5 Planning and Location

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5.1 INTRODUCTION

5.1.1 Preliminary Planning

CDOT often is a developer of transportation facilities that have the potential to stimulate secondary activity along a transportation corridor, just as a major residential development can stimulate commercial activity. Secondary activity is a local planning function that must address overall stormwater management needs in conjunction with other utilities (e.g., water, wastewater, power). Because a transportation corridor often traverses several watersheds, development of an adequate stormwater-management plan can become fragmented and significant problems created if there is a lack of coordinated planning among concerned parties.

To be effective, a stormwater-management plan should consider the total scope of development (i.e., transportation, residential, commercial, industrial and agricultural). CDOT's coordination with responsible local agencies is essential to ensure that proposed facilities are compatible with long-term needs of an area. CDOT also can provide important information to local agencies wishing to develop a comprehensive stormwater-management plan, without assuming responsibility for the planning and decision-making process for the entire watershed.

Prior to design, a level of planning should be undertaken that will properly locate facilities and adequately address local concerns, permitting requirements, legal considerations, and potential problems. This Chapter provides general guidelines for evaluating these factors during the planning and location process. It is important point that the hydraulic designer becomes involved in the early stages of project development.

5.1.2 Flood Hazards

Flood-flow characteristics at a highway stream crossing should be carefully analyzed to determine its effect upon the highway, and to evaluate the effects of the highway upon the flood flow. This will allow determination of locations where construction and maintenance will be hazardous or unusually expensive. It is important to identify flood hazards prior to any highway design to determine if the flood hazard will be increased, decreased or unchanged by a proposed highway improvement. Flood hazards to private property upstream and downstream (i.e., overtopping floodwaters diverted onto previously unaffected property) are important to identify. Often it is best to avoid troublesome and uncertain conditions. Satisfactory solutions sometimes can be obtained by making only minor changes in selected routes to take advantage of better natural hydraulic features at alternative sites.

5.1.3 Construction Problems

Many serious construction problems arise because important drainage and water-related factors were overlooked or neglected in the planning and location phases of the project. With proper planning, such problems can be avoided, or cost-effective solutions developed to prevent extensive damage. Examples of these problems include:

- Soil erosion;
- Sediment deposition;
- Drainage-caused landslides;
- Groundwater;
- Inappropriate timing of project stages; and
- Contamination of pumping and distribution facilities.

Other things to consider during the planning and location phase include:

- Protection for fish habitat;
- Protection of irrigation systems and their continued use during construction;
- Protection of streams, lakes, and rivers;
- Protection of wetlands; and
- Flood proofing.

Analysis of available data, proper scheduling of work and other aspects involved in the early planning and location studies can alleviate many problems encountered in the construction of drainage facilities.

5.1.4 Maintenance Problems

Planning and location studies should consider potential erosion and sedimentation problems occurring after completion of highway construction. If a particular location will require frequent and expensive maintenance due to drainage, alternate locations should be considered unless the potential high-maintenance costs can be reduced by a particular design. Familiarity with an area is the best indicator of potential maintenance problems, and interviews with maintenance personnel are extremely helpful in identifying them. Also, reference to flood reports, damage surveys, newspaper clippings, and interviews with local residents are helpful in identifying potential maintenance problems.

Minor drainage and channel modifications, and modifications of irrigation systems usually obligate CDOT, as owner of the highway, to perform future maintenance. Potential damage from erosion, degradation of stream channels, and problems caused by ice and debris are significant from a maintenance standpoint.

5.2 CRITERIA

5.2.1 Interagency Coordination

Interagency cooperation is an essential element for serving the public interests. Coordination between stakeholder agencies during the project-planning phase will result in a design that is more satisfactory to all. Substantial cost savings and other benefits frequently can be realized on highway and water resource projects through coordinated planning among the Federal, State and local agencies engaged in water-related activities (e.g., flood control, water resources planning).

5.2.2 Intra-agency Coordination

Early planning and location studies must be coordinated between CDOT and specialty groups to minimize duplication of effort. It is important that all who may be involved in future project work be informed of any ongoing studies and results. Among these groups are Colorado Water Conservancy Board (CWCB), Colorado Division of Homeland Security and Emergency Management (DHSEM), Colorado Resiliency and Recovery Office (CRRO) and Colorado Department of Local Affairs (DOLA) who are all part of the Flood Technical Assistance Partnership, and federal partners at Federal Emergency Management Agency (FEMA) and Federal Highway Administration (FHWA).

5.2.3 Legal Aspects

Details of the legal aspects related to drainage are discussed in Chapter 2 of this manual. Additionally, the following generalizations found in AASHTO's *Highway Drainage* should be considered:

- A goal of highway drainage design is to perpetuate natural drainage as practical and to prevent damage that could have reasonably been avoided.
- Courts look with disfavor upon infliction of damage that could reasonably have been avoided, even where some alteration in flow is legally permissible.
- Basic laws relating to liability of governmental entities are undergoing radical change, with a trend toward increased governmental liability.
- Drainage laws are also undergoing change. Older and more specific standards are being replaced by more general and flexible standards that depend on the circumstances of a particular case.
- In water law matters, designers must recognize that the State is held to a higher standard than a private citizen. Designers should not address legal questions without the aid of legal counsel.
- Whenever drainage problems are known to exist and can be identified, drainage and flood easements, or other means of avoiding future litigation, must be considered, especially in locations where a problem could be caused or aggravated by the construction of a highway.
- It is often helpful in the planning and location phase of a project to document the history and present status of conditions or problems, and supplement the record by photographs and descriptions of field conditions. Such thoroughness is essential as CDOT is sometimes blamed for flooding or erosion damage caused by conditions that existed prior to highway construction.

5.2.4 Environmental Considerations

CDOT Environmental is responsible for overseeing and implementing the environmental process in coordination with the hydraulics engineer. This process includes:

- Identifying the environmental class of action; and
- Performing any necessary environmental studies (e.g., wetlands impact, archeological impact, Section 106 impact).

Appropriate environmental studies must be performed for all projects. These studies must comply with all Federal, State and local laws and regulations related to environmental quality, and identify all environmental impacts of a project, positive and negative. If a project requires Federal action, then NEPA rules must be followed.

Environmental considerations for a proposed project must be documented, including alternatives considered. Encroachments onto adjacent areas (including environmental encroachments) should be avoided whenever possible. Identifying environmental considerations early in the planning process prevents major problems as project design and construction proceed.

5.2.5 Permits

Specific Federal, State and local permits needed for a highway project must be identified in the environmental document early in the planning stages. For Federal permits, applications for construction are filed with U.S. Army Corps of Engineers.

Prior to initiating design work, the designer must review the environmental documents to identify regulatory commitments, constraints and any permits required. All required permits must be obtained before construction begins, preferably before detailed plans are prepared. Examples include:

- Water quality (Section 401);
- National Pollutant Discharge Elimination System (NPDES) permits (Section 402);
- Dredge and fill permits (Section 404);
- Navigable waterways (U.S. Army Corps of Engineers Section 10);
- Navigational clearances (U.S. Coast Guard Section 9); and
- County and municipal permits.

Additionally, FEMA's National Flood Insurance Program (NFIP) floodplain permits and no-rise certifications must be obtained from local agencies prior to mobilization, and in some cases post-construction with as-built certified documentation.

5.2.6 Location Considerations

The primary drainage consideration for facility location in highway planning is evaluation of the impact of floodplain encroachments for a stream crossing. Hydraulic and environmental considerations of highway river crossings and encroachments are discussed in FHWA's HDS-6, *River Engineering for Highway Encroachments - Highways in the River Environment.*

Principal factors to be considered in locating a stream crossing involving encroachment within a floodplain are:

- Floodplain extent;
- River type (straight or meandering);
- River characteristics (stable or unstable);
- River geometry and alignment;
- Geomorphology;
- Hydrology;
- Hydraulics;
- Needs of the area;

- Livestock and wildlife access;
- Landowner impacts;
- Local concerns including utilities and right of way; and
- Social, economic, and environmental concerns.

A detailed evaluation of these factors is part of a location hydraulics study. When a suitable crossing location has been selected, specific details of the crossing can be determined. These include:

- Geometry and length of the approaches to the crossing;
- Probable type and approximate locations of the abutments;
- Probable number and approximate locations of the piers;
- Estimated depth to the footing supporting the piers (to protect against local scour);
- Locations of longitudinal encroachment in the floodplain;
- Amount of allowable longitudinal encroachment into the main channel; and
- Required river-guiding procedures to ensure that river flows approach the crossing or encroachment in a beneficial way.

5.3 Stormwater Quality and Quantity Concerns

5.3.1 Introduction

Planning for drainage and stormwater management facilities should include a consideration of the potential problems associated with stormwater quality. To be truly effective, a stormwater management plan should consider the total scope of development (i.e., transportation, residential, commercial, industrial, agricultural). CDOT coordination with the responsible local agencies is essential to ensure that the proposed facilities are compatible with the long-term needs of the area. CDOT can provide important information to local agencies wishing to develop a comprehensive stormwater management plan without assuming responsibility for the planning and decision-making process for the entire watershed.

5.3.2 Quality

Several broad categories of degradation have been defined to describe levels of stormwater impact:

Aesthetic Deterioration: Presence of undesirable general appearance features (dirty, turbid or cloudy) and actual physical features (odors, floating debris, oil films, scum or slime).

Dissolved Oxygen Depletion: Where oxygen demand of bacteria has been stimulated by organics, and the subsequent reduction in oxygen levels has disturbed the balance between higher and lower forms of the food chain. Unoxidized nitrogen compounds (ammonia) can also cause problems.

Pathogen Concentrations: When high concentrations of pathogens have reduced the acceptable uses of the receiving waters.

Suspended Solids: When the physical buildup of solids has covered a productive stream bottom, is aesthetically objectionable, or disrupts flow and navigation.

Nutrients: When accelerated eutrophication that stimulates growth of aquatic vegetation has caused a water body to become aesthetically objectionable, depleted dissolved oxygen, and decreased recreational value by creating odor and overgrowth. Also, when advanced eutrophication has led to sediment buildup and reduced storage capabilities.

Toxicity: When toxins in stormwater (metals and pesticides/persistent organics) have built up in sensitive areas over time. At high levels, they can have serious effects on aquatic life. Low levels can become significant by transmission up the food chain.

Hazardous Spills: Depending on the characteristics of the spill, serious water quality problems can result.

Other Physical and Chemical Attributes: These can include pH, temperature, hydrocarbons, road salts, etc.

A listing and description of common contaminants found on roadways is presented in Table 5.1. This table includes examples of contaminants, analytical methods for identifying them, and their primary sources.

TABLE 5-1 — Listing of Common Stormwater Contaminants

Classification	Examples	Analytical Determination	Primary Sources
Particulates	Dust and dirt, stones, sand, gravel, grain, glass, plastics, metals, fine residue	Settleable solids	Pavement, vehicle, atmosphere, litter, maintenance
Heavy metals	Lead, zinc, iron, copper, nickel, chromium, mercury	Specific heavy metal via atmospheric absorption	Vehicle, atmospheric fallout and washout
PCB, pesticides, herbicides	Chlorinated hydrocarbons, organo-phosphorous	Gas chromatography	Spraying of vegetation
Inorganic salts	$CaC1_2$, NaC1, SO_4, Br	C1, SO_4, Br, non-volatile solids, conductivity	Deicing salts, atmospheric washout, vehicle
Organic matter	Vegetation, dust and dirt, humus, roadway accumulations, oil, fuels	Volatile fraction hexane extractables (oil and grease), BOD, COD, TOC	Vehicular airborne fallout, vegetation, vehicle, litter, aerosols
Nutrients	Nitrogen, phosphorous	TKN, NO_2, NO_3, PO_4	Fertilizer
Pathogenic bacteria (indicators)	Coliforms	TC, FC, FS and other specific indicators	Soil, litter, excreta, bird droppings
Other	Asbestos, rubber, special compounds	Chemical diffraction and electron microscopy, special techniques	Vehicle, specific additives

Quantification of levels of contaminants washed off a roadway is complicated by the variable effects of, and the periods between, storm events. Contributing factors include rainfall intensity, street-surface characteristics, and particle size. The varying interaction of these factors makes it difficult to accurately estimate the effect a discharge will have on water quality. In general, erosion and sediment transport should be limited by developing and implementing an erosion and sediment control plan that addresses both temporary and permanent control practices.

For additional information on design criteria for permanent water quality control measures, see Chapter 16 - Permanent Water Quality.

5.3.3 Quantity

Determination of stormwater quantity is primarily useful for evaluating and mitigating the impact of a project. Without detention ponds (basins, storage areas), land development increases peak-runoff rates and volumes from storm events which can lead to higher flood elevations. Appropriate hydrologic and hydraulic calculations presented in various chapters of this manual should be made to determine the required conveyance through the CDOT right-of-way and to aid in mitigating impacts to downstream property owners.

Typical facilities discussed in this manual include:

- Onsite storage;
- Offsite storage;
- Open channels;
- Storm drain systems;
- Culverts;
- Bridges;
- Gutters, inlets and pavements; and
- Energy dissipators.

Procedures contained in this manual should be used to evaluate the ability of a facility to accomplish the following controls for a particular area:

- Reduce runoff rates by increasing infiltration, and by storing precipitation and runoff where it falls, releasing it slowly.
- Protect areas subject to flood damage by confining runoff to drainage facilities (e.g., pipes or channels), and by building appropriate flood-control facilities.
- Keep floodplain encroachment outside the limits of regulated floodways.

During the planning and location stage of a project, the hydraulics engineer should consider the following when planning for stormwater runoff:

- Assess the capacity and adequacy of existing drainage systems.
- Assess the compatibility of design discharges with proposed drainage plans and regulatory criteria.
- Assess the potential need for retention or detention storage areas to mitigate the impacts of increased runoff if the increase cannot be handled by other project features.
- Assess the availability of right-of-way to locate a retention or detention pond. Determine the availability of alternate sites for storage of stormwater.

- Identify any unusual groundwater or soil conditions such as impermeable soil layers, and locate the water table.
- Identify any jurisdictional, permit, or economic restrictions.
- Identify any unusual site conditions such as woods, wetlands or other environmental features that may influence the development of a stormwater management system.

5.4 PRELIMINARY DATA GATHERING

5.4.1 Drainage Surveys

Because hydraulic considerations can influence the selection of a highway corridor and alternate routes within the corridor, the type and amount of data needed for planning studies can vary widely depending on environmental considerations, class of the proposed highway, land use development, and individual site conditions.

Topographic maps, aerial photographs and streamflow records provide helpful preliminary drainage data. Data on historical high-water elevations and flood discharges is of particular interest in establishing waterway requirements. Comprehensive hydraulic investigations may be required where route selection involves important hydraulic features (e.g., water supply wells and reservoirs, flood control dams, water resource projects, encroachment on floodplains of major streams). Special studies and investigations, including consideration of the environmental and ecological impact, may be appropriate depending on the importance and magnitude of the project, and the complexity of the problems encountered.

5.4.2 Data Collection

As part of data collection studies, several categories of data should be collected and evaluated, including:

- Physical characteristics of drainage basins;
- Maps and topographic data, including channel surveys and cross sections;
- Runoff-quantity data (hydrologic and precipitation data);
- Channel and floodplain delineations and related studies;
- Flood history and problem inventory;
- Characteristics of existing stormwater management facilities;
- Development of alternate plan concepts;
- Hydrologic and hydraulic analysis of alternate concepts;
- Consideration of multipurpose opportunities and constraints;
- Cost/benefit analysis and evaluation; and
- Quality of runoff.

5.4.3 Types of Data

Details associated with data collection, data needed, where to obtain data, etc., are outlined in Chapter 6 - Data Collection of this manual. The following are brief descriptions of types of data needed for planning and location studies.

Topographic

Topographic data should be acquired at most sites requiring hydraulic studies. This data is needed to analyze existing flow conditions, and those caused by various design alternatives. Elevations and dimensions of significant physical and cultural features in the project area should be identified and documented. Such features as residences, commercial buildings, schools, churches, farmlands, other roadways and bridges, and utilities can affect, and be affected by, the design of any new hydraulic structures. Often, recent topographic surveys will not be available at the early stage of project development. If so, aerial photographs, photogrammetric maps, USGS quadrangle maps, existing digital elevation models, old highway plans as well as digital information from LiDAR, DEM and aerial photo resources from the Colorado GeoData Cache may be utilized. When better survey data become available, usually during the design phase, these data early estimates should be revised to correspond with the most recent field information.

Channel Characteristics

To perform an accurate hydraulic analysis, the stream profile, horizontal alignment, and cross sections must be obtained. Detailed data usually is not available during the planning and location phases. The designer must therefore make preliminary analyses based on less-than-optimal data (e.g., aerial photographs, USGS maps and old plans).

One method that can be useful in determining channel characteristics (e.g., material in the stream beds and banks, type and coverage of vegetal material, and evidence of drift, debris or ice) is taking photographs in the field. Visits made early in the project can include photographing the channel upstream and downstream, and the adjoining floodplain. These photos can be valuable aids for not only preliminary studies, but also for documentation of existing conditions. Among the study aids on channel characteristics and expected changes to channel geomorphology due to construction of proposed structures are FHWA's HDS-6, River Engineering for Highways Encroachments - Highways in the River Environment and FHWA's HEC-20, Stream Stability at Highway Structures.

During early phases of project development, the designer should determine details of field surveys required at the site. These include upstream and downstream limits of the survey, the number of or distance between cross sections, and how far to either side of the channel that sections should extend. The number of cross sections needed will vary with the study requirements and the characteristics of the particular reach. For some projects the accuracy achieved by aerial photogrammetry will be sufficient for the hydraulic study. Others may require a higher level of accuracy. The level of accuracy of a survey is determined by the degree of hydraulic analysis needed. The U.S. Army Corps of Engineers Hydrologic Engineering Center has made a detailed study of survey requirements for one-dimensional hydraulic modeling. Results of this study are available in the technical paper, "Accuracy of Computer Water Surface Profiles."

Hydrologic Data

Information required by the hydraulic designer includes not only physical characteristics of the land and channel, but all features that may affect the magnitude and frequency of the flood flow in the site. This data may include climatological characteristics, surface runoff characteristics, streamgage records, high-water marks, and sizes and past performances of existing structures in the vicinity. The specific data required will depend upon the methods used to estimate flood discharges, frequencies and stages. Although much of the hydrologic data will not be used during the planning and location phase, it is important to determine the need for the data at that time because of the time needed for collection and evaluation. By starting this process during planning and location, delays during the design stage will be minimized.

Basin Characteristics

Hydrologic characteristics of the basin or watershed of a stream are needed for methods used to forecast flood flows. Although many of these characteristics can be found in studies, some are better found by a field survey of the basin. Size and configuration of the watershed, geometry of the stream network, storage volumes of ponds, lakes, reservoirs and floodplains, and the general geology and soils of the basin can be determined from maps. Land use and vegetal cover may be also be determined from maps. But, with rapidly changing land uses, a more accurate survey will result from current aerial photographs and field visits.

Having determined basin characteristics, it is possible to calculate runoff times, infiltration values, storage values and runoff coefficients used in calculating flood flow values.

Precipitation

A precipitation survey normally consists of collection of rainfall records for rainfall stations within the study site. Unlike streamflow records or basin characteristics, rainfall records from outside the watershed can be useful for the study. These records may contain several years of events, every month and season, and duration values for rainstorms of various lengths. Snowfall accumulation records may also be available and are often helpful.

If rainfall records do not exist, NOAA publications are available that give general rainfall amounts for various storm durations. NOAA Atlas 14, *Precipitation-Frequency Atlas of the United States*, is a useful source of this information.

Flood Data

The collection of flood data is a basic survey requirement when performing a hydraulic analysis. This data can be collected both in the office and in the field. Office acquisition includes collection of past flood records, streamgage records, and newspaper accounts. Field collection consists mainly of interviews with residents, maintenance personnel, and local officials who may recall or have photos of past flood events in the area. If there is a stream gauging station on the stream under study close to the crossing site with several years of measurements, this may be the only hydrologic data needed. This data should be analyzed to ensure streamflows have not changed over the measurement period due alteration of the watershed (e.g., the construction of a large storage facility, diversion of flow to another watershed, addition of flow from another watershed, or development that has significantly altered the runoff characteristics of the watershed).

High-Water Information

Sometimes, high-water marks are the only available records of past floods. When collected, this data should include the date and elevation of the flood event if possible. The cause of the high-water mark should also be noted. Often, the mark is caused by an unusual debris or ice jam rather than an inadequate structure. Designing roadway or structure grades based on that elevation may lead to an unrealistic, uneconomical design.

High-water marks can be identified in several ways. Some types of small debris (e.g., grass or twigs caught in tree branches, matted-down hay or crops, mud lines on buildings or bridges) are high-water indicators. However, because grass, bushes and tree branches are bent over during flood flows and spring back after the flow has passed, they may not accurately indicate a high-water elevation. Ice will often cut or gouge tree bark, indicating high-water elevations.

Existing Hydraulic Structures

Records of existing hydraulic structures on a stream under study can be valuable when selecting the size and type of any new structure. Important data for existing structures includes size, type, age, existing flow-line elevation, and condition, particularly in regard to the channel. Scour holes, erosion around abutments or only upstream or downstream, and abrupt changes in material gradation or type may indicate the existing structure is too small for its application. With information about flood history, the age and overall substructure condition also may aid in determining if the existing structure is too small.

If a structure is relatively new, information still may be available on any previous one and why it had to be replaced. Although normally crossings are replaced due to poor structural condition, sometimes other conditions, often hydraulic in nature, influenced the decision to build a new structure. Also, the durability of the existing structure may indicate how a proposed structure will survive at this location. Old plans also may contain useful high-water or flood information. When structures upstream or downstream of the site exist, they should always be studied for the above factors. This includes highway and railroad structures, and any private crossings that may exist.

Environmental Data

When studying water resources of an area, an environmental team must obtain any data needed to evaluate potential highway impacts on the surface water. A coordination meeting with representatives of relevant environmental disciplines is beneficial at this stage. Data may have to be collected on fish and wildlife, vegetation, and water quality. Decisions may have to be made on aesthetic values.

Fish and Wildlife

There are many sources of information available about fish and wildlife. A primary source is the Colorado Division of Wildlife. Biologists can provide useful information about types of animals and fish, their spawning seasons, and critical habitat areas. Maps may also be available showing this information. Discussions with local residents and field visits can yield information not available elsewhere.

Vegetation

Types and extent of vegetal cover affect the rate and quantity of runoff. They may also affect water quality. There are three primary sources of information on vegetation:

Maps: Geological maps show generally where land is covered and where it is clear. The EROS data center produces GIS-based maps of vegetation and land-use for the entire United States. Often, particularly during the preliminary stages of a study, this may be sufficient. Later in the process, more recent and accurate data may be needed.

Aerial Photographs: An experienced designer often can distinguish types of vegetation from aerial photographs. If color or infrared photos are available, identification of different types is easier. Aerial photos must be current, good quality, and at an appropriate scale to be of value.

Field Visit: It may not be possible to survey an entire watershed; only a sample area may have to be studied. It is important to determine study requirements to ensure all necessary information is collected and all important areas are visited.

Water Quality

Water quality data can be the most expensive and time-consuming information to collect. Sometimes water quality records are available for the site under study or nearby. But, these records may not include the information most often required for highway studies. Sample collection is expensive because of the equipment and laboratory facilities needed. If CDOT chooses not to do the testing, then the cost of other laboratories taking and analyzing samples must be considered.

Sample collection is a long process because information from samples taken at only one time is usually not satisfactory. Water quality can reflect seasonal, monthly or even daily variations depending on the weather, flow rate and traffic. If possible, a long-term sampling program should be developed at key locations.

Water quality data collection and analysis must be conducted by qualified persons, whether from CDOT or an outside firm.

5.5 PRELIMINARY HYDRAULIC REPORTS

5.5.1 Introduction

Preliminary hydraulic reports must be as complete as possible, and tailored to satisfy the requirements of the specific location and size of a project. Too much data and information is uneconomical and difficult to reduce to a meaningful level. Coordination with all CDOT specialty groups requiring survey data before the initial field work is begun will ensure the acquisition of sufficient, but not excessive, survey data.

5.5.2 Report

All data used in reaching conclusions and recommendations during the preliminary study should be included in a report. This should include hydrologic and hydraulic data, pertinent field information, photographs, calculations, and structure sizes and locations. At this stage of the study, several structure sizes and types can be considered because the designer only needs general information to obtain a rough estimate of needs and costs. Often, details cannot be provided until an accurate topographic survey of the area has been made and precise hydraulic calculations performed. Sometimes, however, the report requires detailed design studies to determine the extent of mitigation required. In general, environmentally sensitive sites and those in highly urbanized areas require more detail at earlier stages.

All this information serves as documentation for decisions made in early stages, and is excellent reference material when later, more detailed studies are performed. It is important that preliminary material is carefully collected, prepared, referenced, and organized in a preliminary report folder just as would be done for a final study. It is also important that this work be clearly marked as preliminary. Otherwise, the preliminary work mistakenly could be used as final data and no further involvement of the designer requested.

The hydraulic designer must provide information for a Draft Environmental Impact Statement (DEIS) if appropriate for a project. A DEIS requires information on effects of the project on water quality, flooding, and general water resource values. Typically, these factors are evaluated for several different alignments. Sampling programs that extend over a long period of time may be necessary to obtain this information.

REFERENCES

1. AASHTO, *Drainage Manual.* 1st Edition, Hydrology, Chapter 9, Technical Committee on Hydrology and Hydraulics, American Association of State Highway and Transportation Officials, Washington DC, 2014.

2. Burnham, M.W. and Davis, D.W., "Accuracy of Computer Water Surface Profiles," Technical Paper No. 114, Hydrologic Engineering Center, US Army Corps of Engineers, 1987.

3. Colorado GeoData Cache, Colorado Office of Information Technology (OIT). Internet site for delivery of elevation, imagery and other spatial data owned by state and local agencies in Colorado at: https://data.colorado.gov/dataset/Colorado-GeoData-Cache/p6nr-fvcw

4. FHWA. *River Engineering for Highways Encroachments - Highways in the River Environment.* Hydraulic Design Series No. 6, FHWA-NHI-01-004. Federal Highway Administration, U.S. Department of Transportation, Washington DC, 2001.

5. FHWA. *Stream Stability at Highway Structures.* Hydraulic Engineering Circular No. 20, 4th Edition, FHWA-HIF-12-004. Federal Highway Administration, U.S. Department of Transportation, Washington DC, 2012.

6. FHWA. *Bridge Scour and Stream Stability Countermeasures, Experience, Selection, and Design Guidance*. Hydraulic Engineering Circular No. 23, 3rd Edition, Vol. 1, FHWA-NHI-09-111, Federal Highway Administration, U.S. Department of Transportation, Washington DC, 2009.

7. FHWA. *Bridge Scour and Stream Stability Countermeasures, Experience, Selection, and Design Guidance*. Hydraulic Engineering Circular No. 23, 3rd Edition, Vol. 2, FHWA-NHI-09-112, Federal Highway Administration, U.S. Department of Transportation, Washington DC, 2009.

8. National Oceanic and Atmospheric Administration, National Weather Service, "Precipitation-Frequency Atlas of the United States, Volume 8, Version 2.0, Midwestern States," Silver Springs, Maryland, 2013.