Category: Water Quantity
Indicator: Modeled River Flow Alteration

Methodology

Modeled River Flow Alteration is an indicator of the effects of water withdrawals for human use on Texas river flows and water security. This indicator is measured as the ratio of model estimates of current (or "regulated") river flows to historical (or "naturalized") flows from the Texas Commission on Environmental Quality's Water Availability Models (WAM). Two sub-indicators evaluate a) major river flow depletion and b) alteration of environmental flows. Each of these sub-indicators includes several flow alteration metrics calculated from monthly water budget outputs for selected control points in the WAMs. These metrics are then mapped to stream segments corresponding to those control points.

WAM Analysis

This indicator is calculated using naturalized and regulated flows as estimated from the WAMs. Naturalized flows are "sequences of monthly streamflows representing natural hydrology. They are developed typically by adjusting historical gaged streamflow data to remove the impacts of reservoir construction, water use, and other human activities" (Water Right Analysis Package (WRAP) Reference Manual). Regulated flows "represent the physical streamflow after accounting for all the water rights. The simulation starts with naturalized flows and computes regulated flows" (WRAP Reference Manual). This indicator assumes that naturalized flows are a suitable estimate of what flows would be without human uses of water and that regulated flows reflect the effects of local, upstream and downstream human use of water on river flows. As a result, the ratio of regulated to naturalized flows allows an estimate of river flow depletion (or augmentation) that results from human uses.

To evaluate the effects of both current levels of water withdrawal and full potential utilization of water rights we used two sets of model outputs: Run3 and Run8 of the WAMs. Run3 (i.e., "Full Authorization") is a simulation in which water demand is set at the fully authorized volume for each water right in the model. Run8 (i.e., "Current Conditions") is a simulation where demand is set to the maximum withdrawal volume for each water right in the last 10 years of the model's simulation period; for most WAMs this is usually in the late 1990s or early 2000s. Water rights in the model do not change their demands during the time period of the model, but remain fixed over the entire period of record.

For each WAM, we produced monthly and annual outputs of water budget components including naturalized flows, regulated flows and return flows and then quality checked and organized them in spreadsheets for further analysis. The Nature Conservancy acknowledges and thanks Richard Hoffpauir, Texas A&M University, for his significant assistance with this analysis.

The model outputs were generated for a set of control points for each WAM that included all primary control points and a selection of secondary control points (see *Control Point Selection and Segment Mapping* below). Primary control points in the WAM are locations where

naturalized stream flows are provided as input. These are usually stream gaging locations, but are sometimes also major reservoir locations. Secondary control points are locations that are assigned naturalized flows within the simulation using (typically) a drainage area ratio based method to transfer naturalized flow from the primary control points.

Analysis of WAM Outputs

We derived two sub-indicators that included 5 total metrics and calculated these metrics for both Run8 (Current Conditions) and Run3 (Full Authorization).

a) Flow depletion: This sub-indicator estimates the level of flow depletion as a metric of water security risk. This sub-indicator summarizes the percent of months in the WAM periods with flows at least 50% and 80% depleted relative to naturalized flows (i.e., regulated flows as a percent of naturalized flows).

b) Environmental flow alteration: This sub-indicator is a simple estimate of alteration of environmental flows that could be developed for rivers statewide. We utilized the presumptive standard (Richter et al. 2013) that could be applied to all control points. The presumptive standard is an assignment of upper and lower boundaries around hydrology measures such as daily or monthly flows that represent a sustainable range for maintenance of ecological integrity. We defined the sustainability boundary as the monthly naturalized flow +/- 20%. We noted the percent of the time that monthly regulated flows are within this boundary or are either above or below the boundary.

We recognize that SB3 environmental flow rules have been adopted for several locations in various Texas river basins and the SB3 and SB2 processes have resulted in flow recommendations have been derived for several more locations. However, for this analysis we needed a method that could be applied to all locations.

Control Point Selection and Segment Mapping and Basin-level Summarization

In order to map WAM analysis results to stream segments we first selected a subset of control points from each WAM for inclusion in our segment maps. We then mapped these control points to stream segments by identifying the NHDPlus segment that each selected control point occurs on and assigning the control point ID to that segment. We then attributed the control point ID to upstream NHDPlus segments until we came to another control point. Control points on smaller tributary streams were generally assigned to the entire tributary.

Three types of control points were selected for inclusion in the map: 1) all primary control points from each WAM were included, 2) intervening control points constituting major withdrawal points were included, and 3) control points on significant tributaries not already represented by primary control points. The number of control points selected ranges from 3 (San Jacinto-Brazos coastal basin) to 101 (Brazos River basin). The only streams mapped are the rivers and tributary streams on which selected control points fall. This results in only a small fraction of the total stream segments in NHDPlus being mapped for this indicator.

Maps of both sub-indicators have legends to indicator increasing (or decreasing, in the base of within the presumptive standard) levels of flow alteration. The legend is divided into 5 equal bin ranges from 0 to 100%.

To summarize the segment-level measures to basin-level we calculated the proportion of the mapped streamlength in each basin in each of the 20% bins described above.

Caveats

There are several important points to consider when interpreting this indicator. Some of these are:

- The WAMs are models and as such the outputs derived from them are not empirical data, but model outputs. These outputs represent the best fit to a large hydrological dataset and reasonable assumptions related to water management. However, the uncertainties associated with any model should be considered.
- The time periods of the WAMs generally end in the late 1990s. Several of the WAMs are currently being updated and their periods of record extended, but we did not utilize these in-progress versions.
- Naturalized flows do not contain adjustments for historical uses that are exempt from state surface water permitting, i.e., qualified domestic and livestock uses. In that sense, naturalized flows are only "naturalized" to the extent that the gaged flows have been reversed for those water rights to be simulated by the model.
- Simulated regulated flow is not be confused with real-world gaged flow. WRAP/WAM is not a tool for estimating real-world flows. Simulated regulated flows are a computation of how the naturalized flows are changed by the actions of water rights represented in the model.
- The WAM Run8 (Current Conditions) is based on water use that was current when the WAMs were completed but are now somewhat dated. The “current” use for most WAMs was defined as the largest water withdrawal amount (per TCEQ water use survey data) from the last 10 years in the period of record of the WAM. In the simulations, this use amount was applied to each year throughout the simulation period.
- The WAM Run3 (Full Authorization) assumes no return flows, which is likely not a reasonable assumption for many water withdrawal points.

Data Sources

Texas Commission on Environmental Quality Water Availability Models (WAM) covering all 23 Texas river basins; control point locations from WAM GIS layers.
https://www.tceq.texas.gov/permitting/water_rights/wr_technical-resources/wam.html

WAM monthly and annual water budget outputs, as post-processed by Richard Hoffpauir.

National Hydrography Dataset Plus (NHDPlus) Version 1. Medium-resolution 1:100,000.
http://www.horizon-systems.com/NHDPlus/NHDPlusV1_data.php

Texas Water Development Board. Major River Basins shapefile.
http://www.twdb.texas.gov/mapping/gisdata.asp