

*Thresholds*

Before discussing the specifics of each indicator, an issue that requires some attention is a discussion of how achievement of these indicators is assessed. This leads directly to a discussion of thresholds. The natural flow paradigm suggests that healthy aquatic systems do not require strict adherence to precise flow targets but rather that the natural range of variation in flow levels and events will maintain a broad suite of ecosystem resources. While it is not necessary to conserve the entire range of variation, it is necessary to conserve the ecosystem so that it remains within some appropriate limits to this variation. Identifying such thresholds provides a scientific, objective basis for saying whether a sound ecological environment is intact. The minimal conservation goal for an ecosystem should be to ensure that all of its ecological indicators are within the bounds of their critical ecological thresholds or “minimum integrity thresholds” (TNC 2001; Parrish et al. 2003). This provides an explicit definition of what acceptable conservation means, and hence an explicit basis for rating the ecosystem’s status.

The Minimum Integrity Threshold for an ecological indicator is the outer limit of its acceptable range of variation. Once this threshold has been crossed, the overall integrity of the river cannot be restored so long as the altered indicator is outside of its range of acceptable variation. The composition, structure, and function of a river may not begin to degrade immediately when one of its indicators moves outside of its acceptable range of variation. However, we can expect this shift to set in motion chains of events, that will (if unchecked) result in additional alterations to other indicators and leave them vulnerable to significant disruptions from additional disturbances, that in turn will push them still further outside of their acceptable ranges of variation. Defining the Minimum Integrity Threshold for individual indicators is the mechanism by which scientific knowledge of the river influences the Ecological Integrity rating. This threshold becomes the fixed dividing line between ratings of Good (or better) and Fair (or worse) for each indicator. Therefore, this is the principle threshold that will help define a consistent, scientifically defensible means of rating the integrity of the river.




The idea of "minimum integrity thresholds" comes from the concept of "natural range of variation":

Each key ecological factor for a target will have a natural range of variation. Key ecological factors such as species population sizes; river flows; water quality, sediment transport, frequency and area of riparian inundation all naturally vary within certain ranges.

There are recognizable patterns to this variation, which can be described in terms of frequency, timing, duration, and limits of variation. This pattern includes both "normal" variation and extreme disturbances.

Natural communities and ecological systems recover from extreme disturbances -- although this may take a long time.

A naturally functioning target can generally only be driven beyond its natural range of variation and ability to recover (breakdown of resistance and resilience) by disturbances foreign to the system.

"Minimum integrity thresholds" are those boundaries beyond which the target loses its natural ability to recover.

Planning teams can use key factors as tools to define a desired future status for each conservation target by setting thresholds that define the preferred status for each key factor. These conservation area-defined Optimal Integrity Thresholds are the means to measure the improvement of a target's key factors beyond their minimum integrity thresholds and toward the more ecologically desirable status at the conservation area. To receive a “Very Good” rating, a key factor must:

- Be less vulnerable to being pushed outside its acceptable range of variation by chance events or human caused disturbances perturbations, and therefore is perceived with greater confidence to be “secure”, and/or,
- Require little to no human intervention to be maintained within its acceptable range of variation, and/or,
- More closely approximate what is best known as its “natural state” or functions within its “natural range of variation.”

Conservation targets with one or more key ecological factors outside their minimum integrity thresholds cannot be considered “conserved”, and should be rated as “Fair” or “Poor” in this framework. Planning teams again can use key factors as tools to distinguish between these two rating levels, by defining Imminent Loss Thresholds for each target’s key factors. These conservation area-defined thresholds are means to measure the improvement of a target’s key factors toward their minimum integrity thresholds, when they are severely altered. To receive a “Poor” rating, a key factor must be so severely altered from its minimum integrity threshold, that allowing it to remain in this condition or trajectory for another 10-25 years will make restoration of the target or prevention of its extirpation practically impossible. The rating thus takes into account the magnitude of alteration, the possible reversibility of this alteration, and the ecological consequences of allowing the alteration to persist.

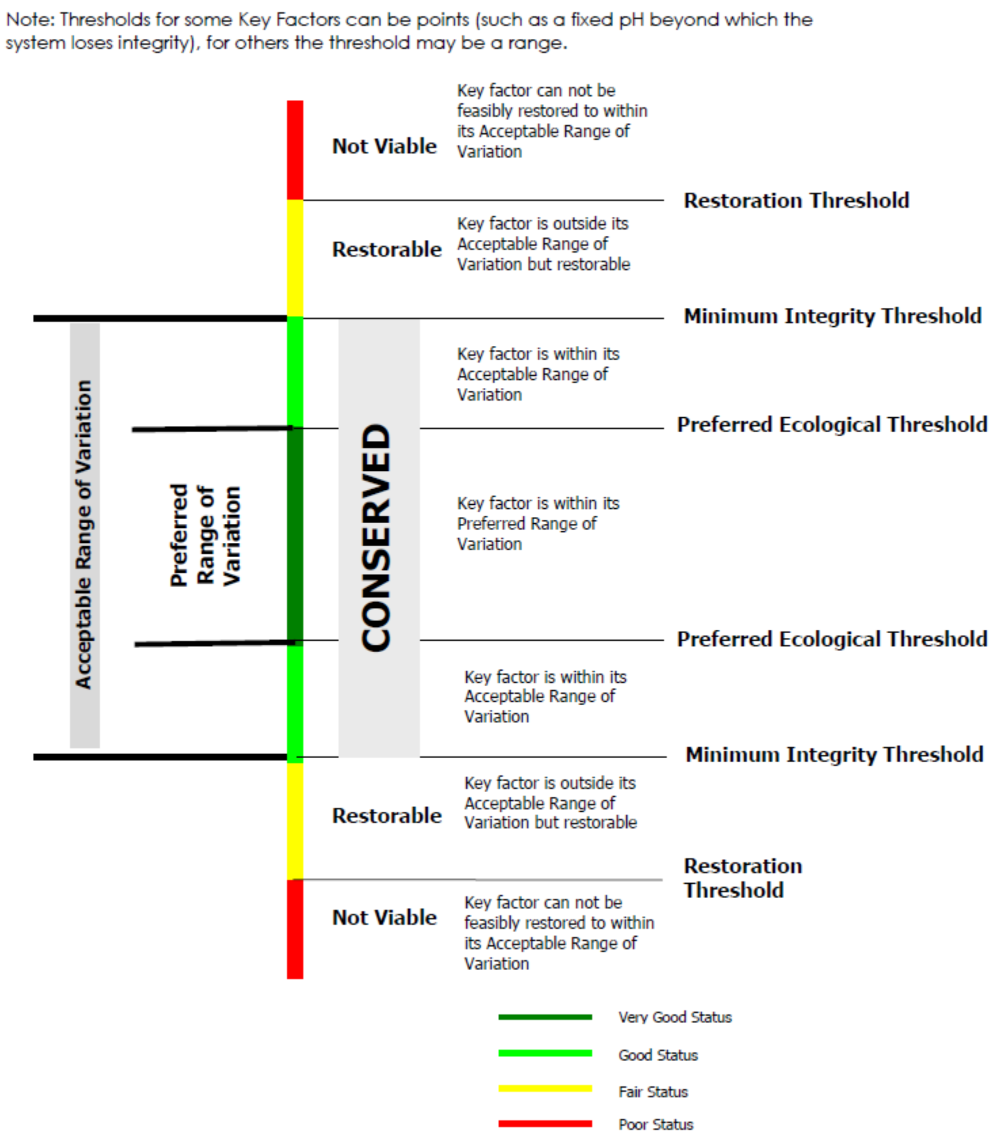



**Figure 13 Key Factor Thresholds and Status Assessment**

*Indicators specific to riverine components*

Key factors for indicators for the main riverine categories (hydrology and hydraulics, biology, water quality, geomorphology and connectivity) will be described, including the quantifiable metric that will be used, threshold targets, and a workplan proposed to evaluate their status. There is an order in which the indicators should be evaluated. Although it is necessary to monitor baseline conditions before implementing a flow recommendation, there is no point in evaluating the species richness response to a flow recommendation (a biological long term/resource level indicator of ecosystem health) unless it has first been determined that the recommended flows are actually being provided to the river (a hydrologic short-term/management indicator). While this chronological or bottom up approach to discussing indicators has some appeal the overall goal is to protect a sound ecological environment and a long term/resource indicators thus indicators will be discussed from this top down perspective. Starting from the end goal and working backward to the intermediate indicators that are necessary precursors to these goals.

**Long-term/Resource Indicators**

The overall objective of the Cypress Caddo SRP is to maintain a sound ecological environment, which includes maintaining the plant and animal that comprise the aquatic community. The success in restoring or maintaining these resources is measured in terms of native richness and diversity of plants and animals. This may require special emphasis on the protection of species of concern (including threatened and endangered).

Indicators of Biological Integrity (IBI) are used to dictate the level of protection streams receive in accordance with surface water quality standards. They are used in conjunction with water quality, benthic macroinvertebrate and habitat data to set aquatic life use in wadeable streams (exceptional, high, intermediate, or limited). Using the IBI's as a starting point the CFP will determine if the regional is IBI, or components of that index are well suited to be used as indicators of the ecological health of the aquatic community that is responsive to flow alterations. It is possible that the metrics and rating thresholds will need to be modified to provide accurate and meaningful assessment of Cypress basin fish communities.

Specific Indicators, thresholds and a workplan to assess these criteria will be developed.

**Mid-term/Conditions Indicators**

These are indicators of the conditions that are believed to be necessary in order to have a sound ecological environment. They include flow dependent habitat suitable for the species or guilds identified above, channel maintenance (cleaning riffles scouring pools etc.), suitable water quality conditions and periodic inundation of identified wetland areas. These intermediate indicators bridge the gap between the flows or hydrology produce by the implementation of a water management plan the ecological response of the system. Predictions of these conditions (i.e. available habitat or area of inundation at a given flow rate) have been made based on models or other types of analysis. These indicators can be used to verify and if necessary modify these predictions.

Indicators in this groups will include those that evaluate Instream Habitat (Biology/Hydraulics), Riparian/Wetland Connectivity (Biology/Hydraulics), Water Quality and Channel Maintenance (Geomorphology)

**Short-term/Management indicators**

Before any resource measures of ecosystem response to recommended flows can be evaluated, it will be necessary to implement the flow recommendations and evaluate whether the prescribe flows are indeed observed at their prescribed magnitudes, frequencies, durations, and timing. Although this is in many ways the most straightforward of all of the indicators, it presents a number of challenges that need to be addressed, including translating the building blocks recommendations into target hydrographs, addressing implementation and water supply constraints, and practical management issues like the development of triggers to identify hydrologic conditions and the time frame over which to specify these conditions (e.g. is the hydraulic condition reevaluated every day, month, season, or year?). Finally, there needs to be some discussion the period of time needed to make an assessment. If the recommendations call for base dry conditions 30 percent of the time does that mean 30 percent of the time over the next year or next ten years? With hydrologic indicators, unlike many of the other indicators, models exist to forecast future flow conditions. In Texas the model that is used is call a WAM (Water Availability Model) which overlays current and future water demand projections on historical flows in order to estimate future flows. The WAM is not without its shortcomings an important one being that it runs on a monthly time step whereas most analysis of environmental flows requires a finer time step, probably daily. Accepting the WAM limitations and employing techniques to address them, allows for an assessment of hydrologic indicators over a time frame that is comparable to the time frame of the basic data that was used to develop the preliminary recommendations (approximately 40 years). While this time frame may not be suitable for a real time assessment (we can't wait 40 years to know if the flow recommendations have been adequately implemented) they can provide some direction as to what appropriate expectation should be on short timeframes.

REFERENCES

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