North Central Texas
Council of Governments

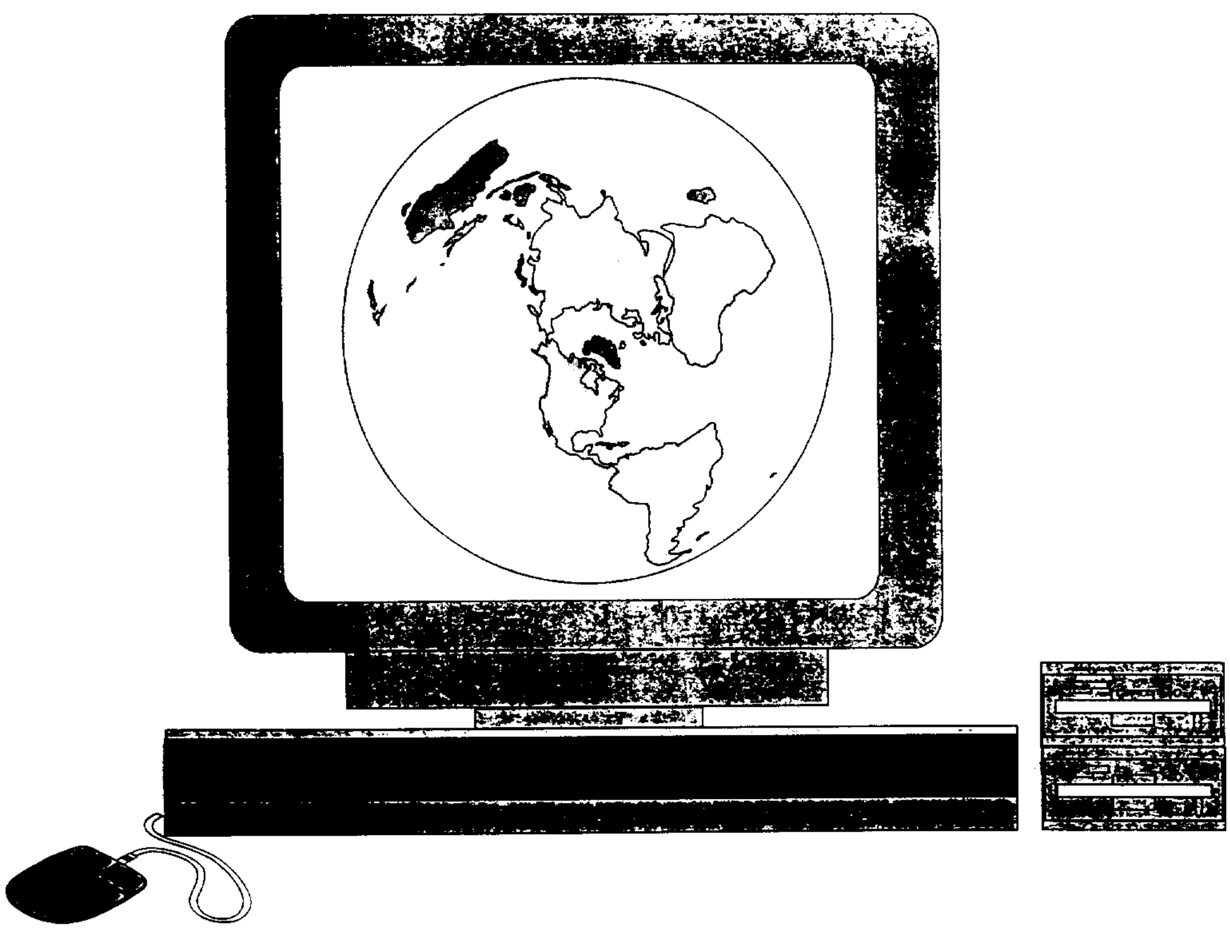
In Partnership for
the Betterment of the
Trinity River Corridor

US Army Corps
of Engineers
Fort Worth District

INTERIM REPORT

PROTOTYPE METHODOLOGY STUDY

UPPER TRINITY RIVER BASIN, TEXAS



SEPTEMBER 1991

PROTOTYPE METHODOLOGY STUDY

UPPER TRINITY RIVER BASIN

Trinity River, Texas

MAIN REPORT AND APPENDIXES

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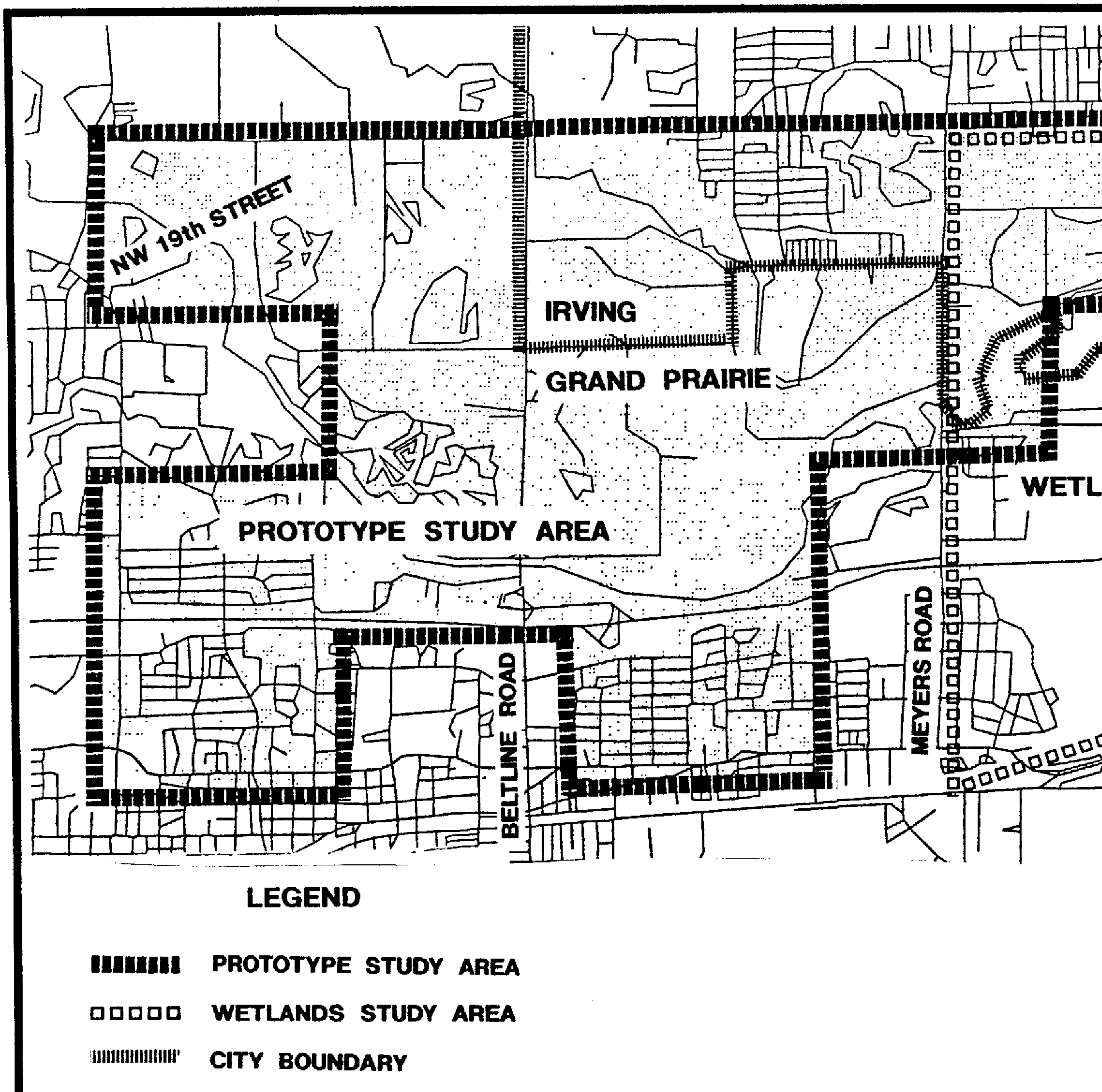

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
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FORT WORTH, TEXAS

PROTOTYPE METHODOLOGY STUDY
DALLAS - FORT METROPLEX, TEXAS

PROTOTYPE STUDY AREA

FIGURE 1 - 2

PROTOTYPE METHODOLOGY STUDY

Upper Trinity River Basin
Trinity River, Texas

EXECUTIVE SUMMARY

This report presents the results of interim investigations made concerning various uses of Geographic Information Systems (GIS) for water and land resources planning within the Prototype Methodology Study area within the city boundaries of Grand Prairie and Irving, Texas. These processes investigated herein are to be used for feasibility-level planning efforts within the Upper Trinity River Basin. The study is an interim part of the comprehensive 5-year effort of the $8.0 million Feasibility Study which began September 1, 1990. The Feasibility Cost Sharing Agreement, signed August 29, 1990, documents the mutual intent to conduct this Prototype Methodology Study to definitize the GIS methodology for water and land resources planning.

This study was conducted in cooperation with the cost-sharing Sponsor, the North Central Texas Council of Governments (NCTCOG) and its fourteen member governments: nine area communities (Arlington, Carrollton, Coppell, Dallas, Farmers Branch, Fort Worth, Grand Prairie, Irving, and Lewisville), three Metroplex counties (Denton, Dallas, and Tarrant Counties), and two special districts (Tarrant County Water Control and Improvement District Number One, and the Trinity River Authority), all of which are located within the Dallas-Fort Worth Trinity River Corridor area. The Texas Water Development Board is also a cost-sharing sponsor with NCTCOG.

The primary purpose of this study was to investigate different methods by which the GIS could be integrated into the water and land resources planning arena for feasibility-level investigations. The primary objective of this study was to automate computer linkages between the GIS and the Corps HEC-1 hydrologic model, HEC-2 hydraulic model, and economic flood damage model. This flood damage model is linked to the Dallas County Tax Appraisal District (DCTAD) database for property values. Existing conditions were evaluated as well as a simulated "modified" condition to determine if economic flood control benefits could be generated automatically by the GIS. The use of the GIS to determine potential wetland areas using various data sources was also investigated.

The process of using the GIS as an investigative tool proved to be very effective and the study objectives were successfully met, if not, exceeded.

Because these study methodologies described herein are also to be used for feasibility-level investigations, it is **VERY IMPORTANT** to have these methodologies validated and understood **PRIOR TO** initiation of further studies for the Upper Trinity River Basin Study area. The two major GIS programs used for this study were the GRASS and ARC/INFO software packages.

As a major work effort of the Feasibility Study, new surveying and digitizing of the Trinity River Corridor is currently underway by the firm of Greenhorne & O'Mara (G&O), Duluth, Georgia, and is scheduled for completion December 1992. Engineering base scale mapping of 1" = 200' at 2-foot contour intervals using NAD 83 horizontal datum and National Map Accuracy Standards will be produced. This data will form the basis of all future feasibility-level study investigations and enhance the water resource planning efforts in the region.

The process of using the GIS to more fully automate the HEC-1 hydrologic model was successful. Using detailed soils data from SCS, engineering judgment was applied to estimate the percent sand for each soil type. Similarly, using NCTCOG land use data, the percent urbanization and imperviousness factors were assigned to each land use classification. With these percent values, the GIS generated the required percents urbanization, imperviousness, and sand for the designated subareas. For the entire Upper Trinity watershed upstream of the Dallas and Tarrant Counties, the State Soil Geographic Data Base (STATSGO) general soils database is to be used. Resolution of the differences in computer "platforms" between the Corps SUN computers and the SCS AT&T computers will allow the GRASS GIS to automatically assign percent sand values to the queried STATSGO and detailed soils databases' soil characteristics and parameters. It will also be investigated if these different parameters can be used to automatically estimate the percent sand value for each soil type. Should this interface problem not be resolved, the Corps will continue to attach percent sand values to these soil attributes manually from within the GIS without any delay to the overall Feasibility Study schedule.

The process of using the GIS to delineate floodplain maps worked better than expected. The process of accessing the HEC-2 summary output file and digitized HEC-2 cross-sections to define water surface elevations at each cross-section was successfully developed. These elevations were then interpolated between the HEC-2 cross-sections to delineate a smooth floodplain boundary for every selected flood event.

The process of using the GIS to automatically determine economic flood control benefits was also very successful. This procedure worked for both the Upper Zacate Creek and the Prototype Methodology Study areas. Through the ingenuity of personnel at NCTCOG, it was possible to use the MAPSCO street mapping database to assist in determining where particular DCTAD structures were located within the study area. We were also successful in linking the DCTAD structure identification data to the Corps STDMA depth-damage curves allowing single event and expected annual flood damages to be calculated. Through the use of this process the county tax appraisal district information of the region can be used to evaluate the potential economic flood damage within the entire Trinity River Corridor.

The investigation of the GIS for wetlands determination helped prove the validity of existing NWI maps and the ability of hydric soils and the 2-year floodplain to predict where other potential wetlands may occur. Further investigation of the different weighting of these various parameters and the use of specific wetland "signatures" for image classification is underway.

The strength of the GIS was its ability to graphically show how the data is being "matched" and to provide error messages when "glitches" in the input data were detected.

The refinements discussed in this study are currently being pursued to help the GIS be more compatible with the data inputs and to further ease data manipulation efforts. With every investigation, several important lessons were learned as well as new ways of obtaining required data. As these GIS processes are more carefully analyzed, more refinements will likely be made to obtain more accurate information easily and to make the processes more streamlined.

Although we have looked at only three ways that the GIS can be used for water resource planning (hydrologic modeling, flood damage analysis, and wetlands determination), there are numerous other possible ways that water resource planning can be enhanced and those possibilities should be fully explored as a part of the continuing Feasibility Study of the Upper Trinity River Basin Study.

PROTOTYPE METHODOLOGY STUDY

Upper Trinity River Basin
Trinity River, Texas

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PROTOTYPE METHODOLOGY STUDY

Upper Trinity River Basin
Trinity River, Texas

MAIN REPORT

This report presents the results of interim investigations made concerning various uses of Geographic Information Systems (GIS) for water and land resources planning within the overall comprehensive scope of the Upper Trinity River Basin Feasibility Study.

This summary outlines the study authority, purpose and scope of this Prototype Methodology Study, study areas, study participants, and a discussion of the final conclusions of this study. The last part of this chapter discusses additional issues to be investigated during the remainder of this Feasibility Study.

The results of this study and methodologies described herein will be used to investigate, in detail, the water and land resource opportunities for the much larger Trinity River Corridor study area as a part of the overall Feasibility Study requirement. Thus, it is **VERY IMPORTANT** to have these methodologies validated and understood **PRIOR TO** initiation of further feasibility investigations for the Upper Trinity River Basin study area.

STUDY BACKGROUND

Since mid-1986, the North Central Texas Council of Governments (NCTCOG) has been serving as convener and facilitator of affected local governments in pursuit of a *Common Vision* for the Trinity River Corridor. A Steering Committee of elected local government officials is guiding the interjurisdictional program. The adopted *Regional Policy Position on the Trinity River Corridor* states, in part, "*Until a major flood control program can be completed to reduce or eliminate existing flooding threats, the continuing pressure for development of the flood plain must be managed in the most practical and equitable manner possible to at least stabilize current levels of flooding risk. Attention must also be placed on meeting water and other environmental quality goals and implementing desired regional public facilities.*" The NCTCOG is the local sponsor for the Upper Trinity River Basin Feasibility Study. The Texas Water Development Board is cost sharing this study with NCTCOG under its Research and Planning Program.

The *March 1990 Upper Trinity River Basin Reconnaissance Study*, herein referred to as the "Recon Study", was the necessary step toward more detailed investigative studies of the Dallas-Fort Worth Metroplex area. This study followed the completion of the 1988 Upper Trinity Regional Environmental Impact Statement which identified the potential catastrophic impact of further loss of flood control protection for the area. The area within the Trinity River Corridor Standard Project Flood (SPF) floodplain is approximately 42,460 acres and has significant urban development with an estimated $10.5 billion worth of property within these boundaries. Flood damages of a single SPF event would be about $4.2 billion.

The Feasibility Study was initiated with NCTCOG on September 1, 1990 following the execution of a 5-year $7.5 million Feasibility Cost Sharing Agreement (FCSA) signed August 29, 1990. This FCSA was amended on August 1, 1991 to increase the total study cost to $8.0 million to reflect the total actual cost of surveying and digitizing the study area. The FCSA also documents the mutual intent to use GIS methodology that is described herein.

The requirement for this Prototype Methodology Study is stated in the FCSA, Appendix A, Scope of Services, page A-5, and in the Initial Project Management Plan, page IPMP-7.

The two primary study tasks of the Feasibility Study during Fiscal Year (FY) 91 were:

(1) the completion of this Prototype Methodology Study and

(2) award and initiation of a surveying and digitizing contract for the Trinity River Corridor area.

This later task is contracted to the firm of Greenhorne & O'Mara (G&O), Duluth, Georgia, in February 1991 and is scheduled for completion December 1992. Regional monumentation, the first part of this surveying task, was completed in July 1991 and consisted of new regional surveying for the Trinity River Corridor tied to a network of 18 pairs of concrete monuments.

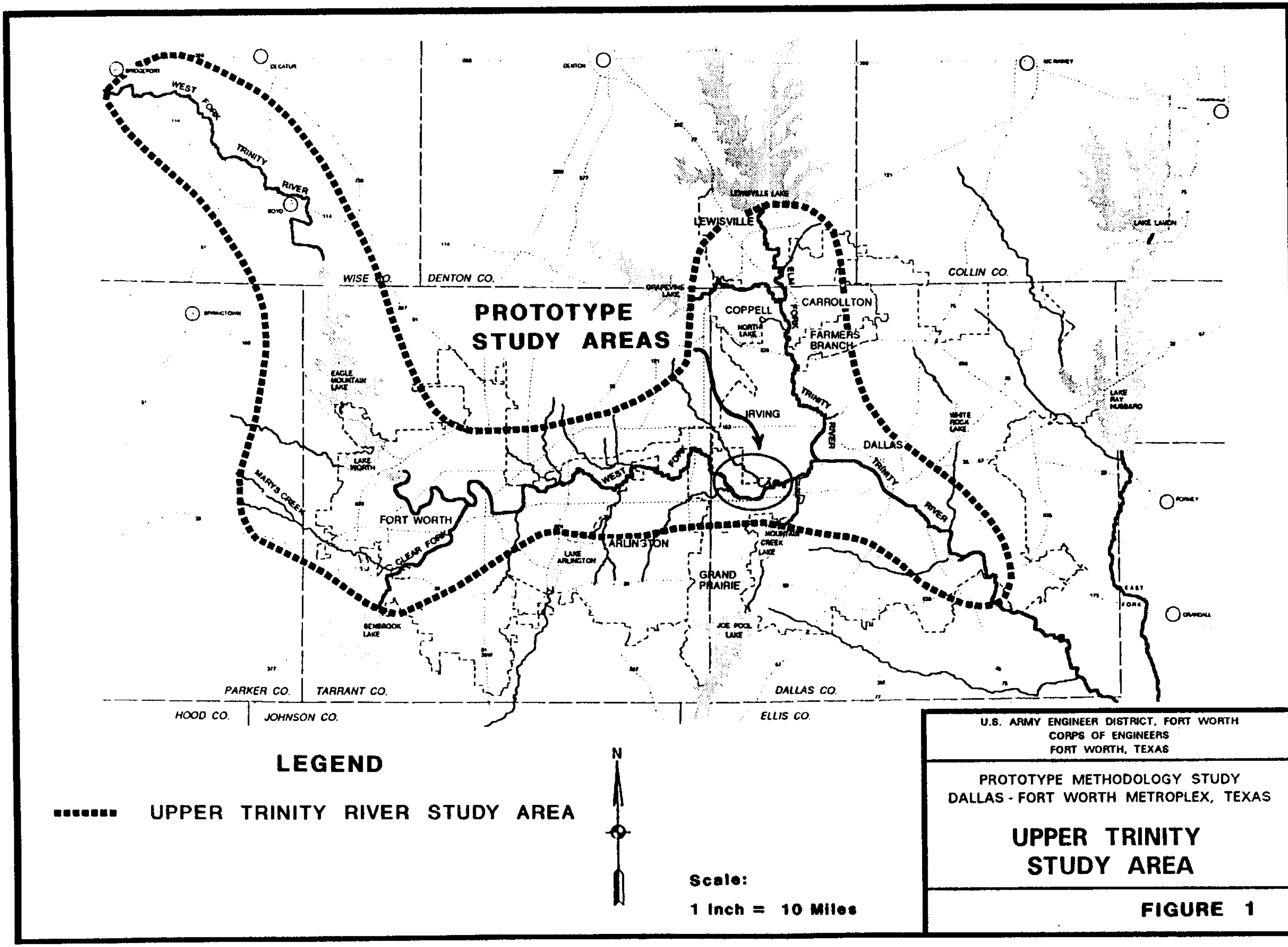
The next phase is production of 1" = 200' engineering base scale mapping at 2-foot contour intervals using the NAD 83 horizontal datum and National Map Accuracy Standards. The planimetric information will be compiled for both the INTERGRAPH and ARC/INFO formats. During FY 92, a portion of Dallas area will be investigated to verify and finalize the INTERGRAPH and ARC/INFO software database dictionaries.

NCTCOG, the designated Sponsor for the 5-year $8.0 million Feasibility Study, is acting on behalf of nine Trinity River Corridor communities (Arlington, Carrollton, Coppell, Dallas, Farmers Branch, Fort Worth, Grand Prairie, Irving, and Lewisville); Denton, Dallas, and Tarrant Counties, the Tarrant County Water Control and Improvement District Number One, and the Trinity River Authority. NCTCOG is acting as the single point of contact with the U.S. Army Corps of Engineers as affirmed by the Interlocal Agreement dated November 16, 1989. NCTCOG and the Fort Worth District will coordinate study efforts with other local, state, and Federal initiatives affecting the Trinity River Corridor in pursuit of a *Common Vision*.

The Federal authorizing legislation for this study, a Senate Resolution adopted April 22, 1988, defined the area of investigation as the Upper Trinity River Basin, with specific emphasis on the Dallas-Fort Worth Metroplex. For the Feasibility Study, this area is defined as all of the Trinity River watershed upstream of Post Oak Road in southeast Dallas County. The study area includes the Trinity River Corridor which is defined as the bed and banks of the river segments downstream from the dams of the lakes of Lewisville, Grapevine, Lake Worth, Benbrook, Arlington, and Mountain Creek to Post Oak Road in southeast Dallas County, and all of the adjacent land area and watercourses contained within the SPF floodplain boundary. A portion of the Upper Trinity River Study area is shown in figure 1.

PURPOSE AND SCOPE

The primary purpose of this study was to investigate different methods by which the GIS could be integrated into the water and land resources planning arena for feasibility-level investigations and to evaluate these GIS methodologies for use in the overall Feasibility Study. In more specific terms, the primary objective of this study was to automate computer linkages between the GIS and the Corps (1) HEC-1 hydrologic model, (2) HEC-2 hydraulic model, and (3) economic flood damage model using the Dallas County Tax Appraisal District (DCTAD) database. Existing conditions were evaluated as well as a "modified" condition, whereby the water surface elevations of the existing conditions HEC-2 model were decreased to simulate


PROTOTYPE
STUDY AREAS
WEST FORK TRINITY RIVER
WISE CO.
DENTON CO.
COLLIN CO.
PARKER CO.
TARRANT CO.
DALLAS CO.
HOOD CO.
JOHNSON CO.
ELLIS CO.
LEWISVILLE
LEWISVILLE LAKE
GRAPEVINE LAKE
COPPELL
NORTH LAKE
CARROLLTON
FARMERS BRANCH
ELM FORK
TRINITY RIVER
IRVING
DALLAS
WHITE ROCK LAKE
LAKE RAY HUBBARD
LAKE LAVON
EAGLE MOUNTAIN LAKE
LAKE WORTH
FORT WORTH
CLEAR FORK
MARYS CREEK
BENBROOK LAKE
ARLINGTON
LAKE ARLINGTON
GRAND PRAIRIE
MOUNTAIN CREEK LAKE
JOE POOL LAKE
EAST FORK
LEGEND
UPPER TRINITY RIVER STUDY AREA
N
Scale:
1 inch = 10 Miles
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS
PROTOTYPE METHODOLOGY STUDY
DALLAS - FORT WORTH METROPLEX, TEXAS
UPPER TRINITY
STUDY AREA
FIGURE 1

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the operation of a theoretical flood control project. The difference in expected flood damages between these two conditions derive the economic flood control benefits of a flood control project. The linkages investigated for this study area will assist in manipulating the study area data more easily.

During the investigative process, a possible GIS link was analyzed between the detailed soils survey of the study area conducted by the Soil Conservation Service (SCS), 2-year floodplain boundary, land cover information, and U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) maps in order to automate a process to determine potential wetlands in the study area. The detailed soils information from SCS was also used to determine permeable (percent sand) soil characteristics within the watershed for use in the Corps HEC-1 hydrologic model and to define hydric soil characteristics within the wetlands study area. Representatives from U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, NCTCOG, SCS, and the Corps of Engineers participated in the field-verification of these potential wetland areas identified using the GIS.

Because of the large database expected to be generated for the entire Upper Trinity River Basin study area (Dallas-Fort Worth Metroplex), a smaller subsection in the Grand Prairie and Irving area was primarily investigated during this Prototype Methodology Study. The location of this study area in relation to the larger Trinity River Corridor is shown in figure 1. This area was selected because of the variety of structures and wetland areas within these cities' boundaries and the availability of Grand Prairie's recent 2-foot contour interval topographic data which would approximate the new contour information being developed for the Feasibility Study. Figure 2 shows a detailed view of the Prototype Methodology Study areas used for economic flood damage analysis and determination of potential wetlands.

With the exception of Appendix 1, GIS Overview, and Appendix 7, Acronyms, the outline of each appendix is designed to:

(1) provide a brief background of each task element,

(2) describe how this task was performed for the Recon Study,

(3) describe the methodologies and processes investigated for this study,

(4) describe the pros and cons of these investigations, and if any changes to this methodology is warranted for use in the Feasibility Study, and

(5) what further refinements which may be warranted prior to examination of the updated G&O planimetric data for the Trinity River Corridor.

Appendix 1 provides an overview discussion of the GIS capabilities and features. Appendixes 2 thru 5 discuss the specific GIS tasks investigated necessary to examine an area for flood control analysis. Appendix 6 discusses the use of the GIS for determination of wetland areas, not from a "Regulatory Jurisdictional" basis but **FOR PLANNING PURPOSES ONLY** within the Prototype Methodology Study wetland area. Appendix 7 lists a roster of acronyms used in this study. The term "User" used herein these appendixes refers to the GIS operator who must perform a variety of functions to manipulate the input data.

It should be stressed that the most important factor common to all GIS data layers is the proper registration to a common geographic coordinate system. For this Prototype Methodology Study, the use of Universal Traverse Mercator (UTM) coordinates was used because of the Corps familiarity with this coordinate system and because of the immediate availability of GIS information already under this coordinate system. However, for the

Feasibility Study, the State Plane coordinate system will be used because the G&O planimetric data will use this system. Any previous UTM coordinate information will be converted to use the State Plane coordinate convention.

Upon completion of the DCTAD economic data integration into the GIS model, the County Tax Appraisal District for Tarrant and Denton Counties will also will be investigated. Of these CTAD databases, DCTAD is the most complex. The TCTAD data should be easier and more straight-forward to use. Only limited information from the Denton CTAD will be needed because of the small area of the Elm Fork in this county.

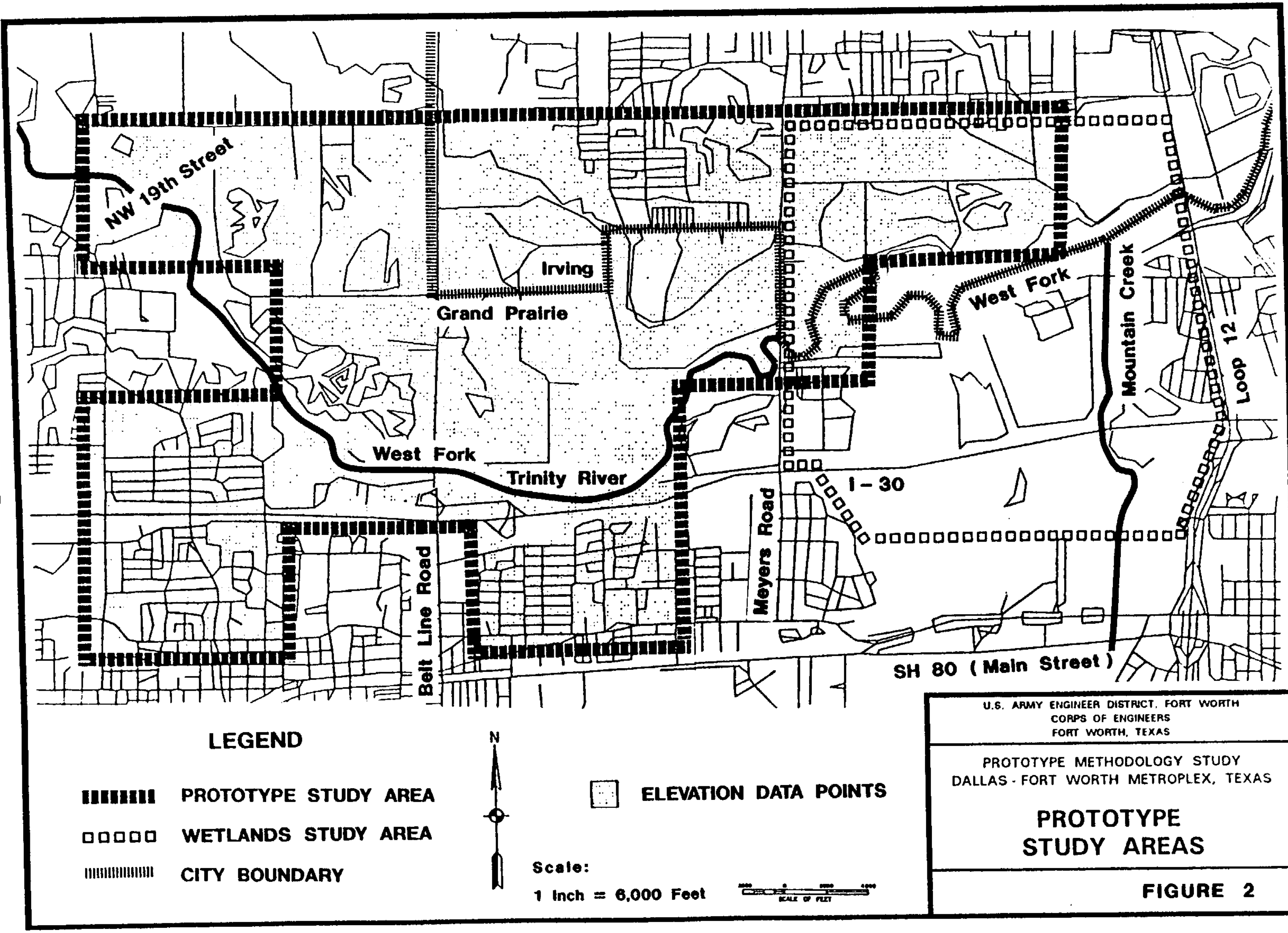
STUDY PARTICIPANTS

This study was conducted by the Fort Worth District, U.S. Army Corps of Engineers, in close cooperation with the Sponsor, the North Central Texas Council of Governments (NCTCOG). In addition, the Federal agencies of the U.S. Department of Agriculture, Soil Conservation Service (SCS), U.S. Environmental Protection Agency (USEPA), and the U.S. Fish and Wildlife Service (USFWS) had major roles in this study's investigations. Locally, the city of Grand Prairie provided the required 2-foot interval planimetric digital data of both the Grand Prairie and Irving areas due to the city of Grand Prairie's data overlay into the Irving area. The Dallas County Tax Appraisal District (DCTAD) was instrumental in helping NCTCOG acquire the necessary DCTAD data for the Prototype Methodology Study area and in answering the numerous questions that have been forthcoming. Coordination of this Prototype Methodology Study was maintained with the Study Management Team and the Executive Committee made up of members of the Corps of Engineers, NCTCOG, the area's nine city members (Arlington, Carrollton, Coppell, Dallas, Farmers Branch, Fort Worth, Grand Prairie, Irving, and Lewisville); three counties (Dallas, Denton, and Tarrant Counties); and two special Districts (Tarrant County Water Control and Improvement District Number One and the Trinity River Authority), and the State agency of the Texas Water Development Board. The GIS programmer, Ms. Terri Betancourt of Mother Earth Systems, Boulder, Colorado, was very instrumental in the completion of this study by the early completion of the required f.tools described in the appendixes herein. Personnel from the U.S. Army Corps of Engineers Construction Research Laboratory (USACERL) in Champaign, Illinois, who are developers of the raster-based public domain GIS Geographic Analysis Support System known herein as GRASS, have also been kept informed on the progress of this study.

STUDY CONCLUSIONS

Significant accomplishments in GIS compatibility have been made since the use of the GIS for the *March 1990 Upper Trinity Reconnaissance Study*. The overall goal of using the GIS as an investigative tool to promote water resources planning was a success. Although we have looked at only three ways that the GIS can be used for water resource planning (hydrologic modeling, flood damage analysis, and wetlands determination), there are numerous other possible ways that water resource planning can be enhanced and those possibilities should be fully explored as a part of the continuing Feasibility Study of the Upper Trinity River Basin Study.

The objectives of this study were fully met and many of these objectives were exceeded. The process of automating various computer database linkages including that of the DCTAD database was extensively analyzed. Many of the refinements discussed herein this study are currently underway to make the GIS operate faster and for the required GIS data sources to be more compatible and easier to use.



PROTOTYPE STUDY AREAS

FIGURE 2

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The process of using the GIS for use in the automation of the HEC-1 hydrologic model was successful. Using detailed soils data from SCS, engineering judgment was applied to estimate the percent sand for each soil type. Similarly, using NCTCOG land use data, the percent urbanization and imperviousness factors were assigned to each land use classification. With these percent values, the GIS generated the required percents urbanization, imperviousness, and sand for the designated subareas. Detailed soils maps are to be compiled by SCS for Dallas and Tarrant Counties. For the entire Upper Trinity watershed upstream of the Dallas and Tarrant Counties, the STATSGO general soils database at a scale of 1:250000 is to be used. The GRASS GIS was not able to automatically query these STATSGO and detailed soil maps to attach percent sand factors to each soil type because of the difference in computer "platforms" between the Corps SUN computers and the SCS AT&T computers. This interface problem is being rectified by SCS and fully query capabilities for the STATSGO and detailed soils databases are to be available to the Corps SUN computers in early FY 92. These attributes could be manually attached if necessary to meet the overall Feasibility Study schedule.

The process of using the GIS for economic analyses worked as planned. This is based on the result of economic studies of both the Upper Zacate Creek and the Prototype Methodology Study areas. To assist in the process of data by the GRASS GIS system, a series of program modules called f-tools were developed as discussed in Appendix 1, GIS Overview, and Appendix 2, GIS. The process of accessing the HEC-2 summary output file and its corresponding digitized HEC-2 cross-sections into the f.input tool to define water surface elevations at each cross-section was successfully developed. Using the f.wsurf tool to interpolate between the HEC-2 cross-section locations to delineate a floodplain boundary for every selected flood event worked better than expected. Because of the faster speed with which this "C" program module operated, the floodplain delineation did **NOT** have to be cut up into smaller pieces for GRASS to be able to use, as was the case for the Recon Study.

Through the ingenuity of personnel at NCTCOG, it was possible to use the MAPSCO street mapping data file to assist in determining where a particular DCTAD structure was located within the study area. The correct configuration of the DCTAD structure identification data to match those used for the Corps STDMA depth-damage curves was the most bothersome piece of analytics. This required the economist to be able to sort out what building type the DCTAD structure was and to match that building type with the equivalent type in the STDMA depth-damage curve. Through the use of the ARC/INFO GIS program, building centroids were calculated from the area within each building's "footprint". From a general economic analyses standpoint, only a centroidal point of the building footprint would be required since the area of most buildings would have the same elevation of floodwater around the structure.

Although a large amount of data manipulation was performed to use the DCTAD database, it continues to be the best means of accurately defining the flood damage potential within the entire Upper Trinity River Basin study area. The progress made in the use of the use of this area's County Tax Appraisal District (CTAD) databases will help define the best nonstructural or structural flood control alternative to be investigated and will greatly expedite and promote water resources planning of this region.

The investigation of the GIS for wetlands determination helped proved the validity of existing NWI maps and the ability of hydric soils and the 2-year floodplain to predict where other potential wetlands may occur. Further investigation of the different weighting of these various parameters and the use of specific wetland "signatures" for image classification is underway.

The strength of the GIS is its ability to graphically show the User how the data is being "matched". The GIS error messages provided to the User also helps detect "glitches" in the input data. One such occurrence was that of the differences in the horizontal datum registration used for the structure location data and features such as roads and streams (NAD 27) overlaid on the floodplain derived from the Grand Prairie spot elevation data (NAD 83). Discrepancies between known locations of selected data items in each layer were noted and measured with standard GRASS utilities. Systematic corrections were then applied to bring the data sets into correct horizontal registration. Without the ability to look at the roads and stream overlay superimposed over the floodplain delineation, these horizontal datum differences would not have been so easily discovered. To use digital terrain modeling for accurate water resource planning, the consistency of the elevation data is most important. Fortunately, the use of the updated G&O elevation and planimetric data with a single horizontal datum (NAD 83) will solve this datum problem.

Coordination and communication between the GIS staff, the hydrologic and hydraulic engineers, and economists is essential and should not diminish as the predominance of GIS automation increases. Error-checking and verification of GIS results, i.e., GIS-generated floodplain delineated maps, should be encouraged. Although the GIS has proven to be an excellent planning tool, the GIS-generated information should be verified by a qualified hydrologic or hydraulic engineer or economists, as required.

With every investigation, several important lessons were learned as well as new ways of obtaining required data. As these GIS processes are more carefully analyzed, more refinements will likely be made to obtain more accurate information easily and to make the processes more streamlined. The added capability of the GIS to produce different recreation and open space concepts with flood control alternatives is presently being investigated.

Inherent in the use of new data sources are the associated problems with data conversion and transmission, raster resolution, accuracy of the data obtained, and the use of different horizontal datums. There are a number of remaining issues being investigated during the remainder of this Feasibility Study. These issues are not expected to be a hindrance in the completion of the Feasibility Study but are under investigation. Some of these are as follows:

- There were a number of problems encountered with the translation of data for the GIS from both an equipment and software standpoint. For example, the SCS relational database link for both the STATSGO general soils types and the detailed soils performed for the Prototype Methodology Study area on their AT&T computers would not export these databases directly to the Corps SUN computers because of the different computer system platforms. This problem is to being rectified by SCS during the early part of FY 92. Until then, the soil characteristics attribute data will be manually queried but this should not impact the Feasibility Study schedule.

- Translation of data from one media to a standard DXF format can cause a loss of accuracy of some of the key features of the original media. The transfer of data is many times very cumbersome and cannot be quickly sent over phone lines, thus, a cartridge tape must be hand-carried or mailed, if time permits. Many times, the data file is so large that it must be dissected into smaller pieces and carefully reconstructed to avoid data loss or irregularities. To compensate, larger capacity cartridge tapes and other media can be used. Data compression utilities are also to be used to compress data to manageable sizes. Additional hard disk storage space will need to be acquired by both the Corps and NCTCOG to store this GIS database to be generated for the Trinity River Corridor.

- The CTAD data for Tarrant and Denton Counties have not yet been investigated in detail. It is expected that the same processes used in obtaining the DCTAD data will also be used to link this other CTAD data to building centroids within their respective areas.

- The issue of what size cell resolution is still under investigation. In the use of 10-meter versus 30-meter resolution data, the amount of data to be manipulated increases tenfold. It is not known yet how much of an accuracy difference there will be between the use of these two resolution sizes. Key property areas are to be investigated to determine if more refined investigations are warranted. It could be that the 30-meter grid cell resolution may be adequate for floodplain analyses. Since it is assumed the water surface depth is held constant on any chosen grid cell size, the difference in a building being located on a theoretical 10-meter grid cell versus a 30-meter grid cell should not make that much difference in floodwater heights if the terrain does not steepen appreciably. It may also be that 10-meter data should be used for certain types of structures or terrain slopes. This issue is to be addressed during further feasibility-level investigations.

APPENDIX 1

GIS OVERVIEW

APPENDIX 1 - GIS OVERVIEW

This appendix discusses the background of the GIS system, describes the GRASS and ARC/INFO software packages, and provides an overview of the GIS economic analysis investigation performed to enhance water resources planning within the overall scope of the Upper Trinity River Basin Feasibility Study.

GEOGRAPHIC INFORMATION SYSTEMS

A Geographic Information System (GIS) is a computer system which allows the User to collect, manage, and analyze large volumes of spatially-referenced and associated attribute data. Spatial data consist of the various features that are defined by their geographic location and descriptive attributes. These features can have point, line, or aerial characteristics that are visually discernible, such as streams, roads, lakes; or invisible boundaries, such as county lines or zoning districts. A GIS also provides analytic and manipulative tools for functions that are difficult, if not impossible, to perform with a traditional geographically-oriented structured database.

A GIS affords a planner great flexibility in the way data can be analyzed by allowing any type of geographically-oriented information to be digitally recorded and stored according to a specified map coordinate system. Spatial data sets that are useful in land use and urban planning could include information such as soils, topography, geology, utilities, zoning, census, and any other data that is oriented or referenced by a geographic location. Data can be digitized from existing maps and databases. This information in a digital format is compatible with the digital satellite imagery and can be used in a cell-by-cell/pixel-by-pixel digital analysis. Once a digital database has been recorded according to geographic coordinates, any future data can be easily related or updated into the existing database.

REMOTE SENSING

Remote sensing is considered one of the most effective means of performing a quantitative digital analysis for resource planning over a large area of interest. Remote sensing is the science of acquiring information about objects without coming into direct contact with them. Aircraft and satellites are the most common platforms from which remote sensing observations can be made. This definition is restricted to methods that employ electromagnetic energy as the means of measuring and detecting the characteristics of the targeted objects. By this definition, remote sensing collecting techniques would include photography, radar, sonar, and multi-spectral sensors. The principle advantages of using digital image processing methods are their relative economy, versatility, repeatability, and preservation of original data precision.

Multi-spectral sensors operate on the principal that all matter reflects and radiates a range of electromagnetic energy that can be measured in wavelength ranges called channels or bands. The spectral resolution of a multi-spectral sensor refers to how many bands a device is capable of recording. Each band of information is stored on computer compatible tapes as digital data. The digital nature of the data makes it possible to restore, enhance, and extract information based on the digital values of individual pixels. A pixel is the area on the ground represented by each digital value recorded by the multi-spectral sensor. The position of any pixel is determined by an "x" and "y" coordinate system. The size of a pixel is determined by the sensor's resolution. Spatial resolution, usually recorded in meters, is the measure of the sensors ability to define closely spaced objects. For the Recon Study and this Prototype Methodology Study, grid cell resolution sizes of 40 and 30-meters, respectively, were used.

Remote sensing is widely used in establishing land use and vegetative cover for a large study area. Using the Earth Resources Data Analysis System, Atlanta, Georgia, ERDAS image processing software package (currently Version 7.4), the agricultural land use and vegetative cover was performed for the Prototype Methodology Study area.

Geographic Information System (GIS) technology plays an important role in several major aspects of this Prototype Methodology Study. The GIS is used to facilitate the analysis of spatially-referenced data in the hydrologic, hydraulic, economic and wetland determination investigations of this study. Various data layers were created by importing into the GIS data from various sources. The common factor among all of these data layers is that all are required to be geocoded to the same map coordinate system. Once the map layers are geocoded, integration and analysis of the data in the GIS becomes a straight-forward task.

RASTER versus VECTOR

There are at least two possible ways of representing topological data in a GIS: raster and vector representations. A raster structure (GRASS, ERDAS, etc.) divides an area into a regular grid of cells or pixels, each referenced by coordinates and containing a value of an attribute. In contrast, a vector structure (ARC/INFO) contains points, lines, and areas. Points are similar to cells in that they are referenced to coordinates, but have no area. Lines consist of sets of points (polygons) that are linked to bound an area that is assigned an attribute. Raster structures are perhaps the simplest because entities are represented implicitly whereas vector entities are explicitly stored in a linked database. Many low cost GIS's such as GRASS and large-scale environmental applications that use satellite data are based on a raster system. In vector systems, much effort is expended in defining polygons for overlaid data layers.

GRASS

Researchers at the U.S. Army Construction Engineering Research Laboratory (USACERL) at Champaign, Illinois, have developed a GIS to support environmental planning and land management on military installations. This GIS, the Geographic Analysis Support System (GRASS), is currently in use at several military installations and Corps of Engineers District offices. GRASS is in a continual state of development and refinement to assist the Corps of Engineers and military installations in the management and analysis of a wide range of environmental problems. GRASS has been commonly used to help site new facilities, manage natural and/or cultural resources, and evaluate the environmental impacts of proposed actions via spatial modeling.

The primary GIS used in this study was GRASS Version 3.1. The 4.0 Version of GRASS was released in July 1991 and represents a significant refinement over Version 3.1. Only limited uses of this new version were used for this Prototype Methodology Study but will be widely used for the Feasibility Study. GRASS is a raster-based public domain GIS with vector overlay capabilities developed by USACERL. The GRASS software is written in the "C" programming language and operates in the UNIX operating system.

Because of the type of floodplain analyses to be performed, a raster-based GIS environment work quite well. Both GRASS and ARC/INFO have raster as well as vector capabilities. Both have their weaknesses and strengths. Currently, GRASS's open system architecture allows for easy, flexible integration of floodplain mapping tools as those that have been developed by Ms. Terri Betancourt. Floodplain delineation by ARC/INFO would require the use of the GRID module, which is under development in Version 6.0.1, to perform raster processing in a vector-based environment.

ARC/INFO

The Environmental Systems Research Institute (ESRI), Redlands, California is the developer of the ARC/INFO software. The ARC/INFO software organizes geographic data using a relational and topological model. The fully relational Data Base Management System of this software allows the User to create and manage georeferenced tables of statistical or thematic data including real and integer numbers, dates, text, and references to tables of interpretive data or graphic symbols. This system allows the User to associate and interrelate information from several files by matching selected codes which are common to each field. This proprietary vector-based GIS package, called ARC/INFO Version 5.0.1, was used in this Study by NCTCOG for certain data conversion tasks, calculation of building centroids, and linkage of the DCTAD database to specific geographic coordinates through use of the MAPSCO roadway network (discussed below). The Corps used the ARC/INFO TINCONTOUR module to develop 2-foot contour interval line point data. This information was then imported into GRASS and converted into a raster format. From this file, GRASS developed a digital terrain model for the Prototype Methodology Study area.

Another primary difference between these two GIS systems is that the ARC/INFO program is linked to a relational database, whereas GRASS is not. The choice of a GIS system gets even tougher since both GIS systems are develop similar/overlapping capabilities as new versions of these GIS software systems are developed.

ROADWAY NETWORK

Rectification, or geocoding, is the process of assigning known map coordinates to an unregistered map, aerial photo or satellite image. For this study, a rectified digital roads file (a Digital Line Graph or DLG file) existed for the entire Upper Trinity River Basin study area. This file was converted from ARC/INFO vector format to GRASS raster format using modules from the GRASS 4.0 software package. Landmark points were chosen which could be easily recognized on both the classified satellite image and the DLG roads file, such as highway intersections or characteristic road bends. Map coordinates for each of these landmark points on the roads file were assigned to the corresponding points on the image file. When a large enough number of points was chosen to sufficiently sample the geographic extremes of the image, the computer systematically rotated each pixel to correspond to the proper map coordinate system. Because many of our map files were already in the UTM coordinate system, we geocoded all additional incoming map layers to this coordinate system. All files will eventually be transferred to the State Plane coordinate system for further use during the Feasibility Study.

The MAPSCO roadway network is a computerized grid network of roads and streets through out the Metroplex. This network also shows the beginning and ending block address at each street intersection throughout the area. NCTCOG used this MAPSCO roadway network to automatically link the structure address of a data file to a specific geographic coordinate within the region. By knowing the specific address, the ARC/INFO program was able to interpolate the approximate address location of this structure based on the location of the beginning and ending MAPSCO block registration numbers.

HEC MODELING PROGRAMS

The U.S. Army Corps of Engineers (USACE) expends a great amount of time and resources on flood analysis and cost benefit studies to determine the relative priority of and optimum location for construction of flood control structures in the Nation's waterways. Most USACE Districts use the HEC-2 Water Surface Profiles program, developed by the Hydrologic Engineering Center (HEC) at Davis, California, to compute water surface elevations for steady, gradually-varied flow in natural or man-made channels. The results of this modelling are traditionally drafted manually on maps or drawings and subsequently cross-referenced to land use and structures to evaluate the extent of damages from flooding. These manual methods are time consuming and result in little or no intrinsic analysis of alternative locations for flood control projects. A concerted effort was made in this study to integrate the results of the HEC-2 hydraulic model with the GIS, thus allowing the computer to delineate the floodplain boundary and calculate water depth for any given flood event. This process was also taken to the next logical step; calculation of economic damages for structures in the floodplain in terms of Expected Annual Damages (EAD's) for any given flood event. Integration of the HEC-2 model output data and County Tax Appraisal District (CTAD) data into the GIS automates the process of generating floodwater depths and calculating EAD's on a city-by-city basis through a metropolitan region. This in turn, expedites the evaluation of different flood control alternative conditions. One of the great advantages of using the GIS for analysis is the consistency and reproducibility of results.

The HEC-1 computer program is a widely used hydrologic model also developed by HEC. The HEC-1 model is designed to simulate the surface runoff response of a river basin as an interconnected system of hydrologic and hydraulic components. The GIS was used as a tool to automate the input of data into the HEC-1 hydrologic model. Mapping layers were compiled representing soils, surface topography, land use, and land cover. The hydrologists assigned values to the various land use categories of the individual map layers to represent the percent imperviousness and percent urbanization for the study area. Soil categories were classified to reflect the percent of sand in each category. The values derived from analysis of these map layers were compiled into a report format by the GIS software, printed to hard-copy, and delivered to the Hydrologic Engineering Section for direct input into the HEC-1 hydrologic model.

G I S OVERVIEW

A thorough understanding of the operation of the GIS is critical in understanding the reasons for the data requirements and the usefulness of the GIS for water and land resource planning purposes.

The most complex GIS investigation was the automatic generation of economic flood damage information from the various hydraulic and CTAD information. As an aid to understanding how the GIS processes data for the **CORPS FLOOD DAMAGE ECONOMIC ANALYSES**, the following information is provided. The verification of this economic analysis methodology prior to implementation is critical in saving countless amount of time and resources when the actual G&O planimetric and economic data becomes available and the subsequent economic analyses can be performed.

Figure 1-1 shows a systematic flow chart of the procedure in which the economic flood damage report is generated from the input of the HEC-2 summary output file and corresponding vector GRASS HEC-2 cross-section information, STDMA depth-damage curves file, CTAD economic data files, and other GIS User-prompted input. For the Prototype Methodology Study, the DCTAD data was used as the CTAD data sources in the diagram. Three separate f-tools programs have been developed as discussed in Appendix 2, GIS. These tools are written so that after these tools are invoked sequentially, they can also be invoked separately as needed. As an explanation of the figure 1-1 diagram, the tools are described as follows:

- The f.input tool reads specific variables in the HEC-2 summary output file and the GRASS cross-section vector map which is based on the cross-sections in the HEC-2 hydraulic model. It creates a GRASS vector water surface elevation at each HEC-2 cross-section for each flood event.

- The f.wsurf tool uses a GRASS raster-based digital terrain elevation model and f.input water surface elevation data and interpolates the water surface elevations between HEC-2 cross-sections using a GRASS interpolation routine. These interpolated water surface elevations are then overlaid and compared with the raster-based terrain elevation model to determine the floodplain delineated boundary and floodwater depths for each specified flood event.

- The f.econ tool uses a GRASS building centroid vector map which is created from the polygon footprints of each building in the study area. Specifically, the ARC/INFO building polygons in vector format are put into another ARC/INFO module which determines the building centroid for each polygon which would then be downloaded into ARC/INFO EXPORT DXF format for the Corps. The Corps would then input this file into the ARC/INFO program and translate this file into a GRASS vector format for input into the f.econ tool. Structure data from the applicable CTAD associated with each building centroid, STDMA depth-damage curves, and water depth information from the f.wsurf tool are also read into the f.econ tool which then calculates the single event and expected annual damages for each property type within the floodplain delineation. It also produces a summary report of the single event and expected annual flood damages per property type for each event. For further explanation of these GIS programs, refer to Appendix 2, GIS.

GIS PROGRAM TOOLS INPUT / OUTPUT FEATURES

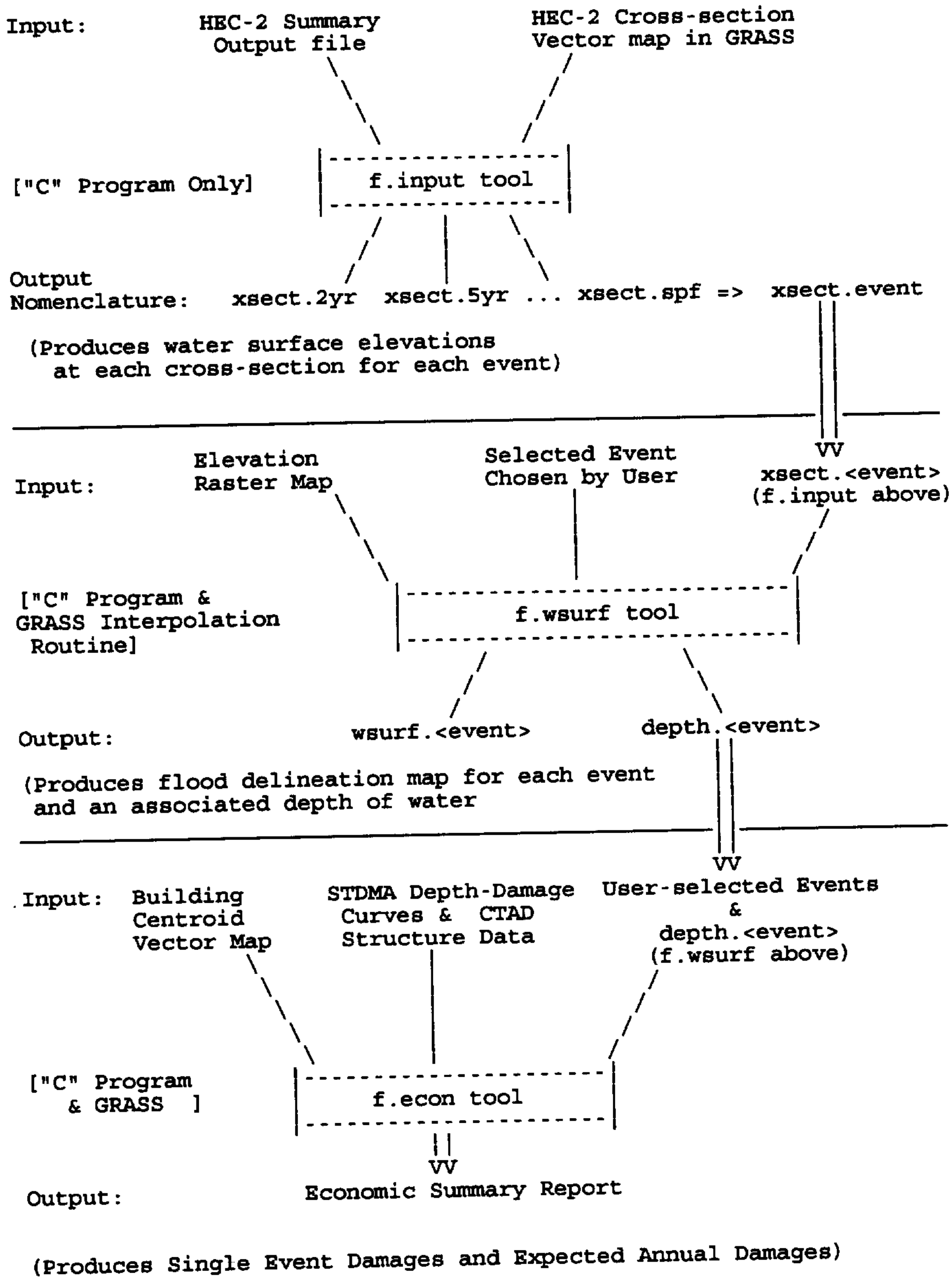


FIGURE 1 - 1

APPENDIX 2

G I S

APPENDIX 2 - G I S

This appendix discusses the various GIS investigations used in the hydrologic, hydraulic, and economic analyses of the Prototype Methodology Study area **from a GIS perspective**. Discussions concerning the use of the GIS for determination of potential wetland areas is entirely contained within Appendix 6, Wetlands Determination. Refer to the other applicable appendixes for a more detailed discussion of the these other investigations. Also discussed in this appendix are the types of computer hardware and GIS software used, different input data sources, and issues and refinements to be investigated during the Feasibility Study. In this narrative, the term "User" means those functions to be performed by the GIS operator.

PARTICIPANTS

GIS personnel Scott Walker, Tom Nelson, and Marsha Potts from the Corps of Engineers Environmental Section; GIS Programmer Ms. Terri Betancourt; and NCTCOG personnel Waymon Meeks and Lyssa Jenkens.

HARDWARE

To perform the required GIS processing and data manipulation it is important to know the type and sophistication of the computer equipment used. The following is a list of hardware used for these interim GIS investigations.

a. SUN Sparc 2 workstation with 16 MB of RAM, 669 MB of disk capacity, and a 150 MB 1/4" tape backup

b. M-4 Data Systems 6250 BPI, 9-track tape drive

c. Dell 386/25 Personal Computer with 4 MB of RAM, 350 MB of disk capacity, a 14" VGA color monitor for text, and a 14" Mitsubishi RGB monitor with a 32 bit color card for display

d. Cipher 1600 BPI, 9-track tape drive

e. SUN 4/110 workstation with 8 MB of RAM, 320 MB of disk capacity, and a 60 MB 1/4 " tape backup

f. Calcomp 9100 digitizing tablet

g. Summus erasable optical disk drive with a 650 MB disk capacity

h. Shinko CHC-635 color thermal wax printer

SOFTWARE

The primary GIS used in this study by the Corps of Engineers was the raster-based GRASS software Version 3.1. A vector-based GIS package called ARC/INFO Version 5.0.1, was also used in the study by NCTCOG for certain data conversion tasks, calculation of building centroids, and for the linkage of the DCTAD database to specific geographic coordinates through use of the MAPSCO roadway network. The Corps used the ARC/INFO TINCONTOUR module to develop 2-foot contour interval data from the spot elevation data provided via NCTCOG. This information was then imported into GRASS and converted into a raster format. From this file, GRASS developed a digital terrain model for the Prototype Methodology Study area. A more thorough discussion of these GIS software programs is in Appendix 1, GIS Overview.

Image processing, to determine land use and land cover of the Prototype Methodology Study area, was performed using the ERDAS image processing package, Version 7.4.

GIS METHODOLOGY FOR HYDROLOGY

RECON STUDY:

No attempt was made in the Recon Study to use the GIS to automate the HEC-1 process.

PROTOTYPE METHODOLOGY STUDY:

Spatially referenced data layers were accumulated from a number of different sources to assist in the automation of the required values into the HEC-1 hydrologic model. Data layers assembled for the hydrology analysis included Digital Elevation Model (DEM) data for the entire Upper Trinity River watershed from the U.S. Geological Survey (USGS), land cover data derived from classification of a LANDSAT Thematic Mapper (TM) satellite image of the study area, urban land use information obtained from NCTCOG, detailed soils and STATSGO general soils delineations provided by SCS, and subarea delineations from the Hydrologic Engineering Section of the Corps of Engineers. The details of these data sources, and resulting GIS investigations, are as follows:

What Was Tried:

Subarea Delineation: DEM data, produced by the Defense Mapping Agency was obtained through USGS on 1600 BPI, 9-track tapes, were read into the GRASS software package on the SUN Sparc 2 workstation. DEM data are digital records of terrain elevations for ground positions at regularly spaced intervals. The data are assembled contour plates which have been digitized and resampled at a latitude/longitude interval of 3 arc-seconds. Accuracy of these DEM data files is consistent with the 50-foot contours on the 1:250000 scale topographic maps used to produce the data. The use of 50-foot contour interval topographic data to delineate subwatershed areas is sufficient for larger regional studies such as that of the Upper Trinity River watershed. Analysis of the DEM provided a regional terrain model which was used to verify the location of the subarea boundary determinations provided by the Hydrologic Engineering Section. Further processing of these data within the GRASS software package produced computer map layers representing the slope and aspect of the study area allowing for quantification of these surface terrain factors. The following is a list of the steps involved in the delineation and verification of the subarea boundaries:

(1) DEM tapes covering the entire Upper Trinity River watershed were loaded onto the SUN Sparc 2 workstation using the GRASS 4.0 software and the M-4 tape drive. These tapes consisted of the Dallas, Sherman, and Wichita Falls sheets at a 1:250000 scale,

(2) the three files were merged into one using the "Gpatch" feature of GRASS 3.1,

(3) watershed and subarea boundaries, supplied by the Hydrologic Engineering Section on 1:250000 map sheets and on 1:24000 quad sheets, respectively, were digitized into vector files and labeled in GRASS 3.1 using the Calcomp digitizer on the SUN 4/110,

(4) the subarea vector files were converted to raster files in GRASS 3.1 and this file was used to "mask out" the areas outside the watershed boundary,

(5) slope and aspect calculations were performed on the masked DEM file using GRASS 3.1 on the SUN 4/110,

(6) the subarea vector boundaries were overlain on the aspect file to verify that the boundaries matched the surface terrain, and

(7) a report was run in GRASS on the watershed raster file to determine the exact area in each subarea which was verified against those subarea volumes used in the HEC-1 hydrologic model.

Land Cover Mapping: A full LANDSAT TM satellite image recorded September 11, 1988, was obtained on three 9-track tapes from the Earth Observation Satellite Company (EOSAT) from Lanham, Maryland, and was used to produce land cover data for the Prototype Methodology Study area. This imagery has a spatial resolution of 30 meters for six spectral bands and a spatial resolution of 120 meters for one thermal radiation band. This imagery was chosen for the land cover mapping for the following reasons:

(1) suitable digital data tapes were readily available,

(2) the 30-meter resolution was considered adequate for the level of land cover mapping required,

(3) LANDSAT TM imagery is taken from a stable satellite platform insuring that the data could be readily registered to the ground with a great deal of accuracy, and

(4) the multi-spectral data is extremely useful in performing an accurate and reliable land cover classification.

There are many advantages to using digital imagery for land cover mapping. In most cases, satellite imagery can greatly reduce the need for data gathering methods such as field work ("windshield" surveys) or aerial photography. Besides the digital nature of satellite imagery, there are other advantages that should be considered. Satellite imagery is collected from a stable satellite platform orbiting the earth and can provide reliable imagery over an area on a bimonthly or weekly basis. Satellite imagery is collected at the same altitude, same sun angle and azimuth, year-round making it easier to compare imagery collected from different days or times of year.

Most objects display a distinct pattern of reflected or emitted energy known as its spectral "signature". Spectral pattern recognition using these distinct signatures is the basis for classifying any type of multi-spectral imagery. During the classification process, objects identified by their signature are statistically analyzed by a predetermined set of criteria that recognizes similar patterns of signatures and separates individual pixels into classes. Six of the seven spectral bands (all bands except the thermal) were loaded into the ERDAS software package on the Dell PC for processing. An unsupervised classification program (Isodata) performed a "Cluster Analysis" on all six bands of the multi-spectral image.

Cluster Analysis operates in two steps. In the first step, the data is sequentially grouped by spectral signature into clusters (groups of points in spectral space) based on statistical parameters (maximum number of clusters, maximum number of points before merging clusters, etc.) provided by the User. In the second step, a minimum distance classification is performed on the statistical means of the clusters. The resulting classification helps to separate the data into various categories but gives no information as to what each category represents. In this case, the initial classification produced a GIS file with 20 spectrally distinct categories.

Non-Urban Land Cover. The resulting classified data was interpreted into the chosen individual non-urban land cover classes based on ground-truth information and interpretive knowledge of the User that identifies each cluster or group of clusters as a particular land cover type. The results of the land cover mapping for this Prototype Methodology Study were verified with information about the land cover derived from aerial photos of the study area. Obvious errors were found in the database and corrected. Excluding urban areas, the nine land cover categories used for the classification in the Prototype Methodology Study were as follows:

1. OPEN WATER - All types of surface water.

2. WETLANDS - Predominantly emergent wetlands.

3. PASTURE/OPEN FIELDS/RANGE GRASSES - Without intense effort, the spectral signatures of these types of land uses could not be separated. It was determined that these three land uses could be combined for the purposes of a reconnaissance-level assessment.

4. RIPARIAN FOREST - Forested woodlands adjacent to streams and river channels. Primarily American elm, hackberry, pecan, and post oak species.

5. UPLAND TREES - A combination of vegetation which occurs as an intermediate step in floodplain succession and vegetation which occurs in the transition between uplands and bottomlands. Consists primarily of cottonwood, willow, sycamore, hackberry, cedar elm, mesquite, honey locust, and persimmon species.

6. MANICURED GRASSES - The areas where grasses are typically mowed including lawns, highway easements, levees, golf courses, parks, etc.

7. CROPS - Areas that are actively being used for cropland.

8. RIVERINE - Vegetation associated with river bottoms and streambanks.

9. SHRUB/SAVANNA - Areas that consist of shrub cover and are not densely forested and cannot be classified as RIPARIAN.

The GIS file resulting from the classified satellite image was transferred from the Dell PC to the Sun Sparc 2 over the Local Area Network (LAN) and converted from a DOS to a UNIX file and then from an ERDAS format file to a GRASS format file. Once the file was in GRASS, it was rectified to Zone 14 of the UTM map coordinate system.

Urban Land Use. Because the 30-meter spatial resolution provided by the LANDSAT TM imagery was not sufficient to obtain the level of detail in the urban areas needed by HEC-1 hydrologic model for accurate assessment of urbanized land use categories, another method for obtaining these data was devised.

Digital land use files for the Prototype Methodology Study area were provided by the NCTCOG to augment the data obtained from the satellite land cover classification. These land use files were created by NCTCOG in the ARC/INFO format from visual interpretations of black and white aerial photographs. These aerial photographs, from Landis Aerial Survey in Dallas, Texas, were flown originally at a scale of 1:33000 in October 1988, enlarged to a scale of 1" = 1000', and reproduced on black-line mylar maps. The visual interpretation of the selected land uses were made by NCTCOG staff in association with the Texas Department of Transportation (formerly known as the State Department of Highways and Public Transportation). This interpretation was subsequently verified by the staff of each of the members cities involved in the Recon Study. The urban land use interpretations were transferred onto clear overlays for manual digitizing into the ARC/INFO GIS. The land use categories were interpreted based on the USGS Level I, II and III classifications for land use and land cover. These categories included:

1. Single family residential - Single family detached units. Duplexes are also included.

2. Multi family residential - Apartments, condominiums, residential hotels, converted apartments, and townhouses.

3. Mobile homes - Includes both mobile homes inside mobile home parks and free standing units outside parks.

4. Commercial office - Generally includes any administrative functions. Activities include corporate and government offices, banks, etc.

5. Commercial retail - Includes retail trade and services, such as department stores, repair shops, supermarkets, restaurants, etc. Hotel/motel facilities were also aggregated into this class.

6. Institutional - Churches, governmental facilities, museums, education, hospitals, military bases, are among those uses included. Group quarters such as nursing homes, orphanages, college dormitories, jails, and military base personnel quarters were also aggregated into this category.

7. Industrial - Manufacturing plants, warehouses, office showrooms, etc. are included.

8. Parks and recreation - All public and private parks, golf courses, cemeteries, public and private tennis courts, swimming pools, and amusement parks were aggregated for the purpose of economic evaluation.

9. Transportation and communications - Railroads, radio and television stations, truck terminals, etc.

10. Roadways - Includes all major roads.

11. Utilities - Sewage treatment and power plants, power lines easements, pump stations, water treatment plants, and water systems were included.

12. Nondevelopment - For the purposes of economic evaluation, all nondevelopment categories were aggregated. A detailed map of these classes was made in the vegetative cover analysis.

13. Landfills - Sanitary landfills, land applications, and similar waste management facilities were included.

14. Under construction - Land that appears to have undergone site preparation. Barren and/or disturbed land where soil or bare rock is exposed.

15. Flood control - Major flood control structures which includes levees and channels.

These land use files were obtained on 150 MB 1/4" tapes and imported onto the SUN Sparc 2 workstation and transformed into GRASS vector format for analysis. When the urban delineation from the NCTCOG land use file was merged (using the Gpatch feature in GRASS Version 3.1) with the satellite-derived non-urban classification, the resulting file provided an accurate representation of the overall urban and non-urban land use. A report was then run on the resulting file to calculate the area of each land use type in the study area. This file was then overlaid in GRASS with the watershed file to determine the area of each land use class in each of the subareas. A report was printed of these results and delivered to the Hydrologic Engineering Section for inspection. The percent urbanization and imperviousness factors were assigned to each land use category by Hydrologic Engineering Section. These values were coded into the GIS and another report was generated showing percent urbanization and imperviousness by subarea.

SCS Soils Data: General soils data were obtained for the entire Upper Trinity River watershed from the SCS. These data, compiled nationwide by SCS at a 1:250000 scale, are called State Soil Geographic Data Base **(STATSGO)** soils files. The data were obtained from the SCS in GRASS vector format on 1/4" tapes and included the Dallas, Sherman, and Wichita Falls map sheets at a scale of 1:250000. The watershed boundary file described above was used to mask out all but those areas inside the Upper Trinity River watershed. To develop the STATSGO data files, detailed soil types within the State were grouped by SCS into similar associations, hence, the term "general" soils map. These mapped soil associations were physically joined or edge-matched and relabeled at the junction of each map sheet by the GIS User. Because of the difference in computer "platforms" between the Corps SUN computers and the SCS AT&T computers, GRASS on the Corps SUN computers was not able to automatically query these STATSGO soil files for soil characteristics and attach percent sand factors to them. Thus, the STATSGO data was **not** used for the Prototype Methodology Study area. A more detailed discussion of these SCS linking problems can be read in Appendix 6, Wetlands Determination.

Detailed soils data were also obtained for the Prototype Methodology Study area at a 1:24000 scale. The ability to automatically query soil characteristics also did not work for these files. For each soil type, the GIS User assigned a corresponding identification number. A percent sand value was assigned by the Hydrologic Engineering Section to each of these identification numbers. These percent sand values were manually coded by the GIS User to attach these values to their respective soils types. A percent sand evaluation was run by the GIS and a report was generated showing percent sand by subarea.

The determination of the percents urbanization, imperviousness, and sand were then used to more fully automate the HEC-1 hydrologic program as discussed in Appendix 3, Hydrology.

What Didn't Work: Most of the GIS procedures used in this part of the study worked quite well. Because of the difference in computer "platforms" between the Corps SUN computers and the SCS AT&T computers, the GRASS GIS was not able to automatically query either the STATSGO soil files or the detailed soils files for soil characteristics and attach percent sand factors to them. This interface problem is being rectified by SCS and full query capabilities for these soil databases are expected to be available to the Corps SUN computers in early FY 92.

What Worked Best: Considerable time and resources were saved in this part of the study because much of the needed data were already available in digital form; the soils from SCS, land use data from NCTCOG, DEM data from USGS, and land cover information derived from the LANDSAT TM data. The actual manual effort to digitize the subwatershed areas and link the percents urbanization, imperviousness, and sand values to the respective land use or soil type within each subarea was minimal.

FEASIBILITY STUDY

Methodology to be used: The methodology described herein is to be used for the Feasibility Study. The automatic querying of soil characteristics would help the attachment of percent sand value to various soils type be more efficient.

Refinements: The SCS is working on the soils characteristics relational database link of the STATSGO and other detailed soils maps to allow full query capabilities of all soil characteristics and parameters in these files by SUN machines. This database link already exists for the AT&T machines. By "porting" this capability to the SUN platform, the soils database link can be fully operational. Any Version 3.1 GRASS modules used for this methodology are to be rewritten to use the enhanced Version 4.0 GRASS program.

GIS METHODOLOGY FOR HYDRAULICS

RECON STUDY:

To determine the economic impacts of flooding within the Upper Trinity River floodplain, an analysis was performed to calculate the depth of floodwater for each 40-meter grid cell for each of seven flood events and for all of the alternative conditions being considered. This type of automated analysis was possible due to the availability of computer software developed by the Corps of Engineers Waterways Experiment Station (WES) in Vicksburg, Mississippi. This software required as data inputs: (1) the digital elevation data described below, (2) a flood simulation model, and (3) a reach boundary map. This software was used originally by WES for the Trinity River Environmental Impact Statement (TREIS) in 1986. Due to the scope of the Recon Study, this software written in FORTRAN, was ported by WES to the SUN 4/110 computer for the Planning Division, Fort Worth District Corps of Engineers.

A raster-based digital elevation file was required as input for the WES model. These digital terrain data were obtained for the Recon Study by digitizing the data directly from USGS 7.5 minute topographic map sheets with 10-foot contour intervals. These data were then converted into a raster format at a resolution of 40 meters per pixel. Reach boundaries were determined as the city boundaries of the nine member cities that participated in the Recon Study. These limits were manually digitized into the GIS for the entire Upper Trinity study area and a GIS reach map was created.

The flood simulation model was created by inputting the water surface elevations generated by the Hydraulics Design Section into GRASS computer files. All seven flood events (2, 5, 10, 25, 50, 100-year and the SPF) were input into a single file for each cross-section used. All of the cross-sections used for in the HEC-2 hydraulic model were not used in the flood simulation model because the accuracy provided by the 40-meter grid cell resolution was not detailed enough to reflect the accuracy of each cross-section. Instead, a representative sampling of cross-sections evenly distributed along the Trinity River Corridor was used. A separate file was created for each of the alternative conditions analyzed. The alternative conditions analyzed included: "With Project" improvements of the various site specific alternatives; "With" and "Without Boyd Detention Structure" on the West Fork and mainstem Trinity River; "With" and "Without Indian Creek Detention Structure" on the Elm Fork and mainstem Trinity River; and "With" and "Without CDC" for the entire study area. The corresponding river mile location for each of the cross-sections was also input into the flood simulation model. A separate computer file was created that listed the Universal Traverse Mercator (UTM) coordinates for each of the selected cross-sections. This file was used to provide a description of the location and orientation of the cross-sections in the digital file. The original cross-sections were extended beyond their original limits to intersect the designated reach boundaries. Once these "control" files were created, the reach and digital elevation database was initialized into a single digital file. This database file was then input into a program called GRID RIVER MILE that indexed the elements of the database (reach and elevation) by the upstream and downstream bounding cross-section and attached the appropriate river mile location to each grid cell. Once this was accomplished, the file was ready to input into the STAGAREA program that calculates the area flooded versus the water surface elevation and the area flooded versus the depth of water (at 1-foot increments) for each flood frequency. This information was recorded in a large digital file that was converted into a GIS format to create separate map layers. A program called GRIDWATER gridded this information into a 40-meter grid cell size and produced a GIS map layer that delineated the flood event and classified these pixels according to the depth of water for each flood event.

The flood simulation model was limited to the main river reaches and the mainstem of the Trinity River and did not incorporate the many tributaries of the Trinity River. A delineation of flooding into several smaller tributaries was only investigated if they received backwater impacts from the Trinity River.

PROTOTYPE METHODOLOGY STUDY:

With the exception of the Expected Annual Damage calculations, the GIS methodologies, automation processes, and the level of detail between the Recon Study and this Prototype Methodology Study have changed (and been improved) significantly. The existing contour data of the Prototype Methodology Study area obtained from the city of Grand Prairie and the base mapping layers that are being generated by the surveying and digitizing contractor, Greenhorne & O'Mara, for the entire Trinity River Corridor are both at a 2-foot contour interval topography and 1" = 200' engineering base scale.

The raster grid cell resolution chosen for any study has a dramatic effect on the size of the files, processing times, and overall precision of the study. For example, changing the resolution of the grid cells from 30 meters to 10 meters causes the file sizes to increase tenfold. For the Prototype Study area, the file size would increase from 4 MB to about 40 MB.

What Was Tried: A major goal of this study was to develop a system which could integrate the HEC-2 summary output file with the GIS to delineate GIS-created floodplain boundaries and perform economic damage analyses for each of the various flood events. The Corps of Engineers contracted with Ms. Terri Betancourt of Mother Earth Systems, Boulder, Colorado, to perform the necessary programming to accomplish this formidable task. Ms. Betancourt was highly recommended for this contract by Mr. Bill Goran, the Chief of the GRASS software group at USACERL, who had been considering tackling this task on a generic level for some time. Ms. Betancourt was the most preferred candidate to perform this task because of her experience as a "C" programmer and as a person with considerable GRASS and hydraulic knowledge.

The contract work scope specified that the programmer integrate floodplain analysis tools into GRASS command line functionality which included the ability to extract HEC-2 cross-section identifications and associated water surface elevations and to provide a capability for modeling "split-flow" river channels. Other features specified in the contract included a mechanism to generate a digital elevation model from digital topographic contours, perform the interpolation of each flood events' water surface elevations from HEC-2 cross-section data provided in the HEC-2 summary output file, delineate floodplain boundaries, calculate floodwater depths over the coverage of the floodplain delineation, and calculate Expected Annual Damages based on STDMA depth-damage curves and DCTAD data with associated building centroid locations.

Five GIS program modules or "tools" (f-tools) are under final development for the purpose of this type of floodplain analysis. These tools are extensions to the GRASS GIS package and provide a loose integration between GRASS and the HEC-2 hydraulic modelling software. These f-tools are useful for both planning and engineering applications and are listed as follows:

1. f.input: Reads HEC-2 summary output results and creates water surface contours at each HEC-2 cross-section for each flood event.

2. f.wsurf: Maps floodplain boundaries and floodwater depths for each flood event over the floodplain delineation.

3. f.econ: Calculates single event damages and Expected Annual Damages.

4. f.volume: Calculates volumes of floodwater within any designated area.

5. f.xsection: Generates hydraulic cross-section profiles after at least two points are selected.

As discussed in Appendix 1, three of the five f-tools have been implemented; f.input, f.wsurf, and f.econ. Figure 1-1, Appendix 1, shows a diagram of the input and output requirements of these tools. When run in sequence, these three tools provide a fully automated means for assessing the economic effects of flooding. The ability to move readily from hydraulic engineering to economic assessment that probable damage benefit studies for potential flood control alternatives become much faster and easier. Each of these three tools is discussed in detail below:

f.input: For this tool to generate a GRASS vector map of water surface elevations at each HEC-2 cross-section, it requires the User furnish an ASCII HEC-2 summary output file and a GRASS vector map of the corresponding HEC-2 cross-sections. In the digitized cross-section GRASS vector map, cross-sections must be labeled with the same cross-section numbers (usually in river miles) as were used in the HEC-2 model. These cross-section numbers must be unique within the integer portion of the identification. It is not necessary for all cross-sections from the HEC-2 model appear in the GRASS map or vice versa. If a cross-section is found in the vector map which was not used in the HEC-2 model, the f.input tool assigns a "no data" value to the water surface elevation. Modeled cross-sections which are located in the summary file but not in the vector map will be ignored by the f.input tool.

The location of the cross-sections used for the HEC-2 file were digitized into GRASS vector files from USGS quad sheets supplied by the Hydraulics Design Section. Each cross-section was then labeled in GRASS with the appropriate river mile location. This GRASS vector file was then input directly into the f.input tool. For the entire Upper Trinity study area, this information will be provided directly by the Surveying and Digitizing contractor, Greenhorne & O'Mara (G&O), in digital form in the ARC/INFO format, ready for immediate conversion to GRASS vector files.

The User must specify to the f.input tool the flood events which are modeled in the HEC-2 model. The order in which the User specifies the flood events must correspond to the order in which the events were modeled in the HEC-2 file. Eventually, a default control file will be created by the GIS programmer.

Within the Trinity River Corridor, there are conditions whereby the river splits into two separate flow patterns which is called a "split-flow" condition. This action would be similar to a river "splitting" and flowing around an island or sandbar within the river channel. To accommodate this split-flow condition, the river section would be modeled as two separate HEC-2 models. The f.input tool is being designed to accommodate this split-flow condition by processing two separate HEC-2 output files. However, the cross-sections for both the primary and split-flow summary files should appear in the same GRASS map but do not necessarily have to be at the same location. Only one split-flow HEC-2 file is allowed and the f.input tool assumes the flood events modeled for the split-flow are the same as those modeled in the primary HEC-2 model. Any cross-section which is modeled in both the primary and split-flow HEC-2 models may have two different water surface elevations calculated by the HEC-2 program. When generating the vector map of these HEC-2 water surface elevations, the f.input tool will overwrite the primary water surface elevation with the elevation in the split-flow file.

Currently, GRASS maps may only contain integer values because of the program design of Versions 3.1 and 4.0. Planned improvements in future versions of the GRASS software will eliminate this problem. In order to maintain a one-tenth foot precision in the hydraulic elevation data, water surface elevations calculated by HEC-2 are multiplied by 10 before being assigned to the GRASS vector maps. This multiplication adjustment factor is accommodated by other f-tools.

f.wsurf: The f.wsurf tool takes the results of the f.input tool along with a raster-based terrain elevation map (DEM) and generates two separate raster maps describing the floodplain. The raster terrain elevation map would probably be to a detailed scale (2-foot contour, if possible) due to the precision needed for accurate estimation of floodwater depths and their associated potential flood damages. A 10-foot contour interval elevation map for the hydrology analysis would probably suffice because a 2-foot contour interval map would probably not be available for a large watershed area. The map wsurf.<event> is an interpolation of flood water elevations between HEC-2 cross-sections for each specified flood event. The map depth.<event> is a calculation of floodwater depths for each flood event based on the difference in the DEM and the GIS-generated water surface map (wsurf.<event>).

Interpolation of water surfaces over a large floodplain area causes the f.wsurf tool to be quite slow. The computational speed is greatly affected by the size of the study area and the cell resolution. Both size and resolution are set by the User with the GRASS command Gwindow. Because of the computation time required for surface interpolation, the User may only want to run the f.wsurf tool on selected flood events. Events are specified in terms of their recurrence interval in years, i.e., 50-year, and may be selected interactively or through the use of a control file. Only those events previously processed by the f.input tool are available to the f.wsurf tool. If run interactively, the f.wsurf tool provides the User with a list of available/selectable flood events.

Like the vector maps generated by the f.input tool, the raster maps generated by the f.wsurf tool contains a multiplication adjustment factor of 10 in order to maintain a one-tenth foot precision within GRASS.

Topographic data for the Prototype Methodology Study area was obtained from digital files provided by the city of Grand Prairie to the Corps via NCTCOG. The topographic information was divided into sections called "tiles" at a 1" = 200' scale with a 2-foot contour interval accuracy. The information was originally input into a Computer Aided Design (CAD) package called AUTOCAD. The appropriate tiles for the Prototype Methodology Study area were imported into ARC/INFO by the NCTCOG GIS staff. A more in-depth description of the importing process involved is discussed under the f.econ discussion later in this appendix.

CAD files of the type generated for the city of Grand Prairie are used primarily for visual display and the lines themselves carry no kind of "intelligence". In a vector-based GIS, the lines have information attached to them that allow the program to perform analysis functions on the file. These lines, however, must be continuous, i.e., unbroken, and must form closed polygons with an elevation attribute in order for information to be attached, as is specified in the contract for the Surveying and Digitizing Contractor, Greenhorne & O'Mara (G&O). In the case of these CAD files, this involved a great deal of manual editing and edge-matching at the juncture of adjacent map sheets.

To build a digital terrain model quickly, it was easier to recreate the DEM using the "x" and "y" coordinates of the spot elevations from the city of Grand Prairie data. This CAD-type data was converted by NCTCOG from a CAD format to a usable format in the vector-based ARC/INFO GIS. Using the TINCONTOUR contouring routine of ARC/INFO, the Corps created smooth 2-foot contour interval lines. This information was then imported into GRASS and converted into a raster format. From this file, GRASS developed a 30-meter digital terrain model for the Prototype Methodology Study area which was used as input into the f.input tool. A GRASS digital terrain model could have also been created directly from the CAD contour data, but it was more expedient and probably just as accurate to recreate the contour lines and then the digital terrain model from these new contour lines.

What Didn't Work: It was not realized until later that the DEM developed from the NAD 83 spot elevation points of the city of Grand Prairie did not overlay correctly over a roadway and stream network based on the NAD 27 horizontal datum. This was easily detected when the floodplain delineation was not near the river. These variances were noted and measured with standard GRASS utilities. Systematic corrections were then applied to bring the roadway and stream data set into correct horizontal registration.

What Worked Best: All aspects of the integration of the HEC-2 summary output and the corresponding cross-section vector files went very smoothly. Delineation of the GIS-generated floodplain and assessment of the floodwater depth by flood event worked extremely well.

FEASIBILITY STUDY

Methodology to be used: The methods described herein are to be used with minor variances. The problem with the differences in horizontal datums will be solved by using a single elevation and topological data source as is being produced by G&O for the Feasibility Study. The following refinements are also to be performed to enhance further feasibility-level investigations.

Refinements: All programming work done for this study to date was provided in the GRASS Version 3.1 format. Each of the f-tools and all subsequent programming are to be written/rewritten to use the enhanced GRASS Version 4.0 to take advantage of the major improvements provided by this most recent software update. The inability of the GRASS software (Versions 3.1 and 4.0) to deal with non-integers is currently not a problem since the f-tools have been written to adjust for a tenth of a foot accuracy. A further refinement in the f.wsurf tool may be realized by investigating improved algorithms for faster interpolation of water surface elevation data between HEC-2 cross-sections.

Although not a condition within the Prototype Methodology Study area, the problem of evaluating and representing the hydraulic conditions associated with levees and sump areas is to be investigated. The issue of how to deal with levees and sumps in the GIS model is a complex problem. It is not known how the GIS will handle a levee break or sump area which is beyond the designated flood delineated boundary.

Two of the five f-tools mentioned in the discussion above have yet to be developed. These two tools, f.volume for calculating flood volumes by event and f.xsection which will generate hydraulic cross-sections from surface points, will provide the hydraulic engineer with advanced utilities for floodplain analyses.

Some possible areas for future GRASS programming work beyond the scope of our initial programming contract include:

1) Improved contour interpolation routines which handle special isolines such as HEC-2 hydraulic cross-sections.

2) An automated strategy for handling large study areas and/or areas of fine cell resolution.

3) A tighter coupling between GRASS and HEC-2 to provide a more sophisticated modeling environment for the hydraulic engineer.

There may also need to be some programming for ARC/INFO applications.

GIS METHODOLOGY FOR ECONOMICS

RECON STUDY:

As mentioned previously, an analysis was performed to calculate the depth of floodwater by pixel for each of seven flood frequencies and for each of the Recon Study alternative conditions investigated to determine the potential economic impacts of floods in the study area. The results of the flood inundation analysis from the HEC-2/GIS integration was used to determine water depths over the Trinity River Corridor area.

Depth-Damage Analysis: Using the results of the flood inundation analysis, a depth-damage map was developed for each of the seven flood events and for each of the alternative conditions analyzed. The results of the flood inundation map (depth of flooding in 1-foot increments) was cross-tabulated with estimated 1995 land use information and a tabulated report was created. This 1995 land use information was derived from the 1988 land use digital provided by NCTCOG for the entire Trinity River Corridor. The STDMA depth-damage curve values used, as shown in table 5-5 of Appendix 5, Economics, were provided by Economics Branch. A matrix identifying the percent damage by 1-foot incremental depth for the eight land use categories evaluated is shown in table 2-1. The percent value of damage was reclassified to each of the categories for the appropriate depth of flooding associated with each land use category. The result was a depth-damage GIS map used to calculate flood damages for each of the seven flood events analyzed for each of the alternative conditions considered in the Recon Study.

TABLE 2-1

PERCENT DAMAGE TO STRUCTURES AND CONTENTS COMBINED PER FOOT OF FLOODING - RECON STUDY (Values Adjusted for Average Floor Correction)

Depth	Single Resident	Multi Resident	Mobile Homes	Office	Retail	Institu-tional	Industrial	Parks & Recreation
0.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0
1.0	11.2	10.8	04.3	01.5	12.2	00.5	01.7	14.1
2.0	28.9	25.6	10.7	09.5	27.5	09.2	07.4	21.2
3.0	38.5	30.6	17.0	12.0	36.9	14.8	12.3	28.0
4.0	45.2	35.5	24.7	14.4	44.6	18.5	15.9	32.1
5.0	50.6	40.6	35.0	16.4	49.8	21.3	19.3	34.0
6.0	55.9	44.2	44.3	19.4	53.5	23.4	23.1	35.6
7.0	58.9	47.2	53.3	22.4	56.1	25.2	27.0	37.4
8.0	61.8	49.4	90.0	25.4	58.1	27.4	30.4	39.1
9.0	64.7	50.9	92.7	28.9	60.0	29.4	34.0	40.8
10.0	67.4	52.6	98.0	32.6	62.1	32.0	37.6	43.1
11.0	68.8	55.3	98.0	36.7	64.4	34.5	41.9	45.6
12.0	70.9	58.1	98.0	40.3	66.9	37.6	46.1	47.8
13.0	73.8	60.8	98.3	43.5	69.5	41.2	50.3	49.6
14.0	76.3	64.4	98.7	46.5	71.9	45.6	54.2	51.0
15.0	79.9	67.3	98.7	49.1	74.2	50.3	57.8	52.1
16-31	92.0	82.0	99.0	60.0	87.9	77.0	74.2	55.0

Flood Damage Analysis: Single event flood damages to existing structures and contents are routinely calculated by multiplying the percent of damage to the property, derived from the depth-damage relationships, by the structural value of that property. For the Recon Study, the land value was used as the structural value of that property. For each pixel area (0.4 acres), flood damages were calculated by the GIS. The GIS was also used to map the location of these damages. This analysis was done by multiplying the depth-damage map by the land value map for the respective alternative areas. The GRASS program, Gmapcalc, calculates the equation input into the program on a pixel-by-pixel basis. This program also created a new map layer for exactly the same study area identifying each pixel by the dollar damages occurring at that pixel location. A report was then generated from this map which tabulated the number of pixels for each different dollar value per $1,000 increment. This information was also cross-tabulated to index the dollars damaged by the land use category and reach boundary.

One of the inherent capabilities of GRASS is the ability to subset the data layers into variable windows or reaches. This was done to calculate the damages for each of the potential damage areas considered in the Recon Study. These areas included: Marys Creek; Clear Fork at University Drive; Fort Worth Floodway; West Fork at Riverside Drive, Parkway North Addition, Johnson Creek, Bear Creek, Belt Line Road, Meyers Road, and Delaware Creek; Elm Fork at Stemmons North Industrial Park and Irving Flood Control District Number One Levee

(Northwest Levee). By windowing the GIS for each of these potential damage areas, reports were generated from the GIS tabulating by city, the number of pixels for each of the damage dollars categories, for each of the eight land use categories analyzed. The results of these reports were furnished to the Economics Branch and put into an EXCEL spreadsheet program to generate figures on the total damages for each potential damage area.

Due to the fact the land use was mapped by NCTCOG in a zoning style, many pixels were classified as commercial office, commercial retail, or industrial, when in fact they were actually parking lots or similar facilities for these commercial areas. On a large study area and for a regional analysis, it was not feasible to remap the entire study area to identify the structures separately. Consequently, a sensitivity analysis was performed by the Economics Branch which indicated the preliminary values of flood damages were extremely high since many pixels of parking lots were given damage dollar values equal to damages which would occur to office, retail, or industrial development. To compensate, the number of pixels of each of those three categories was reduced by a percentage to reduce the corresponding flood damage dollars attributed to each category.

This analysis was performed for the "Without Project" existing conditions using baseline 1995 land use conditions throughout the Trinity River Corridor which were verified by the member cities and subsequently, provided by NCTCOG. This analysis was also performed in a similar manner for the other alternative conditions investigated and for the "With" and "Without Boyd Detention Structure" conditions, "With" and "Without Indian Creek Detention Structure" conditions, and "With" and "Without CDC" conditions.

Expected Annual Damages: Benefit/cost ratios that were used to determine the feasibility of a flood protection project were calculated based on the Expected Annual Damages, herein referred to as EAD's. The EAD's were calculated based on traditional single event flood damages for each of the flood frequency events analyzed. This equation used by the GIS for both the Recon Study and the Prototype Methodology Study to determine EAD's for alternative conditions is:

$$EAD = (((D2 + D5)/2 \times 0.3) + ((D5 + D10)/2 \times 0.1) + ((D10 + D25)/2 \times 0.06) + ((D25 + D50)/2 \times 0.02) + ((D50 + D100)/2 \times 0.01) + ((D100 + Dspf)/2 \times 0.009) + (0.001 \times Dspf))$$

EAD	= Expected Average Annual Damages	D25	= Damages @ 25-year flood
D2	= Damages @ 2-year flood	D50	= Damages @ 50-year flood
D5	= Damages @ 5-year flood	D100	= Damages @ 100-year flood
D10	= Damages @ 10-year flood	Dspf	= Damages @ SPF flood

Flood damages were calculated for all seven flood frequency events on a pixel-by-pixel basis in the GIS. Consequently, using the GRASS Gmapcalc function and inputting a batch program that would calculate the EAD equation, EAD's were calculated by the GIS on a pixel-by-pixel basis and a new EAD map layer was created that identified each pixel by the dollars of potential EAD damages calculated. Cross-indexing of this map layer with the land use map and the reach map was performed and reports were generated which tabulated, by reach and land use category, the number of pixels of each category of EAD dollars. This report was generated for each of the alternative conditions analyzed and for all potential damage areas identified. The results of the reports were provided to the Economics Branch and input into an EXCEL spreadsheet for tabulation and evaluation.

PROTOTYPE METHODOLOGY STUDY:

What Was Tried:

f.econ: The third tool in the sequence of f-tools developed for floodplain analysis is called f.econ. This tool takes as input the results of the f.wsurf tool along with a User-supplied vector map of building centroid information and two ASCII files of economic data. As output, the f.econ tool generates a vector map which shows the total damage to each property type by flood event in the floodplain along with an ASCII report of EAD flood damages categorized by building types (residential, public, etc.) and damage type (structure and contents). The f.econ tool also reports areal extent of flooding, in acres and in square miles.

The User may choose to run the f.econ tool on selected flood events. Events are specified in terms of their recurrence interval in years and may be selected interactively or through the use of a control file. Only those events previously processed by the f.wsurf tool are available to the f.econ tool. If run interactively, the f.econ tool provides the User with a list of available/selectable flood events to choose.

The f.econ tool requires the User to define the recurrence interval associated with a SPF flood event. This specified recurrence interval, however, affects only the calculation of the EAD and not the river hydraulics or floodplain delineation.

For the f.econ tool to operate, two input files, build.dat and damcrv.dat, are required and are described in detail below:

build.dat: The build.dat file consists of economic data used by the f.econ tool in a STDMA-style format. Data in this file includes DCTAD building structure values, DCTAD building content values, finished floor elevations, and more. Since these data are necessary for the STDMA program itself as well as the f.econ tool, this module was designed to accept the STDMA-formatted input file. For this study, the build.dat file was compiled from several sources. DCTAD information, linked by building identification numbers, was formatted by NCTCOG to a Corps of Engineers usable file format. This information was delivered to Economics Branch where the data were transformed into the STDMA format. Finished floor elevations for each structure was calculated by the GIS by adding the ground elevation of the building centroid from the digital surface terrain model to an assigned one foot floor correction factor. In the future, a this floor correction factor may be automated based on the type of DCTAD building structure category. Table 2-2 shows the build.dat file used for the Prototype Methodology Study.

damcrv.dat: This ASCII file contains, in tabular form, the STDMA depth-damage curve values for different property types as shown in table 5-5, Appendix 5, Economics. This table has the following general format:

		depth-1	depth-2 ...	depth-n
crv-1	description	%	%	%
crv-2	description	%	%	%
...				
crv-n	description	%	%	%

TABLE 2-2

EXAMPLE BUILD.DAT FILE

510.00P	504.0	485.2SHEPARD OF LOV	59	1	64370 60	7016	85092841
487.00C	483.0	464.0CLOWN AROUND	395	1	819520524	561683	85102421
491.00C	456.0	436.7RAMADA INN	229	1	655411230	238122	85112841
492.00C	462.0	442.7RAMADA INN	229	1	5270230	1915	85112842
492.00C	460.0	440.7RAMADA INN	229	1	1254026230	455610	85112843
487.00C	502.0	482.4WAX MUSEUM	295	1	1033580296	708002	85122846
487.00C	520.0	500.9MARK IV BUSINE	421	1	114984422	12522	85132465
487.00C	531.0	511.9MARK IV BUSINE	421	1	134046422	14611	85132491
486.00C	516.0	496.9MARK IV BUSINE	421	1	111766422	12182	85142474
486.00C	526.0	506.9MARK IV BUSINE	421	1	116974422	12750	85142506
509.00MFR	472.0	452.8GENTRY PLACE AS	7	1	283255C7	10000	85152822
509.00MFR	468.0	448.8GENTRY PLACE AS	7	1	400301C7	10000	85152823
510.00MFR	462.0	442.8GENTRY PLACE AS	7	1	281325C7	10000	85152824
510.00MFR	468.0	448.8GENTRY PLACE AS	7	1	408142C7	10000	85152825
510.00MFR	462.0	442.8GENTRY PLACE AS	7	1	237644C7	10000	85152826
503.00MFR	466.0	446.8GENTRY PLACE AS	7	1	283133C7	10000	85152827
509.00MFR	480.0	460.8GENTRY PLACE AS	7	1	415494C7	10000	85152828
510.00MFR	480.0	460.8GENTRY PLACE AS	7	1	101607C7	10000	85152829
510.00MFR	485.0	465.8GENTRY PLACE AS	7	1	277772C7	10000	85152830
499.00MFR	470.0	450.8GENTRY PLACE AS	7	1	286135C7	10000	85152831
491.00MFR	462.0	442.8GENTRY PLACE AS	7	1	230966C7	10000	85152833
495.00MFR	47C.0	450.8GENTRY PLACE AS	7	1	411114C7	10000	85152834
492.00MFR	462.0	442.8GENTRY PLACE AS	7	1	413197C7	10000	85152835
510.00MFR	488.0	468.8GENTRY PLACE AS	7	1	276853C7	10000	85152836
508.00MFR	486.0	466.8GENTRY PLACE AS	7	1	245853C7	10000	85152837
504.00MFR	478.0	458.8GENTRY PLACE AS	7	1	247263C7	10000	85152838
499.00MFR	476.0	456.8GENTRY PLACE AS	7	1	280805C7	10000	85152839
506.00MFR	488.0	468.8GENTRY PLACE AS	7	1	276761C7	10000	85152840
506.00C	446.0	446.7MOTEL	229	1	1018120230	369578	85162844
492.00C	479.0	459.8SOUTHWEST AIRL	249	1	1027250250	97946	85172845
487.00C	494.0	474.4WHITE WATER PA	295	1	1749296	1198	85182515
487.00C	493.0	473.4WHITE WATER PA	295	1	6070296	4158	85182529
487.00C	490.0	470.4WHITE WATER PA	295	1	7434296	5092	85182531
470.00C	490.0	470.4WHITE WATER PA	295	1	5231296	3583	85182532
470.00C	494.0	474.4WHITE WATER PA	295	1	1280296	877	85182542
471.00C	500.0	480.4WHITE WATER PA	295	1	7834296	5366	85182545
471.00C	498.0	478.4WHITE WATER PA	295	1	8917296	6108	85182560
471.00C	494.0	474.4WHITE WATER PA	295	1	37685296	25814	85182848
455.00C	442.0	423.2	395	1	124330396	218592	85303315

Depth categories form the table's column headings. All of the column (depth) headings must appear on a single line. Column positions are irrelevant but the values must be separated by one or more spaces. The f.econ tool interpolates depth values to one-tenth of a foot and also interpolates the corresponding damage percentages. In order to interpolate correctly, the f.econ tool assumes the depth values and damage percentages are increasing from left to right. Curve numbers are alpha-numeric identifications contained in columns 1 through 3. Curve descriptions are contained in columns 4 through 45. Damage percentages (%) begin after column 45. The f.econ tool first looks for a building centroid point. If it finds the point, it then looks for a corresponding line of DCTAD economic data. If it is not found, it will give the User an error message saying that no data was found for this point. If their is no centroidal point but economic data exists, the f.econ tool will ignore this data without an error message. Thus, it is every important to have a building centroid point for every building footprint in the economic data file. If the f.econ tool finds both the building centroid points and its associated DCTAD economic information, it then looks at the depth-damage curve in damcrv.bat file. The f.econ tool will give the User an error message, if the water depth cannot be interpolated between lower and upper water depths found in this table. The depth-damage table is assumed to be complete.

A test of the f.econ tool was performed on another study area where economic damages had already been calculated by the Economics Branch using the STDMA program to compare the results. The study area was located on Upper Zacate Creek in Laredo, Texas. The topography and cross-sections and building locations (as site data) for the study area had already been digitized and economic values had been assigned to each building. The building centroid points were calculated by the Corps using the ARC/INFO program.

The ASCII file of the HEC-2 summary table and the corresponding vectorized HEC-2 cross-sections were incorporated in the f.input tool. The resulting water surface elevations for each cross-section were input into the f.wsurf tool. The water surface delineation and the water depth model created in this step were subsequently fed into the f.econ tool. A comparison of the economic damages calculated using the two methodologies showed many similarities and some differences in accuracies. These can be attributed to the grid cell resolution chosen for the analysis. In areas such as commercial complexes where buildings tend to be tightly grouped, the computer would aggregate these buildings into 30-meter grid cell groups with the same ground and water surface elevations.

Building location data and surface topographic spot elevations for the Prototype Methodology Study were obtained from survey-quality Computer Aided Design (CAD) files supplied to the Corps by the city of Grand Prairie via NCTCOG. These initial data files were compiled by Dallas Aerial Survey as DXF files for the city of Grand Prairie. The size of **each tile** varied from approximately 1.5 MB to 26 MB each. Each of 14 separate DXF files was copied by the NCTCOG GIS staff via an Ethernet configuration with transfer times ranging from 20 minutes to 2 hours for each file. Each file then had to be "unzipped" from its compressed format. This step took from 5 minutes to 3 hours per file. Some of the data was supplied to NCTCOG in AUTOCAD DWG (Drawing) format, requiring that the files first be imported by NCTCOG into the AUTOCAD package for translation into DXF format. NCTCOG then imported these files into ARC/INFO and generated coverages of each file. Before centroid locations could be calculated, each building footprint had to be a closed polygon. This involved a great deal of cleaning and editing of these files by NCTCOG staff. Extraction of the building centroid locations involved approximately 1 hour per tile. As discussed above, the process of converting CAD data to usable vector-based ARC/INFO files can be a rather tedious, time-consuming, and disk space-consuming task.

Once the building polygons were closed and centroid locations were calculated, the files were ready for integration with the DCTAD Certified Tax Roll database. Statistical Analysis System (SAS) jobs were written by NCTCOG to extract the DCTAD data into the desired STDMA-style format. The selected records were then linked to the appropriate building centroid using ARC/INFO.

After the ASCII files of build.dat and the damcrv.dat (the STDMA depth-damage curve values) were input into the f.econ tool, it worked flawlessly. This tool generated a tabular report that showed, by flood event, the total number of structures and damages by property type, damage to structures and contents, areal extent of flooding (in acres and square miles). It also showed the calculated EAD for each property type. In Appendix 5, Economics, the economic results of the f.econ tool as shown in tables 5-3 and 5-4 for Existing and Modified Conditions, respectively.

What Didn't Work: Map registration problems arose when the building centroid and spot elevation data layers were overlain on existing map layers. The original map files created by Dallas Aerial Survey were created using the NAD 27 datum. The current version of ARC/INFO (Version 5.0.1) does not allow for the direct translation from NAD 27 files to the current NAD 83 datum if the data does not correspond to the dimensions of a 7.5 minute quadrangle. An approximated method was employed to position the map tiles in the correct location. Registered map layers of roads and streams were used as frames of reference to allow the map tiles to be manually adjusted to the correct location. While it is doubtful that the map tiles were positioned in their precise location, both the NCTCOG and Corps GIS staffs agreed that the close match obtained in this manner was sufficient for the testing of the methodology for this study area. The building centroid locations and the spot elevation points remained constant relative to each other. These map layers were originally created in the State Plane map coordinate system and were projected to the UTM coordinate system and exported to an interchange file using ARC/INFO. This horizontal datum difference problem will be resolved when the new G&O surveying and digitizing data is used which will be registered to a single horizontal datum (NAD 83).

What Worked Best: The economic damages calculated using the f.econ module compared favorably to damages calculated by the traditional STDMA method on the Upper Zacate Creek study area. By developing the f.econ tool within the GIS framework, economic analyses have become available to the spatial domain. Combined with flood damage data, spatial referencing can provide additional information such as the locations of floodprone areas over large areas and the associated economic damages in these areas.

FEASIBILITY STUDY

Methodology to be used: The methodology described herein is to be use for the Feasibility Study with minor variances noted below. The following refinements are also to be performed to enhance further feasibility-level investigations.

Refinements: A programming refinement is being developed to allow economic summary reporting by individual structures. This utility will be included as a part of the existing f.econ tool and will prompt the User for the summary combination for the desired report format. Development of different types of potential economic flood damage maps on a regional analysis should also be investigated.

A procedure is to be investigated for constructing an input file to the f.econ tool wherein, from the DCTAD property address, the location of the building footprint could be determined via the MAPSCO grid coordinate system and then the building centroid coordinate could be automatically calculated and input into the build.dat file.

Finished floor elevations for each structure were calculated by the GIS by adding the ground elevation of the building centroid from the digital surface terrain model to an assigned one foot floor correction factor. In the future, this manual assignment of floor correction factors should be automated based on the type of building structure category or other similar classification.

The Version 3.1 GRASS f.econ tool used for flood damage economic analysis is to be rewritten to use the enhanced GRASS Version 4.0 program.

Additional applications of the GIS ARC/INFO system should also be investigated and evaluated with GRASS.

APPENDIX 3

HYDROLOGY

APPENDIX 3 - HYDROLOGY

BACKGROUND

The purpose of the hydrology portion of the Prototype Methodology Study was twofold:

(1) To develop a procedure to obtain soil characteristics, land cover, and land use information from the GIS and

(2) To automate the procedure for updating the HEC-1 files to reflect changes in soil characteristics, land cover, and land use values obtained from the GIS and/or the routing data obtained from the HEC-2 model.

PARTICIPANTS

Scott Walker and Tom Nelson from Environmental Resources Section, Michael Danella from Hydraulics Design Section, and Paul Rodman, Steve Pilney, and Greg Estep from Hydrologic Engineering Section.

METHODOLOGY

RECON STUDY:

The computer program used to develop the primary hydrologic model for the Recon Study was the HEC-1 Program 723-X6-L2010 developed by the Corps of Engineers' Hydrologic Engineering Center (HEC) at Davis, California. This HEC-1 model is designed to simulate the surface runoff response of a river basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. The area hydrologically modeled in the Recon Study consisted of the entire drainage area of the Trinity River upstream of the point where Five Mile Creek flows into the Trinity River, a total of about 6,275 square mile. The area modeled was divided into 108 subareas in order to be responsive to the timing of each major tributary's runoff contribution to the total flood hydrograph, and also to obtain detailed flood hydrograph information at all major points of interest on the West Fork, Elm Fork, and mainstem of the Trinity River. Separate NUDALLAS hydrology models were developed for the Clear Fork, Marys Creek and for the Elm Fork. These models were originally adopted from available Flood Insurance Studies.

The block and uniform loss method of estimating infiltration losses was used. Two different loss rates were used: (1) the initial loss which must be satisfied before any runoff occurs and (2) a constant loss in inches-per-hour which continues after the initial loss has been satisfied. The values of both loss components vary with the return frequency of the storm. The standard values of loss components for both sand and clay soil corresponding to storm return frequency was used. In the absence of previously determined loss components, the percentage of the watershed with clay soil characteristics and sand soil characteristics for each subarea was manually determined from County Soil Survey Reports published by the U.S. Department of Agriculture, Soil Conservation Service (SCS). The soil percentages for sand were used to manually interpolate between the standard values to determine the subarea's loss component values. The computation of **percent sand** was determined by comparing the permeability rates of the major soil types with those of the Houston and Crosstell series soils. A brief description of each series follows.

The Houston Black series consists of moderately well-drained, deep, cyclic, clayey soils. This series formed in alkaline, marine clay, and material weathered from shale. Land slopes range from 1 to 4 percent. The permeability rate is less than 0.06 inches per hour. This soil is the predominate series found in watersheds used to develop the Blackland Prairie Clay Urbanization Curves. Therefore, this soil has a percent sand of 0 for use with these urban curves.

The Crosstell soil consists of moderately well-drained, deep loamy soils on uplands that formed in shaley and clayey sediment containing thin strata of weakly cemented sandstone. Land slopes range from 1 to 6 percent. The permeability rate for this soil is in the range between 0.6 to 2.0 inches per hour. The Crosstell series is the major soil contained in watersheds used to derive the Cross Timber Sandy Loam Urbanization Curves. This soil, therefore, has a percent sand of 100 for use with these urban curves.

Percent sand values for soil types with permeability rates between those for clay and sand soils were linearly interpolated. After the percent sand for each soil type was determined, a weighting was applied by multiplying the appropriate percent sand for each soil type by the percent of the subarea covered by that soil type. Also, adjustments were made to loss rates for some individual subareas based on flood reproductions and discharge-frequency relationships at gages.

Values of percent urbanization and imperviousness were developed for each subarea. The definitions of urbanization and imperviousness used for the Recon and this Prototype Methodology Study are as follows.

- o Urbanization is defined as the percentage of the basin which has been developed and improved with channelization and/or a storm collection network. The only effect of urbanization is to modify Snyder's time to peak value, Tp, of the unit hydrograph. Tp is the lag time from the mid-point of the unit rainfall duration to the peak of the unit hydrograph, in hours.

- o Imperviousness is defined as an estimate of the percentage of the basin covered with impervious material and hydraulically connected to the subarea's drainage network. The only effect of imperviousness is to decrease the volume of rainfall lost through interception and infiltration.

Utilizing these definitions, the percentages of urbanization and imperviousness were determined for each subarea by using 1985 land cover data derived from the most recent maps, charts, and aerial photography available at the time of the Recon Study.

Unit hydrograph time to peak (Tp) was developed for each subarea using methodology described in "Synthetic Hydrograph Relationships, Trinity River Tributaries, Fort Worth - Dallas Urban Area" by T.L. Nelson, 1970. Urbanization curves available for sand (Cross Timbers) and clay (Blackland) soils indicate elapsed time (Tp) from the midpoint of a unit duration of rainfall to maximum runoff for a given subarea. The geographical characteristics of the subarea such as length of major stream (L), the distance from the subarea outflow point to the location of the subarea center of gravity (Lca), percent urbanization, and weighted slope (sst) of the major stream determine the entering arguments for the urbanization curve from which Tp for the subarea is extracted. The Tp used for each subarea was generated from the Cross Timbers Sandy Loam Urbanization Curves and the Blackland Prairie Clay Urbanization Curves by manually interpolating between them, based on the composite percent sand value within the subarea.

Modified Puls routing was used to route through the shorter reaches of the subareas downstream from the lakes. The storage-discharge data were based on HEC-2 and LRD-1 backwater analyses. The LRD-1 output was handcarried from the Hydraulic Design Section. The output consisted of discharge-elevation-storage data which was modified for use in the HEC-1 model. The data was manually input into the HEC-1 model. The HEC-2 generated routing data was directly accessed for use in the NUDALLAS program.

PROTOTYPE METHODOLOGY STUDY:

Using the same definitions for percents urbanization, imperviousness, and sand as used in the Recon Study, these values were determined for two subareas within the Prototype Methodology Study area (discussed later) using the 1:24000 scale detailed soils maps provided by SCS and NCTCOG estimated 1995 land use conditions data. As explained in Appendix 2, GIS, percent urbanization and imperviousness values were assigned by the Hydrologic Engineering Section to each land use classification. Note that this land use classification is also linked to the GIS by a GIS User land use classification identification number. The "aggregated" percent urbanization and imperviousness values for the subarea were calculated by the GIS by multiplying the respective percent urbanization and imperviousness factors of a particular land use classification by the acreage for that type of land use within that subarea and then dividing by the total acreage of that subarea. These respective percent values for each land use classification area were then summed to make up the total percent value for the subarea.

The percent sand determination was performed in a similar fashion. A percent sand value was assigned by the Hydrologic Engineering Section for each soil type in the subarea. Note that this soil type is also linked to the GIS by a GIS User soil identification number. The percent sand value for each soil type is determined manually by the Hydrologic Engineering Section based on a table of specific soil parameter data for each soil type as classified in the SCS county soils survey manual for that particular region. The "aggregated" percent sand value for the subarea was calculated by the GIS by multiplying the percent sand factor of a particular soil type by the acreage of that soil type in the subarea and then dividing by the total acreage of that subarea. These percent sand values for each soil type area were then summed to make up the total percent sand value for the subarea.

Thus, when these percent values are assigned per land use classification and/or soil type, the GIS can do the specific multiplication and division to generate a percent value for each subarea. The following tables were generated and provided to the Environmental Section for use in the GIS:

(1) A table relating each GIS User-assigned land use classification identification number to a specific percent urbanization and percent imperviousness factor, and

(2) A table relating each GIS User-assigned soil identification number to a percent sand value.

While investigating the Prototype Methodology Study area, it was discovered that not one complete subarea used in the **Recon Study** was totally contained in the Prototype Methodology Study area. However, the Prototype Methodology Study area did contain nine smaller subareas (all but one with a drainage area less than 1.0 square mile) delineated for the Dry Branch and Johnson Creek areas which could be compared with other HEC-1 information for these Section 205 flood control studies. These studies utilized similar methodologies for determining percents urbanization, imperviousness, and sand as those used in the Recon Study. However, percents urbanization and imperviousness were determined for **FULLY DEVELOPED CONDITIONS** for the Section 205 flood control studies. Urbanization and impervious values for fully developed conditions were estimated utilizing the latest available aerial photos, projected land use maps, and USGS 7.5 minute quadrangle maps. These quadrangle maps containing the delineations for the Johnson Creek and Dry Branch watersheds were provided to the Environmental Section for digitizing. The Environmental Section, based upon the tables and maps provided, utilized the GIS to obtain percents urbanization, imperviousness, and sand for each subarea. This data was provided to the Hydrologic Engineering Section in a data file via the LAN. The following table compares the data received using the GIS to data used in the Section 205 planning studies for the Dry Branch and Johnson Creek subareas:

	GIS Data (1995 Existing)			Section 205 Data (Fully developed)		
Subarea	**% Sand**	**% Urb**	**% Imp**	**% Sand**	**% Urb**	**% Imp**
SUB3	86.9318	70.0262	48.9155	100	78	56
SUB4	95.3936	54.0930	39.6851	100	67	47
SUB5	82.4485	58.9740	40.2978	100	91	85
SUB13	47.0229	68.8799	59.4817	55	80	60
SUB14	59.6545	66.8022	53.4437	88	90	65
SUB15	81.6248	86.6184	55.6216	76	90	60
SUB17	4.6254	61.9765	50.9349	50	90	65
SUB18	11.7995	74.9582	47.3375	50	90	50
SUB19	33.1516	48.9456	33.0851	70	90	40

Based on the comparison of these tabular results, the differences between the 1991 Existing Conditions and the Fully Developed Conditions appeared to be reasonable with very few discrepancies.

The Hydraulics Design Section had available an existing HEC-2 hydraulic model of Johnson Creek which was used to generate modified Puls routing data in the HEC-1 format for the lower portion of Johnson Creek. This data as shown in table 3-5 was automatically generated for the HEC1-GIS program from the HEC-2 model through the use of the J4 card in the input portion of the HEC-2 program. This routing data was provided to the Hydrologic Engineering Section via the LAN.

During the Prototype Methodology Study, an investigation was performed by the Hydrologic Engineering Section to determine the availability of existing computer software which would automatically update the loss rates, percent imperviousness, Snyder's Tp, and the modified Puls routing data in the HEC-1 computer models. Loss rates and Snyder's Tp's was determined manually for the Recon Study. Since no existing computer software was found to update the necessary HEC-1 model components, Greg Estep of the Hydrologic Engineering Section developed a FORTRAN program which would automatically update these HEC-1 model parameters. The computer program, named HEC1-GIS, needed the following files to operate:

(1) A HEC-1 basefile containing items which remain constant and blank spaces for items that will be changed by the HEC1-GIS program.

(2) A unit hydrograph data file containing the following information for each subarea; subarea name, stream length, stream length to the centroid of the drainage area, and weighted stream slope. These items are not needed for HEC-1 but are necessary for computing Snyder's Tp from the Blackland Clay and Sandy Loam Urban Curves.

(3) A routing data file produced from the HEC-2 program associated with the subarea.

(4) A file from the GIS containing subarea name, percent sand, percent urbanization, and percent imperviousness.

The program was tested on the Dry Branch and Johnson Creek areas within the Prototype Methodology Study area with satisfactory results. The HEC1-GIS program is shown in table 3-1 and example data files are shown in tables 3-2 through 3-7.

FEASIBILITY STUDY

Methodology to be used: Satisfactory results were generated using GIS to calculate percents urbanization, imperviousness, and sand from detailed soils information of the Prototype Methodology Study area provided by SCS. For the Feasibility Study, detailed soils maps for Tarrant and Dallas Counties are to be performed by SCS and STATSGO general soils data are to be used for the remainder of the Upper Trinity River watershed. The automatic assignment of percent sand values to each soil type is to be continued. Further, a new method of calculating the percent sand value based on the specific soil parameters of a soil type is to be investigated. The automatic generation of input data for the HEC1-GIS program through the use of the J4 card in the HEC-2 program is to be continued. The following refinements are also to be performed to enhance further feasibility-level investigations.

Refinements:

Based on the processes tried for the subareas within the Prototype Methodology Study, there are several refinements which are to be investigated prior to completion of the HEC-1 model for the Feasibility Study. These are detailed as follows:

1. A regional regression analysis is needed to update the Dallas-Fort Worth Urban Curves.

2. An investigation into using the Green and Ampt loss rates for the Feasibility Study.

3. A procedure is needed to automatically incorporate the HEC-2 models with new frequency discharges from the HEC-1 model.

4. Procedures are to be devised to use the STATSGO and detailed soils relational database for various soil types to be automatically linked for with specific percent sand values. Additional investigations are also to be performed to allow automatically calculation of a percent sand value based on specific soil characteristics and parameters. Work to make this database available to the Corps is underway by SCS and is to be completed in early FY 92.

5. The use of the GIS to verify watershed areas and slope characteristics is also to be continued and refined as necessary.

TABLE 3-1

HYDROLOGY PROGRAM HEC1-GIS

The purpose of the HEC1-GIS computer program is to update a base HEC-1 input file with new GIS data and/or routing data. The program was written by Greg Estep of the Hydrologic Engineering Section. To run the program, enter the items in bold, substituting in the proper filenames.

HEC1-GIS

Enter your HEC-1 basefile filename = **base.dat**

Enter your GIS filename or CR to skip = **wtrshd.dat**

Enter your uhg data filename = **uhg.dat**

Enter your routing data filename or CR to skip = **test.sto**

Enter filename for updated HEC-1 input file = **hec1.dat**

Enter frequency in years for this run = **100**

TABLE 3-2

EXAMPLE BASE HEC-1 INPUT FILE

BASE.DAT

```
ID UPPER TRINITY PROTOTYPE METHODOLOGY STUDY
ID 100 YEAR FREQUENCY MODEL
IT    15 27AUG91    0000    300
IO    5
*
KK  SUB3
KM DRY BRANCH WATERSHED FROM PIONEER ROAD TO ROCK IS. ROAD
PH                  1.88    3.90    5.22    5.74    7.00    8.35    9.70
BA  0.66
LU
US        0.72
*
KK RSUB4
KM     REACH EXTENDS FROM X-SECT.   3660.000 TO X-SECT.   7695.000
RS    1   STOR     -1
*
KK  SUB4
KM DRY BRANCH WATERSHED FROM ROCK ISLAND ROAD TO SHADY GROVE ROAD
BA  0.67
LU
US        0.72
*
KK  COM4
HC    2
*
KK RSUB5
KM     REACH EXTENDS FROM X-SECT.   1100.000 TO X-SECT.   3660.000
RS    1   STOR     -1
*
KK  SUB5
KM DRY BRANCH CREEK WATERSHED FROM SHADY GROVE TO BEAR CREEK
BA  0.13
LU
US        0.72
*
KK  COM5
HC    2
*
KK SUB13
KM JOHNSON CREEK ABOVE DUNCAN PERRY ROAD
BA  1.90
LU
US        0.72
*
KKRSUB14
KM     REACH EXTENDS FROM X-SECT.   7020.000 TO X-SECT.  10310.000
RS    1   STOR     -1
*
```

TABLE 3-2 (Continued)

```
KK SUB14
KM JOHNSON CREEK ABOVE TRIB JC-1A
BA  0.83
LU
US        0.72
*
KK COM14
HC    2
*
KKRSUB15
KM      REACH EXTENDS FROM X-SECT.   3560.000 TO X-SECT.   7020.000
RS    1    STOR     -1
*
KK SUB15
KM JOHNSON CREEK AND TRIB JC-1A ABOVE TRIB JC-1
BA  0.49
LU
US        0.72
*
KK COM15
HC    2
*
KK SUB17
KM TRIB JC-1 ABOVE IH 30
BA  0.75
LU
US        0.72
*
KKRSUB18
KM ROUTING TRIB JC-1 THRU AREA 18
RS    1    STOR     -1
SV    0     95    98.6   106.6   112.8   149.1   156.3   163.0   169.0
SQ    0   2250   2500   2750    3000    3250    3500    3750    4000
*
KK SUB18
KM TRIB JC-1 ABOVE JOHNSON CREEK
BA  0.41
LU
US        0.72
*
KK COM18
HC    2
*
KKRSUB19
KM      REACH EXTENDS FROM X-SECT.    330.000 TO X-SECT.   3560.000
RS    1    STOR     -1
*
KK SUB19
KM JOHNSON CREEK ABOVE CONFLUENCE WITH THE WEST FORK OF THE TRINITY
BA  0.81
LU
US        0.72
*
KK COM19
HC    4
ZZ
```

TABLE 3-6 (Continued)

EXAMPLE UPDATED HEC-1 INPUT FILE FROM PROGRAM HEC1-GIS

```
KKRSUB14
KM       REACH EXTENDS FROM X-SECT.   7020.000 TO X-SECT.  10310.000
RS      1     STOR       -1
SV      0       50       69      135      177      216      247      284      342      428
SQ      0     3870     5540     8770    10990    13340    15320    17720    21740    27940
*
KK SUB14
KM JOHNSON CREEK ABOVE TRIB JC-1A
BA  0.83
LU   .84     .088    53.44
US   .52     0.72
*
KK COM14
HC      2
*
KKRSUB15
KM       REACH EXTENDS FROM X-SECT.   3560.000 TO X-SECT.   7020.000
RS      1     STOR       -1
SV      0       56       74      118      148      177      201      229      278      357
SQ      0     4450     6430     9850    12350    15080    17280    20160    24640    31180
*
KK SUB15
KM JOHNSON CREEK AND TRIB JC-1A ABOVE TRIB JC-1
BA  0.49
LU   .87     .094    55.62
US   .53     0.72
*
KK COM15
HC      2
*
KK SUB17
KM TRIB JC-1 ABOVE IH 30
BA  0.75
LU   .76     .071    50.93
US   .33     0.72
*
KKRSUB18
KM ROUTING TRIB JC-1 THRU AREA 18
RS      1     STOR       -1
SV      0       95     98.6    106.6    112.8    149.1    156.3    163.0    169.0
SQ      0     2250     2500     2750     3000     3250     3500     3750     4000
*
KK SUB18
KM TRIB JC-1 ABOVE JOHNSON CREEK
BA  0.41
LU   .77     .074    47.34
US   .32     0.72
*
KK COM18
HC      2
*
KKRSUB19
KM       REACH EXTENDS FROM X-SECT.    330.000 TO X-SECT.   3560.000
```

TABLE 3-6 (Continued)

EXAMPLE UPDATED HEC-1 INPUT FILE FROM PROGRAM HEC1-GIS

```
RS      1     STOR      -1
SV      0      112     145     197     237     293     367     514     721     989
SQ      0     4450    6430    9850   12350   15080   17280   20160   24640   31180
*
KK SUB19
KM JOHNSON CREEK ABOVE CONFLUENCE WITH THE WEST FORK OF THE TRINITY
BA  0.81
LU   .80      .080   33.09
US   .76      0.72
*
KK COM19
HC      4
ZZ
```

TABLE 3-7

EXAMPLE OUTPUT FILE FROM HEC-1 USING THE UPDATED HEC-1 INPUT FILE FROM HEC1-GIS

```
HEC-1.OUT

*****************************************                              ****************************************
*                                       *                              *                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                              *   U.S. ARMY CORPS OF ENGINEERS       *
*             JANUARY 1990              *                              *  THE HYDROLOGIC ENGINEERING CENTER   *
*           REVISED 01 JAN 90           *                              *        609 SECOND STREET             *
*                                       *                              *      DAVIS, CALIFORNIA 95616         *
*  RUN DATE  09/04/91  TIME  07:41:32   *                              *          (916) 551-1748              *
*                                       *                              *                                      *
*****************************************                              ****************************************


                         X     X  XXXXXXX   XXXXX          X
                         X     X  X        X     X        XX
                         X     X  X        X               X
                         XXXXXXX  XXXX     X       XXXXX   X
                         X     X  X        X               X
                         X     X  X        X     X         X
                         X     X  XXXXXXX   XXXXX         XXX


THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81.  THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM
```

TABLE 3-7 (Continued)

EXAMPLE OUTPUT FILE FROM HEC-1 USING THE UPDATED HEC-1 INPUT FILE FROM HEC1-GIS

```
                                  HEC-1 INPUT                                         PAGE  1

LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1         ID   UPPER TRINITY PROTOTYPE METHODOLOGY STUDY
  2         ID   100 YEAR FREQUENCY MODEL
  3         IT      15 27AUG91    0000     300
  4         IO       5
            *

  5         KK    SUB3
  6         KM   DRY BRANCH WATERSHED FROM PIONEER ROAD TO ROCK IS. ROAD
  7         PH                        1.88    3.90    5.22    5.74    7.00    8.35    9.70
  8         BA    0.66
  9         LU     .88    .096   48.92
 10         US     .58    0.72
            *

 11         KK   RSUB4
 12         KM        REACH EXTENDS FROM X-SECT.   3660.000 TO X-SECT.   7695.000
 13         RS       1    STOR      -1
 14         SV       0    16.0    28.2    50.0    68.6    96.7   119.5   165.9   212.0   253.8
 15         SQ       0     500    1000    1500    2000    3000    4000    6000    8000   10000
            *

 16         KK    SUB4
 17         KM   DRY BRANCH WATERSHED FROM ROCK ISLAND ROAD TO SHADY GROVE ROAD
 18         BA    0.67
 19         LU     .89    .099   39.69
 20         US     .40    0.72
            *

 21         KK    COM4
 22         HC       2
            *

 23         KK   RSUB5
 24         KM        REACH EXTENDS FROM X-SECT.   1100.000 TO X-SECT.   3660.000
 25         RS       1    STOR      -1
 26         SV       0    11.6    20.7    29.8    38.6    59.5    78.7   108.1   139.8   168.0
 27         SQ       0     500    1000    1500    2000    3000    4000    6000    8000   10000
            *

 28         KK    SUB5
 29         KM   DRY BRANCH CREEK WATERSHED FROM SHADY GROVE TO BEAR CREEK
 30         BA    0.13
 31         LU     .87    .095   40.30
 32         US     .35    0.72
            *

 33         KK    COM5
 34         HC       2
            *
```

TABLE 3-7 (Continued)

EXAMPLE OUTPUT FILE FROM HEC-1 USING THE UPDATED HEC-1 INPUT FILE FROM HEC1-GIS

```
                                      HEC-1 INPUT                                              PAGE  2

 LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  35           KK   SUB13
  36           KM   JOHNSON CREEK ABOVE DUNCAN PERRY ROAD
  37           BA    1.90
  38           LU     .82     .084   59.48
  39           US     .62     0.72
               *

  40           KK  RSUB14
  41           KM        REACH EXTENDS FROM X-SECT.   7020.000 TO X-SECT.  10310.000
  42           RS        1    STOR      -1
  43           SV        0      50      69     135     177     216     247     284     342     428
  44           SQ        0    3870    5540    8770   10990   13340   15320   17720   21740   27940
               *

  45           KK   SUB14
  46           KM   JOHNSON CREEK ABOVE TRIB JC-1A
  47           BA    0.83
  48           LU     .84     .088   53.44
  49           US     .52     0.72
               *

  50           KK   COM14
  51           HC        2
               *

  52           KK  RSUB15
  53           KM        REACH EXTENDS FROM X-SECT.   3560.000 TO X-SECT.   7020.000
  54           RS        1    STOR      -1
  55           SV        0      56      74     118     148     177     201     229     278     357
  56           SQ        0    4450    6430    9850   12350   15080   17280   20160   24640   31180
               *

  57           KK   SUB15
  58           KM   JOHNSON CREEK AND TRIB JC-1A ABOVE TRIB JC-1
  59           BA    0.49
  60           LU     .87     .094   55.62
  61           US     .53     0.72
               *

  62           KK   COM15
  63           HC        2
               *

  64           KK   SUB17
  65           KM   TRIB JC-1 ABOVE IH 30
  66           BA    0.75
  67           LU     .76     .071   50.93
  68           US     .33     0.72
               *
```

TABLE 3-7 (Continued)

EXAMPLE OUTPUT FILE FROM HEC-1 USING THE UPDATED HEC-1 INPUT FILE FROM HEC1-GIS

```
                                   HEC-1 INPUT                                              PAGE  3

 LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

   69        KK  RSUB18
   70        KM   ROUTING TRIB JC-1 THRU AREA 18
   71        RS       1    STOR      -1
   72        SV       0      95    98.6   106.6   112.8   149.1   156.3   163.0   169.0
   73        SQ       0    2250    2500    2750    3000    3250    3500    3750    4000
             *

   74        KK   SUB18
   75        KM   TRIB JC-1 ABOVE JOHNSON CREEK
   76        BA    0.41
   77        LU     .77    .074   47.34
   78        US     .32    0.72
             *

   79        KK   COM18
   80        HC       2
             *

   81        KK  RSUB19
   82        KM         REACH EXTENDS FROM X-SECT.     330.000 TO X-SECT.   3560.000
   83        RS       1    STOR      -1
   84        SV       0     112     145     197     237     293     367     514     721     989
   85        SQ       0    4450    6430    9850   12350   15080   17280   20160   24640   31180
             *

   86        KK   SUB19
   87        KM   JOHNSON CREEK ABOVE CONFLUENCE WITH THE WEST FORK OF THE TRINITY
   88        BA    0.81
   89        LU     .80    .080   33.09
   90        US     .76    0.72
             *

   91        KK   COM19
   92        HC       4
   93        ZZ
```

TABLE 3-7 (Continued)

EXAMPLE OUTPUT FILE FROM HEC-1 USING THE UPDATED HEC-1 INPUT FILE FROM HEC1-GIS

```
*****************************************                    ****************************************
*                                       *                    *                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                    *   U.S. ARMY CORPS OF ENGINEERS       *
*            JANUARY 1990               *                    * THE HYDROLOGIC ENGINEERING CENTER    *
*          REVISED 01 JAN 90            *                    *        609 SECOND STREET             *
*                                       *                    *     DAVIS, CALIFORNIA 95616          *
*  RUN DATE  09/04/91  TIME  07:41:32   *                    *         (916) 551-1748               *
*                                       *                    *                                      *
*****************************************                    ****************************************


                        UPPER TRINITY PROTOTYPE METHODOLOGY STUDY
                        100 YEAR FREQUENCY MODEL

  4 IO        OUTPUT CONTROL VARIABLES
                    IPRNT          5  PRINT CONTROL
                    IPLOT          0  PLOT CONTROL
                    QSCAL         0.  HYDROGRAPH PLOT SCALE

   IT         HYDROGRAPH TIME DATA
                     NMIN         15  MINUTES IN COMPUTATION INTERVAL
                    IDATE    27AUG91  STARTING DATE
                    ITIME       0000  STARTING TIME
                       NQ        300  NUMBER OF HYDROGRAPH ORDINATES
                   NDDATE    30AUG91  ENDING DATE
                   NDTIME       0245  ENDING TIME
                    ICENT         19  CENTURY MARK

                COMPUTATION INTERVAL    0.25 HOURS
                     TOTAL TIME BASE   74.75 HOURS

       ENGLISH UNITS
           DRAINAGE AREA          SQUARE MILES
           PRECIPITATION DEPTH    INCHES
           LENGTH, ELEVATION      FEET
           FLOW                   CUBIC FEET PER SECOND
           STORAGE VOLUME         ACRE-FEET
           SURFACE AREA           ACRES
           TEMPERATURE            DEGREES FAHRENHEIT
```

TABLE 3-7 (Continued)

EXAMPLE OUTPUT FILE FROM HEC-1 USING THE UPDATED HEC-1 INPUT FILE FROM HEC1-GIS

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	SUB3	1648.	12.75	473.	149.	50.	0.66		
ROUTED TO	RSUB4	1300.	13.00	471.	149.	50.	0.66		
HYDROGRAPH AT	SUB4	1989.	12.50	475.	146.	49.	0.67		
2 COMBINED AT	COM4	2813.	12.50	944.	295.	99.	1.33		
ROUTED TO	RSUB5	2540.	13.00	943.	295.	99.	1.33		
HYDROGRAPH AT	SUB5	412.	12.50	92.	28.	9.	0.13		
2 COMBINED AT	COM5	2834.	12.75	1034.	323.	108.	1.46		
HYDROGRAPH AT	SUB13	4561.	12.75	1373.	446.	149.	1.90		
ROUTED TO	RSUB14	4295.	13.00	1373.	446.	149.	1.90		
HYDROGRAPH AT	SUB14	2198.	12.75	600.	192.	64.	0.83		
2 COMBINED AT	COM14	6265.	12.75	1972.	637.	213.	2.73		
ROUTED TO	RSUB15	6262.	13.00	1971.	637.	213.	2.73		
HYDROGRAPH AT	SUB15	1287.	12.75	354.	113.	38.	0.49		
2 COMBINED AT	COM15	7360.	13.00	2324.	750.	251.	3.22		
HYDROGRAPH AT	SUB17	2443.	12.50	539.	173.	58.	0.75		
ROUTED TO	RSUB18	1597.	12.75	536.	173.	58.	0.75		
HYDROGRAPH AT	SUB18	1356.	12.50	294.	94.	31.	0.41		
2 COMBINED AT	COM18	2615.	12.50	829.	267.	89.	1.16		
ROUTED TO	RSUB19	2297.	13.00	828.	267.	89.	1.16		
HYDROGRAPH AT	SUB19	1755.	13.00	577.	179.	60.	0.81		
4 COMBINED AT	COM19	14149.	13.00	4763.	1519.	508.	6.65		

*** NORMAL END OF HEC-1 ***

APPENDIX 4

HYDRAULICS

APPENDIX 4 - HYDRAULICS

BACKGROUND

The purpose of the hydraulics portion of the Prototype Methodology Study was:

(1) to automate the time-consuming procedures of the development and manual input of the channel and floodplain cross-section data which are essential elements of the HEC-2 hydraulic model(s),

(2) to develop a procedure whereby the HEC-2 output is directly accessed by the Geographic Information System (GIS),

(3) to develop a procedure whereby the routing data generated by the HEC-2 program is directly available to the HEC-1 hydrology program.

PARTICIPANTS

Michael Danella from Hydraulics Design Section, Ms. Terri Betancourt the GIS Programmer, and Greg Estep and Steve Pilney from Hydrologic Engineering Section.

METHODOLOGY

RECON STUDY:

The hydraulic models used were previously developed by the Corps of Engineers in HEC-2 and LRD-1 format, two backwater programs supported by the Fort Worth District. The HEC-2 Water Surface Profiles program was developed by the Hydrologic Engineering Center in Davis, California in 1966. The Harris 1000 mainframe computer version of the program was used in the Recon Study. The LRD-1 Backwater Profiles Program 722-G1-M2130 was developed in 1965 by William A. Thomas of the Little Rock District of the Corps of Engineers. The program was later modified by the Fort Worth District for use on the Harris 500 mainframe computer.

The various hydraulic models used in the Recon Study were a compilation of years of data acquisition, modification, and updating. The basic input requirement of both backwater programs is geometric cross-section data representing the river channel and floodplain. The cross-sections used in the hydraulic models originated from different sources. A large percentage of the cross-sections originated from field surveys generated during previous years. The field notes of the cross-sections were translated into the appropriate backwater program format and input manually into the hydraulic models. Additional cross-section data were developed from 2-foot contour interval topographic maps whereby the elevation and station points were read from the cross-section alignments drawn on the maps and input manually into the model. Supplemental cross-section data was input manually into the HEC-2 and LRD-1 models from data of hydraulic models developed outside the Corps of Engineers, i.e., local engineering consulting firms.

Once the basic input requirements of the backwater models were developed, copies of the floodplain topographic maps indicating a select number of cross-section alignments used in the backwater models were submitted to the GIS staff. These cross-sections were digitized in the GIS database by the GIS staff and functioned as the base for generating the floodplain delineations of each frequency flood event. The complete collection of cross-sections for the entire Upper Trinity River Basin study area were not submitted to the GIS staff due to the time and manpower effort in manually digitizing more than 400 cross-sections used in the hydraulic models. As discussed in Appendix 2, only selected cross-sections were used.

The computation of valley storage, discharge-elevation-volume relationships, were developed by the backwater programs for the development of frequency flood discharges by the Hydrologic Engineering Section. The LRD-1 output was hand-carried to the Hydrologic Engineering Section. The output consisted of discharge-elevation-storage data which was modified by the Hydrologic Engineering Section for use in the HEC-1 model. The data was manually input into the HEC-1 model by the Hydrologic Engineering Section staff. The HEC-2 program generated a storage data file which was modified by the program ST, which generated a routing data file. This file was directly accessed for use in the hydrologic program NUDALLAS.

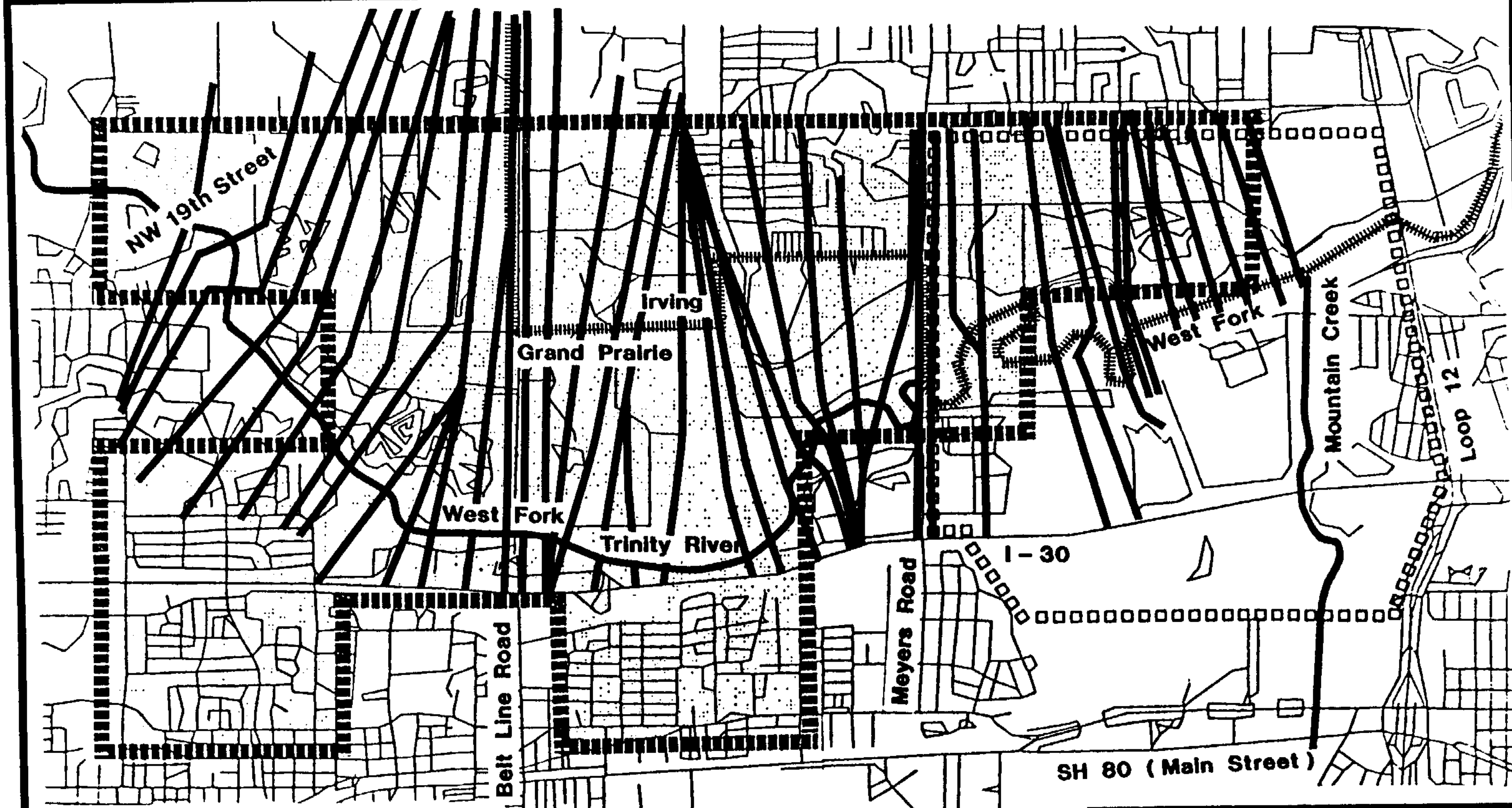
The final hydraulic models computer runs were generated using the computed flood frequency discharges developed by the Hydrologic Engineering Section. The models consisted of the existing conditions output of the mainstem of the Trinity River, West Fork, Elm Fork, Clear Fork, Marys Creek, and the various flood control alternatives identified in the Recon Study. Hard copies of the HEC-2 and LRD-1 summary printouts were hand-carried to the GIS staff. The GIS staff manually input the water surface elevations corresponding to the selected cross-sections previously digitized in the GIS database for each frequency flood event.

PROTOTYPE METHODOLOGY STUDY:

What Was Tried: New methodologies and procedures were developed in the Prototype Methodology Study to achieve the previously stated objectives.

One cross-section was digitized within the Prototype Methodology Study area using previously generated digitized topographic data in Grand Prairie. The cross-section was digitized by the Corps GIS staff to closely match the alignment of a surveyed cross-section. The example digitized cross-section data was submitted in standard HEC-2 format (the X1 card identified the cross-section number, and the GR card identified the ground coordinates x,y) on a floppy disk and uploaded to the PC. The digitization of cross-sections is a standard method which has been used in other studies by the Fort Worth District, particularly Flood Insurance Studies. The results of the comparison indicate the digitized cross-section closely matched the surveyed cross-section profile based on the 2-foot contour interval accuracy from which the digitized cross-section was generated. The f.xsection tool, being developed by Ms. Betancourt, will allow the User of the GIS to locate a cross-section and generate cross-section coordinates in standard HEC-2 format.

A portion of the West Fork between Meyers Road and N.W. 19th Street was selected as the Prototype Methodology Study area as shown previously in figure 2. Since the West Fork was modeled using LRD-1 and since converting the LRD-1 file into HEC-2 format was beyond the scope and time constraints of the Prototype Methodology Study, a simulated HEC-2 summary printout file was created using the identical West Fork existing conditions water surface elevations computed in the Recon Study by the LRD-1 model. Table 4-1 shows this ASCII input file based on a portion of a the West Fork HEC-2 input file within the Prototype Methodology Study area.



LEGEND

PROTOTYPE STUDY AREA
WETLANDS STUDY AREA
CITY BOUNDARY
ELEVATION DATA POINTS
HEC-2 CROSS-SECTION

N

1 Inch = 6,000 Feet

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

PROTOTYPE METHODOLOGY STUDY
DALLAS - FORT WORTH METROPLEX, TEXAS

HEC-2 CROSS-SECTIONS

FIGURE 4 - 1

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This Existing Conditions HEC-2 summary printout file, a portion shown in table 4-2, was downloaded to a floppy disk, submitted to the GIS staff, and then accessed by the GIS staff. A map indicating the cross-sections and corresponding river stations, shown in figure 4-1, was also submitted to the GIS staff for use in the GIS database.

A simulated Modified Conditions HEC-2 summary printout file was created to represent a theoretical modification in the Prototype Methodology Study area reach of the West Fork. This Modified Conditions HEC-2 summary printout file was downloaded to a floppy disk, submitted to the GIS staff, and then accessed by the GIS staff. A portion of the HEC-2 Modified Conditions summary printout file is shown in table 4-3. The Modified Conditions water surface elevations at all cross-sections for all of the frequency flood events were lower than the existing conditions water surface elevations. Although an actual physical modification of the West Fork was not represented in the West Fork hydraulic model, this reduction of the water surface profile could theoretically represent a significant channel enlargement project.

For access of the HEC-2 summary output file by the GIS, a program was written, f.input, by Ms. Betancourt, as discussed in Appendix 2, GIS. This program enabled the GIS to access the HEC-2 summary printout table, specifically the cross-section number representing either river mile or river station (variable SECNO) and the corresponding water surface elevation (variable CWSEL). These variables were read directly into the GIS database by f.input. The HEC-2 summary printout table could either be downloaded to a floppy disk and delivered to the GIS staff or transferred via the LAN for retrieval by the GIS staff. Additional hydrologic/hydraulic data was prompted by the f.wsurf program, such as the frequency of the flood events, number of flood events, and the frequency of the Standard Project Flood event.

The HEC-2 program generates a file which can be directly input into the HEC-1 program when the J4 card in the HEC-2 "deck" is used. The resulting file consists of discharge-volume-reach routing data in a format directly compatible with the HEC-1 program. A program to access this information was written to automate as much of the hydrologic and hydraulic process as possible, a goal stated by Terry Coomes, Chief of Engineering Division in the Fort Worth District.

As part of the programming contract of Ms. Betancourt, the f.volume program module is to be developed to compute the volume of water between each cross-section or reach designation. This GIS volume computation feature will be useful in determining storage volume within particular river reaches, as specified by the User. The User will be prompted for a selection of total volume or area-capacity information.

In the early phases of the programming work by Ms. Betancourt, an ASCII file of the HEC-2 summary printout of the Existing Conditions Upper Zacate Creek Project was submitted to the GIS staff. The Upper Zacate Creek project in Laredo, Texas, is an ongoing project of the Fort Worth District Corps of Engineers. This HEC-2 data file was necessary for the testing of the f.input program capabilities. A separate HEC-2 file for the West Fork region of the Prototype Methodology Study was also provided to the GIS staff.

An error-checking program for HEC-2, as part of f.input, was originally intended for development. The purpose of the program was to identify dips, rises, and similar water surface profiles anomalies which would need further analysis and may indicate an error in the data file. After much discussion between the Prototype Methodology Study team members, the error-checking task was left as the responsibility of the Hydraulics Design Section, and thus, the program was not developed. Similar internal checks currently exist within the HEC-2 program.

What Didn't Work: All investigations for the HEC-2 model program worked as planned.

What Worked Best: After much investigative work, all of the stated objectives worked well. Each were simple, straight-forward procedures which were accomplished without any major problems. The access of the HEC-2 summary output file by the GIS f.input tool worked very well. The task of automatically using this HEC-2 information directly will be a major time and money saving procedure in future studies for the Feasibility Study. Likewise the ability of the f.xsection tool to digitize cross-sections in a standard HEC-2 format and the f.volume tool to compute area volumes will be major timesavers for the hydraulic engineer.

FEASIBILITY STUDY

Methodology to be used: The exporting of HEC-2 storage data for use in the HEC-1 hydrology program using the J4 card in the HEC-2 program is expected to be continued. The following refinements are to be made to enhance the HEC-2 program methodology. The continued use of digitized cross-sections to construct cross-section data in the HEC-2 program is to be continued upon receipt of the digitized cross-sections from G&O. The f.input and f.wsurf tools are to be used to continue the GIS-generation of floodplain delineations and flood depths within the region. More investigative work is needed to determine how the GIS is to process floodplain delineation information of sumps areas behind existing and proposed levee systems. The following refinements are also to be performed to enhance further feasibility-level investigations.

Refinements:

Based on the options tried for the Prototype Methodology Study, there are several refinements which are to be investigated prior to completion of the HEC-2 model(s) for the Feasibility Study. These are detailed as follows:

1. Further work on the ability to compute total volume or area-capacity information in sump areas is necessary. This work is to be done as part of Ms. Betancourt's programming contract for the f.volume tool. The ability to compute elevation-area, area-capacity, and elevation-capacity relationships would be essential parts of this f.volume program.

2. A program which would directly input the frequency-discharge values developed by HEC-1 into the HEC-2 input data file would be useful. This program would save manual data input time and would possibly reduce the manual-input data transfer errors. This work is to be done by the Hydrology and Hydraulics Branch of the Corps of Engineers.

3. Further refinement of f.input, as described in Appendix 2, GIS, is needed to accommodate split-flow conditions which may occur within a study area.

4. In the Feasibility Study, the most current version of the HEC-2 program will be used. The February 1991 HEC-2 Version 4.6.0 is the most current version available. The Compaq 386/20e Personal Computer hardware was used for this Prototype Study and programs designed for this hardware are expected to be developed for its continued use during the remainder of the Feasibility Study.

5. The GRASS Version 3.1 f-tools discussed herein for this methodology are to be rewritten/written to use the enhanced Version 4.0 GRASS program.

TABLE 4-1

EXAMPLE HEC-2 INPUT DATA FILE

```
T1      UPPER TRINITY RIVER - PROTOTYPE METHODOLOGY STUDY
T2      SAMPLE HEC-2 INPUT DATA FILE
T3      TWO CROSS-SECTIONS ALONG THE WEST FORK
J1     0       2       0       0       0       0       0       0  420.60       0
J2     1       0      -1
J3    38      43       1
J5   -10     -10
NC     0       0       0      .1      .3
NH     6    .050    2940    .050    4600    .050    8050    .040    8210    .050
NH 11600    .060   12200
QT     7    5400   13000   18300   24700   31400   41300   73700
X1310.50      33    8050    8210       0       0       0
X3     0       0       0    3500     438
GR   450     100     440     300     439     600     435     700     435    1400
GR   430    2620     430    2940   430.5    4600     431    5500     425    5900
GR   410    5960     410    5990     425    6030     430    7750     432    8050
GR 424.5    8080     404    8100     401    8110   399.5    8120   399.5    8140
GR 401.5    8160     404    8165     415    8180   428.5    8210     431    8310
GR   430    8920     432    9028     450    9030     450   11600     435   11610
GR   430   12090     445   12150     450   12200
NH     6    .070    1400    .070    2940    .060    7040    .040    7240    .070
NH 10480    .060   10570
X1   340      26    7040    7240     900    1560    1250
GR   450     100     440     300     439     600     435     700     435    1400
GR   430    2620     430    2940     425    3070     425    4630     430    5540
GR 432.5    7040     418    7090   406.5    7125   398.5    7130   402.5    7180
GR   422    7200   428.5    7220     431    7240     433    7560     430    7840
GR   430    9300     425    9410     425   10030     430   10480     435   10540
GR   445   10570
.
.
.
```

TABLE 4-2

SUMMARY PRINTOUT - EXISTING CONDITIONS

	SECNO	Q	CWSEL
	310.500	5400.00	425.60
	310.500	13000.00	431.00
*	310.500	18300.00	433.00
*	310.500	24700.00	434.60
*	310.500	31400.00	436.10
*	310.500	41300.00	437.20
	310.500	73700.00	441.60
	340.000	5400.00	426.10
	340.000	13000.00	431.20
	340.000	18300.00	433.10
	340.000	24700.00	434.70
	340.000	31400.00	436.10
	340.000	41300.00	437.30
	340.000	73700.00	441.60
	347.500	5400.00	426.30
	347.500	13000.00	431.30
	347.500	18300.00	433.20
	347.500	24700.00	434.80
	347.500	31400.00	436.20
*	347.500	41300.00	437.40
	347.500	73700.00	441.70
	355.000	5400.00	426.40
	355.000	13000.00	431.30
	355.000	18300.00	433.20
	355.000	24700.00	434.80
	355.000	31400.00	436.20
	355.000	41300.00	437.40
	355.000	73700.00	441.80

1
30 AUG 91 9:23:43

PAGE 9

	SECNO	Q	CWSEL
*	370.000	5400.00	426.40
	370.000	13000.00	431.30
	370.000	18300.00	433.30
	370.000	24700.00	434.80
	370.000	31400.00	436.30
	370.000	41300.00	437.50
	370.000	73700.00	441.90
	398.400	5400.00	426.60
	398.400	13000.00	431.50
	398.400	18300.00	433.40
	398.400	24700.00	435.00
	398.400	31400.00	436.40
	398.400	41300.00	437.70
	398.400	73700.00	442.00

TABLE 4-2 (Continued)

SUMMARY PRINTOUT - EXISTING CONDITIONS

412.200	5400.00	428.00
412.200	13000.00	432.40
412.200	18300.00	434.30
412.200	24700.00	435.80
412.200	31400.00	437.20
412.200	41300.00	438.50
412.200	73700.00	442.10
430.000	5400.00	428.40
430.000	13000.00	432.70
430.000	18300.00	434.60
430.000	24700.00	436.10
430.000	31400.00	437.40
430.000	41300.00	438.70
430.000	73700.00	442.10
443.500	5400.00	428.40
443.500	13000.00	432.80
443.500	18300.00	434.70
443.500	24700.00	436.30
443.500	31400.00	437.60
443.500	41300.00	438.90
443.500	73700.00	442.10
455.300	5400.00	428.50
455.300	13000.00	432.80
455.300	18300.00	434.80
455.300	24700.00	436.40
455.300	31400.00	437.70
455.300	41300.00	439.10
455.300	73700.00	442.20

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PAGE 10

SECNO	Q	CWSEL
462.000	5400.00	428.50
462.000	13000.00	433.00
462.000	18300.00	435.10
462.000	24700.00	436.80
462.000	31400.00	438.10
462.000	41300.00	439.50
462.000	73700.00	442.40
466.000	5400.00	428.50
466.000	13000.00	433.00
466.000	18300.00	435.00
466.000	24700.00	436.70
466.000	31400.00	438.00
466.000	41300.00	439.30
466.000	73700.00	442.20

TABLE 4-2 (Continued)

SUMMARY PRINTOUT - EXISTING CONDITIONS

467.500	5400.00	428.30
467.500	13000.00	432.60
467.500	18300.00	434.40
467.500	24700.00	435.90
467.500	31400.00	437.00
467.500	41300.00	437.70
467.500	73700.00	442.10

TABLE 3-3

EXAMPLE GIS DATA FILE

WTRSHD.DAT

area	% sand	% urb	% imp
SUB3	86.9318	70.0262	48.9155
SUB4	95.3936	54.0930	39.6851
SUB5	82.4485	58.9740	40.2978
SUB13	47.0229	68.8799	59.4817
SUB14	59.6545	66.8022	53.4437
SUB15	81.6248	86.6184	55.6216
SUB17	4.6254	61.9765	50.9349
SUB18	11.7995	74.9582	47.3375
SUB19	33.1516	48.9456	33.0851

TABLE 3-4

EXAMPLE UNIT HYDROGRAPH DATA FILE

UHG.DAT

area	length	lca	sst
SUB3	1.72	0.79	42.60
SUB4	0.97	0.42	60.00
SUB5	0.81	0.53	77.00
SUB13	2.26	1.30	48.24
SUB14	1.85	0.84	54.68
SUB17	1.21	0.77	35.16
SUB18	1.23	0.70	29.35
SUB19	2.54	1.62	40.31

TABLE 3-5

EXAMPLE STORAGE FILE GENERATED AUTOMATICALLY FROM THE HEC-2 PROGRAM

TEST.STO

```
KK RSUB4
KM        REACH EXTENDS FROM X-SECT.   3660.000 TO X-SECT.    7695.000
RS
SV      0     16.0     28.2     50.0     68.6     96.7    119.5    165.9    212.0    253.8
SQ      0      500     1000     1500     2000     3000     4000     6000     8000    10000
KK RSUB5
KM        REACH EXTENDS FROM X-SECT.   1100.000 TO X-SECT.    3660.000
RS
SV      0     11.6     20.7     29.8     38.6     59.5     78.7    108.1    139.8    168.0
SQ      0      500     1000     1500     2000     3000     4000     6000     8000    10000
KKRSUB14
KM        REACH EXTENDS FROM X-SECT. 470020.000 TO X-SECT. 491330.000
RS
SV      0     12.3     22.2     30.0     40.6     51.5     64.0     81.9    106.5    173.7
SV 264.0    342.1    412.0    476.5    594.6
SQ      0      500     1000     2000     3000     4000     5000     6000     7000    10000
SQ 15000    20000    25000    30000    40000
KKRSUB18
KM        REACH EXTENDS FROM X-SECT. 491330.000 TO X-SECT. 520020.000
RS
SV      0     16.2     39.8     48.0     53.3     65.2     77.1     91.1    107.4    151.7
SV 216.6    272.2    320.9    366.7    458.4
SQ      0      500     1000     2000     3000     4000     5000     6000     7000    10000
SQ 15000    20000    25000    30000    40000
KKRSUB19
KM        REACH EXTENDS FROM X-SECT. 470020.000 TO X-SECT. 491330.000
RS
SV      0     22.2     34.3     53.1     68.9     83.1     96.3    108.6    120.3    138.2
SV 207.7    428.5    621.5    775.5   1089.2
SQ      0      500     1000     2000     3000     4000     5000     6000     7000    10000
SQ 15000    20000    25000    30000    40000
```

TABLE 3-6

EXAMPLE UPDATED HEC-1 INPUT FILE FROM PROGRAM HEC1-GIS

HEC-1.DAT

```
ID UPPER TRINITY PROTOTYPE METHODOLOGY STUDY
ID 100 YEAR FREQUENCY MODEL
IT    15 27AUG91     0000      300
IO     5
*
KK  SUB3
KM DRY BRANCH WATERSHED FROM PIONEER ROAD TO ROCK IS. ROAD
PH                            1.88     3.90     5.22     5.74     7.00     8.35     9.70
BA  0.66
LU   .88     .096    48.92
US   .58     0.72
*
KK RSUB4
KM       REACH EXTENDS FROM X-SECT.   3660.000 TO X-SECT.   7695.000
RS     1     STOR       -1
SV     0     16.0     28.2     50.0     68.6     96.7    119.5    165.9    212.0    253.8
SQ     0      500     1000     1500     2000     3000     4000     6000     8000    10000
*
KK  SUB4
KM DRY BRANCH WATERSHED FROM ROCK ISLAND ROAD TO SHADY GROVE ROAD
BA  0.67
LU   .89     .099    39.69
US   .40     0.72
*
KK  COM4
HC     2
*
KK RSUB5
KM       REACH EXTENDS FROM X-SECT.   1100.000 TO X-SECT.   3660.000
RS     1     STOR       -1
SV     0     11.6     20.7     29.8     38.6     59.5     78.7    108.1    139.8    168.0
SQ     0      500     1000     1500     2000     3000     4000     6000     8000    10000
*
KK  SUB5
KM DRY BRANCH CREEK WATERSHED FROM SHADY GROVE TO BEAR CREEK
BA  0.13
LU   .87     .095    40.30
US   .35     0.72
*
KK  COM5
HC     2
*
KK SUB13
KM JOHNSON CREEK ABOVE DUNCAN PERRY ROAD
BA  1.90
LU   .82     .084    59.48
US   .62     0.72
*
```

APPENDIX 5 - ECONOMICS

BACKGROUND

The purpose of the economics element of the Prototype Methodology Study was to develop procedures to use Dallas County Tax Appraisal District (DCTAD) real property records associated with building footprints identified on the city of Grand Prairie topographic maps to estimate the potential flood damages within the study area.

The actual computation of flood damages within the context of a GIS model is discussed briefly herein. The issues affecting the integration of digitized topography and hydraulic information into the GIS are discussed in Appendix 2, GIS, and Appendix 4, Hydraulics. The focus of the economics effort was on the acquisition of data regarding the nature and value of floodplain land development in ready-digitized form (DCTAD). This data could then be used directly in the GIS f.econ tool to compute flood damages within the study area at a structure-by-structure level of detail, without the extremely large and labor-intensive field survey required by traditional Corps flood damage economic models. The desired outcome of this Study effort would be a procedural outline of the field work and data processing tasks required to make this economic flood damage analysis linkage throughout the Trinity River Corridor.

The field work geography included the area within the corporate limits of the city of Grand Prairie between Meyers Road to the east, I-30 in the south, N.W. 19th Street to the west, and the combination of Lower Tarrant, Wildlife and Hunter-Ferrell Roads in the north, as shown previously in figure 2. These boundaries encompass a substantial westward extension beyond the initial pilot area geography (between Belt Line and Meyers Roads) to capture a greater number and wider variety of existing and improved properties.

PARTICIPANTS

Peter Shaw, Economics and Master Planning Branch; Lyssa Jenkens and Robert Prejean, North Central Texas Council of Governments; and personnel from DCTAD.

METHODOLOGY

RECON STUDY:

During the Recon Study, the determination of the nature and value of floodplain land use was done indirectly, on the basis of 1988 LANDSAT multi-spectral imagery at a 40-meter ground resolution, and land use information compiled from the member cities and provided by NCTCOG. The land use categories used in the Recon Study economic analysis were:

single-family residential	retail commercial
multi-family residential	industrial
mobile residential	public and institutional
office commercial	parks and recreation

The definition and field identification of economic land use types for use in the Recon Study was verified by consultation with NCTCOG and Trinity River Corridor member cities.

Representative data on structure value per square foot of gross floor area, per story of building height, were generically selected for each land use category from publications of the Marshall Valuation Service. These data were adjusted on the basis of field observations combined with an assumed floor area ratio (the proportion of a gross acre occupied by structures), a weighted-average ratio of contents value to structure value for each land use category as computed from a sample of previous Fort Worth District flood control studies. These data were used to calculate the total value of damageable development per acre and per 40-meter GIS cell (pixel) for each land use category.

In the actual calculation of flood damages, the GIS compared the water surface elevation at a given pixel for a given flood event to the ground elevation of that cell to obtain the depth of flooding. Reference was then made to the depth-damage relationship for the land use type appropriate to the cell to obtain the percent loss of structure value and contents value associated with that depth of flooding. These percentages were multiplied by the average structure and contents value per cell for that land use type to obtain the flood damages for that cell and flood event. Summation over the cells in a reach defined by the GIS "window" and integration over the range of flood events produced the expected annual damages (EAD) for floodplain properties within that reach. Reiteration of this process for different conditions of improvement yielded the EAD's associated with each alternative. It is noted that this flood damage computation procedure is identical in principle to that of any traditional Corps economic flood damage analysis, the only difference being in the use of a GIS for management and integration of the enormous amounts of data involved. See Appendix 2 for a more detailed discussion of the actual calculation of EAD's by the GIS for the Recon Study.

PROTOTYPE METHODOLOGY STUDY:

What Was Tried: The calculation of flood damages in the Prototype Methodology Study differs from that in the Recon Study only in that damages were computed within the GIS for individual structures instead of for cells of generalized land use types. The computation procedure itself is essentially the same as before, except for improved interpolation and data management software tools.

The analytical linkages for GIS flood damage calculations for this study have also been successfully tested using data from a different study area, that of the Upper Zacate Creek area in Laredo, Texas, for which both GIS and conventional Corps STDMA flood damage models were available. A comparison of the economic damages calculated using the two methodologies showed many similarities and some differences in accuracies. These can be attributed to the grid cell resolution chosen for the analysis. In areas such as commercial complexes where buildings tend to be tightly grouped, the computer would aggregate these buildings into 30-meter grid cell groups with the same ground and water surface elevations whereas STDMA would calculate the damage in each of these structures based on individual water surface elevations. Depending on the building configuration, these two methodologies could yield essentially the same results with some minor accuracy variations.

Nearly all of the economics effort in the Prototype Methodology Study was spent by NCTCOG staff in acquiring DCTAD data tapes, determining the actual nature of the information they contain, and extracting that information in a useful form. Each of these tasks proved to be considerably more difficult than originally anticipated.

DCTAD's Master Appraisal Files contain over 80,000 records for commercial real property in Dallas and portions of surrounding counties, where there are "split" cities. These records include traditional commercial structures, such as retail, office and industrial facilities, as well as multi-family housing, vacant land, and some public buildings. No records for residential properties were available, as discussed later. The method of determining those properties within the Prototype Methodology Study area was based upon a corresponding MAPSCO page and cell for all improved properties within the field work area, yielding a total of 181 records. Manual review eliminated 71 of these that were beyond the specified street or city boundaries and outside of the SPF floodplain of the Study area shown previously in figure 2. Due to DCTAD's unique formulating procedures, the remaining 110 records represented only 31 site-specific properties in the Prototype Methodology Study area.

In DCTAD's record format, typically one record is created for each distinct construction type within a property because of their heavy reliance upon the cost approach to appraised valuations. Hence, an apartment property with 15 similarly-constructed buildings may be reported in one record whereas a bank building with a basement parking lot and drive-through teller windows may have three separate records. Each site-specific property has a coded "parent" record containing administrative, structural, land and valuation data. Additional records, referred to as "child" records, contain only administrative and further structural information.

The DCTAD records were hierarchically sorted by MAPSCO page, street name, and street number by NCTCOG using the MAPSCO roadway grid system as an identifying coordinate system. The business name, DCTAD identification number, and MAPSCO grid information, as well as the type, size and number of buildings on the property, were extracted for each record to enable identification in the field. Thirty of the 31 records (97 percent) were successfully linked to their respective building footprints shown on the city of Grand Prairie's topographic map. One DCTAD property, a 26,000 square foot building of unspecified type on Midway Road, simply did not exist at that location. It is thought that since this property was proposed to be constructed by the developer, it was added to the Tax Rolls to be verified at a later date. Furthermore, there were numerous other structures in commercial use or under construction within the study area that were not contained within the DCTAD records. The largest of these was a metal industrial or warehouse type of structure on Carrier Parkway. The majority of these other missing properties were very small structures along Hunter-Ferrell Road. Other properties missing from the DCTAD files were a variety of small structures without public access. Overall, however, the DCTAD did contain the majority of the properties within the Prototype Methodology Study area.

What Didn't Work: The great bulk of the time required for both the preparatory and final processing of the DCTAD data was spent in identifying a rare coding problem in the DCTAD files in which the key extraction variable was routinely and (fortunately) systematically entered incorrectly, according to their documentation. The coding error encountered is very unusual in NCTCOG's experience with these data tapes.

Another problem with the DCTAD data has been acquiring the correct documentation regarding their Certified Tax Roll data tapes. These tapes contain the basic residential real property and all personal property data, including information of the value of the contents of commercial properties, planned for investigation in this Study. Without proper documentation, this data cannot be properly evaluated. The strict confidentiality requirements of the personal property data may also prevent access to and use of this source of information. Thus, traditional estimates of personal contents within the structure may have to be used.

The remainder of this report, addresses the only available "commercial real property" of DCTAD within the study area which includes traditional commercial structures as well as multi-family housing, vacant land, and some public buildings. Field-verification of these structures was performed by NCTCOG to determine if these structures were located where the GIS specified they would be via the MAPSCO grid network and if these structures were of the type specified by DCTAD. For the Feasibility Study, the residential property data tapes are expected to be available from DCTAD. A similar field-verification will be performed.

The primary problems in terms of the NCTCOG field work were the multiple-record, multiple-structure properties as well as the various properties for which there is no public access. The multiple-record, multiple-structure properties, also, present the greatest data processing challenges. Finally, the city of Grand Prairie topographic maps are difficult to work with in the field due to their large size and great topographical detail. During the Feasibility Study, maps of sufficient scale can be generated for field verification, showing the DCTAD data on each building footprint.

The most difficult problem arising in the field work, and subsequently in the final data processing, concerns multiple-record properties. The Gifford-Hill complex on Meyers Road, for example, contains 49 records on two adjacent sites. These improvements range in size from 100 to over 50,000 square feet, although the majority fall within the 1,000 to 10,000 square foot range. It is impossible to assign each record to each structure in general field work. Further, since DCTAD presents only the total improved value of the property on the "parent" record, specific assignments by "child" records would yield little additional economic detail.

Problems with correct mutual horizontal registration of the data layers were easily detected by using the GIS to visually inspect the elevation data on a desktop monitor. The structure location data and features such as roads and streams based on a NAD 27 horizontal datum overlaid on the floodplain derived from the digital terrain model based on the city of Grand Prairie's NAD 83 spot elevation topography, showed discrepancies between known locations of selected data items in each layer. These variances were noted and measured with standard GRASS utilities. Systematic corrections were then applied to bring the data sets into correct horizontal registration.

The final economic data file from NCTCOG also contained structures which were missing centroid coordinates and vice versa. These problems are thought to result from the use of either (1) data from a number of sources with less-than-perfect comparability and compatibility or (2) miscommunication of data requirements. This problem will be eliminated by the use of the standardized NAD 83 G&O elevation data and with more familiar usage of the DCTAD data.

Unique identification numbers were assigned by NCTCOG to each property located in the field by date and sequence, such as 8/5-3 translated to 8503. The ID numbers were assigned to the mapped building footprints by NCTCOG. The associated building centroid points were then attached to each DCTAD property to form the required linkage between the two sets of data. Multiple structure properties are subsequently assigned an addition sequence nomenclature of up to four characters, such as 8503A, 8503B, etc., so that the derived structure values can be directly assigned.

It was decided to format the economic data file accessed by the GIS f.econ tool in a way consistent with the non-GIS STDMA flood damage program used by the Fort Worth District Corps of Engineers. This would allow subsets of the economic data to be run with the STDMA model for comparison of results with the GIS or analysis of potential project areas for which the use of the a full GIS model would not be appropriate.

The economic master data file format is shown in table 5-1. The first 14 fields are those used by the STDMA program with the remaining fields used for data extracted from the DCTAD master appraisal data file. In a few cases, DCTAD data are entered directly into the initial fields, but most of the data in the initial fields was provided directly by the GIS itself. For example, the GIS would enter the appropriate stream station and ground elevation for each structure based on the location of each structure's centroid. It would compute other required data as well based on the initial DCTAD data provided. The selection for each structure of the appropriate floor correction (the height of the first occupied floor above the ground), the general development type, depth-damage curves for structures and contents, and percentage

TABLE 4-3

SUMMARY PRINTOUT - MODIFIED CONDITIONS

	SECNO	Q	CWSEL
	310.500	5400.00	420.60
	310.500	13000.00	426.00
*	310.500	18300.00	427.00
*	310.500	24700.00	429.60
*	310.500	31400.00	431.10
*	310.500	41300.00	432.20
	310.500	73700.00	436.60
	340.000	5400.00	420.10
	340.000	13000.00	426.20
	340.000	18300.00	427.10
	340.000	24700.00	429.70
	340.000	31400.00	431.10
	340.000	41300.00	432.30
	340.000	73700.00	436.60
	347.500	5400.00	421.30
	347.500	13000.00	426.30
	347.500	18300.00	427.20
	347.500	24700.00	429.80
	347.500	31400.00	431.20
*	347.500	41300.00	432.40
	347.500	73700.00	436.70
	355.000	5400.00	421.40
	355.000	13000.00	426.30
	355.000	18300.00	427.20
	355.000	24700.00	429.80
	355.000	31400.00	431.20
	355.000	41300.00	432.40
	355.000	73700.00	436.80

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	SECNO	Q	CWSEL
*	370.000	5400.00	421.40
	370.000	13000.00	426.30
	370.000	18300.00	427.30
	370.000	24700.00	429.80
	370.000	31400.00	431.30
	370.000	41300.00	432.50
	370.000	73700.00	436.90
	398.400	5400.00	421.60
	398.400	13000.00	426.50
	398.400	18300.00	427.40
	398.400	24700.00	430.00
	398.400	31400.00	431.40
	398.400	41300.00	432.70
	398.400	73700.00	437.00

TABLE 4-3 (Continued)

SUMMARY PRINTOUT - MODIFIED CONDITIONS

412.200	5400.00	423.00
412.200	13000.00	427.40
412.200	18300.00	429.30
412.200	24700.00	430.80
412.200	31400.00	432.20
412.200	41300.00	433.50
412.200	73700.00	437.10

PAGE 9

430.000	5400.00	423.40
430.000	13000.00	427.70
430.000	18300.00	429.60
430.000	24700.00	431.10
430.000	31400.00	432.40
430.000	41300.00	433.70
430.000	73700.00	437.10
443.500	5400.00	423.40
443.500	13000.00	427.80
443.500	18300.00	429.70
443.500	24700.00	431.30
443.500	31400.00	432.60
443.500	41300.00	433.90
443.500	73700.00	437.10
455.300	5400.00	423.50
455.300	13000.00	427.80
455.300	18300.00	439.80
455.300	24700.00	431.40
455.300	31400.00	432.70
455.300	41300.00	434.10
455.300	73700.00	437.20

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PAGE 10

SECNO	Q	CWSEL
462.000	5400.00	423.50
462.000	13000.00	428.00
462.000	18300.00	430.10
462.000	24700.00	431.80
462.000	31400.00	433.10
462.000	41300.00	434.50
462.000	73700.00	437.40
466.000	5400.00	423.50
466.000	13000.00	428.00
466.000	18300.00	430.00
466.000	24700.00	431.70
466.000	31400.00	433.00
466.000	41300.00	434.30
466.000	73700.00	437.20

TABLE 4-3 (Continued)

SUMMARY PRINTOUT - MODIFIED CONDITIONS

467.500	5400.00	423.30
467.500	13000.00	427.60
467.500	18300.00	429.40
467.500	24700.00	430.90
467.500	31400.00	432.00
467.500	41300.00	432.70
467.500	73700.00	437.10

APPENDIX 5

ECONOMICS

of structure value to use to compute contents value, were determined by the Corps economist based on DCTAD's record type, building class, primary land use, and other fields. For the purposes of the Prototype Methodology Study, there were so few structures that this selection was done by hand. For the Feasibility Study, a more automated approach will be necessary.

The economic structure file used in this Study is listed in table 5-2. Example economic summary tables for Existing and Modified Conditions are shown in tables 5-3 and 5-4, respectively. It is emphasized that these data are provided to demonstrate the functioning of the integrated GIS model, and are not intended to reflect actual floodplain conditions. Table 5-5 shows a listing of the STDMA depth-damage curve table used in this GIS investigation as well as for the Recon Study. The GIS uses this table to interpolate the proper percentage damage to structure types based on depth of flooding.

What Worked Best: Many linkages worked better than anticipated. The largest breakthrough was the ability to link the address of a specific property to a specific position on a map through the use of the MAPSCO street network.

The association of a calculated building centroid to the respective DCTAD property data also worked well, although, some discrepancies existed. The ability to assign an additional sequence nomenclature for multiple-structure properties was also successful in deriving aggregated structure values.

FEASIBILITY STUDY

Methodology to be used: The solution to the problem posed by multiple-record properties is to summarize the records for each property to derive the total number of buildings, their total square footage, and the average appraised value per square foot. The GIS needs DCTAD data associated with building centroids to assign a "value per structure" based upon its size and the average value per square foot for the specific location of a particular set of structures within a given property. A similar process will be used for the residential properties when obtained from DCTAD. This approach is expected to yield acceptably accurate structure values since the structural value per square foot typically does not vary much within a group of similar (or at least related) structures. The value of the contents of each structure will then be estimated from the relationship between contents and structure value observed in previous Corps of Engineers studies for each type of property.

Once the DCTAD Master Appraisal files were properly processed, the field work proceeded well. Although the DCTAD linkage is not perfect, the DCTAD data provides the greatest detail available for commercial structures at a reasonably small cost in person-hours, despite the various problems encountered. The DCTAD data linkage also clearly identifies those structures for which data cannot be successfully retrieved, facilitating a decision concerning additional data-collection efforts. If and when plan formulation activities result in site-specific alternatives, the generalized approach to estimating structure and contents values for commercial properties described above will be supplemented with conventional sampled field surveys and interviews with proprietors to refine the level of detail about the properties to be protected in those areas.

During the Feasibility Study, the residential DCTAD property data is to be acquired and properly field verified. Data from the TCTAD and Denton CTAD are also to be investigated for use of this data for economic flood damage evaluation in their respective areas using the processes developed for use of the DCTAD data. The following refinements are also to be incorporated into the enhancement of the databases for the f.econ tool.

The issue of what size cell resolution should be used for the Feasibility Study is still under investigation. In the use of 10-meter versus 30-meter resolution data, the amount of data to be manipulated increases tenfold. It is not known yet how much of an accuracy difference there will be between the use of these two resolution sizes. Key property areas are to be investigated to determine if more refined investigations are warranted. It could be that the 30-meter grid cell resolution may be adequate for floodplain analyses. Since it is assumed the water surface depth is held constant on any chosen grid cell size, the difference in a building being located on a theoretical 10-meter grid cell versus a 30-meter grid cell should not make that much difference in floodwater heights if the terrain does not steepen appreciably. It may also be that 10-meter data should be used for certain types of structures or terrain slopes. This issue is to be addressed during further feasibility-level investigations.

Refinements: In future efforts, smaller and more relevant maps will be developed for field use. Since the MAPSCO grid data is already digitized into the GIS model, the GIS itself can be used to produce field maps including the MAPSCO grids, as well as streets, waterways, and building footprints with building identification notations. The properties to be field verified can even be sorted based on the particular route to be taken during verification.

1. The procedure described above for deriving individual structure values for multiple-record commercial properties will be refined further to account for structural and functional differences in structure values between small structures and large ones (major structures for production and administration, all other things being equal, having a higher value per square foot than small auxiliary storage structures), as well as differences in structure value introduced by multi-story structures. The selection of appropriate entries for the initial fields of the economic structure file will be automated, using a look-up table, in lieu of the manual evaluation and selection for each structure performed in the Prototype Methodology Study.

2. Finished floor elevations for each structure were calculated by the GIS by adding the ground elevation of the building centroid to an assigned one foot floor correction factor. In the future, this manual assignment of floor correction factors may be automated based on the type of building structure category.

3. The GRASS Version 3.1 f.econ tool discussed herein for this methodology is to be rewritten to use the enhanced Version 4.0 GRASS program.

4. The issue of what size cell resolution is still under investigation. Key areas are to be investigated to determine if more refined investigations are warranted. It may also be that 10-meter data should be used for certain types of structures or terrain slopes. This issue is to be addressed during further feasibility-level investigations.

TABLE 5-1

STRUCTURE OF MASTER DATA FILE FOR ECONOMIC ANALYSES

field name	length	columns: from	to	field description	DCTAD field	other
leaveblank	1	1	1	Reserved.		
reach	3	2	4	Label (e.g., for reach or tributary).		Usually blank; manually entered if needed.
river_mile	6	5	10	Stream station of structure(s).		To be computed by GIS from hydraulics model.
struc_type	3	11	13	General type of development.		Computed from rec_type, own_type, num_unit and stories.
grnd_elev	8	14	21	Ground elevation of the structure.		To be computed by GIS from DEM.
floor_corr	6	22	27	Floor correction (height of finished floor above ground).		Default=1.0, else computed or manually entered.
comment	14	28	41	Street address or other brief identifying information.		Truncated from loc_1 through loc_5 if rec_type=R, else from bus_name.
str_damcrv	3	42	44	Depth-damage curve for structure damages.		Computed or manually entered.
number	4	45	48	Number of structures in this record.	BLDG-NUM-AMFI	
struc_val	10	49	58	Value of structure (average value per structure if num > 1).	LAST-YR1-IMPV-VAL-AMFI	May need to be computed for multiple-record commercial properties.
cnt_damcrv	3	59	61	Depth-damage curve for contents damages.		Computed.
cont_val	10	62	71	Value of contents (average per structure if num > 1).		Blank if rec_type=R, else computed or manually entered.
zone	5	72	76	For manual entry of flood event zone.		Usually blank; manually entered if needed.
entry_num	4	77	80	Short structure identification number.		Computed.
entry_id2	4	81	84	Expanded structure identification number.		NCTCOG.
appr_dist	3	85	87	Abbreviated county appraisal district name.		First three letters of county name.
acct_num	17	88	104	Identification number in original database.	ACCT-NUM-AMFI	
rec_type	1	105	105	Development type in original database.	RCD-TYPE-AMFI	
bldg_class	2	106	107	Commercial building class code.	BLDG-CLASS-AMFI	
landuse1	5	108	112	Primary land use code.	PRIMARY-LAND-USE-AMFI	
bus_name	50	113	162	Business name.	CUR-NAME-BUS-ESTAB-AMFI	
location_1	7	163	169	Property location: street number.	STREET-NUM1-AMFI	
location_2	2	170	171	Property location: street direction.	STREET-DIRECTION1-AMFI	
location_3	23	172	194	Property location: street name.	STREET-NAME1-AMFI	
location_4	4	195	198	Property location: street type.	STREET-TYPE1-AMFI	
location_5	2	199	200	Property location: city.	STREET-CITY-CODE-AMFI	
census_tr	5	201	205	Census tract number.	CENSUS-TRACT-AMFI	
census_bl	5	206	210	Census block number.	CENSUS-BLOCK-AMFI	
mapsco	5	211	215	Mapsco page and grid.	MAPSCO-CODES-AMFI	
bldg_area	7	216	222	Building area.	BLDG-AREA-AMFI	
num_units	5	223	227	Number of units in multifamily residence.	NUM-UNITS-AMFI	
stories	3	228	230	Number of stories in commercial or multifamily structure.	NUM-STORIES-AMFI	
owner_type	2	231	232	Public property ownership code.	OWNER-TYPE-AMFI	

TABLE 5-2

EXAMPLE ECONOMIC STRUCTURE FILE

C	0.3	EXXON RAS 6 02	325	1	41730	326	64922	8501	2255	DA	651710505101300	69		EXXON RAS 6 0276	1	N	19TH	ST	CP	64675	41-W	168		1	
C	0.6	STOP GO 445	83	1	140870	84	106939	8502	2253	DA	280655600A00100	30		STOP GO 445	1610	N	19TH	ST	CP		41-T	3600		1	
P	1.2	SISTER OF THE	59	1	3710	60	404	8503	2252	DA	650121835101600	41		SISTER OF THE HOLY FAMILY	1814		EGYPTIAN WAY		CP		41-T	100		1	RE
C	0.5	STRIP COMM.	423	1	187840	424	219473	8508	2254	DA	281340000A00100	35			1800		DANISH	DR	CP		41-X	7280		1	
P	1.2	SHEPARD OF LO	59	1	64370	60	7016	8509	2847	DA	280995000902800	41		SHEPARD OF LOVE CHURCH	1401	N	7TH	ST	CP	46310	41-Y	2560		1	RE
C	1	CLOWN AROUN	395	1	819520	524	561683	8510	2421	DA	650469641102400	45		CLOWN AROUND	1	B	SAFARI	PK	CP	60480	41-Z	24000		1	
C	0.7	RAMADA INN	229	3		230		8511		DA	650469641102800	52		RAMADA INN	402	B	SAFARI	PK	CP	60480	41-Z	83057	130	1	
C	0.7	RAMADA INN	229	1	655411	230	238122	8511	2841	DA	650469641102800			RAMADA INN	402	B	SAFARI	PK	CP	60480	41-Z				
C	0.7	RAMADA INN	229	1	5270	230	1915	8511	2842	DA	650469641102800			RAMADA INN	402	B	SAFARI	PK	CP	60480	41-Z				
C	0.7	RAMADA INN	229	1	1254026	230	455610	8511	2843	DA	650469641102800			RAMADA INN	402	B	SAFARI	PK	CP	60480	41-Z				
C	0.4	WAX MUSEUM	295	2		296		8512		DA	650469641102000	45	1111	WAX MUSEUM	601	B	SAFARI	PK	CP	60480	41-Z	38075			
C	0.4	WAX MUSEUM	295	1	1033580	296	708002	8512	2846	DA	650469641102000	C	1111	WAX MUSEUM	601	B	SAFARI	PK	CP	60480	41-Z				
C	0.9	MARK IV BUSIN	421	2		422		8513		DA	650469641103200	10		MARK IV BUSINESS PARK	605	W	SAFARI	PK	CP	60480	41-Z	41400		1	
C	0.9	MARK IV BUSIN	421	1	114984	422	12522	8513	2465	DA	650469641103200	C		MARK IV BUSINESS PARK	605	W	SAFARI	PK	CP	60480	41-Z				
C	0.9	MARK IV BUSIN	421	1	134046	422	14611	8513	2491	DA	650469641103200	C		MARK IV BUSINESS PARK	605	W	SAFARI	PK	CP	60480	41-Z				
C	0.9	MARK IV BUSIN	421	2		422		8514		DA	650469641103300	10		MARK IV BUSINESS PARK	605	W	SAFARI	PK	CP	60480	41-Z	38700		1	
C	0.9	MARK IV BUSIN	421	1	111766	422	12182	8514	2474	DA	650469641103300	C		MARK IV BUSINESS PARK	605	W	SAFARI	PK	CP	60480	41-Z				
C	0.9	MARK IV BUSIN	421	1	116974	422	12750	8514	2506	DA	650469641103300	C		MARK IV BUSINESS PARK	605	W	SAFARI	PK	CP	60480	41-Z				
MFR	0.8	GENTRY PLACE	57	19		C7		8515		DA	280696700000000	54		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y	336922	360		
MFR	0.8	GENTRY PLACE	57	1	283255	C7		8515	2822	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	400301	C7		8515	2823	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	281325	C7		8515	2824	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	408142	C7		8515	2825	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	237644	C7		8515	2826	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	283133	C7		8515	2827	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	415494	C7		8515	2828	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	101607	C7		8515	2829	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	277772	C7		8515	2830	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	286135	C7		8515	2831	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	270880	C7		8515	2832	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	230966	C7		8515	2833	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	411114	C7		8515	2834	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	413197	C7		8515	2835	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	276853	C7		8515	2836	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	245853	C7		8515	2837	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	247263	C7		8515	2838	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	280805	C7		8515	2839	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
MFR	0.8	GENTRY PLACE	57	1	276761	C7		8515	2840	DA	280696700000000	C		GENTRY PLACE APTS	606	W	SAFARI	PK	CP		41-Y				
C	0.7	MOTEL	229	1	1018120	230	369578	8516	2844	DA	282030000A00100	52			1	W	SAFARI	PK	CP		41A-	33444	129	2	
C	0.8	SOUTHWEST AI	249	1	1027250	250	97946	8517	2845	DA	650469641103100	21		SOUTHWEST AIRLINES RESERVATION CENTER	401	B	SAFARI	PK	CP	60480	41A-	30304		2	
C	0.4	WHITE WATER P	295	30		296		8518		DA	650469641102600	85		WHITE WATER PARK	701	B	SAFARI	PK	CP	60480	41A-	202394			
C	0.4	WHITE WATER P	295	1	1749	296	1198	8518	2515	DA	650469641102600	85		WHITE WATER PARK	701	B	SAFARI	PK	CP	60480	41A-W				
C	0.4	WHITE WATER P	295	1	6070	296	4158	8518	2529	DA	650469641102600	85		WHITE WATER PARK	701	B	SAFARI	PK	CP	60480	41A-W				
C	0.4	WHITE WATER P	295	1	7434	296	5092	8518	2531	DA	650469641102600	85		WHITE WATER PARK	701	B	SAFARI	PK	CP	60480	41A-W				
C	0.4	WHITE WATER P	295	1	5231	296	3583	8518	2532	DA	650469641102600	85		WHITE WATER PARK	701	B	SAFARI	PK	CP	60480	41A-W				
C	0.4	WHITE WATER P	295	1	1280	296	877	8518	2542	DA	650469641102600	85		WHITE WATER PARK	701	B	SAFARI	PK	CP	60480	41A-W				
C	0.4	WHITE WATER P	295	1	7834	296	5366	8518	2545	DA	650469641102600	85		WHITE WATER PARK	701	B	SAFARI	PK	CP	60480	41A-W				
C	0.4	WHITE WATER P	295	1	8917	296	6108	8518	2560	DA	650469641102600	85		WHITE WATER PARK	701	B	SAFARI	PK	CP	60480	41A-W				
C	0.4	WHITE WATER P	295	1	37685	296	25814	8518	2848	DA	650469641102600	85		WHITE WATER PARK	701	B	SAFARI	PK	CP	60480	41A-W				
C	3	POLLOCK PAPE	255	1	5030490	256	4253876	8519	1344	DA	281452000800100	11		POLLOCK PAPER	2050		MIDPOINTE	BL	CP		41A-	212515		1	
C	0.3	CANNON BUMP	13	1	59950	14	42846	8520	511	DA	650778501101000	63		CANNON BUMPER	2538	NE	8TH	ST	CP	61515	41A-	5070		1	
C	0.3	FINA	325	1	8590	326	13366	8521	500	DA	650778501100100	68		FINA	2578	NE	8TH	ST	CP	61515	41A-	350		1	
C	0.3	FINA	325	1	8590	326	13366	8521	501	DA	650778501100100	68		FINA	2578	NE	8TH	ST	CP	61515	41A-	350		1	
C	0.8	JENKINS ROOFI	79	1	28770	80	21759	8522	497	DA	650778501100500	34		JENKINS ROOFING	1001		HUNTER FERRELL	RD	CP	61515	41A-	2880		1	
C	0.3	J H WALKER TR	13	2		14		8523		DA	651184005100500	63		J H WALKER TRUCKING	1555		HUNTER FERRELL	RD	CP	62940	41A-	4292			
C	0.3	J H WALKER TR	13	1	37090	14	26519	8523	498	DA	651184005100500	C		J H WALKER TRUCKING	1555		HUNTER FERRELL	RD	CP	62940	41A-P				
C	0.3	J H WALKER TR	13	1	24770	14	17711	8523	503	DA	651184005100500	C		J H WALKER TRUCKING	1555		HUNTER FERRELL	RD	CP	62940	41A-P				
C	0.8	GIFFORD HILL	249	1	482410	250	45829	8525	1383	DA	650507165100500	21		GIFFORD HILL AMERICAN	1003		MEYERS	RD	CP	60625	41B-	13981		1	
C	1	GIFFORD HILL P	73	16		74		8526		DA	651471400100600	62		GIFFORD HILL PIPE	1		MEYERS	RD	CP	63950	41B-S	143010			
C	3	GIFFORD HILL	393	33		394		8527		DA	651471400100104	11		GIFFORD HILL AMERICAN	1000		MEYERS	RD	CP	63950	41B-	159950			
C	0.8	INTERNATIONA	249	21		250		8528		DA	651225330100709	21		INTERNATIONAL WILDLIFE PARK	601	W	WILDLIFE	PK	CP	63065	41-Q	49878			
C	0.1	INTERNATIONA	427	1	748160	428	97749	8528	1171	DA	651225330100709	C		INTERNATIONAL WILDLIFE PARK	601	W	WILDLIFE	PK	CP	63065	41-Q				
C	1.2		395	1	28280	396	49721	8529	983	DA	650679570101500	11			2507		HUNTER FERRELL	RD	CP	61180	41A-	2272		1	
C	1.2		395	1	124330	396	218592	8530	3315	DA	650778500100801	11			1730		HORSESHOE LAKE	RD	CP		41A-	144		1	

TABLE 5-3

EXAMPLE ECONOMIC SUMMARY TABLE

ECONOMIC DAMAGE ESTIMATES -- UPPER TRINITY RIVER PROTOTYPE METHODOLOGY STUDY -- EXISTING CONDITION

NUMBER OF STRUCTURES	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR
Public	0	0	0	0	0	0	0
Commercial & Industrial	1	1	2	2	3	5	7
Single-Family Residential	0	0	0	0	0	0	0
Multi-Family Residential	0	0	0	0	0	5	6
Mobile Home	0	0	0	0	0	0	0
Privately Owned Vehicle	0	0	0	0	0	0	0
TOTAL	**1**	**1**	**2**	**2**	**3**	**10**	**13**

DAMAGE TO STRUCTURES (in thousands)	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR	EAD
Public	$0	$0	$0	$0	$0	$0	$0	$0
Commercial & Industrial	$4	$23	$43	$104	$149	$320	$944	$24
Single-Family Residential	$0	$0	$0	$0	$0	$0	$0	$0
Multi-Family Residential	$0	$0	$0	$0	$0	$244	$630	$6
Mobile Home	$0	$0	$0	$0	$0	$0	$0	$0
Privately Owned Vehicle	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL	**$4**	**$23**	**$43**	**$104**	**$149**	**$564**	**$1,573**	**$30**

DAMAGE TO CONTENTS (in thousands)	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR	EAD
Public	$0	$0	$0	$0	$0	$0	$0	$0
Commercial & Industrial	$157	$219	$240	$354	$432	$760	$1,471	$123
Single-Family Residential	$0	$0	$0	$0	$0	$0	$0	$0
Multi-Family Residential	$0	$0	$0	$0	$0	$7	$30	$0
Mobile Home	$0	$0	$0	$0	$0	$0	$0	$0
Privately Owned Vehicle	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL	**$157**	**$219**	**$240**	**$354**	**$432**	**$767**	**$1,502**	**$123**

TABLE 5-3 (Continued)

EXAMPLE ECONOMIC SUMMARY TABLE

ECONOMIC DAMAGE ESTIMATES -- UPPER TRINITY RIVER PROTOTYPE METHODOLOGY STUDY -- EXISTING CONDITION

TOTAL FLOOD DAMAGE (in thousands)	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR	EAD
Public	$0	$0	$0	$0	$0	$0	$0	$0
Commercial & Industrial	$162	$242	$283	$458	$581	$1,080	$2,415	$146
Single-Family Residential	$0	$0	$0	$0	$0	$0	$0	$0
Multi-Family Residential	$0	$0	$0	$0	$0	$252	$660	$6
Mobile Home	$0	$0	$0	$0	$0	$0	$0	$0
Privately Owned Vehicle	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL	$162	$242	$283	$458	$581	$1,332	$3,075	$153

AREAL EXTENT OF FLOODING	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR
Acres	42.6	176.4	237.4	290.2	328.3	374.8	472.0
Square Miles	0.1	0.3	0.4	0.5	0.5	0.6	0.7

*** NOTES ***

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TABLE 5-4

EXAMPLE ECONOMIC SUMMARY TABLE

ECONOMIC DAMAGE ESTIMATES -- UPPER TRINITY RIVER PROTOTYPE METHODOLOGY STUDY -- MODIFIED CONDITION

NUMBER OF STRUCTURES	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR
Public	0	0	0	0	0	0	0
Commercial & Industrial	1	1	1	1	1	0	0
Single-Family Residential	0	0	0	0	0	2	5
Multi-Family Residential	0	0	0	0	0	0	0
Mobile Home	0	0	0	0	0	0	5
Privately Owned Vehicle	0	0	0	0	0	0	0
TOTAL	1	1	1	1	1	2	10

DAMAGE TO STRUCTURES (in thousands)	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR	EAD
Public	$0	$0	$0	$0	$0	$0	$0	$0
Commercial & Industrial	$0	$2	$8	$14	$21	$65	$301	$4
Single-Family Residential	$0	$0	$0	$0	$0	$0	$0	$0
Multi-Family Residential	$0	$0	$0	$0	$0	$0	$236	$1
Mobile Home	$0	$0	$0	$0	$0	$0	$0	$0
Privately Owned Vehicle	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL	$0	$2	$8	$14	$21	$65	$537	$6

DAMAGE TO CONTENTS (in thousands)	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR	EAD
Public	$0	$0	$0	$0	$0	$0	$0	$0
Commercial & Industrial	$46	$142	$184	$216	$219	$311	$724	$69
Single-Family Residential	$0	$0	$0	$0	$0	$0	$0	$0
Multi-Family Residential	$0	$0	$0	$0	$0	$0	$7	$0
Mobile Home	$0	$0	$0	$0	$0	$0	$0	$0
Privately Owned Vehicle	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL	$46	$142	$184	$216	$219	$311	$731	$69

TABLE 5-4 (Continued)

EXAMPLE ECONOMIC SUMMARY TABLES

ECONOMIC DAMAGE ESTIMATES -- UPPER TRINITY RIVER PROTOTYPE METHODOLOGY STUDY -- MODIFIED CONDITION

TOTAL FLOOD DAMAGE (in thousands)	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR	EAD
Public	$0	$0	$0	$0	$0	$0	$0	$0
Commercial & Industrial	$46	$145	$191	$231	$240	$377	$1,025	$73
Single-Family Residential	$0	$0	$0	$0	$0	$0	$0	$0
Multi-Family Residential	$0	$0	$0	$0	$0	$0	$243	$1
Mobile Home	$0	$0	$0	$0	$0	$0	$0	$0
Privately Owned Vehicle	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL	$46	$145	$191	$231	$240	$377	$1,268	$75

AREAL EXTENT OF FLOODING	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR
Acres	7.0	46.0	58.5	116.4	177.2	223.7	361.1
Square Miles	0.0	0.1	0.1	0.2	0.3	0.3	0.6

*** NOTES ***

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TABLE 5 - 5

STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																								
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
S0 GENL. RES.	STRUCTURE	0	0	0	0	0	0	0	10	21	28	34	43	48	51	54	58	61	63	65	69	71	75	82	84	85	85
C0 GENL. RES.	CONTENTS	0	0	0	0	0	0	0	7	38	55	66	73	78	82	84	87	88	88	88	89	90	93	99	100	100	100
S1 1 STORY RES.	STRUCTURE	0	0	0	0	0	0	0	10	21	27	32	37	43	46	50	54	58	60	63	67	70	74	82	84	85	85
C1 1 STORY RES.	CONTENTS	0	0	0	0	0	0	0	8	42	60	71	77	82	85	86	87	88	88	88	89	90	93	100	100	100	100
S2 1-1/2 STORY RES.	STRUCTURE	0	0	0	0	0	0	0	10	28	35	41	43	46	48	49	50	50	50	51	51	52	53	57	60	64	70
C2 1-1/2 STORY RES.	CONTENTS	0	0	0	0	0	0	0	2	22	36	45	57	66	71	77	79	82	84	86	87	89	90	92	92	95	97
S3 2 STORY RES.	STRUCTURE	0	0	0	0	0	0	0	5	21	27	31	34	37	39	40	40	42	44	47	49	52	55	60	65	70	74
C3 2 STORY RES.	CONTENTS	0	0	0	0	0	0	0	4	24	34	40	47	53	56	58	58	58	61	66	68	76	81	90	100	100	100
S4 MOBILE RES.	STRUCTURE	0	0	0	0	5	5	5	14	19	31	54	93	96	96	97	97	97	98	98	98	98	98	98	98	98	98
C4 MOBILE RES.	CONTENTS	0	0	0	0	0	0	0	3	23	36	43	55	66	78	86	100	100	100	100	100	100	100	100	100	100	100
S5 HIGH RISE RES.	STRUCTURE	0	0	0	0	0	0	0	0	1	2	3	5	7	8	10	12	18	28	41	48	52	56	58	59	62	70
C5 HIGH RISE RES.	CONTENTS	0	0	0	0	0	0	0	1	2	5	8	10	12	13	13	14	26	38	52	64	78	84	91	95	98	100
S6 1 STORY APT.	STRUCTURE	0	0	0	0	0	0	0	5	18	25	30	34	38	41	43	46	48	50	52	54	55	57	59	63	67	72
C6 1 STORY APT.	CONTENTS	0	0	0	0	0	0	0	6	34	44	55	67	77	87	97	100	100	100	100	100	100	100	100	100	100	100
S7 2 STORY APT.	STRUCTURE	0	0	0	0	0	0	0	5	28	29	31	36	37	39	40	41	42	44	46	48	52	55	61	68	70	74
C7 2 STORY APT.	CONTENTS	0	0	0	0	0	0	0	4	24	34	40	47	53	56	58	58	58	61	66	68	76	81	91	100	100	100
SV RES. VEHICLE	STRUCTURE	0	0	0	0	0	0	0	20	50	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
CV RES. VEHICLE	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 AIRPORT	STRUCTURE	0	0	0	0	0	0	0	0	17	17	20	23	27	28	30	32	34	40	40	40	40	43	59	59	63	63
2 AIRPORT	CONTENTS	0	0	0	0	0	0	0	0	22	30	35	40	53	55	57	57	57	57	70	70	70	70	70	70	70	70
3 ANTIQUE SHOP	STRUCTURE	0	0	0	0	0	0	0	0	17	17	18	19	21	23	25	28	32	35	39	43	47	52	61	70	80	90
4 ANTIQUE SHOP	CONTENTS	0	0	0	0	0	0	0	20	40	78	85	90	95	100	100	100	100	100	100	100	100	100	100	100	100	100
5 APPLIANCE	STRUCTURE	0	0	0	0	0	0	0	0	17	17	18	19	21	23	25	28	32	35	39	43	47	52	61	70	80	90
6 APPLIANCE	CONTENTS	0	0	0	0	0	0	0	0	64	71	90	95	98	100	100	100	100	100	100	100	100	100	100	100	100	100
7 AUTO DEALERSHIP	STRUCTURE	0	0	0	0	0	0	0	0	17	17	18	19	21	23	25	28	32	35	39	43	49	52	61	70	80	90
8 AUTO DEALERSHIP	CONTENTS	0	0	0	0	0	0	0	10	40	70	90	90	90	90	90	90	90	90	95	95	95	95	95	100	100	100
9 AUTO JUNK YARD	STRUCTURE	0	0	0	0	0	0	0	0	2	4	5	7	8	10	11	13	14	15	16	16	16	16	17	18	19	21
10 AUTO JUNK YARD	CONTENTS	0	0	0	0	0	0	0	0	9	13	16	17	18	19	19	19	19	19	19	20	20	20	21	22	23	24
11 AUTO PARTS	STRUCTURE	0	0	0	0	0	0	0	0	5	5	5	5	7	10	14	19	25	32	40	50	57	63	72	79	85	90
12 AUTO PARTS	CONTENTS	0	0	0	0	0	0	0	0	17	28	56	66	85	94	94	94	94	94	94	94	94	94	94	94	94	94
13 AUTO REPAIR	STRUCTURE	0	0	0	0	0	0	0	0	3	3	3	4	5	8	12	17	23	31	40	48	56	64	76	84	90	94
14 AUTO REPAIR	CONTENTS	0	0	0	0	0	0	0	23	53	74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																									
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
15 AUTO SERVICE	STRUCTURE	0	0	0	0	0	0	0	0	3	3	3	4	5	8	12	17	23	31	40	48	56	64	76	84	90	94
16 AUTO SERVICE	CONTENTS	0	0	0	0	0	0	0	10	40	60	85	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
17 AUTO TRANS SVC	STRUCTURE	0	0	0	0	0	0	0	0	3	3	3	4	5	8	12	17	23	31	40	48	56	64	76	84	90	94
18 AUTO TRANS SVC	CONTENTS	0	0	0	0	0	0	0	0	10	20	40	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100
19 BAIT STAND	STRUCTURE	0	0	0	0	0	0	0	0	1	2	5	8	12	17	22	28	36	43	50	58	66	75	92	100	100	100
20 BAIT STAND	CONTENTS	0	0	0	0	0	0	0	0	3	7	11	16	22	29	36	44	52	60	69	79	88	100	100	100	100	100
21 BAKERY	STRUCTURE	0	0	0	0	0	0	0	12	17	21	25	28	31	34	36	38	41	43	45	47	48	50	54	57	61	64
22 BAKERY	CONTENTS	0	0	0	0	0	0	0	53	63	89	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
23 BANK	STRUCTURE	0	0	0	0	0	0	0	0	11	11	12	13	15	17	19	22	24	28	31	34	37	40	48	55	63	74
24 BANK	CONTENTS	0	0	0	0	0	0	0	0	50	78	87	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
25 BARBER SHOP	STRUCTURE	0	0	0	0	0	0	0	0	13	17	18	24	31	37	41	45	47	49	50	50	51	52	56	62	71	80
26 BARBER SHOP	CONTENTS	0	0	0	0	0	0	0	21	28	38	49	63	79	96	96	96	96	96	96	96	96	96	96	96	96	96
27 BATTERY MFG	STRUCTURE	0	0	0	0	0	0	0	0	3	3	3	4	5	8	10	17	23	31	40	48	48	52	55	55	55	55
28 BATTERY MFG	CONTENTS	0	0	0	0	0	0	0	0	10	13	20	23	32	38	42	42	45	45	45	45	55	55	62	62	62	62
29 BEAUTY SHOP	STRUCTURE	0	0	0	0	0	0	0	0	10	14	17	23	28	34	38	43	47	50	54	57	61	64	71	77	83	89
30 BEAUTY SHOP	CONTENTS	0	0	0	0	0	0	0	20	46	61	74	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
31 BICYCLE SHOP	STRUCTURE	0	0	0	0	0	0	0	0	20	24	28	32	35	39	43	47	50	55	60	60	60	60	60	60	60	60
32 BICYCLE SHOP	CONTENTS	0	0	0	0	0	0	0	0	17	25	42	57	59	61	63	63	63	63	63	63	63	63	63	63	63	63
33 BOAT: PARTY FISH	STRUCTURE	0	0	0	0	0	0	0	10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
34 BOAT: PARTY FISH	CONTENTS	0	0	0	0	0	0	0	27	62	76	76	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
35 BOAT SALES	STRUCTURE	0	0	0	0	0	0	0	14	20	32	33	34	36	38	42	50	56	60	63	67	70	73	78	84	88	92
36 BOAT SALES	CONTENTS	0	0	0	0	0	0	0	13	24	43	82	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100
37 BOAT STALLS	STRUCTURE	0	0	0	0	0	0	0	0	10	19	26	32	40	48	56	64	71	78	85	91	97	100	100	100	100	100
38 BOAT STALLS	CONTENTS	0	0	0	0	0	0	0	0	3	6	8	11	13	15	17	19	21	22	24	25	27	28	31	33	36	38
39 BOAT STORAGE	STRUCTURE	0	0	0	0	0	0	0	0	4	5	7	10	13	16	22	26	31	37	43	49	55	60	70	79	86	91
40 BOAT STORAGE	CONTENTS	0	0	0	0	0	0	0	1	4	7	12	18	24	32	40	48	54	58	63	66	68	70	70	70	70	70
41 BOILER BUILDING	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45
42 BOILER BUILDING	CONTENTS	0	0	0	0	0	0	0	0	5	10	10	10	20	20	20	20	20	20	20	20	20	20	20	20	20	20
43 BOOK STORE	STRUCTURE	0	0	0	0	0	0	0	0	2	3	5	8	10	12	15	17	20	23	27	31	35	40	50	60	71	83
44 BOOK STORE	CONTENTS	0	0	0	0	0	0	0	5	10	30	50	70	85	100	100	100	100	100	100	100	100	100	100	100	100	100
45 BOWLING ALLEY	STRUCTURE	0	0	0	0	0	0	0	0	4	7	11	15	19	23	27	31	35	39	44	49	53	53	65	73	81	88
46 BOWLING ALLEY	CONTENTS	0	0	0	0	0	0	0	10	30	50	70	85	100	100	100	100	100	100	100	100	100	100	100	100	100	100

TABLE 5 - 5 (Continued)
STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																								
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
47 BUSINESS SVCS.	STRUCTURE	0	0	0	0	0	0	0	0	1	2	3	5	8	11	13	16	18	21	25	29	34	38	49	59	71	83
48 BUSINESS SVCS.	CONTENTS	0	0	0	0	0	0	0	0	2	6	10	15	19	24	28	33	38	44	49	55	62	69	86	100	100	100
49 CABINET MFG	STRUCTURE	0	0	0	0	0	0	0	0	20	22	24	26	28	30	35	40	43	46	50	50	50	50	50	50	50	50
50 CABINET MFG	CONTENTS	0	0	0	0	0	0	0	40	60	70	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
51 CAR WASH	STRUCTURE	0	0	0	0	0	0	0	0	0	0	2	5	10	10	15	15	20	20	25	25	30	30	35	40	40	40
52 CAR WASH	CONTENTS	0	0	0	0	0	0	0	0	11	26	40	51	62	76	76	76	76	76	76	76	81	81	81	81	81	81
53 CARPET AND PAINT	STRUCTURE	0	0	0	0	0	0	0	0	0	60	60	60	60	60	60	60	60	60	60	80	80	80	80	80	80	80
54 CARPET AND PAINT	CONTENTS	0	0	0	0	0	0	0	0	21	43	65	83	96	97	99	100	100	100	100	100	100	100	100	100	100	100
55 CEMETARY COMPLEX	STRUCTURE	0	0	0	0	0	0	0	0	19	23	25	25	25	26	27	28	31	35	41	50	58	64	73	80	85	90
56 CEMETARY COMPLEX	CONTENTS	0	0	0	0	0	0	0	0	38	43	79	90	97	97	97	97	97	97	97	97	97	97	97	97	97	97
57 CERAMIC CRAFTS	STRUCTURE	0	0	0	0	0	0	0	0	20	22	24	26	27	28	29	30	40	50	50	50	50	50	50	50	50	50
58 CERAMIC CRAFTS	CONTENTS	0	0	0	0	0	0	0	0	20	60	80	96	96	96	96	96	96	96	96	96	96	96	96	96	96	96
59 CHURCH	STRUCTURE	0	0	0	0	0	0	0	0	10	11	11	12	12	13	14	14	15	17	19	24	30	38	52	64	75	85
60 CHURCH	CONTENTS	0	0	0	0	0	0	0	10	38	62	76	87	92	96	98	99	100	100	100	100	100	100	100	100	100	100
61 CITY HALL	STRUCTURE	0	0	0	0	0	0	0	0	1	1	1	2	2	3	4	6	8	12	17	23	31	40	58	70	79	87
62 CITY HALL	CONTENTS	0	0	0	0	0	0	0	0	35	75	85	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100
63 CLEANERS	STRUCTURE	0	0	0	0	0	0	0	0	4	6	6	8	10	13	17	22	28	34	42	50	57	62	71	78	84	90
64 CLEANERS	CONTENTS	0	0	0	0	0	0	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100
65 CLEANERS: SUBSTA.	STRUCTURE	0	0	0	0	0	0	0	0	4	6	6	8	10	13	17	22	28	34	42	50	57	62	71	78	84	90
66 CLEANERS: SUBSTA.	CONTENTS	0	0	0	0	0	0	0	0	47	72	89	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
67 CLINIC: MEDICAL	STRUCTURE	0	0	0	0	0	0	0	0	1	2	2	3	4	6	8	11	14	17	21	25	29	33	42	51	61	72
68 CLINIC: MEDICAL	CONTENTS	0	0	0	0	0	0	0	10	20	40	60	80	90	95	100	100	100	100	100	100	100	100	100	100	100	100
69 CLOTHING	STRUCTURE	0	0	0	0	0	0	0	0	8	10	11	13	15	18	21	24	28	32	37	41	46	51	61	71	82	92
70 CLOTHING	CONTENTS	0	0	0	0	0	0	0	6	37	49	74	87	100	100	100	100	100	100	100	100	100	100	100	100	100	100
71 COLUMN MFG.	STRUCTURE	0	0	0	0	0	0	0	0	15	20	20	20	20	22	24	25	25	25	25	25	25	25	25	25	25	25
72 COLUMN MFG.	CONTENTS	0	0	0	0	0	0	0	0	19	27	39	49	59	59	59	59	59	59	59	59	59	59	59	59	59	59
73 CONCRETE MFG.	STRUCTURE	0	0	0	0	0	0	0	0	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
74 CONCRETE MFG.	CONTENTS	0	0	0	0	0	0	0	0	20	60	67	74	80	90	100	100	100	100	100	100	100	100	100	100	100	100
75 CONTRACTOR: ELEC.	STRUCTURE	0	0	0	0	0	0	0	0	4	7	9	12	13	14	15	15	15	15	18	20	21	22	24	27	29	31
76 CONTRACTOR: ELEC.	CONTENTS	0	0	0	0	0	0	0	0	13	25	33	41	46	49	51	52	53	53	56	57	58	60	62	65	68	69
77 CONTRACTOR: GENL.	STRUCTURE	0	0	0	0	0	0	0	0	14	22	26	29	32	33	34	35	35	35	41	43	45	47	51	55	59	64
78 CONTRACTOR: GENL.	CONTENTS	0	0	0	0	0	0	0	0	25	41	54	63	72	82	91	100	100	100	100	100	100	100	100	100	100	100

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																									
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
79 CONTRACTOR: ROOF.	STRUCTURE	0	0	0	0	0	0	0	0	14	21	25	27	28	30	30	30	30	30	32	34	35	36	38	40	42	44
80 CONTRACTOR: ROOF.	CONTENTS	0	0	0	0	0	0	0	0	13	25	33	41	46	49	51	52	53	53	56	57	58	60	62	65	68	69
81 CONSTRUCTION CO.	STRUCTURE	0	0	0	0	0	0	0	0	0	20	30	40	50	60	70	80	90	100	100	100	100	100	100	100	100	100
82 CONSTRUCTION CO.	CONTENTS	0	0	0	0	0	0	0	0	25	41	54	63	72	82	91	100	100	100	100	100	100	100	100	100	100	100
83 CONVENIENCE STORE	STRUCTURE	0	0	0	0	0	0	0	0	20	22	24	26	28	30	32	34	36	38	39	40	43	47	50	50	50	50
84 CONVENIENCE STORE	CONTENTS	0	0	0	0	0	0	0	0	40	50	70	80	95	95	96	96	96	96	96	96	97	97	97	97	97	97
85 COOLING TOWER	STRUCTURE	0	0	0	0	0	0	0	0	10	20	20	50	50	60	60	75	75	80	80	80	80	80	80	80	80	80
86 COOLING TOWER	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
87 COUNTRY CLUB	STRUCTURE	0	0	0	0	0	0	0	0	7	8	8	9	10	11	12	13	14	15	18	21	24	28	38	50	63	76
88 COUNTRY CLUB	CONTENTS	0	0	0	0	0	0	0	36	39	42	46	51	55	61	66	73	79	86	93	99	99	100	100	100	100	100
89 DAIRY FARM	STRUCTURE	0	0	0	0	0	0	0	0	20	22	24	28	30	32	34	38	42	45	50	55	55	55	55	55	55	55
90 DAIRY FARM	CONTENTS	0	0	0	0	0	0	0	0	25	50	75	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95
91 DAIRY PROCESSING	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45
92 DAIRY PROCESSING	CONTENTS	0	0	0	0	0	0	0	0	8	33	58	66	66	66	66	73	86	86	86	86	86	86	86	86	86	86
93 DAY CARE CENTER	STRUCTURE	0	0	0	0	0	0	0	0	15	16	16	20	25	29	33	37	41	44	47	50	53	56	61	68	77	86
94 DAY CARE CENTER	CONTENTS	0	0	0	0	0	0	0	0	24	50	88	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
95 DENTIST OFFICE	STRUCTURE	0	0	0	0	0	0	0	7	35	35	35	35	35	35	36	37	38	39	41	42	44	45	49	53	57	61
96 DENTIST OFFICE	CONTENTS	0	0	0	0	0	0	0	0	22	47	64	76	88	100	100	100	100	100	100	100	100	100	100	100	100	100
97 DEODORIZER BLDG.	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45
98 DEODORIZER BLDG.	CONTENTS	0	0	0	0	0	0	0	0	11	17	23	23	24	29	29	29	30	30	30	30	30	30	30	30	30	30
99 DEPARTMENT STORE	STRUCTURE	0	0	0	0	0	0	0	0	3	7	7	7	9	11	14	17	20	23	26	30	33	37	44	52	63	78
100 DEPARTMENT STORE	CONTENTS	0	0	0	0	0	0	0	0	18	33	65	88	95	100	100	100	100	100	100	100	100	100	100	100	100	100
101 DOCTOR OFFICE	STRUCTURE	0	0	0	0	0	0	0	0	1	3	4	6	9	11	14	17	20	24	29	35	42	50	63	73	81	88
102 DOCTOR OFFICE	CONTENTS	0	0	0	0	0	0	0	10	20	40	60	80	90	95	100	100	100	100	100	100	100	100	100	100	100	100
103 DOOR MFG.	STRUCTURE	0	0	0	0	0	0	0	0	14	22	26	29	32	33	34	35	35	35	35	41	43	45	49	53	53	53
104 DOOR MFG.	CONTENTS	0	0	0	0	0	0	0	0	17	35	68	90	93	97	98	100	100	100	100	100	100	100	100	100	100	100
105 DRAPERY SHOP	STRUCTURE	0	0	0	0	0	0	0	0	15	20	30	35	40	45	50	60	70	80	85	90	95	100	100	100	100	100
106 DRAPERY SHOP	CONTENTS	0	0	0	0	0	0	0	0	18	30	45	63	83	100	100	100	100	100	100	100	100	100	100	100	100	100
107 DRUG STORE	STRUCTURE	0	0	0	0	0	0	0	0	1	5	5	5	7	8	11	14	18	22	27	33	38	45	57	68	77	87
108 DRUG STORE	CONTENTS	0	0	0	0	0	0	0	0	20	50	80	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100
109 ELECTRONICS SALES	STRUCTURE	0	0	0	0	0	0	0	0	13	20	24	27	28	30	30	30	30	30	32	33	34	34	36	37	39	40
110 ELECTRONICS SALES	CONTENTS	0	0	0	0	0	0	0	0	25	42	59	76	88	100	100	100	100	100	100	100	100	100	100	100	100	100

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																								
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
111 ELECTRONICS MFG.	STRUCTURE	0	0	0	0	0	0	0	0	13	20	24	27	28	30	30	30	30	30	32	33	34	34	36	38	40	41
112 ELECTRONICS MFG.	CONTENTS	0	0	0	0	0	0	0	0	16	32	48	64	73	82	91	100	100	100	100	100	100	100	100	100	100	100
113 ENGINE ROOM	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45
114 ENGINE ROOM	CONTENTS	0	0	0	0	0	0	0	0	20	25	30	35	40	45	50	55	65	65	65	65	65	75	75	75	75	75
115 EQUIP. STORAGE	STRUCTURE	0	0	0	0	0	0	0	0	0	3	5	6	7	8	10	13	17	21	25	30	40	50	70	80	80	80
116 EQUIP. STORAGE	CONTENTS	0	0	0	0	0	0	0	5	10	15	20	30	40	50	60	70	80	90	100	100	100	100	100	100	100	100
117 FABRICATION SHOP	STRUCTURE	0	0	0	0	0	0	0	0	2	5	10	15	20	25	30	35	40	50	75	75	75	75	75	75	75	75
118 FABRICATION SHOP	CONTENTS	0	0	0	0	0	0	0	0	10	20	30	40	50	60	70	75	80	80	80	80	80	80	80	80	80	80
119 FEED STORE	STRUCTURE	0	0	0	0	0	0	0	0	20	24	28	32	34	36	38	40	42	44	46	48	50	50	50	50	50	50
120 FEED STORE	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	15	15	15	15	26	26	26	26	50	50	50	75	100	100	100
121 FEED MILL	STRUCTURE	0	0	0	0	0	0	0	0	0	0	0	20	23	27	30	33	37	40	43	47	50	53	60	60	60	60
122 FEED MILL	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	20	22	24	26	28	30	30	30	30	30	31	55	60	60	60
123 FILTERING PLANT	STRUCTURE	0	0	0	0	0	0	0	0	5	15	30	60	90	90	90	90	90	90	90	90	90	90	90	90	90	90
124 FILTERING PLANT	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125 FIREWORKS SALES	STRUCTURE	0	0	0	0	0	0	0	0	0	10	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
126 FIREWORKS SALES	CONTENTS	0	0	0	0	0	0	0	0	70	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
127 FIRE STATION	STRUCTURE	0	0	0	0	0	0	0	0	1	5	5	5	6	7	9	11	14	17	20	24	28	32	41	51	61	74
128 FIRE STATION	CONTENTS	0	0	0	0	0	0	0	0	10	25	50	75	91	100	100	100	100	100	100	100	100	100	100	100	100	100
129 FLEA MARKET	STRUCTURE	0	0	0	0	0	0	0	1	2	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
130 FLEA MARKET	CONTENTS	0	0	0	0	0	0	0	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
131 FLOOR & CARPET	STRUCTURE	0	0	0	0	0	0	0	0	2	3	4	4	5	7	9	13	18	22	29	35	42	50	63	73	81	88
132 FLOOR & CARPET	CONTENTS	0	0	0	0	0	0	0	0	61	81	91	93	95	97	99	100	100	100	100	100	100	100	100	100	100	100
133 FLORIST	STRUCTURE	0	0	0	0	0	0	0	0	7	7	8	9	11	13	16	19	22	26	30	34	38	42	51	60	69	79
134 FLORIST	CONTENTS	0	0	0	0	0	0	0	0	20	50	70	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100
135 FOOD PROCESSOR	STRUCTURE	0	0	0	0	0	0	0	0	6	6	6	6	10	14	18	20	20	20	20	20	20	20	20	20	20	20
136 FOOD PROCESSOR	CONTENTS	0	0	0	0	0	0	0	21	54	58	62	66	71	77	83	94	94	94	94	94	94	94	94	94	94	94
137 FOOD WAREHOUSE	STRUCTURE	0	0	0	0	0	0	0	0	0	10	11	12	13	13	14	14	15	15	17	18	19	20	24	27	30	30
138 FOOD WAREHOUSE	CONTENTS	0	0	0	0	0	0	0	0	24	39	54	68	83	88	88	88	88	88	88	88	89	89	90	90	90	90
139 FOUNDARY	STRUCTURE	0	0	0	0	0	0	0	0	5	10	20	30	30	50	70	70	70	75	75	80	80	80	80	80	80	80
140 FOUNDARY	CONTENTS	0	0	0	0	0	0	0	10	17	24	29	34	38	43	45	50	58	62	66	69	74	77	81	81	81	81
141 FRAME SHOP	STRUCTURE	0	0	0	0	0	0	0	0	20	22	24	26	28	30	35	40	43	46	50	50	50	50	50	50	50	50
142 FRAME SHOP	CONTENTS	0	0	0	0	0	0	0	0	16	45	80	88	93	95	98	100	100	100	100	100	100	100	100	100	100	100

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

			DEPTH OF FLOODING (IN FEET)																									
			-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
143	FRUIT STAND	STRUCTURE	0	0	0	0	0	0	0	0	1	2	5	8	12	17	22	28	36	43	50	58	66	75	92	100	100	100
144	FRUIT STAND	CONTENTS	0	0	0	0	0	0	0	0	45	80	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
145	FUNERAL HOME	STRUCTURE	0	0	0	0	0	0	0	0	1	5	5	5	6	7	9	11	14	17	20	24	28	32	41	51	61	74
146	FUNERAL HOME	CONTENTS	0	0	0	0	0	0	0	0	10	30	60	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100
147	FURNITURE	STRUCTURE	0	0	0	0	0	0	0	0	2	4	4	5	6	7	9	11	14	17	21	25	29	33	42	51	60	72
148	FURNITURE	CONTENTS	0	0	0	0	0	0	0	40	60	70	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
149	FURNITURE MFG.	STRUCTURE	0	0	0	0	0	0	0	0	0	20	24	28	32	38	42	46	48	50	50	50	50	50	50	50	55	55
150	FURNITURE MFG.	CONTENTS	0	0	0	0	0	0	0	0	0	40	50	60	70	80	90	100	100	100	100	100	100	100	100	100	100	100
151	GARAGE	STRUCTURE	0	0	0	0	0	0	0	0	3	5	6	7	8	10	13	17	21	25	30	35	41	47	58	71	81	88
152	GARAGE	CONTENTS	0	0	0	0	0	0	0	0	11	17	20	23	25	29	35	42	51	63	77	93	100	100	100	100	100	100
153	GAS-BUTANE SUPPLY	STRUCTURE	0	0	0	0	0	0	0	17	17	17	17	23	32	45	55	61	66	69	73	76	78	80	85	87	90	93
154	GAS-BUTANE SUPPLY	CONTENTS	0	0	0	0	0	0	0	0	25	46	65	75	81	86	90	94	96	100	100	100	100	100	100	100	100	100
155	GIFT SHOP	STRUCTURE	0	0	0	0	0	0	0	0	5	8	9	9	9	11	14	18	24	31	40	50	58	64	73	80	85	90
156	GIFT SHOP	CONTENTS	0	0	0	0	0	0	0	0	54	63	75	88	100	100	100	100	100	100	100	100	100	100	100	100	100	100
157	GOLF COURSE	STRUCTURE	0	0	0	0	0	0	0	0	1	4	6	8	9	11	14	17	21	26	31	37	43	50	63	73	81	88
158	GOLF COURSE	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
159	GREENHOUSE	STRUCTURE	0	0	0	0	0	0	0	0	5	11	16	21	26	31	37	42	47	52	56	61	65	70	78	84	89	93
160	GREENHOUSE	CONTENTS	0	0	0	0	0	0	0	0	62	84	96	97	98	99	100	100	100	100	100	100	100	100	100	100	100	100
161	GROCERY	STRUCTURE	0	0	0	0	0	0	0	0	3	4	5	6	7	10	14	20	29	37	44	50	55	59	67	75	82	88
162	GROCERY	CONTENTS	0	0	0	0	0	0	0	4	31	51	77	97	100	100	100	100	100	100	100	100	100	100	100	100	100	100
163	GROCERY: DRIVE-IN	STRUCTURE	0	0	0	0	0	0	0	0	3	4	5	6	7	10	14	20	29	37	44	50	55	59	67	75	82	88
164	GROCERY: DRIVE-IN	CONTENTS	0	0	0	0	0	0	0	2	56	69	85	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100
165	GUN SHOP	STRUCTURE	0	0	0	0	0	0	0	0	10	10	10	11	12	13	14	16	18	20	22	25	29	34	50	63	72	79
166	GUN SHOP	CONTENTS	0	0	0	0	0	0	0	21	37	56	85	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
167	HALL	STRUCTURE	0	0	0	0	0	0	0	0	1	5	5	5	5	6	8	9	11	14	18	22	28	34	50	64	76	86
168	HALL	CONTENTS	0	0	0	0	0	0	0	0	5	8	10	12	14	18	24	32	44	60	85	95	100	100	100	100	100	100
169	HARDWARE	STRUCTURE	0	0	0	0	0	0	0	0	12	12	12	12	12	12	14	15	18	21	25	30	35	40	52	64	75	85
170	HARDWARE	CONTENTS	0	0	0	0	0	0	0	7	29	46	62	68	80	92	93	95	96	97	99	100	100	100	100	100	100	100
171	HEALTH CENTER	STRUCTURE	0	0	0	0	0	0	0	0	18	20	20	20	20	20	22	27	33	39	44	49	53	58	66	73	80	88
172	HEALTH CENTER	CONTENTS	0	0	0	0	0	0	0	0	25	45	75	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100
173	HEAT EXCHANGER MFG.	STRUCTURE	0	0	0	0	0	0	0	0	3	4	5	6	7	7	7	7	7	7	8	9	9	10	10	11	12	13
174	HEAT EXCHANGER MFG.	CONTENTS	0	0	0	0	0	0	0	0	11	18	24	29	33	36	38	41	43	45	50	55	59	62	68	70	73	75

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																									
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
175 HWY. MATL. STORAGE	STRUCTURE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176 HWY. MATL. STORAGE	CONTENTS	0	0	0	0	0	0	0	0	4	4	8	8	19	19	38	38	38	58	58	58	58	58	58	58	58	58
177 HOBBY SHOP	STRUCTURE	0	0	0	0	0	0	0	0	18	20	20	20	20	20	22	27	33	39	44	49	53	58	66	73	80	88
178 HOBBY SHOP	CONTENTS	0	0	0	0	0	0	0	0	28	53	67	78	88	99	99	99	99	99	99	99	99	99	99	99	99	99
179 HOSPITAL	STRUCTURE	0	0	0	0	0	0	0	0	0	0	20	25	30	35	40	43	47	50	53	55	57	60	60	60	60	60
180 HOSPITAL	CONTENTS	0	0	0	0	0	0	0	0	0	0	15	25	35	58	66	74	82	95	95	95	95	96	96	96	96	96
181 HOTEL	STRUCTURE	0	0	0	0	0	0	0	0	1	2	2	2	3	5	6	9	11	15	18	22	26	30	39	48	59	75
182 HOTEL	CONTENTS	0	0	0	0	0	0	0	0	11	22	28	33	37	41	44	46	49	54	60	69	81	100	100	100	100	100
183 IMPORT SALES	STRUCTURE	0	0	0	0	0	0	0	0	25	30	35	40	42	44	46	48	50	50	65	65	65	65	65	65	65	65
184 IMPORT SALES	CONTENTS	0	0	0	0	0	0	0	0	59	65	70	75	80	90	90	90	90	90	90	90	90	90	90	90	90	90
185 INSTRUMENT MFG.	STRUCTURE	0	0	0	0	0	0	0	0	5	8	12	14	16	17	19	20	20	20	24	26	28	29	33	36	39	43
186 INSTRUMENT MFG.	CONTENTS	0	0	0	0	0	0	0	0	14	24	32	40	48	56	62	69	79	86	89	95	100	100	100	100	100	100
187 JEWELRY SALES	STRUCTURE	0	0	0	0	0	0	0	0	1	2	2	2	3	4	6	8	9	12	15	20	25	32	50	64	73	81
188 JEWELRY SALES	CONTENTS	0	0	0	0	0	0	0	0	22	40	62	81	86	90	92	94	95	96	96	96	96	96	96	96	96	96
189 JEWELRY MFG.	STRUCTURE	0	0	0	0	0	0	0	0	20	22	24	26	28	30	32	34	36	36	36	40	40	40	40	40	40	40
190 JEWELRY MFG.	CONTENTS	0	0	0	0	0	0	0	0	22	40	62	81	86	90	92	94	95	96	96	96	96	96	96	96	96	96
191 LABORATORY: CHEM.	STRUCTURE	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45	45
192 LABORATORY: CHEM.	CONTENTS	0	0	0	0	0	0	0	0	27	28	51	51	60	70	79	89	89	90	90	91	91	91	91	91	91	91
193 LAUNDRY	STRUCTURE	0	0	0	0	0	0	0	0	2	5	8	12	15	18	21	23	26	28	31	33	36	39	47	57	69	81
194 LAUNDRY	CONTENTS	0	0	0	0	0	0	0	0	20	55	78	100	86	95	100	100	100	100	100	100	100	100	100	100	100	100
195 LAWNMOWER SALES	STRUCTURE	0	0	0	0	0	0	0	0	12	13	15	16	17	18	21	25	30	35	42	50	57	63	72	79	85	90
196 LAWNMOWER SALES	CONTENTS	0	0	0	0	0	0	0	0	9	76	89	91	93	94	96	97	98	100	100	100	100	100	100	100	100	100
197 LEATHER GOODS MFG.	STRUCTURE	0	0	0	0	0	0	0	0	9	15	17	21	23	24	25	25	25	25	30	31	33	35	38	41	44	48
198 LEATHER GOODS MFG.	CONTENTS	0	0	0	0	0	0	0	0	4	7	10	13	16	19	22	25	27	30	33	36	39	42	48	54	60	66
199 LIBRARY	STRUCTURE	0	0	0	0	0	0	0	0	1	2	2	2	3	4	6	8	9	12	15	20	25	32	50	64	73	81
200 LIBRARY	CONTENTS	0	0	0	0	0	0	0	0	35	50	75	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100
201 LIQUOR STORE	STRUCTURE	0	0	0	0	0	0	0	0	1	1	2	2	3	5	6	8	11	16	22	29	39	50	67	77	84	90
202 LIQUOR STORE	CONTENTS	0	0	0	0	0	0	0	0	19	39	58	79	99	100	100	100	100	100	100	100	100	100	100	100	100	100
203 LOADING DOCK: IND.	STRUCTURE	0	0	0	0	0	0	0	0	1	1	1	3	3	5	8	12	16	21	26	32	38	45	58	73	80	80
204 LOADING DOCK: IND.	CONTENTS	0	0	0	0	0	0	0	0	8	8	8	10	10	14	18	30	30	30	30	30	38	38	45	45	45	45
205 LUMBER MILL	STRUCTURE	0	0	0	0	0	0	0	0	3	5	8	10	13	15	18	20	23	25	28	30	33	35	40	45	50	50
206 LUMBER MILL	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																									
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
207 LUMBER YARD	STRUCTURE	0	0	0	0	0	0	0	0	1	1	1	1	1	4	4	5	5	7	9	13	17	21	33	46	61	78
208 LUMBER YARD	CONTENTS	0	0	0	0	0	0	0	0	20	30	45	60	75	90	100	100	100	100	100	100	100	100	100	100	100	100
209 MARINE SERVICE	STRUCTURE	0	0	0	0	0	0	0	0	1	2	3	4	5	6	7	8	9	10	10	10	10	10	10	10	10	10
210 MARINE SERVICE	CONTENTS	0	0	0	0	0	0	0	40	52	89	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
211 MACHINE SHOP: LT.	STRUCTURE	0	0	0	0	0	0	0	0	1	1	1	3	5	8	12	16	21	26	32	38	40	40	40	40	40	40
212 MACHINE SHOP: LT.	CONTENTS	0	0	0	0	0	0	0	0	1	37	47	57	57	58	67	67	68	68	68	69	78	79	79	79	79	79
213 MACHINE SHOP: HVY.	STRUCTURE	0	0	0	0	0	0	0	0	1	1	1	3	5	8	12	16	21	26	32	38	40	40	40	40	40	40
214 MACHINE SHOP: HVY.	CONTENTS	0	0	0	0	0	0	0	0	6	13	20	28	35	42	50	58	67	72	79	84	85	85	85	85	85	85
215 MAINT. BLDG.: MFG.	STRUCTURE	0	0	0	0	0	0	0	0	5	10	20	30	50	70	70	70	70	70	70	80	80	80	80	80	80	80
216 MAINT. BLDG.: MFG.	CONTENTS	0	0	0	0	0	0	0	0	10	15	20	25	35	45	45	45	45	50	50	50	55	55	60	60	60	60
217 MFG.: DETERGENT	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	50	50	50	50	50	50
218 MFG.: DETERGENT	CONTENTS	0	0	0	0	0	0	0	0	19	28	35	41	47	50	52	55	59	64	81	90	91	91	91	91	91	91
219 MEAT MARKET	STRUCTURE	0	0	0	0	0	0	0	0	10	10	10	11	12	14	17	23	31	38	44	50	55	61	71	79	87	92
220 MEAT MARKET	CONTENTS	0	0	0	0	0	0	0	0	84	86	88	93	100	100	100	100	100	100	100	100	100	100	100	100	100	100
221 MEAT PACKING	STRUCTURE	0	0	0	0	0	0	0	0	20	23	26	29	32	35	38	41	44	47	50	55	56	57	60	60	60	60
222 MEAT PACKING	CONTENTS	0	0	0	0	0	0	0	0	21	21	52	79	83	90	93	97	97	97	97	97	97	97	97	97	97	97
223 MEDICAL SUPPLIES	STRUCTURE	0	0	0	0	0	0	0	0	15	23	27	30	32	33	34	35	35	35	41	43	45	47	51	55	59	64
224 MEDICAL SUPPLIES	CONTENTS	0	0	0	0	0	0	0	0	17	33	48	63	67	71	75	80	85	89	93	98	100	100	100	100	100	100
225 METAL COATING SVC.	STRUCTURE	0	0	0	0	0	0	0	0	18	25	25	25	25	25	25	25	25	25	26	27	27	28	28	29	30	31
226 METAL COATING SVC.	CONTENTS	0	0	0	0	0	0	0	0	37	56	68	78	89	100	100	100	100	100	100	100	100	100	100	100	100	100
227 MIXER BLDG.: DTRGNT.	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45
228 MIXER BLDG.: DTRGNT.	CONTENTS	0	0	0	0	0	0	0	0	15	34	52	69	69	69	69	69	73	73	77	77	81	81	81	81	81	81
229 MOTEL	STRUCTURE	0	0	0	0	0	0	0	0	4	7	10	12	15	18	22	26	31	37	43	50	56	61	69	76	83	89
230 MOTEL	CONTENTS	0	0	0	0	0	0	0	0	30	48	63	75	90	100	100	100	100	100	100	100	100	100	100	100	100	100
231 MOTORCYCLE SALES	STRUCTURE	0	0	0	0	0	0	0	0	20	25	30	35	40	45	50	60	70	80	80	80	80	80	80	80	80	80
232 MOTORCYCLE SALES	CONTENTS	0	0	0	0	0	0	0	0	45	75	90	90	90	90	90	90	90	90	95	95	95	95	95	100	100	100
233 MUN. STRG. WHSE.	STRUCTURE	0	0	0	0	0	0	0	0	1	5	10	10	10	10	20	30	50	50	50	50	55	55	55	55	55	55
234 MUN. STRG. WHSE.	CONTENTS	0	0	0	0	0	0	0	0	11	17	20	22	24	29	36	48	67	85	90	90	90	90	90	90	90	90
235 MUSIC CENTER	STRUCTURE	0	0	0	0	0	0	0	5	10	13	14	15	15	15	16	18	23	27	37	50	59	66	75	82	87	91
236 MUSIC CENTER	CONTENTS	0	0	0	0	0	0	0	0	63	70	75	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100
237 NEWSPAPER PLANT	STRUCTURE	0	0	0	0	0	0	0	0	2	3	4	5	6	7	8	8	9	11	14	19	24	31	50	67	78	87
238 NEWSPAPER PLANT	CONTENTS	0	0	0	0	0	0	0	0	5	8	11	13	16	20	25	31	39	48	59	70	82	95	100	100	100	100

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																									
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
239 NEWSPAPER OFC.	STRUCTURE	0	0	0	0	0	0	0	10	15	18	24	25	25	26	27	28	31	33	36	40	43	47	56	65	74	84
240 NEWSPAPER OFC.	CONTENTS	0	0	0	0	0	0	0	0	5	11	23	37	77	100	100	100	100	100	100	100	100	100	100	100	100	100
241 NURSING HOME	STRUCTURE	0	0	0	0	0	0	0	0	7	10	14	15	15	16	18	20	23	26	30	34	38	42	52	62	72	84
242 NURSING HOME	CONTENTS	0	0	0	0	0	0	0	0	38	60	73	81	88	94	100	100	100	100	100	100	100	100	100	100	100	100
243 NURSERY: PLANT	STRUCTURE	0	0	0	0	0	0	0	2	2	3	6	10	15	22	27	32	37	41	46	50	54	58	65	73	80	87
244 NURSERY: PLANT	CONTENTS	0	0	0	0	0	0	0	0	50	65	75	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100
245 NURSERY: CHILD	STRUCTURE	0	0	0	0	0	0	0	0	15	16	16	20	25	29	33	37	41	44	47	50	53	56	61	68	77	86
246 NURSERY: CHILD	CONTENTS	0	0	0	0	0	0	0	0	24	50	88	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
247 OFFICE: MFG. FAC.	STRUCTURE	0	0	0	0	0	0	0	0	2	10	15	28	32	39	43	44	45	51	58	62	65	65	65	65	65	65
248 OFFICE: MFG. FAC.	CONTENTS	0	0	0	0	0	0	0	0	0	12	20	30	40	48	56	66	78	88	96	96	100	100	100	100	100	100
249 OFFICE BUILDING	STRUCTURE	0	0	0	0	0	0	0	0	12	14	17	19	23	27	31	35	40	45	50	55	59	63	71	77	83	89
250 OFFICE BUILDING	CONTENTS	0	0	0	0	0	0	0	0	16	21	24	25	26	28	31	36	42	50	71	84	100	100	100	100	100	100
251 OIL STORAGE TANKS	STRUCTURE	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2
252 OIL STORAGE TANKS	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
253 PAINT STORE	STRUCTURE	0	0	0	0	0	0	0	0	0	30	37	43	55	60	67	75	80	83	86	90	90	90	90	90	90	90
254 PAINT STORE	CONTENTS	0	0	0	0	0	0	0	0	0	20	40	59	69	72	75	79	79	79	79	79	79	79	79	79	79	79
255 PAPER PROD. WHSE.	STRUCTURE	0	0	0	0	0	0	0	0	18	25	25	25	25	25	25	25	25	25	26	27	27	28	28	29	30	31
256 PAPER PROD. WHSE.	CONTENTS	0	0	0	0	0	0	0	0	18	29	38	47	56	64	71	76	82	91	98	100	100	100	100	100	100	100
257 PAWN SHOP	STRUCTURE	0	0	0	0	0	0	0	0	20	30	33	36	39	42	45	47	50	50	50	60	60	60	60	60	60	60
258 PAWN SHOP	CONTENTS	0	0	0	0	0	0	0	0	19	38	91	91	93	93	94	94	94	94	94	94	94	94	94	94	94	94
259 PHOTO STUDIO	STRUCTURE	0	0	0	0	0	0	0	0	20	25	30	35	40	45	50	60	65	70	75	75	75	75	75	75	75	75
260 PHOTO STUDIO	CONTENTS	0	0	0	0	0	0	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100
261 PHOTO SVC.: AERIAL	STRUCTURE	0	0	0	0	0	0	0	0	11	17	22	24	27	28	29	30	30	30	35	37	39	41	45	49	53	57
262 PHOTO SVC.: AERIAL	CONTENTS	0	0	0	0	0	0	0	0	72	87	92	95	97	99	99	99	100	100	100	100	100	100	100	100	100	100
263 PIERS	STRUCTURE	0	0	0	0	0	0	0	20	40	60	80	85	100	100	100	100	100	100	100	100	100	100	100	100	100	100
264 PIERS	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
265 PIER DRILLING CO.	STRUCTURE	0	0	0	0	0	0	0	0	35	35	35	35	41	47	53	60	60	60	60	60	60	60	60	60	60	60
266 PIER DRILLING CO.	CONTENTS	0	0	0	0	0	0	0	0	20	23	39	55	55	56	56	57	57	57	57	57	57	57	57	57	57	57
267 PIPE THREADER FAC.	STRUCTURE	0	0	0	0	0	0	0	0	1	5	10	10	10	20	30	50	50	50	75	75	75	90	90	90	90	90
268 PIPE THREADER FAC.	CONTENTS	0	0	0	0	0	0	0	0	25	25	50	50	50	50	75	75	75	75	90	90	90	100	100	100	100	100
269 PLBG./HTG. CNTRCTR.	STRUCTURE	0	0	0	0	0	0	0	0	0	20	25	30	35	40	45	50	60	60	60	60	60	60	60	60	60	60
270 PLBG./HTG. CNTRCTR.	CONTENTS	0	0	0	0	0	0	0	0	40	50	60	70	80	80	80	80	80	80	80	80	80	80	80	80	80	80

TABLE 5 - 5 (Continued)
STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																							
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
271 PLASTIC MFG.	STRUCTURE	0	0	0	0	0	0	0	0	12	18	23	24	27	28	29	30	30	30	35	37	39	40	44	48	51	55
272 PLASTIC MFG.	CONTENTS	0	0	0	0	0	0	0	0	17	30	40	49	58	67	75	83	90	93	97	100	100	100	100	100	100	100
273 PLUMBING CO.	STRUCTURE	0	0	0	0	0	0	0	0	20	32	40	47	53	57	61	64	67	70	72	74	77	78	82	85	89	92
274 PLUMBING CO.	CONTENTS	0	0	0	0	0	0	0	0	19	41	51	70	95	95	95	95	95	95	100	100	100	100	100	100	100	100
275 POLICE STATION	STRUCTURE	0	0	0	0	0	0	0	0	12	14	17	19	23	27	31	35	40	45	50	55	59	63	71	77	83	89
276 POLICE STATION	CONTENTS	0	0	0	0	0	0	0	0	5	15	25	35	48	62	78	95	100	100	100	100	100	100	100	100	100	100
277 POST OFFICE	STRUCTURE	0	0	0	0	0	0	0	0	8	15	24	25	26	27	29	32	36	40	45	50	56	62	71	78	85	90
278 POST OFFICE	CONTENTS	0	0	0	0	0	0	0	25	43	63	70	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100
279 PRESSURE TEST FAC.	STRUCTURE	0	0	0	0	0	0	0	0	1	5	10	10	10	20	30	50	50	50	75	75	75	90	90	90	90	90
280 PRESSURE TEST FAC.	CONTENTS	0	0	0	0	0	0	0	0	20	20	25	25	30	30	40	40	40	40	40	40	40	40	40	40	40	40
281 PRINTING: COMMER.	STRUCTURE	0	0	0	0	0	0	0	0	20	23	26	29	32	35	39	42	45	47	50	60	60	60	60	60	60	60
282 PRINTING: COMMER.	CONTENTS	0	0	0	0	0	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
283 PRIVATE CLUB	STRUCTURE	0	0	0	0	0	0	0	0	5	8	8	9	9	9	10	12	14	17	21	26	32	40	58	70	79	87
284 PRIVATE CLUB	CONTENTS	0	0	0	0	0	0	0	0	28	36	41	45	50	54	60	66	73	84	92	97	100	100	100	100	100	100
285 PRIVATE STORAGE	STRUCTURE	0	0	0	0	0	0	0	0	0	4	8	12	16	20	25	30	35	40	45	50	50	50	50	50	50	50
286 PRIVATE STORAGE	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
287 QUONSET HUT STRG.	STRUCTURE	0	0	0	0	0	0	0	0	2	4	5	8	10	12	15	20	25	35	45	60	70	70	70	70	70	70
288 QUONSET HUT STRG.	CONTENTS	0	0	0	0	0	0	0	0	11	16	19	21	23	28	35	47	67	85	90	90	90	90	90	90	90	90
289 RADIO STATION	STRUCTURE	0	0	0	0	0	0	0	0	8	15	24	25	26	27	29	32	36	40	45	50	56	62	71	78	85	90
290 RADIO STATION	CONTENTS	0	0	0	0	0	0	0	0	20	40	65	85	95	100	100	100	100	100	100	100	100	100	100	100	100	100
291 REAL ESTATE OFC.	STRUCTURE	0	0	0	0	0	0	0	0	8	15	24	25	26	27	29	32	36	40	45	50	56	62	71	78	85	90
292 REAL ESTATE OFC.	CONTENTS	0	0	0	0	0	0	0	12	21	35	55	77	95	100	100	100	100	100	100	100	100	100	100	100	100	100
293 RECYCLING: METAL	STRUCTURE	0	0	0	0	0	0	0	0	5	10	20	40	50	60	70	80	100	100	100	100	100	100	100	100	100	100
294 RECYCLING: METAL	CONTENTS	0	0	0	0	0	0	0	0	0	0	10	20	20	20	40	40	40	40	40	40	50	50	50	50	50	50
295 RECREATION FAC.	STRUCTURE	0	0	0	0	0	0	0	0	0	0	2	5	10	10	15	15	20	20	25	25	35	35	45	45	45	45
296 RECREATION FAC.	CONTENTS	0	0	0	0	0	0	0	0	15	30	35	53	73	80	80	80	80	80	80	80	80	80	88	100	100	100
297 REFINERY: CAUST. MTL.	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45
298 REFINERY: CAUST. MTL.	CONTENTS	0	0	0	0	0	0	0	0	37	48	73	78	78	78	79	79	79	79	79	79	80	80	80	80	81	81
299 REFINERY: LEAD	STRUCTURE	0	0	0	0	0	0	0	0	2	10	15	20	32	39	43	44	45	51	58	62	65	65	65	65	65	65
300 REFINERY: LEAD	CONTENTS	0	0	0	0	0	0	0	0	11	20	30	40	49	59	69	79	81	81	81	81	81	81	81	81	81	81
301 REMNANT SHOP	STRUCTURE	0	0	0	0	0	0	0	0	0	15	15	20	25	30	35	40	45	50	55	65	75	80	80	80	80	80
302 REMNANT SHOP	CONTENTS	0	0	0	0	0	0	0	0	0	22	40	58	77	86	91	95	95	95	95	98	98	98	98	98	98	98

TABLE 5 - 5 (Continued)
STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																									
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
303 RENDERING PLANT	STRUCTURE	0	0	0	0	0	0	0	0	12	14	17	19	23	27	31	35	40	45	45	50	50	50	55	55	55	55
304 RENDERING PLANT	CONTENTS	0	0	0	0	0	0	0	0	17	29	50	67	83	87	87	87	87	87	87	87	87	87	87	87	87	87
305 RESEARCH LAB: MACH.	STRUCTURE	0	0	0	0	0	0	0	0	12	14	17	19	23	27	31	35	40	45	50	55	60	60	70	70	70	70
306 RESEARCH LAB: MACH.	CONTENTS	0	0	0	0	0	0	0	0	20	32	43	55	60	63	64	65	66	68	68	68	70	70	70	70	70	70
307 RESTAURANT	STRUCTURE	0	0	0	0	0	0	0	0	15	18	20	23	25	27	28	30	33	37	43	50	58	64	72	78	85	90
308 RESTAURANT	CONTENTS	0	0	0	0	0	0	0	0	20	40	80	90	92	94	100	100	100	100	100	100	100	100	100	100	100	100
309 RESTAURANT: DRIVE-IN	STRUCTURE	0	0	0	0	0	0	0	0	2	4	7	10	14	18	23	28	33	39	44	50	56	61	70	77	83	89
310 RESTAURANT: DRIVE-IN	CONTENTS	0	0	0	0	0	0	0	0	25	50	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
311 REUPHOLSTERY SHOP	STRUCTURE	0	0	0	0	0	0	0	0	10	10	10	11	12	13	14	15	20	30	30	30	30	30	30	30	30	30
312 REUPHOLSTERY SHOP	CONTENTS	0	0	0	0	0	0	0	0	23	28	36	41	45	50	53	58	58	59	60	60	60	60	60	60	60	60
313 SAFETY EQUIPMENT	STRUCTURE	0	0	0	0	0	0	0	0	8	16	23	28	33	37	39	40	40	40	43	44	45	47	49	52	54	57
314 SAFETY EQUIPMENT	CONTENTS	0	0	0	0	0	0	0	0	12	25	37	50	62	75	85	93	97	100	100	100	100	100	100	100	100	100
315 SAND & GRAVEL CO.	STRUCTURE	0	0	0	0	0	0	0	0	2	4	6	8	10	11	12	13	14	15	15	15	15	15	15	15	15	15
316 SAND & GRAVEL CO.	CONTENTS	0	0	0	0	0	0	0	0	0	1	5	7	8	9	10	11	12	13	18	23	23	23	27	30	33	33
317 SANDBLASTING CO.	STRUCTURE	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
318 SANDBLASTING CO.	CONTENTS	0	0	0	0	0	0	0	0	15	45	68	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
319 SCHOOL	STRUCTURE	0	0	0	0	0	0	0	0	8	12	15	15	16	17	19	22	25	28	32	36	40	45	54	64	74	85
320 SCHOOL	CONTENTS	0	0	0	0	0	0	0	10	18	26	45	66	76	88	100	100	100	100	76	88	100	100	100	100	100	100
321 SCALE BUILDING	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45
322 SCALE BUILDING	CONTENTS	0	0	0	0	0	0	0	0	0	5	15	25	40	50	75	85	100	100	100	100	100	100	100	100	100	100
323 SEPARATORS	STRUCTURE	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
324 SEPARATORS	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
325 SERVICE STATION	STRUCTURE	0	0	0	0	0	0	0	0	0	1	3	5	7	10	13	16	19	23	27	33	38	49	69	82	90	94
326 SERVICE STATION	CONTENTS	0	0	0	0	0	0	0	0	13	40	60	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100
327 SEWAGE TREATMENT	STRUCTURE	0	0	0	0	0	0	0	0	2	4	4	4	5	6	8	12	16	21	27	34	42	50	68	87	97	97
328 SEWAGE TREATMENT	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
329 SHEET METAL	STRUCTURE	0	0	0	0	0	0	0	0	30	30	30	30	33	36	39	40	40	40	40	40	40	40	40	40	40	40
330 SHEET METAL	CONTENTS	0	0	0	0	0	0	0	0	29	41	46	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58
331 SHOE STORE	STRUCTURE	0	0	0	0	0	0	0	0	3	6	9	12	15	18	21	24	27	30	33	36	39	40	50	50	50	50
332 SHOE STORE	CONTENTS	0	0	0	0	0	0	0	0	10	23	35	48	59	73	85	98	98	98	98	98	98	98	98	98	98	98
333 SKATING RINK	STRUCTURE	0	0	0	0	0	0	0	0	12	15	15	15	15	15	15	15	15	15	16	16	16	16	16	17	17	17
334 SKATING RINK	CONTENTS	0	0	0	0	0	0	0	0	10	25	50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

DEPTH OF FLOODING (IN FEET)

		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
335 SPORTING GOODS WHSE.	STRUCTURE	0	0	0	0	0	0	0	0	10	17	22	24	26	27	28	30	30	30	35	37	39	41	45	49	53	57
336 SPORTING GOODS WHSE.	CONTENTS	0	0	0	0	0	0	0	0	35	50	63	75	87	100	100	100	100	100	100	100	100	100	100	100	100	100
337 STORAGE: MACH. PARTS	STRUCTURE	0	0	0	0	0	0	0	0	5	10	20	30	50	70	70	70	70	70	70	70	70	70	70	70	70	70
338 STORAGE: MACH. PARTS	CONTENTS	0	0	0	0	0	0	0	0	20	30	40	50	50	50	75	75	75	100	100	100	100	100	100	100	100	100
339 STORAGE: CHEM.	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45
340 STORAGE: CHEM.	CONTENTS	0	0	0	0	0	0	0	0	11	16	22	28	38	48	60	72	80	80	80	80	80	80	80	80	80	80
341 SWIMMING POOL	STRUCTURE	0	0	0	0	0	0	0	0	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
342 SWIMMING POOL	CONTENTS	0	0	0	0	0	0	0	0	25	50	75	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
343 TAR VAT BUILDING	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	51	58	65	80	80	80
344 TAR VAT BUILDING	CONTENTS	0	0	0	0	0	0	0	0	5	10	15	25	35	50	50	60	60	60	60	60	60	60	60	60	60	60
345 TAVERN	STRUCTURE	0	0	0	0	0	0	0	0	15	18	20	22	24	27	31	34	38	42	46	50	54	58	66	73	80	87
346 TAVERN	CONTENTS	0	0	0	0	0	0	0	38	60	74	89	97	100	100	100	100	100	100	100	100	100	100	100	100	100	100
347 TELEPHONE EXCHANGE	STRUCTURE	0	0	0	0	0	0	0	0	12	14	17	19	23	27	31	35	40	45	50	55	59	63	71	77	83	89
348 TELEPHONE EXCHANGE	CONTENTS	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
349 THEATER	STRUCTURE	0	0	0	0	0	0	0	0	2	3	4	4	4	5	7	10	13	16	21	25	30	36	47	60	72	84
350 THEATER	CONTENTS	0	0	0	0	0	0	0	0	3	4	5	6	6	6	9	12	16	22	28	37	46	57	80	95	100	100
351 THEATER: DRIVE-IN	STRUCTURE	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	3	4	5	5	6	7	12	20	30	42
352 THEATER: DRIVE-IN	CONTENTS	0	0	0	0	0	0	0	0	0	2	2	2	4	5	9	13	18	23	30	37	46	54	72	93	100	100
353 TRACTOR SALES	STRUCTURE	0	0	0	0	0	0	0	0	9	13	18	21	22	23	24	25	25	25	26	27	28	29	30	31	33	35
354 TRACTOR SALES	CONTENTS	0	0	0	0	0	0	0	0	6	17	29	44	58	69	76	80	83	87	91	94	98	99	100	100	100	100
355 TRAILER MFG.	STRUCTURE	0	0	0	0	0	0	0	0	2	2	2	2	3	4	5	6	7	10	10	10	10	10	10	10	10	10
356 TRAILER MFG.	CONTENTS	0	0	0	0	0	0	0	0	27	30	37	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
357 TRANSPORT CO.	STRUCTURE	0	0	0	0	0	0	0	0	9	11	12	16	20	24	28	30	30	30	30	30	30	30	30	30	30	30
358 TRANSPORT CO.	CONTENTS	0	0	0	0	0	0	0	0	60	75	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
359 TRAILER SALES	STRUCTURE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
360 TRAILER SALES	CONTENTS	0	0	0	0	0	0	0	0	18	37	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100
361 TRAILER PARTS	STRUCTURE	0	0	0	0	0	0	0	0	0	5	10	15	20	25	30	32	36	38	40	50	60	60	60	60	60	60
362 TRAILER PARTS	CONTENTS	0	0	0	0	0	0	0	0	0	7	13	24	27	34	36	39	50	50	50	50	55	55	55	55	55	55
363 TRUCK MFG. & SALES	STRUCTURE	0	0	0	0	0	0	0	0	12	18	23	26	27	28	29	30	30	30	32	33	35	35	37	39	41	42
364 TRUCK MFG. & SALES	CONTENTS	0	0	0	0	0	0	0	0	39	57	63	70	75	80	83	90	91	91	100	100	100	100	100	100	100	100
365 TROPHY SHOP	STRUCTURE	0	0	0	0	0	0	0	0	8	9	10	12	15	17	18	18	19	20	23	29	33	38	49	61	74	88
366 TROPHY SHOP	CONTENTS	0	0	0	0	0	0	0	0	17	26	31	49	62	66	69	71	71	72	73	74	76	77	83	100	100	100

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																									
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
367 TV REPAIR	STRUCTURE	0	0	0	0	0	0	0	0	0	0	20	30	40	50	60	70	75	80	80	80	80	80	80	80	80	80
368 TV REPAIR	CONTENTS	0	0	0	0	0	0	0	0	0	0	20	37	54	71	76	80	80	81	81	82	82	82	82	82	82	82
369 TV STATION	STRUCTURE	0	0	0	0	0	0	0	0	1	5	5	5	5	5	6	6	8	10	14	19	25	32	50	65	76	86
370 TV STATION	CONTENTS	0	0	0	0	0	0	0	0	20	40	65	85	95	100	100	100	100	100	100	100	100	100	100	100	100	100
371 USED APPL. & CLOTHING	STRUCTURE	0	0	0	0	0	0	0	0	10	12	14	16	18	20	23	26	30	40	45	55	55	55	55	55	55	55
372 USED APPL. & CLOTHING	CONTENTS	0	0	0	0	0	0	0	0	18	33	65	88	95	100	100	100	100	100	100	100	100	100	100	100	100	100
373 USED FURNITURE	STRUCTURE	0	0	0	0	0	0	0	0	0	20	24	28	32	36	40	44	48	50	50	55	55	60	60	60	60	60
374 USED FURNITURE	CONTENTS	0	0	0	0	0	0	0	40	60	70	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
375 UTILITY COMPANY	STRUCTURE	0	0	0	0	0	0	0	0	0	0	10	14	18	22	26	30	34	36	38	40	40	45	50	50	50	50
376 UTILITY COMPANY	CONTENTS	0	0	0	0	0	0	0	0	1	1	5	7	10	11	12	13	14	15	15	16	16	16	16	16	16	16
377 VACUUM CLEANER SALES	STRUCTURE	0	0	0	0	0	0	0	0	10	15	20	25	30	33	36	40	50	55	60	60	60	60	60	60	60	60
378 VACUUM CLEANER SALES	CONTENTS	0	0	0	0	0	0	0	0	44	58	66	71	74	78	78	78	85	85	85	85	93	93	93	93	93	93
379 VACANT BLDG.: CNCR.	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45
380 VACANT BLDG.: CNCR.	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
381 VARIETY STORE	STRUCTURE	0	0	0	0	0	0	0	0	8	9	10	12	15	17	18	18	19	20	23	26	29	33	43	55	67	80
382 VARIETY STORE	CONTENTS	0	0	0	0	0	0	0	10	20	40	70	85	90	95	100	100	100	100	100	100	100	100	100	100	100	100
383 VETERINARY CLINIC	STRUCTURE	0	0	0	0	0	0	0	0	1	3	4	6	9	11	14	17	20	24	29	35	42	50	63	73	81	88
384 VETERINARY CLINIC	CONTENTS	0	0	0	0	0	0	0	25	50	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
385 WAREHOUSE: HVY. MACH.	STRUCTURE	0	0	0	0	0	0	0	0	2	4	5	6	7	8	10	13	17	21	25	30	35	35	35	35	35	35
386 WAREHOUSE: HVY. MACH.	CONTENTS	0	0	0	0	0	0	0	0	9	24	24	33	38	47	70	71	72	73	74	75	84	84	89	89	89	89
387 WAREHOUSE: BEER	STRUCTURE	0	0	0	0	0	0	0	0	2	4	5	6	7	8	10	13	17	21	25	30	30	35	35	35	35	35
388 WAREHOUSE: BEER	CONTENTS	0	0	0	0	0	0	0	0	21	84	88	92	96	97	97	97	97	97	97	97	97	97	97	97	97	97
389 WAREHOUSE: BTL. GASES	STRUCTURE	0	0	0	0	0	0	0	0	1	2	3	4	5	8	12	16	21	26	32	38	45	51	65	82	82	82
390 WAREHOUSE: BTL. GASES	CONTENTS	0	0	0	0	0	0	0	0	8	8	8	14	16	20	28	28	30	30	30	30	38	41	41	41	41	41
391 WAREHOUSE: PETR.	STRUCTURE	0	0	0	0	0	0	0	0	2	4	5	6	7	8	10	13	17	21	25	30	30	35	35	35	35	35
392 WAREHOUSE: PETR.	CONTENTS	0	0	0	0	0	0	0	0	0	0	9	20	40	59	77	77	77	78	78	78	78	78	78	78	78	78
393 WAREHOUSE: CEMENT	STRUCTURE	0	0	0	0	0	0	0	0	1	1	3	5	8	12	16	21	26	32	38	45	45	45	45	45	45	45
394 WAREHOUSE: CEMENT	CONTENTS	0	0	0	0	0	0	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100
395 WAREHOUSE	STRUCTURE	0	0	0	0	0	0	0	0	0	1	1	1	3	5	8	12	16	21	26	32	38	45	58	73	88	96
396 WAREHOUSE	CONTENTS	0	0	0	0	0	0	0	20	30	40	50	60	70	80	90	100	100	100	100	100	100	100	100	100	100	100
397 WASHATERIA	STRUCTURE	0	0	0	0	0	0	0	0	6	6	6	7	8	10	12	15	18	23	27	32	38	44	56	69	82	95
398 WASHATERIA	CONTENTS	0	0	0	0	0	0	0	0	20	55	78	100	86	95	100	100	100	100	100	100	100	100	100	100	100	100

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																							
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
399 WATER SUPPLY	STRUCTURE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
400 WATER SUPPLY	CONTENTS	0	0	0	0	0	0	0	0	0	0	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
401 WATER WELL SVC.	STRUCTURE	0	0	0	0	0	0	0	0	5	20	40	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
402 WATER WELL SVC.	CONTENTS	0	0	0	0	0	0	0	0	0	25	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
403 WELDING REPAIR	STRUCTURE	0	0	0	0	0	0	0	17	17	17	17	23	32	45	55	61	66	69	73	76	78	80	85	87	90	93
404 WELDING REPAIR	CONTENTS	0	0	0	0	0	0	0	0	1	6	15	18	20	21	22	24	27	30	33	37	41	45	54	63	73	84
405 WELDING SUPL.: WHLSL.	STRUCTURE	0	0	0	0	0	0	0	0	7	13	18	22	25	27	30	32	34	37	40	44	47	51	59	67	76	85
406 WELDING SUPL.: WHLSL.	CONTENTS	0	0	0	0	0	0	0	0	15	35	45	50	57	66	80	100	100	100	100	100	100	100	100	100	100	100
407 WELLHEAD	STRUCTURE	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2
408 WELLHEAD	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
409 WESTERN AUTO STORE	STRUCTURE	0	0	0	0	0	0	0	0	4	6	7	11	11	18	24	30	36	41	46	50	53	57	64	71	78	86
410 WESTERN AUTO STORE	CONTENTS	0	0	0	0	0	0	0	0	21	46	69	84	97	97	97	98	98	98	99	99	99	100	100	100	100	100
411 X-RAY SERVICE	STRUCTURE	0	0	0	0	0	0	0	0	5	7	12	13	14	15	15	15	15	15	18	19	20	21	23	25	27	29
412 X-RAY SERVICE	CONTENTS	0	0	0	0	0	0	0	0	20	40	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
413 YMCA	STRUCTURE	0	0	0	0	0	0	0	0	25	33	33	33	33	33	33	33	33	33	35	35	35	36	37	38	39	39
414 YMCA	CONTENTS	0	0	0	0	0	0	0	0	0	5	24	50	82	100	100	100	100	100	100	100	100	100	100	100	100	100
415 BALL PARK	STRUCTURE	0	0	0	0	0	0	0	0	10	26	42	52	57	61	66	70	73	77	80	80	80	80	80	80	80	80
416 BALL PARK	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
417 BARN	STRUCTURE	0	0	0	0	0	0	0	0	8	13	18	25	35	45	55	65	72	78	85	85	85	85	85	85	85	85
418 BARN	CONTENTS	0	0	0	0	0	0	0	0	8	13	18	25	35	45	55	65	72	78	85	85	85	85	85	85	85	85
419 TENNIS COURT	STRUCTURE	0	0	0	0	0	0	0	0	25	29	33	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
420 TENNIS COURT	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
421 GENL. OFFICE COMM.	STRUCTURE	0	0	0	0	0	0	0	0	8	10	12	14	17	20	23	26	30	34	38	43	48	52	61	69	77	84
422 GENL. OFFICE COMM.	CONTENTS	0	0	0	0	0	0	0	12	21	55	77	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100
423 GENL. RETAIL COMM.	STRUCTURE	0	0	0	0	0	0	0	0	8	10	12	14	16	19	22	25	29	33	38	43	48	52	60	67	73	79
424 GENL. RETAIL COMM.	CONTENTS	0	0	0	0	0	0	0	0	18	33	65	88	95	100	100	100	100	100	100	100	100	100	100	100	100	100
425 GENL. WHLSL. & IND.	STRUCTURE	0	0	0	0	0	0	0	1	4	8	10	14	18	23	26	30	33	38	42	46	48	50	52	55	58	60
426 GENL. WHLSL. & IND.	CONTENTS	0	0	0	0	0	0	0	0	9	16	21	24	28	31	34	37	41	45	46	47	48	48	49	50	51	51
427 GENL. PUB. OPEN SP.	STRUCTURE	0	0	0	0	0	0	0	0	15	23	30	34	35	37	39	41	43	45	48	50	52	55	58	62	65	68
428 GENL. PUB. OPEN SP.	CONTENTS	0	0	0	0	0	0	0	4	12	13	21	23	25	26	26	27	28	29	30	31	31	31	31	31	31	31
429 GENL. PUB. STRUC.	STRUCTURE	0	0	0	0	0	0	0	0	8	9	11	12	13	14	17	18	21	24	27	30	36	41	52	61	70	78
430 GENL. PUB. STRUC.	CONTENTS	0	0	0	0	0	0	0	3	26	45	59	69	74	79	81	84	87	90	93	96	98	98	99	100	100	100

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

DEPTH OF FLOODING (IN FEET)

		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
431 ELEC. POWER SUBSTA.	STRUCTURE	0	0	0	0	0	0	0	0	6	12	18	24	27	30	33	36	39	42	45	48	51	54	60	66	72	78
432 ELEC. POWER SUBSTA.	CONTENTS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
433 RAILROAD	STRUCTURE	0	5	6	8	8	8	8	10	15	20	45	65	75	90	95	95	95	95	95	95	95	95	95	95	95	95
434 RAILROAD	CONTENTS	0	0	0	0	0	0	0	0	50	54	65	73	86	87	87	89	90	90	90	90	90	90	90	90	90	90
522 6 FLAGS FOOD SERV	CONTENTS	0	0	0	0	0	0	0	0	4	32	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
524 6 FLAGS TX STA	CONTENTS	0	0	0	0	0	0	0	0	10	45	80	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100
526 6 FLAGS CAR MAINT	CONTENTS	0	0	0	0	0	0	0	0	5	25	45	73	100	100	100	100	100	100	100	100	100	100	100	100	100	100
528 6 FLAGS SPINDLETOP	CONTENTS	0	0	0	0	0	0	0	0	5	45	85	93	100	100	100	100	100	100	100	100	100	100	100	100	100	100
530 6 FLAGS CAVE	CONTENTS	0	0	0	0	0	0	0	0	10	43	75	88	100	100	100	100	100	100	100	100	100	100	100	100	100	100
532 6 FLAGS MAINT BLDG	CONTENTS	0	0	0	0	0	0	0	0	30	53	85	93	100	100	100	100	100	100	100	100	100	100	100	100	100	100
534 6 FLAGS GFT&SOUVEN	CONTENTS	0	0	0	0	0	0	0	0	0	5	10	43	75	100	100	100	100	100	100	100	100	100	100	100	100	100
536 6 FLAGS GIFTS	CONTENTS	0	0	0	0	0	0	0	0	5	10	15	45	75	100	100	100	100	100	100	100	100	100	100	100	100	100
538 6 FLAGS SKEEBALL	CONTENTS	0	0	0	0	0	0	0	0	2	9	16	18	20	22	24	26	28	30	32	34	36	38	42	46	50	54
540 6 FLAGS PORTRAITS	CONTENTS	0	0	0	0	0	0	0	0	10	18	25	53	80	100	100	100	100	100	100	100	100	100	100	100	100	100
542 6 FLAGS SHOOT GAL	CONTENTS	0	0	0	0	0	0	0	0	6	19	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
544 6 FLAGS VIDEOGAMES	CONTENTS	0	0	0	0	0	0	0	0	0	50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
546 6 FLAGS SHIRTS&HAT	CONTENTS	0	0	0	0	0	0	0	0	14	32	50	68	85	100	100	100	100	100	100	100	100	100	100	100	100	100
548 6 FLAGS GAMES	CONTENTS	0	0	0	0	0	0	0	0	4	5	6	8	9	11	12	14	15	17	18	20	21	23	26	29	32	35
550 6 FLAGS WAREHOUSE	CONTENTS	0	0	0	0	0	0	0	0	7	17	27	34	41	48	55	62	69	76	83	90	97	100	100	100	100	100
551 AIRCRAFT PARTS MFG.	STRUCTURE	0	0	0	0	0	0	0	1	4	8	10	14	18	23	26	30	33	38	42	46	48	50	52	55	58	60
552 AIRCRAFT PARTS MFG.	CONTENTS	0	0	0	0	0	0	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100
553 CORK AND SEAL MFG.	STRUCTURE	0	0	0	0	0	0	0	1	4	8	10	14	18	23	26	30	33	38	42	46	48	50	52	55	58	60
554 CORK AND SEAL MFG.	CONTENTS	0	0	0	0	0	0	0	0	10	20	35	50	60	70	80	90	95	100	100	100	100	100	100	100	100	100
555 SOFT DRINK BOTTLING	STRUCTURE	0	0	0	0	0	0	0	1	4	8	10	14	18	23	26	30	33	38	42	46	48	50	52	55	58	60
556 SOFT DRINK BOTTLING	CONTENTS	0	0	0	0	0	0	0	0	20	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
557 CHEMICAL MFG. CO.	STRUCTURE	0	0	0	0	0	0	0	1	4	8	10	14	18	23	26	30	33	38	42	46	48	50	52	55	58	60
558 CHEMICAL MFG. CO.	CONTENTS	0	0	0	0	0	0	0	0	20	40	60	80	90	100	100	100	100	100	100	100	100	100	100	100	100	100
559 RADIO TOWER FACILITY	STRUCTURE	0	0	0	0	0	0	0	1	4	8	10	14	18	23	26	30	33	38	42	46	48	50	52	55	58	60
560 RADIO TOWER FACILITY	CONTENTS	0	0	0	0	0	0	0	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
561 OIL FIELD SUPPLIES	STRUCTURE	0	0	0	0	0	0	0	1	4	8	10	14	18	23	26	30	33	38	42	46	48	50	52	55	58	60
562 OIL FIELD SUPPLIES	CONTENTS	0	0	0	0	0	0	0	0	10	20	40	75	100	100	100	100	100	100	100	100	100	100	100	100	100	100
563 OFFICE SUPPLIES	STRUCTURE	0	0	0	0	0	0	0	0	8	10	12	14	16	19	22	25	29	33	38	43	48	52	60	67	73	79

TABLE 5 - 5 (Continued)

STDMA DEPTH-DAMAGE CURVE VALUES

		DEPTH OF FLOODING (IN FEET)																								
		-4.1	-4.0	-3.0	-2.1	-2.0	-1.0	-0.1	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	16.0	18.0	20.0	22.0
564 OFFICE SUPPLIES	CONTENTS	0	0	0	0	0	0	0	0	20	40	65	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100
565 CLOCK SHOP	STRUCTURE	0	0	0	0	0	0	0	0	8	10	12	14	16	19	22	25	29	33	38	43	48	52	60	67	73	79
566 CLOCK SHOP	CONTENTS	0	0	0	0	0	0	0	20	80	83	86	90	93	96	100	100	100	100	100	100	100	100	100	100	100	100
567 CAMERAS & PHOTO SUP	STRUCTURE	0	0	0	0	0	0	0	0	8	10	12	14	16	19	22	25	29	33	38	43	48	52	60	67	73	79
568 CAMERAS & PHOTO SUP	CONTENTS	0	0	0	0	0	0	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100
569 SHOE & BOOT REPAIR	STRUCTURE	0	0	0	0	0	0	0	0	8	10	12	14	16	19	22	25	29	33	38	43	48	52	60	67	73	79
570 SHOE & BOOT REPAIR	CONTENTS	0	0	0	0	0	0	0	0	10	15	20	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100
571 AIR CONDITIONING SVC	STRUCTURE	0	0	0	0	0	0	0	0	8	10	12	14	16	19	22	25	29	33	38	43	48	52	60	67	73	79
572 AIR CONDITIONING SVC	CONTENTS	0	0	0	0	0	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
573 VIDEO RENTAL STORE	STRUCTURE	0	0	0	0	0	0	0	0	8	10	12	14	16	19	22	25	29	33	38	43	48	52	60	67	73	79
574 VIDEO RENTAL STORE	CONTENTS	0	0	0	0	0	0	0	0	10	20	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100
575 PARK	STRUCTURE	0	0	0	0	0	0	0	0	10	26	42	52	57	61	66	70	73	77	80	80	80	80	80	80	80	80
576 PARK	CONTENTS	0	0	0	0	0	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
577 CAMPGROUND	STRUCTURE	0	0	0	0	0	0	0	0	10	26	42	52	57	61	66	70	73	77	80	80	80	80	80	80	80	80
578 CAMPGROUND	CONTENTS	0	0	0	0	0	0	0	20	40	60	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
579 PECAN FARM	STRUCTURE	0	0	0	0	0	0	0	0	8	13	18	25	35	45	55	65	72	78	85	85	85	85	85	85	85	85
580 PECAN FARM	CONTENTS	0	0	0	0	0	0	0	20	10	40	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

APPENDIX 6

WETLANDS DETERMINATION

APPENDIX 6 - WETLANDS DETERMINATION

BACKGROUND

One primary goal of the Prototype Methodology Study was to develop a methodology which would allow the GIS to assist in further evaluation of processes used to delineate wetlands throughout the study area. The GIS was used to analyze the inter-relationships of several spatial data layers in order to produce a "first-cut" determination of wetland locations in the study area. This analysis was **NOT** meant to provide a jurisdictional wetlands determination, but rather to establish a methodology to allow the GIS to assist in the initial assessment as to the likelihood of wetlands occurring in a given location. Fundamental to this process is the question of "what is a wetland?". This question has recently become even more pertinent as the rules governing wetlands determination have changed. At the time of this writing, the final directive for jurisdictional wetland determinations had not been officially mandated. The methodology for wetland determination used in this Study was based on the joint delineation rules established in **1989** because this is the only joint resolution manual available for all of the Federal agencies to use. The technical criteria used in this manual is a good indicator for potential wetland areas and provides a good basis for investigative planning work. While the basic definition of a wetland should remain essentially the same, modifications to the 1989 Wetland Identification Manual may require that the data layers used in this analysis be modified or adjusted to account for the changes. These 1989 rules are currently suspended and are not being enforced in providing jurisdictional wetland determinations.

PARTICIPANTS

Tom Cloud from the U.S. Fish and Wildlife Service (USFWS), Dennis Ressel and John Allison from the U.S. Department of Agriculture, Soil Conservation Service (SCS), MaryBeth Guenther from NCTCOG, Carol Langston from Environmental Protection Agency (USEPA), Arver Ferguson and Scott Walker from the Corps of Engineers Environmental Section, and Stan Walker from the Corps of Engineers Regulatory Branch.

WETLANDS DETERMINATION METHODOLOGY

RECON STUDY:

The USFWS has produced a complete set of maps for the entire Nation to assist in the determination of wetlands, called National Wetland Inventory (NWI) maps. These maps are based on the USGS 1:24000 scale topographic map sheets. The location of various wetland categories was determined by interpretation of vegetation types on aerial photographs and the resulting delineations were plotted on the appropriate map sheet. NWI maps provide a very good, if somewhat coarse, delineation of the various wetland categories. All the NWI maps for the study area were digitized into the GIS in the Recon Study and were combined with a vegetative cover map produced by classifying satellite imagery as a method of delineating wetlands. While the general wetland determinations provided by this methodology was detailed enough for the Recon Study, a more accurate method of delineating wetlands is needed for the Feasibility Study. Thus, the need for this Prototype Methodology Study to investigate new ways of determining potential wetlands.

PROTOTYPE METHODOLOGY STUDY:

The wetlands study area is located in Grand Prairie, Texas, and is bounded on the south by State Highway 80, east by Loop 12, west by Meyers Road, and on the north by Shady Grove Road. This area was shown earlier in figure 2 of the Executive Summary.

What Was Tried: The data layers evaluated in this wetlands determination procedure included detailed soil maps, vegetative cover, NWI maps, location of previous Corps of Engineers Section 404 permits and the 2-year floodplain delineation. These map layers were weighted and combined within the GIS to produce a map that supplied a "best estimate" for initial wetland determinations. The resulting map from this effort was ground-truthed by a joint contingency from the SCS, EPA, USFWS, NCTCOG, and the Corps of Engineers.

Detailed soil maps for the wetlands study area as a scale of 1:24000 were obtained from the State office of the SCS in Temple, Texas. The source data came from the published soil survey of Dallas County. These source data were on a non-planimetric base. In order to make the information useable by a GIS system, the soil information had to be recompiled on a planimetric base, a task contracted to SCS for this Study. Two USGS 7.5 minute clear film topographic quadrangle maps that covered the Prototype Methodology Study area were used as a base. The published soil maps covering this area were then rectified by SCS to the base scale. Mylar overlays were registered to the topographic base and the soil lines were traced on the mylar overlay for scanning into the computer. After an editing process, the compiled overlays were scanned and attribute symbols were assigned.

The importance of the recompilation and transfer of the soil lines is stressed. The work was performed under the guidance of a SCS soil scientist who was familiar with soil mapping and landform analysis to ensure that the recompiled map truly reflected the soils as they exist on the ground. In the Prototype Methodology Study area, soil mapping was joined from two separate soil survey maps. Since each county soil survey has a symbol legend which is unique to that survey map, it was necessary for a SCS soil scientist to correlate the soils in the entire Prototype Methodology Study area (which included the wetlands study area) and produce a separate symbol legend for this combined total area.

Detailed soils files were obtained from the SCS in GRASS vector format on a 60 MB, 1/4" tape and were imported into GRASS on the SUN 4/110. Initial problems were encountered when the files were displayed on the SUN machines. After consulting with the SCS, it was found that a data format problem existed. The files from SCS were created on an AT&T machine and format problems existed in transferring these files to the SUN platform. This problem was remedied by carrying the tape to the SCS National Cartographic Center in Fort Worth and having their staff read up the data on an AT&T machine, transfer the data over their LAN to a SUN computer and then recopy the file onto the 1/4" tape directly from their SUN computer.

These detailed soil delineations were used to identify the hydric soils in the wetlands study area. Only 2 of the 21 soil types in the wetlands study area (Trinity and Wilson) were determined to be hydric. These two hydric soils were determined by comparing the list of soils identified in the SCS Hydric Soils Manual provided by SCS. A hydric soil is a soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper soil horizons. The following criteria reflect those soils that meet this definition.

1. All Histosols except Folist, or

2. Soils in the Aquic suborder, Aquic subgroups, Albolls suborder, Salorthids great group, Pell great groups of Vertisols, Pachic subgroups that are:

   a. Somewhat poorly drained and have a frequently occurring water table at less than 0.5 foot from the surface for a significant period (usually more than 2 weeks) during the growing season, or

   b. poorly drained or very poorly drained and have either:

      (1) a frequently occurring water table at less than 0.5 foot from the surface for a significant period (usually more than 2 weeks) during the growing season if textures are coarse sand or fine sand in all layers within 20 inches, or

      (2) a frequently occurring water table at less than 1.0 foot from the surface for a significant period (usually more than 2 weeks) during the growing season if permeability is equal to or greater than 6.0 in/horizon (h) in all layers within 20 in, or

      (3) a frequently occurring water table at less than 1.5 foot from the surface for a significant period (usually more than 2 weeks) during the growing season if permeability is less than 6.0 in/h in any layers within 20 in, or

3. Soils that are frequently ponded for long duration or very long duration during the growing season, or

4. Soils that are frequently flooded for long duration or very long duration during the growing season.

An attempt was made to use the GIS to address the hydrology of the study area. Map layers of the 2-year floodplain delineation created during the Recon Study were used for the wetlands study area. This raster file was reclassed to represent only the areas inside the floodplain delineation and this file was used as the boundary delineation for the wetlands study area.

The NWI maps at a scale of 1:24000 were digitized for the Recon Study were used as an additional layer in the GIS analysis for this study. All of the many categories were originally digitized into the GIS database, but for the purpose of this study, all of the categories were aggregated into a single group in the GIS for analysis with the other data layers.

Vegetative cover for the wetlands study area was determined by classifying and subsequently ground-truthing a LANDSAT TM satellite image based on a 30-meter grid resolution. For the purpose of wetland identification in the wetlands study area, bottomland hardwoods, scrub-shrub vegetation, and herbaceous vegetation categories were determined to be of primary importance. The same image classification techniques were used in this wetlands determination exercise as were used in the HEC-1 hydrology analysis described in Appendix 3, Hydrology. The image was reclassified to represent only those vegetative cover classes mentioned above, with all other categories being classed to zero.

Areas within the wetlands study area which had already been granted Section 404 permits by the Corps of Engineers were input into the GIS for analysis. These permitted areas had already been input as GRASS format files by the Corps of Engineers Regulatory Branch. The files were copied from the Regulatory Branch computers to the Environmental Section computers using the LAN. The files were then reclassed to represent only the permitted areas.

Weighting factors were assigned by Corps of Engineers Environmentalists to each category in the map layers described above based on their perceived ability to predict the occurrence of wetlands in the study area. Areas which were already permitted as wetlands received the highest weight; a value of 10. Areas of bottomland vegetation were determined to be a good indicator of wetlands and were weighted to a value of 2. All other factors were considered to be about equal in their wetland prediction capabilities and were weighted to a value of 1. These included the 2-year floodplain delineation, scrub-shrub vegetation, hydric soils, and the NWI determinations. The various weighted map layers were then combined in GRASS using the PATCH function to create a new map layer predicting wetland locations. Color copies of all the map layers used in this analysis and of the resulting final file were made for use when field-verifying this information.

What Didn't Work: Field verification of the results of the final wetlands map created using the methodology described herein revealed the need for modifications in the weighting of the various map layers. In addition to those soil units identified as being hydric in nature, several other mapped soil units were determined to have a high probability for the occurrence of hydric soil inclusions. Because these isolated inclusions are too small to be mapped on the detailed SCS maps, the soils with a high probability for hydric inclusions need to be weighed more heavily to reflect the importance of these inclusions in the ultimate determination of a wetland. Ground-truthing also verified that all areas delineated on the NWI maps as being wetlands were, in fact, wetlands. This conclusion suggests that these NWI delineated areas should be weighted more heavily in future wetlands delineation analyses.

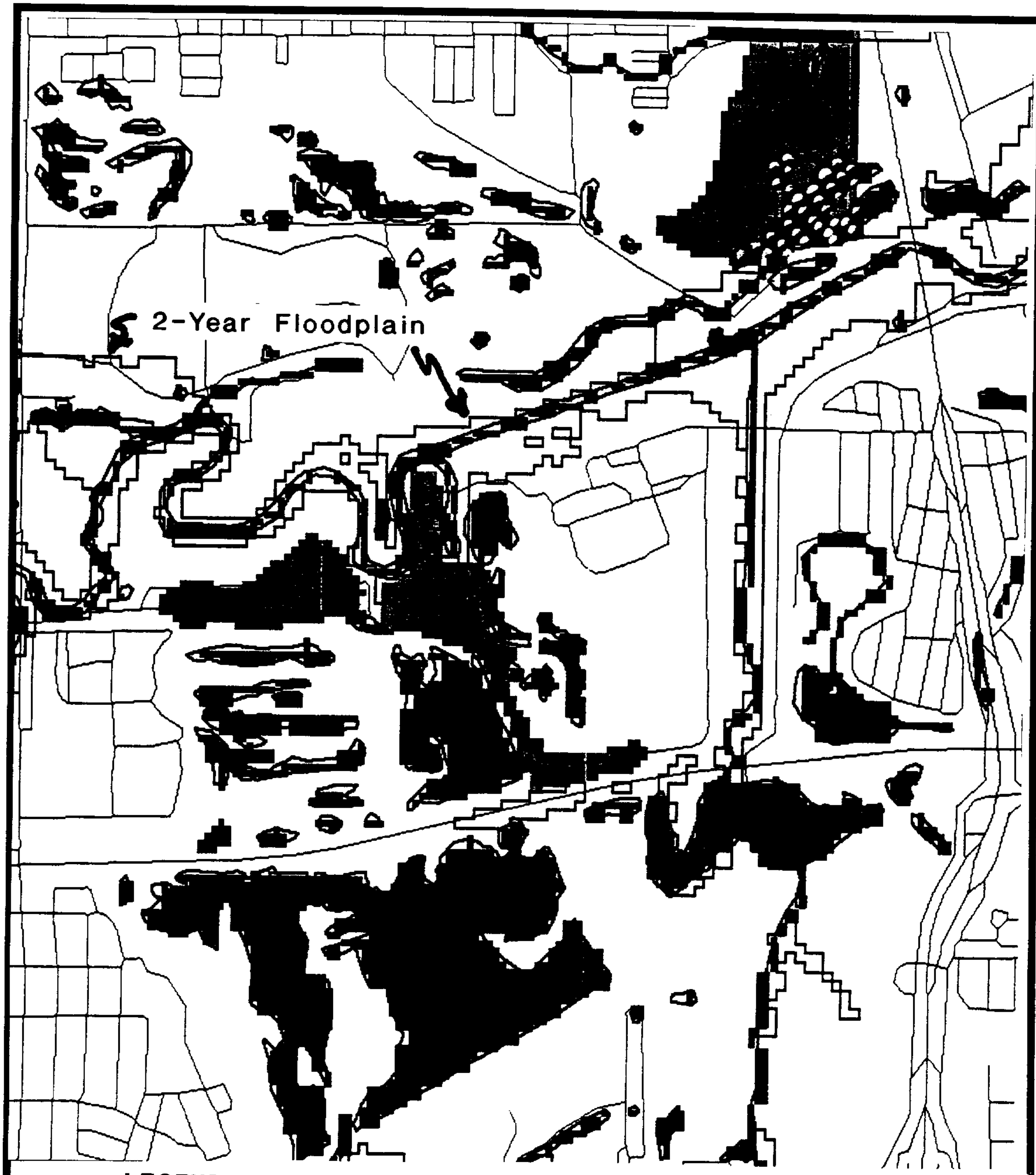
What Worked Best: Several aspects of this phase of the study proved to be extremely valuable. The wetland delineations provided by the NWI maps proved to be very accurate. While the level of detail provided by these maps alone was not sufficient for the accuracy requirements of this project, the NWI maps proved to be a very valuable first-cut analysis tool for the study. The field trip with the SCS, USFWS, NCTCOG and the EPA for field verification of the wetlands maps produced some very productive comments. The multi-disciplinary and multi-agency approach to the wetland determination task appears to be a good way to assure that all aspects of the issue are considered. Figure 6-1 shows the final map used to help determine where potential wetlands may occur. Areas where hydric soils were present and areas identified as part of the NWI maps are also shown.

FEASIBILITY STUDY

Methodology to be used: The same processes described herein are to be used. Additional analyses are to be performed to determine the proper weighting of the various wetland factors. The presence of NWI wetland areas within the area is to be weighted more heavily in determination of potential wetland areas. The following refinements are also to be performed to enhance further feasibility-level investigations.

Refinements: Several possible refinements to the wetland determination methodology described herein have been suggested. After the field investigation, the team concluded that wetland hydrology criterion should be used in conjunction with the other methodology previously mentioned.

1. The hydrology and hydric soil criterion should be refined and applied to determination weighting factors which would make the delineation of potential wetlands more accurate. An area has wetland hydrology when saturated to the surface or inundated at some point in time during an average rainfall year, as defined below:



LEGEND

- NWI WETLAND AREAS
- HYDRIC SOILS
- COMBINATION OF BOTH

Scale:

1 Inch = 2,000 Feet

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

PROTOTYPE METHODOLOGY STUDY
DALLAS - FORT WORTH METROPLEX, TEXAS

POTENTIAL WETLANDS

FIGURE 6 - 1

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A. Saturation to the surface normally occurs when soils in the following natural drainage classes meet the following conditions:

1). In somewhat poorly drained mineral soils, the water table is less than 0.5 feet from the surface for usually one week or more during the growing season; or

2) In highly permeable, poorly drained or very poorly drained mineral soils, the water table is less than 1.0 feet from the surface for usually one week or more during the growing season, or

3) In low permeable, poorly drained or very poorly drained mineral soils, the water table is less than 1.5 feet from the surface for usually one week or more during the growing season, or

4) In poorly drained or very poorly drained organic soils, the water table is usually at a depth where saturation to the surface occurs more than rarely. (Note: Organic soils that are cropped are often drained, yet the water table is closely managed to minimize oxidation of organic matter, thus, these soils often retain their hydric characteristics and, if so, meet the wetland hydrology criterion.)

B. An area is inundated at some time if ponded or frequently flooded with surface water for one week or more during the growing season.

2. The effectiveness of the LANDSAT Thematic Mapper Satellite Imagery in delineating wetlands could be improved by including supervised classification signatures based on known wetland locations. Unsupervised classification schemes provide a good "first cut" at identifying the predominate land covers of an area. By enhancing this information with spectral signatures taken from known wetland sites, the role of satellite imagery in identifying probable wetlands will be substantially enriched.

3. Consideration should be given to the data format of any additional soils files obtained from the SCS office in Temple, Texas. An investigation must be made to determine if it is easier for these files to be downloaded by SCS as GRASS vector files from a SUN machine or exported as ARC/INFO files from their AT&T computer platform. The attribute information of the detailed soils data provides a key link in determining potential wetland areas.

4. Any GRASS Version 3.1 program modules that were used herein for this methodology is to be rewritten using the enhanced Version 4.0 GRASS program.

APPENDIX 7

ACRONYMS

APPENDIX 7 - ACRONYMS

Acronym	Description
ARC/INFO	Vector-based GIS system used primarily by NCTCOG
ASCII	American Standard Code for Information Interchange - Type of universal format for digital text files
AT&T	Type of computer system used by SCS
AUTOCAD	Type of CAD computer system used by city of Grand Prairie
BPI	Bytes per inch
CAD	Computer Aided Design
CTAD	County Tax Appraisal District
DCTAD	Dallas County Tax Appraisal District
DEM	Digital Elevation Model
DLG	Digital Line Graph
DWG	Drawing file for AUTOCAD
DXF	Digital Export File - ASCII type of universal format for CAD/GIS data files
EAD	Expected Annual Damages
EOSAT	Earth Observation Satellite Company, Lanham, Maryland
ERDAS	Earth Resources Data Analysis System, Atlanta, Georgia
EXCEL	Type of computer worksheet program
FCSA	Feasibility Cost Sharing Agreement
f.econ	GIS program which analyzes potential flood damage economics
f.input	GIS program which uses HEC-2 data to create water surface elevations at each HEC-2 cross-sectioni
f.wsurf	GIS program which creates flood delineation maps
FY	Fiscal Year
GIS	Geographic Information System
G&O	Greenhorne & O'Mara, Inc, Duluth, Georgia.
GRASS	Raster-based GIS Geographic Analysis Support System developed by USACERL
HEC	Hydrologic Engineering Center, Davis, California.
HEC-1	Flood Hydrograph Package - Name for Corps hydrologic computer program
HEC1-GIS	Name for hybrid hydrologic and GIS computer program
HEC-2	Water Surfaces Profiles computer program
INTERGRAPH	Type of GIS and CAD format system
LAN	Local Area Network
LANDSAT TM	Land and Satellite Thermatic Mapper
LRD-1	Backwater Profiles computer program
MAPSCO	Name of mapping company in Dallas-Fort Worth Metroplex which has grid mapping coordinate system of Metroplex area.
MB	Megabyte - Volume of 1,024,000 bytes
NAD 27	North American Datum 27 - Type of horizontal datum originally used by USGS surveying
NAD 83	North American Datum 83 - A more refined horizontal datum than NAD 27 since it is based on global positioning stations
NCTCOG	North Central Texas Council of Governments, Arlington, Texas.
NUDALLAS	Corps hydrologic model program
NWI	USFWS National Wetlands Inventory maps
SAS	Statistical Analysis System - Type of batch job that runs under ARC/INFO
SCS	U.S. Department of Agriculture, Soil Conservation Service
SPF	Standard Project Flood

Acronym	Description
STATSGO	State Soil Geographic Data Base - Name of SCS soils relational database for general soil types
STDMA	Structure Damage Model Analysis - Traditional Corps economic flood damage analysis computer model
SUN	Type of computer system used by Corps
TCTAD	Tarrant County Tax Appraisal District
Tp	Lag time from the mid-point of the unit rainfall duration to the peak of the unit hydrograph.
TREIS	Trinity River Environmental Impact Statement
UNIX	Type of computer platform system
USFWS	U.S. Fish and Wildlife Service
USACE	U.S. Army Corps of Engineers
USACERL	U.S. Army Corps of Engineers Construction Research Laboratory, Champaign, Illinois.
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UTM	Universal Traverse Mercator
WES	Waterways Experiment Station, Vicksburg, Mississippi