1. Introduction

The Texas Department of Transportation (TxDOT) is responsible for the design, construction and maintenance of more than 40,000 waterway bridges and culverts, and thousands of miles of storm drains on the highway system in Texas. The provision of cost-effective, safe hydraulic structures is paramount.

For TxDOT and other highway agencies, a continuing concern is the need to apply current engineering hydrologic and hydraulic design and analysis procedures that balance simplicity with accuracy. Most hydrologic and hydraulic calculation procedures are now available in computer programs, the use of which has substantially reduced the mathematical effort involved. However, a substantial effort is required to establish and manipulate the data required for input into computer programs.

The estimation of hydrologic runoff parameters is currently performed manually. For example, the delineation and measurement of drainage area may require piecing together several topographic maps on which a designer must establish drainage boundaries by interpreting the elevation contours. Measurement of area involves the use of planimeters or digitization on computer-aided design systems. Other required parameters include:

- land use/cover characteristics,
- soil types and properties,
- design rainfall characteristics, and
- watershed slope.

Hydrologic parameters vary spatially and require interpretation of maps which often vary in scale and accuracy. Data requirements can be extensive, and acquisition and manipulation of the data are time-consuming. Generally, to avoid an extensive data collection effort, simplified hydrologic and hydraulic mathematical models are employed, sometimes at the expense of accuracy.

State-of-the-art photogrammetry, surveys using global positioning systems, and total station surveys provide means of developing extensive spatial data sets. Furthermore, the emergence and continued development of geographic information systems and digital

terrain modeling offer the potential to automate much of the spatial data manipulation. Federal agencies such as the United States Geological Survey and the Soil Conservation Service are developing and providing a wealth of spatial data which have direct application for hydrologic and hydraulic analysis procedures.

Geographic information systems (GIS) are specifically designed to manage and analyze spatial data. They offer the capability to relate the location and geometric aspects of a feature to the feature's properties, and as such they offer significant potential for hydrologic analysis. Several GIS software packages are currently available which differ in complexity. Arc/Info (ESRI, 1994) is an extensive package of GIS tools which is used in this research.

1.1 Hydrologic Data Development System (HDDS)

The focus of this research is on the design and programming of an integrated set of Arc/Info programs and associated data called the Hydrologic Data Development System (HDDS). This system provides a user with the capability of establishing some of the most important hydrologic parameters used in hydrologic analysis methods. HDDS incorporates a menu-driven system within which a user can identify a highway stream crossing or other site and determine the following:

- drainage basin boundaries, areas and subareas,
- maximum flow path length,
- estimated travel time,
- watershed average slope,
- hydrologic soil group,
- design rainfall,
- weighted runoff coefficients, and
- other hydrologic parameters.

The data may be passed automatically from the system to THYSYS, the Texas Department of Transportation hydrologic and hydraulic computer program to calculate design flood frequency relationships. The resulting data may then be manipulated easily to

create drainage area maps, tables and other documentation using ARCVIEW, a GIS data query and visualization package.

The system is a prototype and is intended to demonstrate potential capabilities of using a GIS for highway-based hydrologic data development and analysis. Though the programming described here is specific to Arc/Info, the data are transferable and the general methodologies should be applicable to any GIS package that has similar capabilities.

1.2 Outline

This thesis documents the concepts, data requirements, data processing procedures, development and application of HDDS. The reader is initially provided with an introduction to GIS-based concepts. The primary goal is to demonstrate the potential speed and precision with which GIS may help develop important hydrologic parameters for flood frequency determination, especially those used by highway agencies such as TxDOT for hydraulic design.

A literature review and results of a nationwide questionnaire on the use of GIS in state highway agencies appear in Section 2. A discussion of some relevant GIS application to surface hydrology and hydraulics analysis is followed by an appraisal of the state of the practice in use of GIS within highway agencies for drainage feature design. Section 3 discusses concepts that are considered important to the successful use of systems such as HDDS. These include spatial data modeling methods used in GIS, elements of geodesy such as georeferencing systems and map projections, and hydrologic methods commonly used by TxDOT for which data can be derived in HDDS.

Section 4 details the data requirements, data development methods for the HDDS spatial database, and the methods employed by HDDS during execution of the system. Section 5 provides a guide to the steps necessary to perform an analysis using HDDS. Included is a sample application on a study area of the North Sulphur River Basin in Northeast Texas above State Highway 24 (SH 24). Hydrologic parameters are established for determination of discharge versus frequency relations using the hydrologic methods discussed in Section 3. Additionally, a discussion is provided on the way in which HDDS

was employed to use several stream gauge sites in the Trinity River basin in Texas as outfall locations for drainage boundary delineation. Results of these are presented in Section 6. Section 7 provides an assessment, a discussion of future potential and general conclusions.