Bacterial Total Maximum Daily Load Analysis for Copano Bay
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ABSTRACT: With over 300 bacterial total maximum daily load (TMDL) studies to be completed in the State of Texas, the Texas Commission on Environmental Quality (TCEQ) is looking for rapid, non-controversial modeling approaches. Of particular interest is the development of a “simple” modeling approach for coastal systems where many of the TMDL studies are required. The focus of our work is to develop a new bacterial TMDL modeling approach for the Texas Gulf Coast by combining previously approved models with nationally available datasets. This paper discusses the methods used to calculate bacterial loadings from the Copano Bay watershed to Copano Bay. It also explores how the tidal prism method will be modified for application to Copano Bay and its tidal river segments.

KEY WORDS: water quality modeling, total maximum daily loads (TMDLs), tidal prism method, schematic network
1.0 INTRODUCTION
1.1 Background
The State of Texas currently has over 300 water segments listed on their “303(d) List” as impaired for bacteria (Texas Commission on Environmental Quality 2007a). Under the Clean Water Act, each of these water segments must have a bacterial TMDL study completed and accepted by the US Environmental Protection Agency (EPA). Due to more stringent water quality standards in segments that are classified as oyster waters, many of the bacterially impaired waters are along the Texas Gulf Coast. The project area for this work is the six bays shown in Figure 1. For the purposes of this paper, we focus on Copano Bay.

Figure 1: Study Area – Texas Gulf Coast

1.2 Motivation
In September of 2006, TCEQ and The Texas State Soil and Water Conservation Board formed the Bacterial TMDL Task Force to make recommendations on how Texas’ bacterial TMDLs should be addressed. In June of 2007, the Task Force completed their study and recommended that simple mass balance models be developed for all bacterial TMDLs before more complicated methods are employed (Bacteria TMDL Task Force, 2007). The TCEQ is now looking for new methods to calculate bacterial TMDLs in coastal systems.
2.0 METHODOLOGY
The main goal of this project is to assist the TCEQ in developing a simple approach to modeling bacterial TMDLs along the Texas Gulf Coast. Since the TMDL program is a nationwide effort to improve water quality, we aim to create an easily replicable, transferable procedure so that other areas of the country may benefit from our findings. Since all TMDL studies must ultimately be approved by the EPA, the methodologies developed under this project should rely on nationally accepted models and available datasets as much as possible.

2.1 Models
2.1.1 Tidal Prism Method
The tidal prism method is a mass balance model that has been successfully used in developing bacterial TMDLs in bays/estuaries in other parts of the U.S. (Virginia Department of Environmental Quality 2005). The model assumes a well-mixed system using a time step of one or more tidal cycles. Over this time step, the modeler is able to consider tidal influences (floods and ebbs from the ocean or outer bays), freshwater inflows, and interior reactions, such as decay. Based on the simple nature of the model and other states’ success with using it, the TCEQ is interested in exploring the application of the tidal prism model to Texas bays.

2.1.2 Watershed Loading
Application of the tidal prism method requires an estimate of the runoff and pollutant loading from the watershed of concern. Pollutant loading is calculated as a combination of point and non-point sources within the watershed, with non-point loadings being a function of overland runoff and land use.

The schematic processor is a framework for performing hydrologic calculations in the GIS (geographic information system) environment. The processor simulates the movement of water or contaminants through a hydrologic network by assigning two types of values to each feature: a “received” value and a “passed” value (Whiteaker et al. 2006). Previous studies have used the schematic processor to successfully model bacterial loading from the watershed to Galveston Bay including considerations for first-order decay (Whiteaker et al. 2006).

The schematic processor works with the schematic network, which is created from the ArcHydro toolset. ArcHydro is a GIS tool that can perform various mapping procedures based on the hydrology of an area. The schematic network is a network of links and nodes that replicate hydrologic features on the ground. SchemaNodes are created to represent hydrologic features, such as catchments or stream junctions. SchemaLinks dictate the connections between the nodes. Figure 2 shows a piece of the schematic network that was created for the Copano Bay watershed. Further information on the development of the Copano Bay schematic network is available in Johnson et al. 2008.
2.2 Data Sources

2.2.1 Hydrography and Elevation

The primary source of information on hydrologic features within the study area is the National Hydrography Dataset (NHDPlus). NHDPlus is a suite of datasets compiled by a joint effort of the EPA and US Geological Survey (USGS). The datasets include information related to the hydrography of the United States such as: flowlines, catchments, monitoring locations, elevation, land use, precipitation, and various other attributes (Horizon Systems 2007).

Newly available LiDAR (light detection and ranging) data from the Texas Natural Resources Information System (TNRIS) is used for a detailed analysis of elevation immediately around the bays. The data has a reported accuracy of 1.2 vertical and 2.4 horizontal feet (95% confidence level) which allows for a better understanding of elevation in the low slope coastal areas (Texas Natural Resources Information System 2008).

2.2.2 Water Quantity

Data on freshwater inflows is retrieved from the USGS National Water Information System (NWIS) (U.S. Geological Survey 2007). The USGS maintains over 24,600 gauging stations nationwide at which it measures daily time-series discharge and stage data. Mean daily streamflow data from these gauges are used in this project.
Information on water quantity in the bays is provided by the Texas Coastal Ocean Observation Network (TCOON) (Texas A&M University - Corpus Christi 2007). TCOON maintains 34 monitoring stations along the Texas Gulf Coast at which it monitors various weather and tidal parameters. Monitoring stations within our study area are the source of information on daily tidal levels.

2.2.3 Water Quality
Water quality data for this project is provided by the TCEQ Regulatory Activities and Compliance System (TRACS) database (Texas Commission on Environmental Quality 2007b). TRACS is a statewide database that contains all the surface water quality monitoring information that has been collected in Texas since 1967. As of March 2007, TRACS had over 730,000 water quality sampling events recorded at over 7,000 stations (Jantzen 2007).

3.0 MODELING PROCEDURE
3.1 General
The newly developed model uses the schematic processor to calculate the bacterial loading to the bays from the watershed. This information will be combined with water quantity and first-order decay parameters and simulated with the tidal prism model on an annual time step. The proposed setup allows us to meet the TMDL program requirements, while meeting the TCEQ’s objectives of using a simple model that effectively accounts for tidal interactions.

3.2 Tidal River Segments
The first step in determining where the newly developed tidal model will be applied is to understand the extent of tidal action in the coastal system. For regulatory purposes, TCEQ has denoted areas near the intersection of rivers and bays as tidal river segments. This classification, however, does not imply that tidal hydraulics are actually felt across the entire length of the reach. To define the tidally impacted rivers for modeling purposes, it is necessary to analyze historic tidal levels and elevation data within the immediate area of the bays.

Flushing rate is a major consideration when modeling water quality. It is suspected that tidal river segments are regularly flushed and have low residence times, while the bays have low flushing rates and high residence times. Variations in these rates may imply a slightly different application of the modeling approach to tidal rivers than bays. We must, therefore, understand the flushing rates of the tidal water segments and how that may impact the appropriate implementation of our model.

3.3 Bays
Previous models of the bays within this system have considered the bays as multiple well-mixed cells (Gibson et al. 2006). In this project we aim to understand the benefits of modeling the bays as multiple versus single cells under the newly developed modeling scheme. As an initial step, water quality data will be analyzed to determine mixing patterns within the bays. Results of this analysis will be compared with previous studies to determine the appropriate segmentation of the bays for this project.
4.0 RESULTS
To this point in time, the following results have been achieved:

- The schematic network has been created and modified for modeling point and non-point sources within the Copano Bay watershed (Johnson et al. 2008).
- Historic tidal levels were analyzed and extracted back to points of intersection with the LiDAR elevation data. We can now segment the study area’s waterbodies into three distinct categories for modeling purposes: pure riverine, tidally impacted riverine, and tidally impacted bays.

5.0 FUTURE WORK
Now that the tidal and non-tidal segments of the study are have been defined we are able to move forward with model development. Future work toward these efforts will include:

- Calculate the flushing rates of tidal rivers and bays. Determine how these flushing rates impact the application of the model to these tidal segments.
- Analyze water quality data and previous studies on the bays to determine the appropriate segmentation for modeling purposes.
- Run the schematic processor to calculate bacterial loads to Copano Bay from the watershed.
- Implement the tidal prism method on Copano Bay.

6.0 CONCLUSIONS
Efforts discussed in this paper have shown us that the TCEQ-classified tidal water segments may not be appropriate for use in water quality modeling. By analyzing historic water level data within the bays and extrapolating these levels back to their intersection with the land around the bays, we have delineated the water segments where tidal influences are felt. These tidal segments can now be classified as non-tidal river, tidal river, and bays and the residence time within each can be computed. Understanding the residence times of the segments will allow us to tailor the application of the tidal prism method to areas with different flushing rates. Results from the schematic processor will indicate the bacterial loadings that will be modeled with the new methodology.

7.0 REFERENCES


