

Chapter 6

Conclusions and Recommendations

In this research project, the GIS software, ArcView was connected to the USEPA water quality model, WASP5. The study area utilized as a test case for this linkage was the Upper Houston Ship Channel, located in Galveston Bay, Texas. The connection successfully reads the necessary model input for the model and writes it to text files, executes a FORTRAN program which formats the data into the WASP5 input file, runs the WASP5 model, processes the output, and allows the user to view the output in the form of charts, GIS coverages, and tables. This initial connection establishes a primary link, which, with further development, can be used as a watershed management tool to investigate the impact of engineering practices on the water quality of a given system.

Specific conclusions, limitations, and recommendations for the five phases outlined in [Chapter 1](#) are enumerated below.

Phase I Literature Review

- Previous model connections and environmental modeling integrations were found in the literature. However, the majority of these modeling efforts were performed using the GIS software, Arc/Info.

Phase II GIS Data Development

- The Upper Houston Ship Channel and its surrounding watershed characteristics were digitally represented through GIS using coverages and tables.
- In particular, the watershed boundary was successfully established using an Arc/Info, Grid-based watershed delineation technique developed from previous research efforts. In addition, the watershed areas draining into each water quality segment were delineated.

- The land use, precipitation, streams, water quality data, channel segmentation, and point source loading data were also represented through GIS.
- The accuracy of these coverages and tables is dependent on the source and scale from which the original data was obtained.

Phase III Non-point Source BOD Loading Determination

- A rainfall/runoff/urbanization relationship was established for the Upper Houston Ship Channel watershed, using available flow, precipitation, and land use data, to spatially distribute the steady state runoff over the entire watershed area. This relationship proved to be reasonably accurate for long-term steady state results.
- The total steady state areal BOD loading across the watershed was determined by multiplying the spatially distributed runoff and a land use-based estimated mean concentration (EMC), determined specifically for the Houston area. This pollution assessment procedure was performed with a method developed in Arc/Info.
- The total annual steady state BOD loading into each water quality segment was calculated by "routing" all of the areal loads from a segment's subwatershed to its final outlet point.
- The NPS loadings established in this study are a good representation of average steady-state values; however, more representative results would be possible if both time-varying loading and EMC values were investigated.
- Future work in this area should include the possibility of developing this loading analysis through ArcView to extend the current GIS/WASP5 connection.

Phase IV WASP5 Modeling

- A water quality model was established in the Upper Houston Ship Channel and calibrated using salinity, with WASP5's subprogram, TOXI5. Once calibrated, EUTRO5 was employed to model BOD and DO in the Channel.

- For the EUTRO5 model, the total point source and NPS loading of BOD to each model segment was determined from previous calculations and available data. However, the point source loading used was incomplete, since it represented only about half of dischargers along the channel. In addition, each tributary was modeled as a boundary, with a concentration and flow to account for the loadings.
- Four model runs were performed to simulate steady state BOD/DO processes with a simple Streeter-Phelps level of complexity. The runs included an average year, a dry weather condition, and two cases to investigate model sensitivity to the system constants.
- The flow conditions were established using a relationship similar to the rainfall/runoff/urbanization correlation from Phase III. Once the flow and runoff (from Phase III) was known, the baseflow was calculated by subtracting the runoff from the total flow.
- For the average year modeling case, total flow, along with point and NPS loadings were input to the system. In contrast, the dry weather condition, which was meant to represent a worst case scenario in relation to flow, only considered baseflow with the point source discharges.
- The DO results were found to be extremely sensitive to the choice of the reaeration coefficient, k_2 , but not as dependent on the value of the deoxygenation coefficient, k_d . The BOD results were dependent only on the k_d .
- The DO and BOD concentrations resulting in the channel also depended on the value chosen for the downstream boundary condition.
- Future modeling would be more accurate if it were to consider the entire Houston Ship Channel, from the Turning Basin to Morgan's Point. In this way, the influence of the downstream boundary condition may be reduced.
- More research into the point source loadings and the boundary concentrations should be performed to more accurately represent the system.
- Time varying inputs, flows and parameters should also be investigated to explain the NPS loading and overall system more accurately.

Phase V GIS/WASP5 Connection

- The WASP5 model was connected to GIS, using FORTRAN programming and the ArcView programming language, Avenue.
- The current Arc/Info connection to WASP4, GEO-WAMS (DePinto, *et al.*, 1993 and DePinto, *et al.*, 1994) is more developed than this ArcView interface; however, with more research, this link has the potential to reach, and possibly exceed, the level GEO-WAMS has attained.
- This connection includes the ability to create WASP5 input files, to execute WASP5, and to view the output from the model run, all through an ArcView interface. The results of the model can be viewed through ArcView as either new charts, tables, or themes.
- The interface allows the user to choose three types of modeling cases: model calibration with salinity, average year BOD/DO conditions, or dry weather conditions.
- Presently, this connection is set only for steady state conditions and the BOD/DO modeling is established only for level one complexity in WASP5 (simple Streeter-Phelps equation).
- Limitations to the connection included the slowness of a model run through ArcView, the inability to relate more than one chart to a table, the constraint on number of time steps the output program could process, and the restriction on the number of new themes that are saved to a project.
- The constraint on the naming of tables and coverages should be studied in relation to the Avenue language.
- New versions of ArcView would support investigation into the establishment of a more direct link to WASP5 as the text formatting capabilities of Avenue become more refined.
- More development of the connection should alleviate the dependency of the scripts on tables and attempt to utilize GIS's relational capabilities within the coverage topology beyond what is established in this study.

Future work should also include the consideration of linking higher levels of complexity in the WASP5 model, which would entail the incorporation of more state variables, parameters, and constants. In addition, the modeling of time-varying conditions within the connection should be studied.

- The final ultimate goal of future research should be to establish a representative model of the loading analysis and overall system within GIS so that, with a link to a water quality model, the overall connection could be used as a powerful watershed management tool.