CHAPTER 6

DATA COLLECTION

Chapter Table of Contents

6.1 Introduction

It is necessary to identify the types of data that will be required prior to conducting the engineering analysis. The importance of the project determines the level of effort needed for data collection. A comprehensive, accurate, and economical highway drainage design requires reliable and accurate data for its success. Failure to base the design on sufficient and appropriate data can lead to economic loss, potential loss of life and damage and temporary closure of the highway. Not all data discussed in this chapter will be needed for every project. Data collection for a specific project must be commensurate with the project scope and tailored to:

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

In addition to the data in the preceding list, it may be necessary to collect information to assure and verify the design satisfies Oregon drainage law.

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 designer for unique sites.

This chapter outlines 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:

- data collection sequence,
- sources and types of data,
- field reviews,
- drainage survey requirements, and
- data evaluation.

6.2 Data Collection Sequence

The data collection sequence for a typical ODOT highway improvement project with bridges and culverts is described in this section. Projects with storm drains, water quality systems, irrigation systems, etc. use a similar sequence and procedure. The data that is collected may be considerably different. Typical maintenance projects will not require all of these steps. The

remainder of this chapter discusses the data sources and the types of needed information. Field survey checklists are included in the appendices.
This sequence begins at the notification of project scoping, with the first visit to the site occurring during the initial scoping trip with the project team.

Step 1 - Obtain preliminary information. Detailed design information is not needed or available at this time. The intent is to collect the data for the initial scoping visit. Useful information for scoping includes the following.

- Plans of the existing road and the project prospectus. Preliminary road alignment and typical cross-section may have been developed. They should be obtained if available.
- Environmental documents that discuss hydraulic features. Copies are needed of both draft and issued documents.
- Planning documents and floodplain use regulations that discuss hydraulic features, obtain from the ODOT planner assigned to the project.
- Plans, maintenance history, and inspection reports for existing structures.
- Scour reports, flood data, and relevant information from the hydraulic files for existing structures.

Step 2 - Obtain preliminary information from outside sources. Some of this information may also be available from the ODOT contacts. Typical preliminary information includes the following.

- FEMA Flood Insurance Study and maps, from the FEMA website.
- Drainage Master Plans for projects within an Urban Growth Boundary.

Step 3 - Review all material obtained in the previous two steps. Note all items pertaining to hydraulic structures. Planning documents for urban projects often list allowable increases in flood elevations. Environmental documents will usually discuss proposed hydraulic structures. The statements in these documents will often affect hydraulic designs.

Step 4 - Attend the scoping visit with the project development team. Note and record hydraulic concerns. Collect data as needed to issue the Preliminary Hydraulic Recommendations shortly after the initial scoping visit. Mention to the team any hydraulic requirements based on the information collected in Steps 1 and 2.

An additional site visit is often needed to address concerns or to collect more information. The goal is to collect enough data for the preliminary recommendations. Detailed design information will be obtained later. The preliminary recommendations, including an example, are discussed in **Chapter 4**.

During the initial site visit look for roadway/waterway crossings that have the potential for fish passage issues. This could be crossings that passed fish historically, presently, or in the future if fish passage would be provided. The appropriate time to address the number and location of fish passage culverts is the preliminary stage of project development. Replacing existing small roadway cross-culverts with larger fish passage culverts can add considerable cost to a project. Preliminary hydraulic recommendations are not complete until the number and location of fish passage culverts are known and addressed in the recommendations.

Note: An ODFW opinion is needed if there are potential fish passage culverts on the project. This opinion will provide the needed information. The ODFW representative visits the site prior to issuing the opinion. Experience shows it is good practice for the hydraulic designer to also attend this visit. This will give the designer a chance to provide input and address concerns.

Look for proposed roadway embankments that would extend into water bodies, riparian areas, or wetlands. Although these are mainly geotechnical issues, considerable hydraulics assistance may be needed. The scour protection for these embankments, walls, etc. is a topic for the Preliminary Hydraulic Recommendations.

Look at existing culverts to see if they need to be replaced. Critical culverts that cannot be inspected visually can be looked at by video cameras. Requests for this service are made to the project team leader.

Consider each culvert from a construction, cost, and future maintenance viewpoint, whether to leave the existing pipe in-place, extend the pipe, rehabilitate the pipe, replace the pipe in-kind, or install a different size or type of pipe. Items to consider include the following.

- Will an existing culvert remaining in-place or extended provide an adequate service life?
- Is it more economical to rehabilitate than replace a culvert?
- Will the rehabilitated culvert meet all requirements?
- Will all culverts left in-place, rehabilitated, or extended meet fish passage requirements?
- Is trenchless installation more feasible than open-cut installation, or vice-versa?
- Will a new bridge be more economical than a culvert replacement?
- How will water be conveyed through the site during construction?
- How will traffic be conveyed through the site during construction?

Additional expertise will probably be needed to answer these questions. This preliminary stage in the project development is the appropriate time to address these issues.

Limited survey work may be needed in some instances to make preliminary recommendations. This is done only if the added information will be critical to the recommendations. The survey is usually done by level, rod, and tape, using an assumed datum. The survey results are used for the preliminary estimates only, and the more detailed and the more accurate project design survey is used for the facility design.

The sample recommendations in **Chapter 4** are an example of a limited preliminary survey. Roadway cross-sections and stream profiles were needed to verify if fish passage culverts could be installed without significantly excavating the streambeds or elevating the roadway. It was verified the culverts could be installed without road elevation or channel excavation. Knowing this was essential to the initial project development.

Step 5 - Request the hydraulic portion of the project design survey. The survey crew must get an accurate representation of the channel and overbank areas. Geotechnical exploration is almost always needed for hydraulic structure design, and this is the time to make the exploration request. It is good practice to meet on-site with the survey team leaders and the geotechnical exploration crew leader to discuss the data request. Many items should be marked in the field as well as described in the survey request. Ordinary high water elevations are an example.

Note: The data collected during the design survey depends on the type, size, location, and quantity of hydraulic structures on the project. The project team needs to evaluate the preliminary hydraulics recommendations for each crossing and agree on the basic structure type (i.e. bridge, fish passage culvert, or culvert) to be considered during the detailed design. This should be done before the detailed hydraulic design survey is ordered.

Step 6 - Verify that the roadway designer has ordered critical utility location information in areas of concern near hydraulic structures (e.g. pothole explorations to locate existing gas mains, storm drains, etc.).

Step 7 - Obtain information from internal and external sources to finish the hydraulic design, such as the following.

- Refined roadway alignment, cross-sections, and processed project and hydraulic survey data, including project vicinity map.

- Vertical control information to reference the project datum to other datums, such as the datum used by FEMA.
- Preliminary traffic staging plan.
- Up-to-date environmental documents and drafts.
- Up-to-date planning documents.
- Information to determine drainage areas, etc., from internal and external sources.
- Preliminary Foundations Report and geological exploration data.
- Floodplain maps and hydraulic computer models if needed, from FEMA.
- Utility location information.

Note: Most of this information will also be used in subsequent structural designs.

6.3 Data Sources with Website Addresses

Much of the data and information necessary for the design of highway drainage facilities is available from Federal Agencies involved in water resource activities. Other sources include cities and counties, local irrigation districts, and data developed and obtained by ODOT during the design of past highway projects. The following sections discuss potential sources of data and the type of data the source can provide.

6.3.1 External Data Sources

The following is a list of the principal external data sources and the type of data that is available. Much of the data is available on the Internet, and websites for the data sources are listed.

1. **U.S. Geological Survey (USGS)** Hydrologic data stations are maintained by the USGS at selected locations throughout Oregon and constitute the major water resources data network in the state for obtaining records on stream discharge and stage, reservoir and lake storage, ground-water levels, well and spring discharge, and the quality of surface and ground water. Every year some new stations are added and other stations are discontinued; thus, the USGS has both a current and a historical record of hydrologic data. The principal data obtained from the USGS is stream-flow data. The USGS also publishes topographic maps. The maps are commonly called 7.5-minute quadrangles and are plotted to a scale of 1:24,000. The maps are used to determine the drainage areas of watersheds. The USGS surface water data website address for Oregon is ***http://or.water.usgs.gov/*** and the mapping address is ***https://www.usgs.gov/core-science-systems/national-geospatial-program/topographic-maps***

2. **Oregon Water Resources Department (OWRD)** Data available from OWRD includes data on water rights, groundwater data, data on wells, and surface water data. The OWRD website features a comprehensive listing of surface water gaging stations throughout the

state, both current and historical. Surface water data collected by the USGS, OWRD, and other agencies is available at the website ***https://www.oregon.gov/owrd/Pages/index.aspx***

3. **Federal Emergency Management Agency (FEMA)** Many streams have been analyzed for local flood insurance studies (see **Chapter 2**). The flood insurance studies contain hydrologic data, water surface profiles, and floodplain maps of flood hazard areas. Even though these studies are a good source of data, their technical content should be reviewed prior to using the data. Many of the studies are outdated and/or will not reflect changes that may have occurred in the study reach since its initial publication. In these cases, additional data collection is necessary to supplement and update the FEMA hydraulic models used to develop the local flood insurance studies. FEMA studies and maps are available at ***www.fema.gov***

4. **Natural Resources Conservation Service (NRCS)** NRCS publishes soil surveys and soil maps. The soil data is needed when NRCS hydrologic methods are used to estimate runoff from a watershed. NCRS is also a source of many technical references pertaining to hydrology and hydraulic design. The NRCS website address is ***www.nrcs.usda.gov***

5. **U.S. Army Corps of Engineers (USACE)** USACE is the source of data and information on most of the major dams and reservoirs in the state. USACE is also a source for hydrology and water surface profiles for major rivers in Oregon, particularly the Columbia River and Willamette River. Both rivers are significantly regulated with a series of dams and reservoirs. The Corps is also a source of many technical references pertaining to hydrology, coastal protection, and hydraulic design.
   Oregon is part of three USACE districts. The majority of western and central Oregon is in the Portland District. Their website address is ***www.nwp.usace.army.mil*** The far eastern part of the state is in the Walla Walla District ***www.nww.usace.army.mil*** The Klamath River basin in southern Oregon is in the San Francisco District ***www.spn.usace.army.mil*** The national office of the USACE website address is ***www.usace.army.mil***

6. **National Oceanic and Atmospheric Administration (NOAA)** NOAA is the source of historical climatological data such as precipitation and temperature and is also the source for historical tide data. Climatological data is available from the National Weather Service (NWS) and the National Climatic Data Center (NCDC), which are both part of NOAA. Tide data is available from the National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS), which is also part of NOAA. Tide data includes mean lower low water (MLLW), mean low water (MLW), mean high water (MHW), mean higher high water (MHHW), and extreme tide levels. NOAA also maintains surface water gaging stations throughout the state. The national NOAA website address is ***www.noaa.gov*** The NWS address is ***www.nws.noaa.gov*** The NCDC address is ***www.ncdc.noaa.gov*** The NOS CO-OPS address is ***https://tidesandcurrents.noaa.gov/***

7. **Oregon Climate Service (OCS)** The OCS is a source of historical climatological data for Oregon. The data available includes precipitation and temperature data. The website address is ***http://ocs.oregonstate.edu/***

8. **U.S. Bureau of Reclamation (USBR)** The USBR is a source of data for many dams and reservoirs associated with irrigation in Oregon. It is also a potential source of peak flow data and other design data for major irrigation systems such as the system of irrigation canals in the Klamath Falls area. The website address for Oregon (except the Klamath River basin) is ***www.usbr.gov/pn/*** The address for the Klamath River basin is ***www.usbr.gov/mp/***

9. **Local Irrigation Districts** Local irrigation districts are a source of peak flow data and other design and operational details for local irrigation systems.

10. **Cities and Counties** Cities and counties can often provide topographic maps, design data for local storm sewer systems, and drainage master plans. The drainage master plans usually include peak flow data for various storm recurrence intervals for existing land use conditions as well as future land use conditions. Cities and counties are also the source for local drainage ordinances that ODOT projects must satisfy.

6.3.2 Internal Data Sources

The following is a list of data sources within ODOT and type of data that is available. Website addresses for ODOT sources are included. Website addresses for other sources are listed in the previous subsection.

1. **Geo-Environmental Section's Engineering and Asset Management Unit** This information is the Engineering and Asset Unit files. Copies of this information are available to external personnel, such as consultants by visiting the Transportation Building, 355 Capitol Street N.E., Salem, Oregon. Some types of hydrologic data are available on the Geo-Environmental Section website. The address is ***www.oregon.gov/odot/hwy/geoenvironmental***

    a. Flood photographs. Most of the photographs that are available are photos of flood damage to the highway system during the December 1964 and January 1974 floods. Many oblique aerial photographs are available.

    b. Historic highwater marks. Historic highwater marks are available for several locations around the state.

    c. FEMA Flood Insurance Studies (FIS) for the cities and counties participating in the National Flood Insurance Program including the Flood Hazard Boundary Maps, Flood Boundary and Floodway Maps, and the Flood Insurance Rate Maps developed for each

FIS. The Hydraulics Unit has one copy of each available FIS and the maps that were produced for each study. FIS including maps are available on the internet at FEMA's website. It is recommended the FEMA website be searched for available material before the Engineering and Asset Management Unit is contacted.

d. USGS surface water records. The Engineering and Asset Management Unit has one copy of the annual water resources data report published by the USGS. The annual reports contain the data that is gathered at the active stream gages around the state. The data is also available on the Internet. It is recommended available material be retrieved from the USGS website before the Engineering and Asset Management Unit is contacted.

e. OWRD surface water records. The Engineering and Asset Management Unit has one copy of the surface water records published by OWRD from 1965 through 1978, and limited records after 1978. This data is also available on the OWRD website. It is recommended available material be obtained from the OWRD website before the Engineering and Asset Management Unit is contacted.

f. NOAA climatological data and tide data. The Engineering and Asset Management Unit receives the monthly NOAA publications *Climatological Data* and *Hourly Precipitation Data*. These publications summarize climatological data for the weather stations throughout Oregon. Climatological data and tide data is also available on the NOAA website. It is recommended the NOAA websites be searched for available material before the Engineering and Asset Management Unit is contacted.

g. Hydraulic project files. These files contain the data and calculations that were used to develop the hydraulic design for highway projects. These files were established in 1965. The files contain limited data from hydraulic studies prior to 1965. A Hydraulics Report will be in the file if one was prepared for the project. Typical data includes the topographic survey data required for the hydraulic design such as river cross-sections and longitudinal profiles of the channel bottom, site hydrology, backwater data for bridges and culverts, site photographs, flow velocities, flow depths, water surface profiles, and other miscellaneous hydraulic data. Project files include data for bridges, culverts, storm drains, drainage complaints, detention basins, and water quality facilities.

h. Rainfall intensity-duration-recurrence interval curves have been developed by the Engineering and Asset Management Unit for the entire state. These curves are available in **Chapter 7**.

i. Mean daily flow data for the entire state has been compiled by the Engineering and Asset Management Unit. This data is available at the Engineering and Asset Management Unit website.

2. **Geometronics Unit** The Geometronics Unit needs to be contacted for the availability of site-specific information discussed below. They are located at 200 Hawthorne Avenue S.E., B250 Salem, Oregon. Much of this information is listed, along with ordering instructions, at the Geometronics website *www.oregon.gov/odot/hwy/geometronics*

   Aerial photography. Geometronics is the primary source of aerial photography for the highway system. They, along with the Engineering and Asset Management Unit, have aerial flood photography.

   a. Maps. The unit also produces mosaics, planimetric maps, and contour maps.

   b. Benchmarks. Geometronics maintains information on benchmarks.

3. **Bridge Section** The listed information is available to ODOT personnel by contacting the Bridge Section. Copies of this information are available to consultants and others by visiting ODOT Bridge Section Business Support, Transportation Building, 355 Capitol Street, N.E., Salem, Oregon.

   Note: Some information is available on a limited basis.

   a. Bridge maintenance and inspection files. These files contain information on the maintenance and inspection history of a bridge. Typical data and information includes past bridge inspection reports, underwater inspection reports, sounding data, periodic cross-sections of the bridge opening, performance of riprap at piers and abutments, and scour countermeasures constructed at the bridge site.

   b. Bridge drawing files. These files contain the as-constructed drawings that show the details and dimensions of existing bridges. The drawings will usually show the subsurface soil exploration data (drill logs) that was obtained for the bridge foundation design. The files may also contain vicinity maps and drawings of box culverts and pipes that are 6 feet or larger in diameter. The vicinity maps are a source of historic channel cross-sections that can be used to evaluate the lateral and vertical stability of the channel.

   c. Bridge construction records. The bridge construction records have copies of the daily diaries and weekly construction reports during the time the bridge foundations were constructed. These records have invaluable information about foundation types, the materials under and around the foundations, and footing bottom and pile tip elevations. This information is useful to determine the scour susceptibility of structures. Construction records for older bridges are either in the archives or on microfilm in the Bridge Section library.

d. Bridge scour files. These files contain the data and calculations that were used to estimate scour depths for the bridges that were analyzed as part of ODOT's bridge scour evaluation program. Typical data includes site hydrology, site photographs, river cross-sections, water-surface elevations, flow depths, and flow velocities.

e. Pile records. These records list the pile type, number, and tip elevations for piling supported foundations. Other useful information, such as the blow count and pile driving hammer size can be used to estimate the properties of the underlying materials. This information can be useful when predicting potential scour depths, and it is ordered from ODOT's Bridge Section Business Support.

4. **Roadway Section** Roadway drawing files. The roadway drawing files, often called "vertical" or "V" files, contain the as-constructed drawings for all highway projects exclusive of bridge drawings. The drawings are a source of data and information on the highway's horizontal and vertical alignment, typical roadway section, size and location of culverts, storm sewer details including pipe sizes and profiles as well as manhole and inlet locations, details of specially designed drainage appurtenances, and other miscellaneous details. Copies of these files are available from the ODOT Maps and Plans Center, Transportation Building, 355 Capitol Street, N.E., Salem, Oregon.

5. **Region Technical Center** Each of the five ODOT Region Technical Centers is a source of geotechnical information.

a. Geotechnical exploration has been done for almost all significant hydraulic structures. Usually this is subsurface exploration using a drill to retrieve core samples. Geotechnical exploration records are available from the Region Technical Center.

b. Bridge and large culvert preliminary and final foundation reports. These reports summarize the results of the subsurface exploration conducted for a bridge or large culvert. They also recommend the types of foundations suitable for either. The reports are the source of subsurface data that is used to identify the presence of erosion resistant rock that can limit the scour depth. The data is not only useful for the scour analyses of new bridges, but is also useful for scour analyses and scour countermeasure designs for existing bridges. Copies of these reports are available from the Region Technical Centers.

6. **Specifications Unit** Standard drawings and specifications for many aspects of highway construction are available from the Specifications Unit. All material is easily retrieved and printed from the Specifications Unit website

http://www.oregon.gov/ODOT/HWY/SPECS/index.shtml

a. Bridge Standard Drawings. The Bridge Standard Drawings include details and dimensions for bridge deck drains, box culverts and large culvert details, prestressed slabs, prestressed beams, and other miscellaneous items.

b. Roadway Standard Drawings. An entire section of the roadway standard drawings is devoted to drainage, and it includes dimensions and details for manholes and inlets, allowable fill height tables for pipes, sloped ends for pipes, and other miscellaneous drainage items.

6.4 Types of Data Needed

The designer must compile the data that are specific to the subject site. Often the data needed to conduct the hydraulic analysis will depend on the permit requirements, floodplain and environmental regulations. Therefore, the designer should be aware of these requirements. Following are the major types of data that may be required:

- floodplain use regulations (most counties require floodplain development permits),
- biological information,
- watershed characteristics,
- site characteristics, and
- hydrologic and meteorologic data.

Each of these types of data is discussed in more detail in the following sections.

6.4.1 Floodplain Use Regulations

Land use and development in floodplains is regulated near most large rivers, estuaries, and the ocean shore where these water bodies abut populated areas. These regulations often influence the type, size, and location of structures and roadway embankments within the floodplain. These regulations vary from jurisdiction to jurisdiction, and they are constantly being refined and updated. For this reason, it is recommended that current regulations be obtained for each project in the floodplain. These documents should be reviewed prior to the start of the design. Copies of these regulations can be requested from the local ODOT planner.

Floodplain use regulations require a hydraulic study for any work in a floodway, either temporary or permanent. These studies vary in complexity, from simple calculations and a one-page statement, to a comprehensive hydraulic study of the stream reach using hydraulic modeling.

A floodway boundary revision request is an example of a study requiring a hydraulic model. The model compares existing and proposed conditions using computer analysis. The input data describing existing conditions is ordered from FEMA, and it may take 6 months or more to get the information. As a result, if a floodway boundary revision request will be submitted, the existing model should be ordered from FEMA as soon as possible.

6.4.2 Environmental Requirements and Biological Information

Almost all hydraulic projects have biological impacts, and there are a myriad of federal, state, county and city regulations, standards, and criteria that apply to both the design and construction methods. As an example, state requirements are in legislative acts, Oregon Revised Statutes, Oregon Administrative Rules, and ODOT policy and criteria. These requirements vary considerably at different locations throughout the state, and they are constantly being revised.

The fish passage requirements are of utmost importance. They may significantly affect the scope of hydraulic work and the total project costs. An opinion from the Oregon Department of Fish and Wildlife is required for all highway stream crossings where fish pass, both currently and historically.

Documents such as Biological Assessments, Environmental Impact Statements, Biological Opinions, etc. may be in the process of being prepared, or are prepared, for the project. These documents almost always describe both the hydraulic structures and the construction activities along with their environmental impacts.

Biological information is also needed to design the project and temporary water management during construction. This information almost always includes at least the following:

- species affected,
- lifestages affected, and
- in-water work period.

Environmental requirements, biological information and recommendations, and draft and issued environmental documents, can be obtained from the ODFW, the regulatory agencies, and the ODOT Region Environmental Coordinator.

6.4.3 Watershed Characteristics

Watershed characteristics in conjunction with either hydrologic or meteorologic data are needed to estimate the site hydrology. The exception is when a stream gage having a sufficient period of record is located at the site and the gage data reflects current land use conditions. The principal watershed characteristics of interest are the drainage area, land use, basin slope, and soil type(s).

6.4.3.1 Drainage Area

Several methods can be used to determine the drainage area. Topographic maps or auto-delineation using digital elevation model are often used to determine the size and boundaries of larger basins. Aerial photographs or field surveys are often used to determine the size and boundaries of smaller basins. Published references and existing reports can often provide data on drainage areas of all sizes. Often one or more methods are used in combination. It may be necessary to use topographic maps together with aerial photographs, a field review, and spot elevations checks with surveying instruments in order to determine the drainage area, particularly in watersheds that have little relief.

Care must be used when determining the size of the contributing drainage area. Any areas outside the physical boundaries of the drainage area that divert runoff into the drainage area being analyzed must be included in the total contributing drainage area. In addition, it must be determined if flow is diverted out of the basin before reaching the site. In Central Oregon where there has been relatively recent volcanic activity in geologic time, the hydrologic boundary or true drainage area is often uncertain because of groundwater exchange. There are also watersheds, particularly in Eastern Oregon, where a system of irrigation canals and ditches may divert water from one watershed into another. The irrigation systems are typically designed to pass the natural runoff, however, this should be field verified or verified with the local irrigation district.

Topographic Maps - The drainage area expressed in acres or square miles is usually determined by tracing the watershed divide on a topographic map with a planimeter. The USGS quadrangle maps are the most commonly used topographic maps and are the best maps available to determine the drainage areas of major rivers. Other sources of topographic maps include cities and counties and the ODOT Geometronics Unit. The topographic maps obtained from cities and counties are often used for urban drainage design such as storm drains and detention systems.

Auto-Delineation Using a Digital Elevation Model – Several methods to determine drainage areas can be used with the OWRD procedure for rural regression equations. One method is to delineate the watershed by automated procedures using elevations from a digital model. The user executes this option while logged onto the OWRD website. OWRD programs and data are used to determine the watershed properties.

Aerial Photographs – Aerial photographs can be used to determine drainage boundaries of smaller watersheds. Typically a magnifying stereoscope is placed over a pair of aerial photographs. The drainage area is plotted on paper or a map based on the three-dimensional image viewed in the stereoscope. Two overlapping photographs taken directly above the study site are needed to make the image. The Geometronics Unit has images from flights over almost all of the highway system and many other areas. It is helpful when ordering the photos to specify that multiple pictures are needed to provide a stereoscopic image.

Field Surveys – A direct field survey using conventional surveying instruments can also be used to determine the drainage area. The direct field survey may be needed to delineate the drainage area in very flat terrain or to verify the area determined with maps or aerial photographs. In flat watersheds or urban areas where the natural drainage pattern may have been changed, a field review may be necessary to delineate the drainage area. The best time to conduct a field review and observe the runoff pattern is when it is raining.

Published References and Reports – Published references and reports are a good source of drainage basin information. FEMA Flood Insurance Studies list the contributing areas of significant watersheds within the study area. Almost all of the bridges and large culverts on the state highway system have been the subject of one or more ODOT hydraulic studies, and the watershed areas are often listed in the reports or in the project files.

Drainage Master Plans have been prepared for almost all areas within urban growth boundaries. These plans show existing drainage boundaries, and they also show anticipated changes in drainage boundaries when the urban area develops. These drainage plans are often the best source of information about urban storm drain systems.

Drainage areas published in master plans should be used with caution. Sometimes the drainage area listed in the master plan is only the contributing area within the urban growth boundary, and there is additional contributing drainage area outside of the boundary. Watersheds adjacent to the urban growth boundary should be inspected to verify if the drainage area listed in the master drainage plan is the entire area.

6.4.3.2 Land Use

Many of the techniques, materials, and references used to determine the drainage area can also be used to determine the land use. Information on existing land use and future urbanization trends may be obtained from:

- aerial photographs,
- zoning maps and drainage master plans,
- field review,
- NRCS soil surveys,
- USGS quadrangle maps, or
- a combination of the above techniques.

Existing land-use data for small watersheds can best be determined or verified from a field review. Changes discovered during the field review should be used to update information on maps and aerial photographs used to document the existing land use. The best source of information on future land use is zoning maps and master plans obtained from municipal planning agencies.

6.4.3.3 Basin Slope

A topographic map or a field survey is needed to determine the slope of the stream channel. The field survey is the usual technique to determine the local channel slope at a site where a drainage structure will be located, whereas topographic maps are used to determine the overall channel slope. The overall channel slope and channel length are needed to calculate the time of concentration or sub-basin flow times when using the Rational method or NRCS methods to estimate peak flows. The channel slope is also an input variable in some OWRD and USGS regression equations.

6.4.3.4 Soil Type

Soil types are needed to estimate peak flows when using NRCS techniques. Soil types can be determined from the soil surveys and soil maps published by the NRCS.

6.4.4 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 characteristics of a stream reach must be studied to determine its effect on the flow pattern and water surface profile. The principal site characteristics of interest are discussed in this section.

6.4.4.1 Roughness Coefficients

Roughness coefficients, ordinarily in the form of Manning’s n values, must be estimated for the entire limits of the stream reach being analyzed. A tabulation of Manning’s n values with descriptions of their applications can be found in **Chapter 8**. Manning’s n values are usually determined based on the designer’s experience and judgment. The roughness coefficients can be estimated during a site visit or from photographs of the site.

The range of Manning’s n values used in FEMA Flood Insurance Studies is often listed in the study report. Although these values are often a good reference, they should not be used for the stream to be analyzed unless it is verified they are appropriate.

6.4.4.2 Stream Profile and Water Surface Profile

A profile of the channel thalweg and a profile of the water surface at the time of the survey must be obtained in order to determine the slope of the channel. The profiles should extend a sufficient distance upstream and downstream from the project site to accurately determine the slope of the channel. For bridge or culvert crossings the profiles should extend upstream and downstream as shown in the following chart.

The channel slope can be determined from either the thalweg or the water surface profile. The water surface profile is usually a better indicator of the slope, as it will smooth out the irregularities of the thalweg profile. At sites where there is little or no flow at the time of the survey, an effective way to calculate the channel slope from the thalweg profile is to base the elevation change on the elevations of the thalweg at "zero-flow points." Zero-flow points are points in the profile that would control the pool elevations upstream of major riffles if there were no water flowing in the channel.

Stream Profile Chart

Bridge length "L" in feet *	Upstream and downstream profile distance from centerline of bridge, in feet
"L" less than 100	500
100 less than or equal to "L" less than 300	1000
300 less than or equal to "L" less than 500	2000
500 less than or equal to "L" less than 800	½ mile
800 less than or equal to "L"	1 mile

Culvert diameter "D" in feet *	Upstream and downstream profile distance from centerline of culvert in feet
"D" less than 6	300 to 500
6 less than or equal to "D"	500 to 700

* greater of distance listed above or 20 times bankfull width per section 6.4.4.11 should be used.

Additional information is also included in the profile notes. Stream gages should be shown on the profiles if they are relatively close. The elevation of the gage reading and the actual gage reading should be obtained in order to tie the gage datum to the survey datum. Ordinary high water elevations, flow controls, and headcuts should also be noted on the profiles, as discussed in the remainder of this chapter.

6.4.4.3 Stream Cross-Sections

Multiple cross sections are required to compute water surface profiles. Cross-sections are required at representative locations throughout a stream reach and at locations where changes occur in discharge, slope, shape, or roughness, at locations where levees begin or end and at bridges or control structures such as weirs. The cross-section must capture the channel and especially the channel surface below the water. The cross-section also must capture the floodplain and be able to contain the highest expected water surface elevation to be considered. Cross-sections should be placed at intervals that will divide a total reach into a series of subreaches each of which is as uniform in geometry and roughness as practical. Fairly uniform channels will require fewer cross-sections than those having many irregularities in size, shape, slope, or roughness. The sections should be located to enable proper evaluation of energy losses. Therefore, where abrupt changes occur such as at bridges, several cross-sections should be used to define the change. The cross-section should be perpendicular to the direction of flow. Note that perpendicular to the flow in the floodplain may differ from perpendicular to the flow in the channel in which case the section will have a “dogleg” and the direction of the section in floodplain will be different than in the channel.

6.4.4.4 Structures and Roadway Data

The structure geometry and channel geometry of existing structures on the stream reach and near the site are needed to determine their capacities and effects on the stream flow. With bridges, needed data includes span lengths, deck width, deck profile, type of bridge rail (i.e., solid or flow through), bottom-of-beam elevations, type and number of piers, pier widths, and substructure orientation. The necessary culvert data includes size, inlet and outlet geometry, slope, end treatment, culvert material and flow-line profile. “As-built” highway construction plans may be available to obtain the required bridge and/or culvert data. Any structures, downstream or upstream, that may cause backwater or retard stream flow should be investigated.

Also, the manner in which existing structures have been functioning with regard to such items as scour, overtopping, debris and ice passage, fish passage, etc., should be noted. Photographs and high-water profiles or high-water marks of flood events at the structure and past flood scour data are invaluable in assessing the hydraulic performance of the existing facility. Maintenance personnel are often the best source of information on the hydraulic performance of existing structures and information on past floods.

The roadway embankment associated with existing structures usually obstructs the flow and in order to include the effect of the roadway, certain data on the roadway is needed. Needed data includes the profile, width, and alignment of the road. The profile of the road should reflect the highest part of the roadway and should define the overtopping limits of the roadway if the roadway is subject to overtopping.

For projects where an existing structure will be replaced, data on the proposed structure and roadway are needed. The data requirements for proposed structures and the associated roadway is the same as for existing structures.

Existing culverts, storm drains, and water quality facilities within the project limits that will remain after the project is built should be inspected to determine their condition and remaining service life. These facilities may need to be rehabilitated or replaced. This is especially critical for culverts and storm drain that will be extended. Direct visual inspection and remote inspection by television are usually used. Culvert and Storm Drain Pipe inspection forms are shown in Appendices D and F, respectively.

6.4.4.5 Acceptable Flood Elevations

Development and property use adjacent to the proposed site, both upstream and downstream, may determine acceptable flood elevations. Floor elevations of buildings or structures should be obtained. The presence of upstream development may limit the amount of backwater that the proposed crossing can create. In the absence of upstream development, acceptable flood levels may be based on freeboard or overtopping requirements of the highway. In these instances, the presence of downstream development may determine appropriate overflow points when an overtopping design of the highway is considered.

6.4.4.6 Flood History

As mentioned in Subsection 6.4.4.4, the history of past floods and their effect on existing structures are invaluable in making flood hazard evaluation studies, and they provide needed information for sizing structures. Information may be obtained from newspaper accounts, local residents, maintenance personnel, apparent flood marks or other positive evidence of the elevation of historical floods. High water marks can be very useful when calibrating a hydraulic model. Changes in channel and watershed conditions since the occurrence of the flood must be evaluated in relating historical floods to present conditions.

Recorded flood data are available from federal agencies such as USACE, USGS, NRCS, FEMA, and USBR. Cities and counties may have flood data for structures under their jurisdiction. The ODOT Geo-Environmental Sections' Engineering and Asset Management Unit has flood photographs and high-water marks for the State highway system.

6.4.4.7 Debris and Ice

The quantity and size of debris and ice carried or available for transport by a stream during flood events should be investigated. The data obtained may determine the amount of freeboard necessary at the site. If possible, 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 when using stream flow records. The records will usually state if the flood heights were affected by debris or ice. Data related to debris and ice considerations can be obtained by interviewing maintenance personnel. The potential for debris can be assessed during a site visit by noting the presence of debris being transported in the channel, the accumulation of debris against existing bridge piers, or the potential for debris based on the presence of trees growing along the channel banks or the adjacent floodplain.

6.4.4.8 Channel Stability

Channel stability is an important consideration relative to the stability of the structure and highway over time. A site inspection will usually reveal obvious channel instabilities such as active bank erosion, headcuts, channel degradation, channel migration and/or local scour problems at bridge piers and abutments. Typical data required to perform a stability analysis includes:

- maps,
- a series of historic aerial photographs,
- historic channel profiles and cross sections (structure opening cross-sections are surveyed periodically during the bridge inspection program),
- notes and photographs from field inspections,
- information on man’s activities in the watershed, both recorded and obtained from personal interviews with ODOT maintenance personnel, landowners and others,
- sediment data including transport rate and gradation,
- observations from a visit to the site, and
- changes in stream hydrology and hydraulics over time.

More detailed information on the data requirements for evaluating and analyzing channel stability can be found in the following reference:

Lagasse, P.F., J.D. Schall, and E.V. Richardson, 2001, “Stream Stability at Highway Structures”, Third Edition, Publication No. FHWA NHI 01-002, Hydraulic Engineering Circular No. 20, Federal Highway Administration, Washington, D.C.

6.4.4.9 Flow Controls

In addition to existing structures and roadways discussed in Section 6.4.4.4, other flow controls may exist upstream and/or downstream of the site. The controls must be identified in order to include their effects in the hydraulic analysis.

Dams and Reservoirs - Any existing dams or reservoirs near the site should be noted. Spillway elevations and design levels of operation should be obtained. These controls can affect water surface elevations and sediment transport at the project site. Upstream control of runoff in the watershed should also 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 operational designs for these features should be obtained. NRCS, USACE, USBR, Water Resources Dam Safety, consulting engineers and other reservoir sponsors often have complete reports concerning the operation and design of proposed or existing conservation and/or flood control reservoirs.

Installation of a nearby dam during the design life of a proposed structure can affect the crossing's hydraulic performance. If it appears a dam may be built, it should be noted on the location data. Upstream from a dam, the water surface elevations in the impounded reservoir can raise elevations and lower flow velocities in the contributing tributaries. This can lead to increased sediment buildup in the reservoir and at the mouths of the tributaries. Downstream from a dam, the peak discharges and sediment transport can be reduced due to storage of both water and sediment in the reservoir. This can cause a lowering of the channel bottom.

Removal of an upstream or downstream obstruction such as a dam or weir can also affect the hydraulic conditions at a crossing. It should be verified that nearby dams will remain in-place during the design life of the proposed structure. In recent years it is not uncommon for man-made dams or weirs to be removed from streams or rivers. Usually these are smaller dams that do not provide significant flood control. Removal of these dams can restore natural sediment transport to a stream, and result in a loss of sediment upstream from the dam and a corresponding increase in sediment downstream.

Diversions – Diversions upstream from a structure can affect the discharges through the site. Significant diversions upstream from the site should be noted. Any anticipated changes to the diversions should also be noted. Diversions can be artificial or natural.

Artificial diversions include flood control facilities, irrigation facilities, or undersized highway or railroad crossings. Flood control diversions can occasionally make an existing highway crossing obsolete or require a new crossing. Undersized culverts or bridges that have insufficient hydraulic capacity can divert flood flows. There may be an increase in peak flood flows downstream when these structures are replaced with hydraulically adequate or fish-passable crossings. The owners of the diversions are the best source for information about them.

Natural diversions include debris jams, mudflows, rock slides, or beaver dams. These diversions may be permanent or temporary. Diversions that divert flow onto developed property may be removed. Maintenance personnel and local officials are good sources for information about natural diversions and their possible removal.

Natural diversions also occur in rivers and streams on alluvial fans. This happens most often in the Columbia River Gorge and the slopes of Mount Hood. These streams periodically undergo natural diversions when a channel fills with sediment and the stream shifts to a new channel. In these areas all stream crossings on the fan are usually designed to convey the entire stream discharge, regardless of whether or not the stream is currently using the crossing. Also, some crossings need to be raised periodically when the channel fills with sediment. Region geologists and maintenance personnel are good sources of information about these sites.

Downstream Water Bodies – Downstream water bodies such as rivers, lakes, estuaries, or the ocean can often influence water surface elevations at highway crossings, as discussed in **Chapter 10**. These nearby water bodies should be described in the location notes. In some cases, the downstream water body needs to be included in the hydraulic model, and additional survey information will be needed, such as cross-sections or profiles. The hydraulic designer should be contacted to see if additional data is needed.

A crossing is sometimes located on a tributary just upstream from its confluence with a larger river or stream. The channel bottom of the larger waterway should be inspected downstream from the tributary mouth. Headcuts or channel degradation in larger waterway may progress upstream into the tributary and cause the channel bottom to drop at the crossing. This possibility, if it is likely to occur, should be mentioned in the hydraulic survey. Headcuts are discussed in **Chapter 9**.

Geologic Controls – An important aspect of hydraulic design is to predict future changes in channel alignment, both in the horizontal and vertical planes. Geologic controls such as rock ledges across the channel bottom can influence channel movement in the vertical plane. Hard rock outcroppings can influence lateral movement in the horizontal plane. These ledges and outcroppings should be noted if they are within the hydraulic survey limits.

6.4.4.10 Bed Material

Bed material is the sediment mixture found in and on the streambed. Knowledge of the size and gradation of the bed material is necessary for most sediment transport analyses, including incipient motion analysis, armoring potential of the channel bed, sediment transport capacity, and scour calculations. The most common sediment characteristic needed is the median, D_{50}, sediment size. The size and gradation of the bed material can be determined with a sieve analysis of a bed sample or by using the pebble count method. The sieve analysis is appropriate when the bed material size ranges from 0.002 – 1.25 inches. The pebble count method is used to obtain the size distribution of coarse bed materials (i.e., gravel and cobbles) that are too large to be sieved and is used when the bed material size ranges from 0.5 – 40 inches. A sieve analysis can be obtained by submitting a sample to the Materials Section. Appendix A explains several methods to determine bed material size and gradation.

6.4.4.11 Ordinary High Water

The following definition was obtained from the Division of State Lands. "The Ordinary High Water (OHW) mark is a line on the bank or shore to which the high water ordinarily rises each year and is the waterward limit of upland vegetation and soil. This line is not established based on the level to which the water rises during major floods. It is generally recognizable by a visible change in the soil and vegetation." OHW is used by regulatory agencies to define the boundary of in-water work. Any work below the OHW elevation is considered to be in-water work and special measures must be taken to protect the waterway.

OHW corresponds to the elevation or stage where water just begins to overflow onto the floodplain for streams with well-defined floodplains. OHW will be contained in the channel and field stage indicators will need to be used to determine OHW for streams that are entrenched in the landform. Field stage indicators must also be used at sites where floodplains are not well developed. Following are field indicators of OHW. These are the same indicators geomorphologists use to determine bankfull stage. As many corroborating features as possible should be used to determine the OHW elevation.

- The elevation of the floodplain. This is the most reliable indicator of OHW.
- The lowest extent of woody vegetation in the bank or where aquatic vegetation changes to terrestrial vegetation. Willows can be misleading as willows may become established below OHW, especially during periods of drought or low flow. Certain mature species of birch, dogwood, and alder tend to consistently colonize and become established at levels very close to OHW.
- The elevation associated with the top of the highest depositional features (e.g., point bars, central bars within the active channel). This is typically considered the lowest elevation to be considered as OHW.
- A break in the slope of the banks and/or a change in the particle size distribution.
- The top of the zone of washed roots (exposed root hairs below an intact soil layer indicating exposure to erosive flow).
- Staining of rocks and lower limit of lichen or moss growth on rocks.
- Stains on bridge piers or culverts.
- Evidence of inundation features such as small benches.
- The elevation of flood deposited debris if corroborated by other indicators. High water marks are used to confirm OHW and should not be used as the primary evidence.

It is important to know the recent flood and/or drought history of the area to avoid being misled by false indicators such as colonization of riparian species below OHW during drought. A recent flood can give the impression that OHW is higher than it actually is.

The most common means to establish OHW is by the field marks previously discussed. These marks are used when OHW elevations are staked in the field by the biologist or hydraulics designer. The requirements for field assessment, flagging, and documentation of the OHW are outlined in ODOT Geo-Environmental Technical Bulletin GE09-07(B). A link to this bulletin is provided below:

ODOT Geo-Environmental Technical Bulletin GE09-07(B)

Occasionally OHW can be determined or verified by calculation. This is often the best method where field marks have been obliterated by a recent flood, or where there is an absence of appropriate field indicators. This is done by determining the 2-year event profile. This is the typical recurrence interval of the OHW. Stage-discharge relationships from nearby stream gages can also be used to calibrate or verify OHW elevations based on field marks.

Published data can also provide OHW elevations. As an example, OHW elevations for the Portland-Vancouver Harbor are available in a published study. These elevations are often acceptable to regulatory agencies. A critical aspect of using published elevations is to convert them to the project elevations while considering any differences in reference datums. The ODOT project elevation datum is often different than the published study elevation datum.

6.4.5 Hydrologic and Meteorologic Data

Hydrologic and meteorologic data includes historic streamflow and precipitation data for the watershed as well as low flow data. The data is needed to estimate the hydrology of a site using the methods presented in **Chapter 7**. The major source of stream flow data is the USGS. Stream flow data for Oregon is also available from the Oregon Water Resources Department (OWRD). The major source of meteorologic data is the National Weather Service (NWS) and the National Climatic Data Center. The Oregon Climate Service is also a source of meteorological data for Oregon.

6.5 Field Reviews

Field reviews should be made by the hydraulic designer in order for the designer to become familiar with the site. It also allows the designer to determine required cross-section locations and other survey requirements unique to the site. The most complete survey data cannot adequately depict all site conditions or substitute for personal inspection by someone experienced in drainage design. Site and watershed characteristics that most often need to be confirmed or determined by field inspection are:

- selection of roughness coefficients,
- evaluation/observation of flow patterns, flow diversions, flow concentration, and likely flood patterns,
- watershed characteristics including land use and watershed boundaries,
- high-water marks or profiles,
- existing bridge/culvert dimensions and features (e.g., culvert size and material, culvert inlet and outlet geometry, etc.)
- drift/debris characteristics,
- location and length of roadway overtopping,
- evaluation of channel stability (e.g., signs of active bank erosion, observation of headcuts, potential for channel migration, etc.)
- location and existence of flow controls,
- location and size of overflow structures,
- size and limits of existing riprap protection,
- existence of pier and/or abutment scour problems and scour countermeasures,
- size of bed material (i.e., obtain bed sample for sieve analysis or conduct pebble count),
- existence of upstream and/or downstream structures that need to be included in the hydraulic analysis, and
- location of buildings or structures that may effect the allowable backwater elevation.

The visit to the project site should be made before final hydraulic design is undertaken. If possible, this should be combined with the scoping trip involving other disciplines involved in the project design (e.g., the roadway and structural designers, environmental specialists/coordinators, regulatory agencies, local officials, etc.). As much information as possible about the site should be gathered in the office prior to the site visit. The site visit is also an excellent time to meet onsite with maintenance personnel in order to get their input on the flood history and maintenance requirements unique to the site. It is also an opportunity to meet with the survey party chief responsible for the drainage survey to go over the survey data requirements.

Photographs should be taken. At a minimum, photos should be taken looking upstream and downstream from the site and along the contemplated highway centerline in both directions. Details of the streambed and banks should also be photographed plus structures in the vicinity both upstream and downstream. Close-up photographs complete with a scale or grid can be taken to facilitate estimates of the streambed gradation. Site photographs are invaluable if a lawsuit ever develops. The photographer should be identified on the photo submittal. They may need to provide information to legal counsel.

6.6 Drainage Survey Requirements

Complete and accurate survey information is necessary to develop a design that will best serve the requirements and characteristics of the site. Ideally, the individual in charge of the drainage survey should have a general knowledge of drainage design. The amount of survey data gathered shall be commensurate with the importance and cost of the proposed structure and the expected flood hazard. The hydraulics designer should meet onsite with the survey party chief to go over the required cross section locations and other unique data requirements of the site. This will ensure that the survey will be cost effective, gather the necessary data and avoid repeat visits to the site by the surveyors to gather additional data. Appendices B, C, and E outline the data requirements for bridges, culverts, and storm drains, respectively.

At some sites, photogrammetry may be effective in supplementing the topographical components of the ground survey. When using photogrammetry, a ground survey is required to provide data in areas obscured on the aerial photos (e.g., underwater and heavy vegetation).

6.7 Data Evaluation

Once the needed data have been collected, the next step is to compile it 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, draw all of the various pieces of collected information together, and fit them into a comprehensive and accurate representation of the hydrologic and hydraulic characteristics of the project site.

Experience, knowledge and judgment are important parts of data evaluation. Reliable data must be separated from that which is less reliable and historical data combined with that obtained from measurements. When combining topographical data from previous surveys and current surveys, the designer should verify that both surveys used the same vertical datum. Data should be evaluated for consistency and to identify any changes from established patterns. The review may include such items as previous studies and old plans for types and sources of data, how the data were used and any indications of accuracy and reliability. Historical data should 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 USGS can usually be considered as valid and accurate. Maps, aerial photographs, and land-use studies must be compared with one another and with the results of the field survey and any inconsistencies resolved.

6.7.1 Sensitivity Analysis

Sensitivity analysis may be used to evaluate data and establish the relative importance of specific data items to the final design. Sensitivity analysis consists 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 should 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.

6.7.2 Data Accuracy

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 or WSPRO, 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, and selection of roughness coefficients.

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

More precision is needed for survey data used to analyze and design roadway drainage, the structural components of stormwater treatment facilities, and other hydraulic structures. ODOT roadway and structural survey guidelines can be used in most applications. In situations the ODOT guidelines do not address, an accuracy of 0.01 feet is usually sufficient.

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 and WSPRO.

For further information on determining the relationships between survey technology and accuracy employed for determining stream cross sectional geometry, degree of confidence in selecting Manning's roughness coefficients, and the resulting accuracy of hydraulic computations, refer to the USACE publication prepared for the Federal Highway Administration, “Accuracy of Computed Water Surface Profiles”, and Technical Paper No. 114, “Accuracy of Computed Water Surface Profiles Executive Summary”, December 1986. These publications also present 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.