CHAPTER 6
DATA COLLECTION

TABLE OF CONTENTS

6.1 OVERVIEW

6.1.1 Introduction

It is necessary to identify the types of data that will be required prior to conducting the engineering analysis. The effort necessary for data collection and compilation shall be tailored to the importance of the project. Not all the data discussed in this chapter will be needed for every project. A well-planned data collection program leads to a more orderly and effective analysis and design that is commensurate with:

- project scope;
- project cost;
- the complexity of site hydraulics; and
- regulatory requirements.

Data collection for a specific project must be tailored to:

- site conditions;
- scope of the engineering analysis;
- social, economic and environmental requirements;
- unique project requirements; and
- regulatory requirements.

Uniform or standardized survey requirements for all projects may prove uneconomical or data deficient for a specific project. Special instructions outlining data requirements may have to be provided to the survey party by the hydraulic designer for unique sites.

6.1.2 Data Requirements

The purpose of this chapter is to outline the types of data that are normally required for drainage analysis and design, possible sources, and other aspects of data collection. The following subjects are presented in this chapter.

- Sources of Data;
- Types of Data;
- Survey Information;
- Field Reviews;
- Data Evaluation;

6.1.3 Survey Methods/Computation Accuracy

The publication "Accuracy of Computed Water Surface Profiles," U.S. Army Corps of Engineers, Dec. 1986, focuses on determining relationships between:

- Survey technology and accuracy employed for determining stream crosssectional geometry;
- Degree of confidence in selecting Manning's roughness coefficients; and
- The resulting accuracy of hydraulic computations.

The report also presents methods for determining the upstream and downstream limits of data collection for a hydraulic study requiring a specified degree of accuracy.

Computer software has been developed to perform the calculations for the various routines presented in this manual. HY-11, Survey Accuracy, is available from the McTrans Center.

6.2 SOURCES OF DATA

6.2.1 Objectives

Objectives of this chapter are summarized as:

- Identify possible sources of data;
- Rely on CDOT experience as to which sources will most likely yield desired data;
- Utilize the guides in this chapter for data sources; and
- Acquaint the designer with available data and CDOT procedures for acquiring the information.

6.2.2 Sources

Much of the data and information necessary for the design of highway drainage facilities may be obtained from some combination of the sources listed in Appendix A of this chapter. The following information is given for each data source on the list:

- type of data;
- address of source; and
- comments on data.

6.3 TYPES OF DATA NEEDED

6.3.1 General

The designer must compile the data that are specific to the subject site. Following are the major types of data that may be required:

- permit requirements;
- watershed characteristics;
- stream reach data (especially in the vicinity of the facility);
- other physical data in the general vicinity of the facility such as utilities or easements;
- hydrologic and meteorologic data (streamflow and rainfall data related to maximum or historical peak as well as low flow discharges and hydrographs applicable to the site);
- existing and proposed landuse data in the subject drainage area and in the general vicinity of the facility;
- anticipated changes in landuse and/or watershed characteristics; and
- flood plain and environmental regulations.

Watershed, stream reach and site characteristic data, as well as data on other physical characteristics, can be obtained from a field reconnaissance of the site. Examination of available maps and aerial photographs of the watershed is also an excellent means of defining physical characteristics of the watershed.

6.3.2 Drainage Surveys

A complete field or aerial drainage survey of the site and its contributing watershed should always be undertaken as part of the hydraulic analysis and design. Survey requirements for small drainage facilities such as 36-inch culverts are less extensive than those for major facilities such as bridges. However, the purpose of each survey is to provide an accurate picture of the conditions within the zone of hydraulic influence of the facility. Appendix B contains instructions for field survey for hydraulic structures.

Following are the data that can be obtained or verified:

- contributing drainage area characteristics;
- stream reach data including cross-sections and thalweg profile;
- existing structures;
- location and survey for development, existing structures, etc., that may affect the determination of allowable flood levels, capacity of proposed drainage facilities, or acceptable outlet velocities;
- drift/debris characteristics;
- general ecological information about the drainage area and adjacent lands, and
- high-water elevations including the date of occurrence.

Much of these data must be obtained from an on-site inspection. It is often much easier to interpret published sources of data after the on-site inspection. Only after a thorough study of the area and a complete collection of all required information, should the designer proceed with the design of the hydraulic facility. All pertinent data and facts gathered through the survey shall be documented as explained in Chapter 4 - Documentation.

6.3.3 Watershed Characteristics

The following is a brief description of the major data topics that relate to drainage facility analysis and design:

Physical Characteristics

Contributing Size. The size of the contributing drainage area expressed in acres or square miles, is determined from some or all of the following.

- Direct field surveys with conventional surveying instruments.
- Use of topographic maps together with field checks to determine any changes in the contributing drainage area such as may be caused by:
  - Terraces;
  - Lakes;
  - Local depression area;
  - Debris or mud flow barriers;
  - Reclamation/flood control structures; and
  - Irrigation diversions.
- USGS topographic maps are available for most areas of the State. Topographic maps might also be obtained from municipal and county entities.
- Use of State Transportation Planning Survey Maps.
- Aerial maps or aerial photographs.

In determining the size of the contributing drainage area, any subterranean flow or any areas outside the physical boundaries of the drainage area that have runoff diverted into the drainage area being analyzed shall be included in the total contributing drainage area. In addition, it must be determined if flood waters can be diverted out of the basin before reaching the site.

Slopes - The slope of the stream, the average slope of the watershed (basin slope), should be determined. Hydrologic and hydraulic procedures in other chapters of this manual are dependent on watershed slopes and other physical characteristics.

Watershed Landuse

- Define and document the present and expected future landuse, particularly the location, degree of anticipated urbanization, and the data source.
- Information on existing landuse and future trends may be obtained from:
    - field review;
    - aerial photographs (conventional and infrared);
    - zoning maps and master plans;
    - USGS, U.S. Forest Service, and other Federal agency maps;
    - municipal planning agencies; and
    - landsat (satellite) images.
- Specific information about particular tracks of land can often be obtained from owners, developers, realtors, and local residents. Care should be exercised in using data from these sources since their reliability may be questionable and since these sources may not be aware of future development plans within the watershed that might affect specific land uses.
- Existing landuse data for small watersheds can best be determined or verified from a field survey. Field surveys shall also be used to update information on maps and aerial photographs, especially in basins that have experienced changes in development since the maps or photos were prepared. Infrared aerial photographs may be particularly useful in identifying types of urbanization at a point in time.

Streams, Rivers, Ponds, Lakes and Wetlands

At all streams, rivers, ponds, lakes, and wetlands that will affect or may be affected by the proposed structure or construction, the following data shall be secured:

- Boundary (perimeter) of the water body for the ordinary highwater;
- Elevation of normal as well as high water for various frequencies;
- Detailed description of any natural or manmade spillway or outlet works including dimensions, elevations, and operational characteristics;
- Detailed description of any emergency spillway works including dimensions and elevations;
- Description of adjustable gates, soil and water control devices;
- Profile along the top of any dam and a typical cross-section of the dam;
- Use of the water resources (stock water, fish, recreation, power, irrigation, municipal or industrial water supply, etc.);
- Existing conditions of the stream, river, pond, lake or wetlands as to turbidity and silt; and
- Riparian ownership as well as any water rights.

These data are essential in determining the expected hydrology and may be needed for regulatory permits.

Environmental Considerations

The need for environmental data in the engineering analysis and design stems from the need to investigate and mitigate possible impacts due to specific design configurations. Environmental data needs may be summarized as follows:

- Information necessary to define the environmental sensitivity of the facility's site relative to impacted surface waters, e.g., water use, water quality and standards, aquatic and riparian wildlife biology, and wetlands information.
- Physical, chemical and biological data for many streams are also available from the Environmental Protection Agency, the USGS and from municipalities, water districts and industries that use surface waters as a source of water supply. In unique instances, a data collection program possibly lasting several years and tailored to the site may be required.
- Information necessary to determine the most environmentally compatible design, e.g., circulation patterns and sediment transport data. Data on circulation, water velocity, water quality and wetlands are available from the U.S. Army Corps of Engineers, universities, state, federal, and local agencies. Information on sediment transport is vital in defining the suitability of a stream for most beneficial uses including fish habitat, recreation and water supply. It may be essential for projects in critical water use areas such as near municipal or industrial water supply intakes.
- Information necessary to define the need for and design of mitigation measures shall be obtained, e.g., fish characteristics (type, size, migratory habits), fish habitat (depth, cover, pool-riffle relationship), sediment analysis, water use and quality standards. Fish and fish habitat information is available from U.S. Fish and Wildlife Service and the Colorado Division of Wildlife.
- Wetlands are unique and data needs can be identified through coordination with the Corp of Engineers, Environmental Protection Agency, U.S. Fish and Wildlife Service and the Colorado Division of Wildlife.

6.3.4 Site Characteristics

A complete understanding of the physical nature of the natural channel or stream reach is of prime importance to a good hydraulic design -- particularly at the site of interest. Any work being performed, proposed or completed, that changes the hydraulic efficiency of a stream reach must be studied to determine its effect on the stream flow. The designer should be aware of plans for channel modifications, and any other changes that might affect the facility design. The stream may be classified as:

- rural or urban;improved or unimproved;
- narrow or wide;
- shallow or deep;
- rapid or sluggish;
- stable, transitional, or unstable;
- sinuous, straight, braided, alluvial, or incised; and
- perennial or intermittent flow.

Geomorphological data are important in the analysis of channel stability and scour. Types of needed data are:

- sediment transport and related information;
- stability of form over time (braided, meandering, etc.);
- scour history/evidence of scour; and

- bed and bank material identification.

Roughness Coefficients

Roughness coefficients, ordinarily in the form of Manning's n values shall be estimated for the entire flood limits of the stream. A tabulation of Manning's n values with descriptions of their applications can be found in Chapter 8 - Channels.

Stream Profile

Stream bed profile data shall be obtained and these data should extend sufficiently upstream and downstream to determine the average slope and to encompass any proposed construction or aberrations. Identification of "headcuts" which could migrate to the site under consideration is particularly important. Profile data on live streams shall be obtained from the water surface. Where there is a stream gage relatively close, the discharge, date and hour of the reading shall be obtained.

Stream Cross-Sections

Stream cross-section data shall be obtained that will represent the typical conditions at the structure site as well as other locations where stage discharge and related calculations will be necessary.

Existing Structures

The location, size, description, condition, observed flood stages, and channel section relative to existing structures on the stream reach and near the site shall be secured to determine their capacity and effect on the stream flow. Any structures, downstream or upstreamthat may cause backwater or retard stream flow shall be investigated. Also, the manner in which existing structures have been functioning with regard to such things as scour, overtopping, debris and ice passage, or fish passage shall be noted. With bridges, these data shall include span lengths, type of piers, and substructure orientation which usually can be obtained from existing structure plans. The necessary culvert data includes other things such as size, inlet and outlet geometry, slope, end treatment, culvert material, and flow line profile. Photographs and high-water profiles or marks of flood events at the structure and past flood scour data can be valuable in assessing the hydraulic performance of the existing facility.

Allowable High Water

Improvements, property use, and other developments adjacent to the proposed site both upstream and downstream may determine allowable high water. Incipient inundation elevations of these improvements or fixtures shall be noted. In the absence of upstream development, acceptable flood levels may be based on freeboard requirements to the highway itself. In these instances, the presence of downstream development becomes particularly important as it relates to potential overflow points along the road grade.

Flood History

The history of past floods and their effect on existing structures are of exceptional value in making flood hazard evaluation studies, as well as needed information for sizing structures. Information may be obtained from CDOT Hydraulic units, Maintenance sections, newspaper accounts, local residents, flood marks or other positive evidence of the height of historical floods. Changes in channel and watershed conditions since the occurrence of the flood shall be evaluated in relating historical floods to present conditions.

Recorded flood data are available from agencies such as:

- U.S. Army corps of Engineers;
- USGS;

- NRCS;
- FEMA;
- US Bureau of Reclamation; and
- Local and State agencies.

Debris and Ice

The quantity and size of debris and ice carried or available for transport by a stream during flood events shall be investigated and such data obtained for use in the design of structures. In addition, the times of occurrence of debris and ice in relation to the occurrence of flood peaks should be determined. The effect of backwater from debris and ice jams on recorded flood heights should be considered in using stream flow records.

Scour Potential

Scour potential is an important consideration relative to the stability of the structure over time. Scour potential will be determined by a combination of the stability of the natural materials at the facility site, tractive shear force exerted by the stream and sediment transport characteristics of the stream. Data on natural materials can be obtained by tests at the site.

Bed and bank material samples sufficient for classifying channel type, stability, and gradations, as well as a geotechnical study to determine the substrata if scour studies may be required. The various alluvial river computer model data needs will help clarify what information is needed. Also, these data are needed to determine the presence of bed forms so a reliable Manning's *n* as well as bed form scour can be estimated.

Controlling Factors Affecting Design Criteria

Many controls will affect the criteria applied to the final design of drainage structures including allowable headwater level, allowable flood level, allowable velocities, and resulting scour, and other site-specific considerations. Data and information related to such controls can be obtained from federal, state and local regulatory agencies and site investigations to determine what natural or manmade controls shall be considered in the design. In additional, there may be downstream and upstream controls that shall be documented.

<u>Downstream Control</u> - Any ponds or reservoirs, along with their spillway elevations and design levels of operation, shall be noted as their effect on backwater and/or stream bed aggradation may directly influence the proposed structure. Also, any downstream confluence of two or more streams shall be studied to determine the effects of backwater or streambed change resulting from that confluence.

<u>Upstream Control</u> - Upstream control of runoff in the watershed shall be noted. Conservation and/or flood control reservoirs in the watershed may effectively reduce peak discharges at the site and may also retain some of the watershed runoff. Capacities and operation designs for these features shall be obtained. The State Engineer, Colorado Water Conservation Board, Natural Resources Conservation Service, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, consulting engineers, and other reservoir owners often have complete reports concerning the operation and design of proposed or existing conservation and/or flood control reservoirs.

The redirection of flood waters can significantly affect the hydraulic performance of a site. Some actions that redirect flows are irrigation facilities, debris jams, mud flows, and highways or railroads.

6.4 SURVEY INFORMATION

6.4.1 General

Complete and accurate survey information is necessary to develop a design that will best serve the requirements of a site. The Project Manager in charge of the drainage survey shall have a general knowledge of drainage design and as such shall coordinate the data collection with the designer. The amount of survey data gathered shall be commensurate with the importance and cost of the proposed structure and the expected flood hazard.

At some sites, photogrammetry is an excellent method of securing the topographical components of drainage surveys. Planimetric and topographic data covering a wide area are easily and cost-effectively obtained in many geographic areas. A supplemental field survey is required to provide data in areas obscured on the aerial photos (underwater, under trees, etc.).

To avoid repeated visits, data collection shall be as complete as possible during the initial survey. Data needs must be identified and tailored to satisfy the requirements of the specific location and size of the project early in the project design phase. Coordination by the Project Manager with the Hydraulics Engineer before the initial field work is conducted will help ensure the acquisition of sufficient, but not excessive, survey data.

6.4.2 CDOT Requirements

The CDOT instructions for hydraulic surveys are contained in the *Survey Manual*. An outline of these requirements is presented in Appendix B of this chapter. Example forms and checklists are provided in Appendix C.

6.5 DATA COLLECTION

6.5.1 Digital and Satellite Data Models

Several methods to use electronic data for hydraulic and hydrologic studies are available. Design of drainage systems can be accomplished using CAD software and electronic surface data. Hydrologic and hydraulic models can be developed using this data.

The types of data normally used by digital models are:

- elevation data;
- features (e.g., streams and roadways);
- landuse; and
- soils and infiltration.

Some of the electronic data is readily available, though not always with the desired resolution. Elevation data is available from the USGS in Digital Elevation Models (DEM) format. The data is normally available in UTM coordinates and in 16.5 ft (5-m) to 300 ft (90-m) resolution, depending on the location. NRCS also maintains soil and land-use data basis in GIS formats in certain areas. Detailed hydraulic and hydrologic studies may require higher resolution elevation data than is normally available through USGS and NRCS. Higher resolution data is sometimes available through local municipalities.

Satellite imagery is available through commercial vendors. However, high-resolution elevation data is not normally available through these sources, and the technology to extract it is not yet available. Satellite imagery can be used to determine land uses. Due to the scarcity or obsolescence of elevation data, the normal approach is to develop topographic surveys for a project. There are two basic methods to develop topographic surveys:

- aerial photogrammetry; and
- field data collection.

Aerial Photogrammetry

Under this method, topographic mapping is developed using pictures of the ground taken from an aircraft or satellite. Ground controls are established using field survey methods and contours are developed.

Aircraft used for taking photographs can be fixed wing (airplane) or helicopter. Fixed wing still is the most economical method; however, helicopter based surveys offer low altitude flights, resulting in much higher accuracy. The pictures taken can also be used as data for hydraulic investigations and studies.

High-resolution satellite and multi-spectral imagery is available and may be substituted for other methods if necessary. Because satellite data is stored for a period of time, multi-spectral satellite imagery can also be used to investigate flooding, actually after an event has occurred. Potentially, the technology can be used to develop “before-and-after” images and topography to investigate a flood event or other significant change in an area of interest.

A new method of aerial topographic generation is using laser or radar beams from an aircraft carrying differential GPS. The laser based method is called Light Detection and Ranging (LIDAR). LIDAR or radar generated data have the advantage of being inexpensive when compared to traditional photogrammetry. However, the accuracy is highly dependent on the technology available to the vendor in aerial equipment and available software to filter trees and other covered land areas.

Field Data Collection

Field data collection is normally accomplished using electronic survey equipment such as Total Station and Global Positioning System (GPS).

Using Total Station as a data collection tool, the engineer can develop topographic mapping directly from the fieldwork, with little additional processing. This information can be directly used in certain highway or hydraulics software, saving time and resources in the tedious process of survey decoding and data entry. Digital Elevation Models or Digital Surface Models can be developed using the data collected using this method. Other feature data (e.g., flood limits, bank full indicators, vegetation markers, point bars, flow boundaries) can also be located by a surveyor and automatically decoded along with the elevation data. The accuracy of this method can be very high and is dependent on the experience of the field personnel.

GPS based surveying is still less accurate because it depends on many factors such as location of the survey reach and time of day. Hand-held GPS units that have sub-meter horizontal precision are available. Vertical precision to collect elevation data is not sufficiently accurate for many design functions. However, this method makes a one-person survey crew possible with minimal training. GPS data can be obtained by a hydraulics engineer during a field visit. This facilitates rapid development of field data, especially location data, and quick office evaluations.

6.5.2 Data Merging

Merging of electronic surface data is common during highway design. Better data is usually collected within the highway area, while the data for the area outside the expected cut/fill lines is less precise. Because watershed limits fall well outside the highway cut/fill lines, hydraulics engineers must negotiate with the data that has multiple resolutions.

Electronic data is available in various forms differentiated by software products, type of data structure (DEMs and TINs), coordinate systems (UTM, State Plane, Latitude-Longitude), units (feet or meters), resolution and datums. While merging data in different forms, care must be taken to ensure proper conversion prior to merging. Standardizing all data to the most current format is the best way to ensure compatibility. There are tools available to accomplish the data “translation.”

A more serious issue in data merging is caused by differences in data resolution. For example, a digital surface model developed using a photogrammetric method is typically of a lower resolution compared to a surface model developed using a field data collection survey. When merging the data, elevation differences at the boundaries of the different data areas must be carefully reconciled.

There is often a problem with artificial pits (sinks) and peaks due to the creation of DEMs and TINs. The engineer must evaluate the data and correct these inconsistencies.

6.5.3 Accuracy of Data

In any engineering computations, it is important to understand the limitations of accuracy of the computations based on the accuracy of the input data. In step-backwater computations utilizing HEC-RAS, WSPRO, or BRI-STARS there are several factors that have significant effects on the accuracy of the results — accuracy of the survey data, spacing between cross sections, correct establishment of upstream and downstream study limits, selection of roughness coefficients.

Most field surveys of channel and floodplain cross sections are recorded to an accuracy of 0.1 ft. If the survey truly represents the cross sections of the reach of the stream being studied to a 0.1 ft accuracy, the greatest accuracy that would result from a step-backwater computation could be no more than 0.1 ft. Any results expressed more precisely than 0.1 ft are simply due to the mathematics.

The accuracy of aerial survey technology for generating cross sectional coordinate data is governed by mapping industry standards. Cross sections obtained from contours of topographic maps developed by photogrammetric methods are generally not as accurate as those generated from field data collection methods. Aerial photography can supplement field survey cross sections. The use of aerial elevation survey technology permits additional coordinate points and cross sections to be obtained at small incremental cost, and the coordinate points may be formatted for direct input into commonly used water surface profile computer programs such as HEC-RAS, WSPRO, and BRI-STARS.

For further information on determining the relationships between (1) survey technology and accuracy employed for determining stream cross sectional geometry, (2) degree of confidence in selecting Manning’s roughness coefficients and (3) the resulting accuracy of hydraulic computations, refer to the US Army Corps of Engineers’ publication Technical Paper No. 114. This publication also presents methods of determining the upstream and downstream limits of data collection for a hydraulic study requiring a specified degree of accuracy. Computer software has been developed to perform the calculations for the various routines presented in these publications. “Preliminary Analysis System” (PAS) is available from the McTrans Center, University of Florida, Gainesville, FL.

6.6 FIELD REVIEWS

6.6.1 On-Site Inspection

Field reviews shall be made by the Hydraulics Engineer in order for him to become familiar with the site. The most complete survey data cannot adequately depict all site conditions or substitute for personal inspection by someone experienced in drainage design. Factors that most often need to be confirmed by field inspection are:

- selection of roughness coefficients;
- evaluation of apparent flow direction and diversions;
- flow concentration;
- observation of land use and related flood hazards;

- geomorphic relationships;
- high-water marks or profiles and related frequencies;
- existing structure size and type;
- bank erosion;
- debris problems;
- scour; and
- existence of wetlands.

An actual visit to the site where the project will be constructed shall be made before any detailed hydraulic design is undertaken. This may be combined with the visit by others, such as the roadway and structural designers, maintenance personnel, environmental reviewers, and local officials.

Before making the field visit, the designer should determine if the magnitude of the project warrants an inspection or if the same information be obtained from maps, aerial photos, or by telephone calls.

The designer needs to consider the kind of equipment that will be needed, and most importantly, critical items at this site.

As a minimum, photos shall be taken looking upstream and downstream from the site as well as along the contemplated highway centerline in both directions. Details of the streambed and banks should also be photographed along with structures in the vicinity both upstream and downstream. Close-up photographs complete with a scale or grid shall be taken to facilitate estimates of the streambed gradation.

6.6.2 Checklist

The forms to be used by the CDOT in identifying and cataloging field information are shown in Appendix C.

6.7 DATA EVALUATION

6.7.1 Objective

Once the needed data have been collected, it needs to be compiled into a usable format. The designer must ascertain whether the data contains inconsistencies or other unexplained anomalies that might lead to erroneous calculations or results. The main reason for analyzing the data is to draw all of the various pieces of collected information together and to fit them into a comprehensive and accurate representation of the hydrologic and hydraulic characteristics of a particular site.

6.7.2 Evaluation

Experience, knowledge, and judgment are important parts of data evaluation. It is in this phase that reliable data shall be separated from that which is less reliable and historical data combined with that obtained from measurements. The data shall be evaluated by the hydraulic designer for consistency and to identify any changes from established patterns. Reviews may include previous studies, old plans, etc., for types and sources of data, how the data were used, and any indications of accuracy and reliability. Historical data shall be reviewed to determine whether significant changes have occurred in the watershed and whether these data can be used. Data acquired from the publications of established sources such as the USGS can usually be considered as valid and accurate. Basic data, such as stream flow derived from non-published sources, shall be evaluated and summarized before use. Maps, aerial photographs, landsat images, and land use studies shall be compared with one another and with the results of the field survey and any inconsistencies resolved. General references shall be consulted to help define the hydrologic character of the site or region under study and to aid in the analysis and evaluation of data.

6.7.3 Sensitivity

Sensitivity studies can be used to evaluate data and the importance of specific items to the final design. Sensitivity studies consist of conducting a design with a range of values for specific data items. The effect on the final design can then be established. This is useful in determining what specific data items have major effects on the final design and the importance of possible data errors. Time and effort shall then be spent on the more sensitive data items making sure these data are as accurate as possible. This does not mean that inaccurate data are accepted for less sensitive data items, but it allows prioritization of the data collection process given a limited budget and time allocation.

The results of this type of data evaluation shall be used so that as reliable a description as possible of the site can be made within the allotted time and available resources. The effort of data collection and evaluation shall be commensurate with the importance and extent of the project and/or facility.

Appendix A - Sources of Data

Principal Hydrology Data Sources

- Meteorological Data;

  US National Oceanography and Atmospheric Agency (NOAA)
  National Climatic Data Center
  37 Battery Park Avenue
  Federal Building
  Asheville, North Carolina 28801
  (704) 271-4800

- Regional and local flood studies;
- U.S. Geological Survey regional and site studies;
- Surveyed high-water marks and site visits by CDOT;
- CDOT Maintenance; and
- Hydrology data from other available sources (see below).

Principal Watershed Data Sources

- U.S. Geological Survey maps ("quad" sheets);

  U.S. Geological Survey
  Rocky Mountain Mapping Center
  Mall Stop 504
  Denver Federal Center
  Denver, Colorado 80225
  (303) 236-5829

- EROS aerial photographs;

  U.S. Geological Survey
  EROS Data Center
  Sioux Falls, South Dakatoa 57198
  (605) 594-6151

- Colorado Geological Survey;
- State geological maps;
- Natural Resource Conservation Service soils maps;
- Bureau of Land Management (BLM) soils maps;
- Site visits by CDOT; and
- Watershed data from other available sources (see below).

Principal Site Data Sources

- CDOT files of aerial drainage surveys;
- CDOT files for existing facilities;

- Site visits by CDOT; and
- Field or aerial surveys from other available sources (see below).

Principal Regulatory Data Sources

- Federal Flood Plain delineations and studies;

  Federal Emergency Management Agency
  Flood Map Distribution Center
  6930 (A-F) San Tomas Road
  Baltimore, Maryland 21227-6227
  (800) 358-9616
- State and local floodplain delineations and studies;
- FHWA design criteria and practices;

  Federal Highway Administration
  U.S. Department of Transportation
  400 Seventh Street SW
  Washington, D.C. 20590

- Federal Registers

  Superintendent of Documents
  US Printing Office
  Washington, D.C. 20402
  (202) 783-3238

- USACE Section 404 Permit Program;
- Colorado Laws;
- Local ordinances and master plans;
- CDOT Policy Statements;

Principal Environmental Data Sources

- Corps of Engineers Section 404 permit program;
- U.S. Environmental Protection Agency (EPA);
- Colorado Department of Environmental Health;
- Federal Registers

  Superintendent of Documents
  U.S. Printing Office
  Washington, D.C. 20402
  (202) 783-3238

Other Data Sources

- U.S. Bureau of Reclamation (USBR);

  U.S. Bureau of Reclamation Center
  Denver, Colorado 80225
  (303) 236-8098

- Regional and State U.S. Bureau of Land Management (BLM);
- Regional U.S. Environmental Protection Agency (EPA);
- Regional U.S. Federal Emergency Management Agency (FEMA);
- Regional and State U.S. Fish and Wildlife Service (USFWS);
- Regional and State U.S. Forest Service (USFS);
- Regional and State U.S. Natural Resource Conservation Service (NRCS);
- Regional and State U.S. Corps of Engineers (COE);
- Regional and State U.S. Geological Survey (USGS);
- Regional and State Federal Highway Administration (FHWA);
- National Weather Service (NWS);
- National Oceanic and Atmospheric Administration (NOAA);
- Urban Drainage and Flood Control District; and
- Denver Regional Council of Governments.

APPENDIX B - HYDRAULIC SURVEY INSTRUCTIONS

General

This Appendix discusses the general guidelines which must be followed when drainage surveys are conducted. The guidelines are intended to ensure that the necessary information needed for hydraulic design will be included in the survey. These guidelines should be supplemented or confirmed through direct contact with the Hydraulics Engineer. The Project Manager should contact the Hydraulics Engineer at least two weeks prior to the Pre-survey Conference. After the survey requirements have been determined, a transmittal of the requirements will be submitted to the Region Survey Manager. Following these guidelines will provide the Hydraulics Engineer with appropriate survey.

General Guidelines for Drainage Surveys

Good surveys are necessary for complete hydraulic designs. Channel locations and changes, bridge skew, water stage and structure relocations are all determined from the drainage survey.

A guideline for the extent of drainage survey is as follows:

1. For large bridges with design flows greater than 20,000 cfs or spans greater than 250 feet:
    a. Consult with the Hydraulics Engineer before scoping the survey. Requirements are discussed further at the Pre-survey Conference.
    b. Aerial surveys should be considered at these sites. See the Photogrammetry Chapter in the CDOT Survey Manual.
2. For large culverts/medium bridges with design flows of 2000 cfs to 20000 cfs or 20ft x 10ft CBC's to 250 feet span bridges:
    a. The survey shall extend 1200 feet upstream and 1200 feet downstream from the roadway centerline. If grade control structures or canal intake structures are present, the survey shall cover these structures.
    b. Additional survey data must be taken near the upstream and downstream edges of the existing structure, including the abutments.
    c. The elevation of the existing structure's lowest girder or clearance must be included.
    d. The width of the survey shall be determined by the Hydraulics Engineer.
    e. Additional requirements are determined at the Presurvey Conference.
3. For medium to large culverts with design flows of 200 cfs to 2000 cfs or 72-inch pipes to 20' x 10' CBC's:
    a. The survey shall extend 500 feet upstream and 500 feet downstream from the roadway centerline.
    b. Additional survey data must be taken near the upstream and downstream edges of the existing structure, including the abutments.
    c. The width of the survey shall be determined by the Hydraulics Engineer.
    d. Additional requirements are determined at the Pre-survey Conference.
4. For small culverts with design flows less tha 200cfs or pipes smaller than 72 inches:

a. The survey shall extend 100 feet upsteam and 100 feet downstream from the roadway centerline.

b. Survey data must be taken at the each end of the culvert to determine the structure centerline, depth of sediment, and headwall dimensions.

c. CDOT form 283 shall be completed for each culvert, except for side drains smaller than 1.5 ft. A sketch of the existing culvert should be included

5. For irrigation canals:

a. The water surface profile and the channel invert must both be surveyed. This may result in two separate surveys, unless the surveyor could mark the water surface during flow and take the measurements at a later date when the canal is not in operation.

b. The survey shall extend 1000 feet upstream and 2000 feet downstream from the roadway centerline. The downstream portion of the survey will not need to extend the full 2000 feet if a difference in water surface elevation of 0.5 feet is achieved. Measurements of the water surface profile shall be taken at 100 feet intervals to an accuracy of 0.05 feet. The date and time of the water surface profile shall be recorded.

c. The name and address of the owner of the ditch should be noted. Inquiries regarding the discharge at the time of the water surface profile should be made from the ditch rider.

d. Irrigation control structures such as turnouts, check structures, etc. within the survey limits should be identified and detailed.

e. Water rights shall be delineated.

6. For storm drains:

a. Survey data must be taken of the profile grade and gutter flow line elevations of the main roadway. The survey must cover all areas of the roadway which contribute drainage. This may entail surveying beyond the project limits. For example, if the project ends in the middle of a crest vertical curve the survey must continue to the top of the curve.

b. Survey data must be taken of the profile grade and gutter flowline elevations of all cross streets or road approaches. The survey shall extend up the road approach 500 feet or to its highest point, whichever is less.

c. The location of all curbs, gutters, inlets, culverts and manholes must be determined. Inlet and pipe depths and sizes (rim and invert elevations) must be indicated and the direction of flow in the pipes must be noted.

d. The location of all utilities must be determined. The size, type and depth of the utilities must be indicated.

7. For existing detention ponds:

a. Detention pond surveys must be accurate enough to draw a contour map with three to five contours.

b. The survey data shall extend up to an elevation equal to the pond overflow elevation.

c. Any significant topography within the potential ponding area, such as building foundations, ground floor elevations, and outlet structures must be shown.

d. In case of concrete structure, a detailed survey is needed to identify the details of the entire structure.

Methods

The terrain and topography data will be taken using current CDOT survey methodologies using the coordinate system of the project control survey.

If photographs are deemed necessary by the Hydraulics Engineer, they will be requested in the Hydraulics survey Requirements transmittal. When requested, photographs shall show existing inlet and outlet configurations, areas of erosion, structures that experience distress during flooding, and natural features of the drainage basin. Photographs shall be labeled with the project number, date of photo, description of photo, orientation of the camera, and the photographer's name.

Direct contact with the Hydraulic's Engineer should be made before starting any drainage survey.

A. For CBC pipe culverts the following photos are required:

1. Looking upstream from the structure inlet.
2. Looking downstream into the entrance of the structure.
3. Looking downstream from the structure outlet.
4. Looking into the structure outlet.
5. Roadway in the direction of inclined station.

B. For bridges the following photos are required:

1. Piers;
2. Abutments; and
3. Minor drainage, rundowns

APPENDIX C - FIELD INVESTIGATION FORMS

Form 1
FIELD VISIT INVESTIGATION FORM

DATE:	
PROJECT:	
BY:	
STRUCTURE TYPE:	**PIERS TYPE**
Size or Span:	Skew:
No. of Barrels or Spans:	Inlet:
Clearance Height:	Outlet:
Abutment Types:	Percent Grade of Road:
Inlet Type:	Percent Grade of Stream:
Existing Waterway Cover:	
Overflow Begins at Elv.:	Length of Overflow:
Maximum AHW (ft):	
Reason:	Check for Debris:
	Side Slopes:
	Height of Banks:
Up or Downstream Restriction:	
Outlet Channel, Base:	
Manning's n Value:	
Type of Material in Stream:	
Ponding:	
Check Bridges Upstream And Downstream:	
Check Land Use Upstream And Downstream:	
Survey Required? YES NO	
REMARKS:	

Form 2
Hydraulic Survey Field Inspection Check List

I. GENERAL PROJECT DATA

1. Project Number: ____________________ 2. County: _______________
3. Road Name: ____
4. Site Name: ____________________, Station: ______________________ M.P.: ______________
5. Site Description: ( ) Cross drain, ( ) Irrigation, ( ) Storm Drain, ( ) Long. Encroach. ( ) Ch. Ch.,( ) Other ____
6. Survey Source: ( ) Field, ( ) Aerial, ( ) Other _______________________
7. Date Survey Received: ____________________, From _______________
8. Site Inspected by: ____ on_____________
(name) (date)

II. OFFICE PREPARATION FOR INSPECTION

1. Reviewed:
Aerial Photos – ( ) Yes, Photo Nos. _______________, ( ) None Available
Mapping/Maps – ( ) Yes, Map Nos._______________, ( ) None Available
Reports – ( ) Yes, ( ) No, ( ) None available at this time
CDOT Permanent File – ( ) Yes, ( ) No, ( ) No file data found

2. Special Requirements and Problems Identified for Field Checking:

( ) Hydrologic Boundary – obtain hydrologic channel geometry Adverse Flood
( ) History – obtain HW Marks/dates/eye witness
( ) Irrigation Ditch – obtain several Water Right depths
( ) Permits Req'd – ( ) COE ( ) Ch. Ch., ( ) Dam
( ) Other ___________________________________
( ) Adverse Channel Stability and Alignment History – Check for headcutting, bank caving, braiding, increased meander activity
( ) Structure Scour – check flow alignment, scour at culvert outlet or evidence of bridge scour. Obtain bed/bank material samples at ____

III. FIELD INSPECTION
The following details obtained at the site are annotated on the Drainage Survey

1. Survey appears correct: – ( ) Yes, ( ) Apparent errors are: ____________________
____
_________________________ which were resolved by: _________________________

2. Flooding Apparent? – ( ) No, ( ) Yes, HW marks obtained, ( ) Yes but HW marks not obtained because ____

3. Do all Floods Reach Site? – ( ) Yes, ( ) No and details obtained, ( ) No but details not obtained because ____

4. Do Floodwaters Enter Irrigation Ditch ? – ( ) N/A, ( ) No, ( ) Yes and details obtained, ( ) Yes but details not obtained because ______________________________

5. Hydrologic Channel Geometry obtained? – ( ) Yes, ( ) No because ______________________

6. Channel Unstable? – ( ) No , ( ) Yes because of ( ) headcutting observed and ( ) amount/location obtained, ( ) bank caving, ( ) braiding, ( ) increased meander activity,
( ) Other____

7. Structure Scour in Evidence? – ( ) No, ( ) Minor, ( ) Yes and ( ) obtained bed/bank samples and ( ) noted any flow alignment problems, ( )Yes and ( ) bed/bank material samples not obtained and ( ) flow alignment not noted because ____
____

8. Irrigation facility? – ( ) No, ( ) Yes and several water right related depths obtained, ( ) Yes and No water right related depths obtained because ____
____

9. Manning's "n" obtained? – ( ) Yes, ( ) No because ____
____

10. Property damage due to BW? – ( ) No ( ) Yes and elevation/property type checked, ( ) Yes but elevation/property type not obtained because ____
____

11. Environmental Hazards Present? – ( ) No, ( ) Yes, details obtained, ( ) Yes, details not obtained because ____

12. Ground Photos Taken?—( ) Upstream floodplain and all property, ( ) Downstream floodplain and all property, ( ) Site looking from downstream, ( ) Site looking from upstream, ( ) Channel Material w/scale, ( ) Evidence of channel instability, ( ) Evidence of scour, ( ) Existing structure inlet/outlet, ( ) Other ____

13. Effective drainage area visually verified? ( ) Yes, No ( ) because ______________

IV. POST INSPECTION SURVEY ANNOTATION

1. Section II Findings annotated on survey? – ( ) Yes, ( ) No and see section attached (attach typed explanation by site station and site name, and check list section and number).

2. Survey Originals and check lists forwarded to CDOT's Roadway Unit,___ - ea, and the CDOT's Hydraulic Unit, ____ea. for hydraulic design.

(signature)

____

Designer Making Inspection