Chapter 6

DOCUMENTATION OF HYDRAULIC STUDIES

SOUTH DAKOTA DRAINAGE MANUAL

October 2011

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DOCUMENTATION OF HYDRAULIC STUDIES

6.1 INTRODUCTION

6.1.1 General

Hydrologic and hydraulic documentation as used in this Chapter is the compilation and preservation of the design and related details and all pertinent information on which the design and decisions are based. This includes the drainage area and other maps, field survey information, source references, photographs, engineering calculations and analyses, measurements and flood history. The objectives of properly documented hydraulic studies include:

- demonstration of the standards used for public safety;
- justification of expenditure of public funds;
- future reference by designers for improvements, changes or rehabilitations that are made to the highway facilities;
- information leading to the development of a defense for litigation; and
- public information.

Plans, specifications and analyses are often referred to long after the actual construction has been completed. Documentation allows the evaluation of the performance of structures after flood events to determine if the structures performed as anticipated, or to establish the cause of unexpected behavior. In case of failure, it is essential that contributing factors can be identified so that recurring damage can be avoided.

6.1.2 Purpose

The major purpose of providing good documentation is to define the design procedure used and to demonstrate how the final design and decisions were determined. Good documentation can provide the following:

- protection for SDDOT by proving that reasonable and prudent actions were, in fact, taken. Good documentation should not increase the potential court award and may decrease it by disproving any claims of negligence by the plaintiff;
- identifying the standard of practice used at the time of design, which might be very important if legal action occurs in the future;

- documenting that rationally accepted procedures and analyses were used at the time of the design that were appropriate for the perceived site importance and flood hazard (this should further disprove any negligence claims);
- providing a continuous site history to facilitate future reconstruction;
- providing the file data necessary to quickly evaluate any future site problems that might occur during the facility's service life; and
- expediting plan development by clearly providing the reasons and rationale for specific design decisions.

6.1.3 Objectives

Following are SDDOT's overall objectives for the documentation of hydrologic and hydraulic designs and analyses:

- Compile hydrologic and hydraulic data, preliminary calculations and analyses and all related information used in developing conclusions and recommendations related to drainage requirements, including estimates of structure size and location.
- Document all design assumptions and selected criteria including the related decisions.
- Include sufficient detail for each design or analysis to be appropriate for the risk and the importance of the facility.
- Organize documentation to be as concise and complete as practical so that future designers can understand what was performed by predecessors.
- Circumvent incriminating statements wherever possible by stating uncertainties in less than specific terms. For example, "the culvert may cause backwater" rather than "the culvert will cause backwater."
- Provide all related references to include such items as published data and reports, memos, letters and interviews. Include dates and signatures where appropriate.
- Include data and information from the conceptual stage of project development through service life to provide successors with all information.
- Organize documentation to logically lead the reader from past history through the problem background, into the findings and through the performance.

- Summarize lengthy documentation assemblies; a summary and table of contents at the beginning of the project file will provide an outline of the documentation presented to assist users in finding detailed information.

6.2 PROJECT SCHEDULING AND HYDRAULIC ANALYSIS

All road and bridge design projects will be managed through the SDDOT Project Scheduling System. The System defines the major preconstruction activities and the sequence in which the activities should be performed. The overall objective is to produce an efficient use of SDDOT's preconstruction engineering resources in the management of its design projects.

Hydraulic analysis is an integral component of the project development process. Hydraulic documentation is a critical element in the decision-making process that determines the final road design and the final bridge design. This Section briefly discusses the timing of hydraulic evaluation and documentation within the project development process.

6.2.1 Project Scoping

Selecting alternative routes for the project to determine, among other objectives, the environmental impacts is completed during the Project Scoping process, prior to scheduling the project.

The hydraulic evaluation supports the decision-making process in alternative route evaluation. Chapter 4 "Planning and Location (Hydraulics)" presents the fundamental hydraulic issues that contribute to the selection of an alternative. These include floodplain impacts, water-related permits and water-related environmental impacts.

For drainage design, the Scope will attempt to identify whether existing drainage structures are adequate or need replacement, and the Scope will identify if special drainage treatments are necessary. This refers to both roadway and bridge drainage appurtenances.

6.2.2 Review/Update Scope

The previously defined Project Scope should be reviewed and/or updated based upon the latest information available as the project develops. Drainage-related issues needing verification may include actual survey information, floodplain changes, recent flood history, land use changes, etc.

6.2.3 Surveys

The Schedule includes several survey activities. Drainage survey information is critical to performing the preliminary and final hydraulic studies. Section 5.6 discusses drainage surveys. See the *South Dakota Survey Manual* for additional information on performing surveys.

6.2.4 Preliminary Drainage Data

Upon establishing the preliminary gradeline, the roadway designer submits a partial set of plans to the Office of Bridge Design and the Geotechnical Section, a request for drainage basin characteristics and a review of the geometrics relating to drainage.

Based on the drainage survey, the Scope Summary and the preliminary gradeline, the hydraulic engineer will determine Preliminary Drainage Data. The drainage data gathered will be consistent with the project scope and includes the data needed for both roadway and bridge drainage appurtenances. See Chapter 5 "Data Collection."

A drainage area determination is required for all drainage crossings of the main line and drainage crossings of intersecting roads and approaches of 10 acres or more. See Section 5.5.2.2 for procedures on determining the drainage area. After the preliminary drainage area identification and computation, a Drainage Area Field Inspection of the project is conducted by the hydraulic engineer. The purpose of the field inspection is to confirm the drainage area boundaries and direction of flow and to identify any other relevant constraints, as defined in Chapter 5 "Data Collection." See Appendix 5.B for the Drainage Area Inspection Checklist. The Drainage Area Field Inspection should include SDDOT Area Office personnel.

The hydraulic engineer should maintain copies of documents used in the development of the project's preliminary drainage area. Documents that may be used for this purpose include:

- watershed map or watershed plan including:
  - + flow directions,
  - + watershed boundaries,
  - + watershed areas, and
  - + natural storage areas;
- flood insurance studies and maps by FEMA;
- identification of NRCS, BLM and USACE dams; and
- NRCS soil maps.

6.2.5 Final Drainage Data

This Activity is performed by the hydraulic engineer after the Drainage Area Field Inspection has been conducted. The output of this Activity will be the Final Drainage Memo. The Final Drainage Memo (or letter) is distributed to the Office of Road Design, the Region Office, the Area Office and the Project Identification Coordinator (PIC). For

projects with special concerns, an expanded distribution may be warranted. At a minimum, the Final Drainage Memo should document the following:

- field inspection date and participants;
- crossing locations (e.g., centerline station, left or right) and stream names, if shown on the quadrangle map;
- total and contributing drainage areas;
- direction flow is going to;
- basin slope, where required (see Figure 7.9-C, Subregion F);
- areas that are located within a FEMA-mapped floodplain;
- sites that include dams and permanent impoundments;
- sites that may require design by the hydraulic staff;
- any apparent drainage for over 10 acres through intersecting roads or approaches;
- hydrologic methods and corresponding design parameters;
- past history of flooding and overtopping;
- wetland outlet elevations;
- roadside drainage areas where there is a channel along the side that carries a sizeable flow; and
- any other information that may be useful for the design.

See Figure 6.2-A for a sample SDDOT Drainage Memo.

Note: At this point in the SDDOT project development process with respect to hydraulic design, the Schedule diverges into roadway hydraulics and bridge hydraulics. The Office of Road Design will prepare the hydraulic design for crossings with drainage areas up to 1000 acres and for storm drainage systems. Section 6.5 presents the hydraulic design documentation used by Road Design. Sections 6.2.6 through 6.2.10 present the activities that address the hydraulic design of structures with drainage areas of 1000 acres or more.

INTER-OFFICE MEMO

TO: Sioux Falls Design Squad
Office of Road Design
Attn: Robert Roberts

FM: Office of Bridge Design
John Johnston

RE: P 3043(08)69 Minnehaha County PCN WXYZ
SD43 from I-90 to SD42
Grading, Structures and Surfacing

DT: April 24, 2006

The drainage inspection for the above-referenced project was held on April 20, 2006. Those attending were John Doe, Sioux Falls Area; Tom Jones, Sioux Falls Maintenance Supervisor; Harry Smith and John Johnson, Office of Bridge Design — Pierre.

Peak discharge calculations provided in the 1998 USGS publication, Techniques for Estimating Peak-Flow Magnitude and Frequency Relations for South Dakota Streams, use regional regression equations to estimate the discharges at drainage crossings. This project is located in Subregion A. The precipitation intensity index for the project is 1.17 inches. The contributing drainage areas (DA) given are for use in the equations provided in the above publication.

Peak discharge equations are also provided in the 1980 USGS publication, Techniques for Estimating Flood Peaks, Volumes, and Hydrographs on Small Streams in South Dakota. The soil infiltration index for the project is 3.33 inches. The drainage area (DA) and basin slopes given are for use in the equations provided in the above publication.

Minnehaha County is participating in the FEMA program. Two locations along the route are identified on the FIRM maps with the locations identified in this memo. Both are unstudied basins.

The receiving waters for the entire project are tributaries to Willow Creek.

The following is a summary of the drainage basin size (DA), slope (if applicable), flow direction (direction of outlet) and comments by station:

Sta. 2+00 DA = 13 acres, flows right.

Sta. 2+63 Rt. DA = 14 acres, flows ahead. Includes flow from Sta. 2+00.

Sta. 8+12 Rt. DA = 16 acres, flows ahead. Includes flows from Sta. 2+00 and 2+63 Rt.

Sta. 13+60 Rt. DA = 20 acres, flows ahead. Includes flows from Sta. 2+00, Sta. 2+63 Rt., and Sta. 8+12 Rt.

Sta. 14+19 DA = 6 acres, flows right. Includes flow from Sta. 9+90 Lt.

Sta. 22+34 **Willow Creek** DA = 11.1 square miles contributing from a total basin area of 16.7 square miles (the additional 5.6 square miles normally contributes to Willow Lake, but will overflow to this crossing), slope = 18 ft/mile, flows right. Includes flows from Sta. 21+81 Lt. and Sta. 27+26 Lt. The downstream channel is an identified FEMA floodplain. **The Office of Bridge Design will recommend a structure at this location.**

Figure 6.2-A — SAMPLE DRAINAGE MEMO

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Sta. 27+26 Lt. DA = 2 acres, flows back.

Sta. 36+68 DA = 20 acres, flows right. Includes flow from Sta. 54+69 Lt. Entrance left acts as a ditch block.

Sta. 54+69 Lt. DA = 2 acres, flows back.

Sta. 59+31 Lt. DA = 2 acres, flows ahead.

Sta. 64+64 Lt. DA = 6 acres, flows ahead. Includes flow from Sta. 59+31 Lt.

Sta. 87+18 DA = 586 acres, slope = 39 ft/mile, flows right. Includes flows from Sta. 59+31 Lt. and Sta. 64+64 Lt.

Sta. 100+32 DA = 74 acres, flows right. Includes flow from Sta. 105+21 Lt.

Sta. 134+22 **Tributary to Willow Creek** DA = 7.3 square miles directly contributes from a total area of 9.1 square miles (the additional 1.8 square miles normally contributes to some slough areas but will overflow to this crossing), slope = 18 ft/mile, flows right. Includes flow from Sta. 130+91 Lt. This crossing is an identified FEMA floodplain. **The Office of Bridge Design will recommend a structure at this location.**

Sta. 142+42 Rt. DA = 4 acres, flows back. Includes flow from Sta. 145+88 Rt. With shown low gradeline, the area from Sta. 150+ will be in the ditch to outlet to the south.

Sta. 145+88 Rt. DA = 2 acres, flows back. With shown low gradeline, the area from Sta. 150+ will be in the ditch to outlet to the south.

cc: Sioux Falls Area Engineer
Mitchell Region

Figure 6.2-A — SAMPLE DRAINAGE MEMO
(Continued)

6.2.6 Preliminary Hydraulic Design

The Hydraulic Section within the Office of Bridge Design will prepare the Preliminary Hydraulic Design for any crossings and/or channels with drainage areas of 1000 acres or more within the project limits. There may be additional sites (less than 1000 acres) included due to special conditions or requests by others. The Preliminary Hydraulic Design will be based on:

- the Scope,
- the preliminary gradeline,
- the drainage survey data,
- the Final Drainage Memo, and
- any identified drainage concerns voiced during public hearings and landowner meetings.

Other chapters in this *Manual* present the hydrologic and hydraulic techniques and methodologies that will be used to perform the Preliminary Hydraulic Design for any hydraulic structures or channels involved on the project. The end product of the Preliminary Hydraulic Design is the Preliminary Hydraulic Data Sheet, which is included in the Draft Hydraulic Design Report. Section 6.3 discusses in detail the objectives and content of the Draft Hydraulic Design Report.

6.2.7 Preliminary Structure Data

The objective of this Activity is for the bridge designer to determine what appears to be the most appropriate structure for the given or anticipated site conditions. The Preliminary Structure Data are based on the evaluation of many factors, including site conditions and structure geometry, hydraulic analysis and scour, structural loads, anticipated foundation conditions, environmental and right-of-way impacts, aesthetics and construction costs.

The bridge designer will prepare a site investigation layout for each structure involved in the project, which will present the following:

- a plan and profile drawing showing the proposed type, size and location (TS&L) of the structure;
- bridge end elevations;
- typical roadway grading section at structure with elevations shown;
- channel cross section at structure;

- minimum horizontal and vertical clearances; and
- design highwater elevations.

6.2.8 Preliminary Structure Site Inspection

For this Activity, the bridge designer and representatives from the Hydraulic Section, Area Office, Environmental Office, local government and others involved in the project will visit the proposed structure site. The objective of this site inspection is to evaluate the practicality of the proposed structure TS&L information prepared in the Preliminary Hydraulic Design and the Preliminary Structure Data Activities. The site inspection attendees will also gather any additional information. See Appendix 5.B for the Structure Site Information Form.

6.2.9 Final Hydraulic Design Report

The output from this Activity will be the Final Hydraulic Data Sheet, scour protection and bridge deck drainage recommendations, if applicable and, ultimately, the Final Hydraulic Design Report. This Report will be based on:

- the Draft Hydraulic Design Report,
- the Preliminary Structure Data, and
- the Preliminary Structure Site Inspection.

Section 6.3 discusses in detail the objectives and content of the Final Hydraulic Design Report.

6.2.10 Preliminary Bridge Design

Once the Office of Road Design determines the roadway alignment and the Final Hydraulic Data Sheet is completed, the bridge designer can proceed with the Preliminary Structure Layout for each structure involved on the project, which will present the following:

- plan and profile of the structure showing the proposed TS&L of the selected structure for each site on the project;
- bridge barrier or sidewalks and bridge railing;
- minimum horizontal and vertical clearances;
- hydraulic data, high-water and low-water elevations, etc.; and
- erosion protection details.

6.3 HYDRAULIC DESIGN REPORT

6.3.1 General

The Hydraulic Design Report is a comprehensive document used to summarize the hydraulic findings and recommendations and to document the design recommendations for selected drainage structures and/or channels with drainage areas of 1000 acres or more. Some sites with drainage areas of less than 1000 acres may also warrant Hydraulic Design Reports, depending on the criticality. Any disagreement with the hydraulic recommendations as prescribed in the Hydraulic Design Report should be resolved prior to final approval by the Bridge Hydraulic Engineer.

The Hydraulic Design Report should be tailored to satisfy the requirements of the specific location and size of project for which the study is required. Too much data and information hinders the objective of locating meaningful information. However, the data that was used in reaching conclusions and recommendations made during the hydraulic studies should be included in the Report.

6.3.1.1 Draft vs. Final Hydraulic Design Report

At the conclusion of the Preliminary Hydraulic Design, the hydraulic engineer will prepare the Preliminary Hydraulic Data Sheet and the Draft Hydraulic Design Report. The Report will be considered in draft format until the conclusion of the Final Hydraulic Design, which culminates with the completion of the Final Hydraulic Data Sheet for culverts or the completion of the final scour analysis for bridges. The following paragraphs briefly identify some of the differences between the Draft and Final HDR phases.

As a general statement, the depth of hydraulic evaluation and analysis for the Draft Hydraulic Design Report should be sufficient to allow for completion and distribution of the Preliminary Hydraulic Data Sheet. The Preliminary Hydraulic Data Sheet will be used by the bridge designer to prepare the Preliminary Structure Data; see Section 6.2.7. At this stage of the study, more than one structure size and type may be considered because the designer only needs generalities to obtain a rough estimate of needs and costs. Often, specifics cannot be provided until individual structures have been selected for each site during the Preliminary Structure Site Inspection (see Section 6.2.8) and subsequent final hydraulic computations are performed. Sometimes, however, the Report will require detailed design studies to justify the extent of mitigation required. In general, the more environmentally sensitive sites and those in urbanized areas may necessitate more detail at the preliminary stage.

From previous activities in the project development process, preliminary hydraulic studies will be based on some or all of the following:

- aerial photographs;
- contour maps;
- vicinity maps;
- topographic maps;
- surveyed data reduced to include:
    + existing hydraulic facilities;
    + existing controls;
    + profiles — roadway, channels, driveways; and
    + cross sections — roadway, channels, structures; and
- reports from other local, State and Federal agencies, SDDOT personnel, newspapers and abutting property owners.

Perhaps the most valuable experience for any designer is gained by observing and analyzing the performance of an existing design under actual field conditions.

The following data may be available for existing hydraulic structures and should be included in the permanent hydraulic file:

- highwater elevations and flow rates;
- ice and drift conditions;
- erosion of approach overflow sections, embankments and spur dikes;
- stream aggradation or degradation;
- scour location, depth and extent;
- performance of scour and erosion preventive measures;
- meander and bend migration;
- performance of stream bank protection and channel stabilization methods; and
- costs of maintenance, repair and corrective measures.

Appendix 6.A presents the SDDOT Hydraulic Data Sheets for State projects designed in-house, State projects designed by consultants and Local Transportation Program projects designed by consultants.

6.3.1.2 Distribution

The hydraulic engineer will distribute the Hydraulic Data Sheet as an attachment, with requests for comments and concurrence from those on the distribution list. There will be a separate distribution for the Preliminary and the Final Hydraulic Data Sheets. The distribution lists are as shown on the respective Hydraulic Data Sheets.

The full Hydraulic Design Report will be available, upon request, from the Bridge Hydraulic Engineer or consultant, as applicable. For a consultant-prepared Hydraulic Data Sheet, a copy of the current draft of the Report will be submitted to the SDDOT Bridge Hydraulic Engineer with the distribution of the Hydraulic Data Sheets.

6.3.1.3 Approval

On State projects, the hydraulic engineer will forward the Hydraulic Design Report (Draft and Final) to the Bridge Hydraulic Engineer for approval. On Local Transportation Program projects, a copy of the Final Hydraulic Design Report should be provided to the SDDOT Bridge Hydraulic Engineer prior to submittal of the project plans for review.

6.3.2 Format and Content

In general, the Hydraulic Design Report should be prepared in the sequence and format discussed in the remainder of Section 6.3. This will provide a uniform presentation for all Hydraulic Design Reports and will ensure that all necessary design elements are addressed. The level of coverage for each item will vary from site-to-site. Although an in-depth discussion for each design element is typically not provided in this Report, sufficient detail should be provided to allow the reader to fully understand the proposed hydraulic design.

See Figure 6.3-A for the Table of Contents of the Hydraulic Design Report.

6.3.3 Project Description

This section of the Report should provide a project number and location, and a brief description of the proposed project based on the Scope. If available, also include the project number(s) for the existing facility.

Table of Contents
Project Description Site Location Physical Characteristics of Existing Site Design Elements Hydrology Hydraulics SDDOT Hydraulic Data Sheet

Figure 6.3-A — HYDRAULIC DESIGN REPORT (Table of Contents)

6.3.4 Site Location

The following may be used to define the site location:

- county;
- section, township and range;
- stream name;
- existing structure number;
- station number;
- distance and direction from nearby cities and towns or route and milepost; and
- location map.

6.3.5 Physical Characteristics of Existing Site

The project's physical characteristics may include a discussion on the following:

- existing road surface type;
- open drainage or closed drainage (i.e., with curb and gutter);
- existing culverts, energy dissipators, storage facilities and other roadway drainage appurtenances;
- general description of surrounding terrain and natural drainage patterns, including direction of flow at crossing;
- size of existing bridge waterway opening;
- year when the existing bridge and roadway were built, reconstructed or rehabilitated;
- width, length and number of spans of existing structure;
- rural or urban location;
- vertical clearance of the existing structure;
- existing overtopping elevation and location, if applicable;
- a description of the major waterway features (e.g., width, location of bends, 100-year flood elevation); and
- any other major physical characteristics related to the project.

6.3.6 Design Elements

The Hydraulic Design Report should provide a general discussion for each of the following design elements, if applicable.

6.3.6.1 Environmental Considerations

Summarize any environmental concerns identified in the available environmental documents. If the environmental document has been approved, include the date and conditions of approval. Also include brief descriptions of any environmental, cultural and/or hazardous waste site mitigation measures required. Note any permits that will be required (e.g., Section 404). Identify the stream's recreational value to the general public.

6.3.6.2 Roadway Elements

Document the basic roadway design features of the highway facility:

1. Functional Classification. Note the functional classification of the highway (e.g., urban arterial, rural collector, rural local road).

2. Horizontal Alignment. Identify all major horizontal alignment features affecting the proposed site. Provide the horizontal alignment (including skew) for both the structure and for the approaches.

3. Vertical Alignment. Provide a description for all major vertical alignment features affecting the proposed site. This may include longitudinal grades, vertical curvature and vertical clearances, and overtopping elevation and location.

4. Typical Sections. Identify the proposed typical roadway section. This includes the overall roadway or bridge width, approach width, number of travel lanes, travel lane widths, shoulder widths, sidewalks, etc.

   Discuss the overall extent of grading for the project. Identify the typical cut and fill slope rates and describe any special proposed slope design for the project (e.g., steep side slopes, rock cuts, non-standard slope rates).

5. Design Speed. Document the design speed used for the roadway design.

6.3.6.3 Right-of-Way Considerations

Briefly describe the existing and proposed right-of-way width. Discuss any impacts that right-of-way considerations may have on the hydraulic design (e.g., open vs. closed

drainage). Also, identify any existing or proposed utilities that may impact the hydraulic design.

Note existing stream access points and stream usage including existing fencing and parking in the vicinity of the project. Identify any public or private access that will be affected by the project. Document approved enhancements or changes to the existing access conditions. Assess and document the right-of-way needs to maintain the existing access or to provide enhancements or other changes as agreed to with other government agencies or private landowners.

6.3.6.4 Geotechnical Considerations

Discuss any geotechnical considerations that impact the hydraulic design of the project (e.g., scour, erosion control).

6.3.7 Hydrology

The hydraulic engineer will use Chapter 7 "Hydrology" to perform the hydrologic analysis for the project. This section of the Hydraulic Design Report should document the hydrologic data for the site used in the analysis including:

- contributing watershed area size and identification of source (e.g., map name);
- basin characteristics;
- design frequency and basis for selection (this may be higher than the typical minimum if in a regulated floodplain);
- hydrologic method(s) used to calculate the discharge (e.g., USGS, Rational, NRCS) and a discussion on the rationale for the design discharge that was selected;
- hydrologic discharge and findings;
- flood frequency curves to include 2-year flood, design flood, 100-year flood, 500-year flood (where required), discharge hydrograph and any historical floods; and
- expected level of development in the upstream watershed over the anticipated life of the facility, including sources of and basis for these development projections.

6.3.8 Hydraulics

6.3.8.1 General

Features that are important to the hydraulic performance of drainage structures include the approach fill alignment, skew and profile; structure location, skew and length; culvert geometry and end conditions; bridge span lengths; bent and pier location and design; and substructure and superstructure configuration and elevations. Design data for the hydraulics of a structure should be assembled in an orderly fashion and retained for future reference. The amount and detail of documentation for each highway-stream crossing system should be appropriate for the risk and the importance of the crossing. For example, a small stream in a rural area would not ordinarily require the same degree of documentation as a small stream in a developed area.

The documentation should include all material used in selecting the design, including notes and observations made from the Preliminary Structure Site Inspection. The documentation should also include the results of studies of alternatives and reasons for rejecting alternatives.

6.3.8.2 Culverts

The hydraulic design of culverts will be based on Chapter 10 "Culverts." A Hydraulic Design Report will be prepared for all culvert installations where the drainage area is greater than 1000 acres; where less than 1000 acres, the need for a Report will be determined on a case-by-case basis. The following information should be documented in the Hydraulic Design Report:

- summarize or reference all pertinent correspondence, field inspection notes, agreements and minutes of meetings, especially those with public involvement;
- landowner concerns (e.g., cattle passes, equipment access, water rights, irrigation);
- environmental concerns, including recommended depths and velocities for high and low fish passage design flows;
- potential flood hazards to adjacent properties;
- relevant information on existing structures in the vicinity;
- observed highwater, dates and discharges (if available);
- evidence of ice or debris problems;
- topography of site;

- drainage area map, if used (see Section 6.3.7);
- design flows (see Section 6.3.7);
- stream profile and cross sections;
- cross section(s) used in the design highwater determinations;
- roughness coefficient (“n” value) assignments;
- the design centerline flowline elevation at the intersection of the channel and the roadway;
- roadway geometry (plan and profile) (see Section 6.3.6.2);
- information on the method used for design highwater determination;
- type of culvert entrance condition;
- allowable headwater elevation and basis for its selection (see Section 17.3 if FEMA-mapped areas are involved);
- magnitude and frequency of overtopping flood;
- water surface profiles through the reach for the 2-year, design, 100-year and any historical floods;
- stage-discharge curve for existing and proposed conditions to include the depth and velocity estimates and locations for the 2-year, design, 100-year, 500-year (where required) and any historical floods;
- performance curves showing the calculated backwater elevations, outlet velocities and scour for the 2-year, design, 100-year, 500-year and any historical floods;
- a summary of the hydraulic calculations for the culvert opening, documenting the optimum;
- structure type, size and location layout;
- culvert outlet appurtenances and energy dissipation calculations and designs;
- copies of applicable computer analyses;
- floodway consistency determination or support for and approval of floodway revision; and
- risk assessment.

6.3.8.3 Bridges

6.3.8.3.1 General Hydraulic Data

The hydraulic design of bridges will be based on Chapter 14 "Bridge Hydraulics." The Hydraulic Design Report should document the following general bridge hydraulic design data, where applicable to the site:

- summarize or reference all pertinent correspondence, field inspection notes, agreements and minutes of meetings, especially those with public involvement;
- landowner concerns (e.g., cattle passes, equipment access, water rights, irrigation);
- environmental concerns, including recommended depths and velocities for high and low fish passage design flows;
- potential flood hazards to adjacent properties;
- relevant information on existing structures in the vicinity;
- observed highwater, dates and discharges (if available);
- evidence of ice or debris problems;
- topography of site;
- drainage area map, if used (see Section 6.3.7);
- design flows (see Section 6.3.7);
- stream profile and cross sections;
- cross section(s) used in the design highwater determination;
- roughness coefficient ("n" value) assignments;
- the design centerline flowline elevation at the intersection of the channel and the roadway;
- roadway geometry (plan and profile) (see Section 6.3.6.2);
- information on the method used for design highwater determination;
- allowable headwater elevation and basis for its selection (see Section 17.3 if FEMA-mapped areas are involved);
- magnitude and frequency of overtopping flood;

- water surface profiles through the reach for the 2-year, design, 100-year and any historical floods;
- stage-discharge curve for existing and proposed conditions;
- velocity estimates and locations (include both the through-bridge and channel velocity) for 2-year, design, 100-year, 500-year (where required) and any historical floods;
- a summary of the hydraulic calculations for the waterway opening, documenting the optimum;
- structure type, size and location layout;
- geotechnical considerations in foundation selection and design;
- performance curve to include calculated backwater, velocity and scour for 2-year, design, 100-year, 500-year and any historical floods for scour elevation;
- bridge scour elevation results;
- copies of applicable computer analyses;
- floodway consistency determination or support for and approval of floodway revision; and
- risk assessment.

6.3.8.3.2 Scour Including Geotechnical Considerations

Bridge scour depths are developed by the Office of Bridge Design (Hydraulic Section). The Hydraulic Design Report should summarize the hydraulic scour calculations. A table summarizing scour depths for the 100-year and 500-year design frequencies should be provided for:

- general scour (long-term channel degradation/aggradation),
- contraction scour,
- pier scour,
- abutment scour, and
- total scour.

When overtopping occurs at lower frequencies, the worst case up to the 100-year flood should be provided.

Figure 6.3-B presents a sample passage that may be used for the documentation of the scour analysis in the Hydraulic Design Report. This is an example only and, because each case may have unique conditions, the document should be tailored to fit.

6.3.8.3.3 Bridge Deck Drainage Recommendations

The Office of Bridge Design (Hydraulic Section) recommends the type, number and spacing of bridge deck drains. A brief narrative for the recommended bridge deck drainage and a table summarizing the recommendations should be provided in the Hydraulic Design Report. Figure 6.3-C provides a sample passage for bridge deck drainage recommendations. This is an example only and, because each case may have unique conditions, the memo should be tailored to fit.

6.3.8.4 Open Channels

The hydraulic design of open channels will be based on Chapter 9 "Roadside Channels," Chapter 14 "Bridge Hydraulics" and Chapter 15 "Bank Protection." If not included elsewhere, the following items should be documented in the Hydraulic Design Report for open channels:

- summarize or reference all pertinent correspondence, field inspection notes, agreements and minutes of meetings, especially those with public involvement;
- landowner concerns (e.g., cattle passes, equipment access, water rights, irrigation);
- environmental concerns, including recommended depths and velocities for high and low fish passage design flows;
- potential flood hazards to adjacent properties;
- relevant information on existing structures in the vicinity;
- observed highwater, dates and discharges (if available);
- evidence of ice or debris problems;
- topography of site;

Scour has been computed for the three-span, two-column bent bridge with x.x-ft diameter cylindrical columns. No angle of attack was used because the bents are aligned with the flow, and the column spacing is sufficient to have minor impact from one column to the other.

All contraction scour and pier scour depths are to be referenced from the defined flowline elevation of xxxx.x ft. One should reference all scour to this defined elevation because the channel could shift laterally across the entire bridge opening during the life of the bridge.

The berm slope protection (previously recommended on the Final Hydraulic Data Sheet) was designed to arrest abutment scour based upon the limits of contraction scour. Because the low channel can migrate laterally in the future, the berm toe protection should be placed to a depth sufficient to ensure protection for the abutment.

	Q_{100} Scour[A]	**Q_{OT}* = Q_{500} Scour[B]**
Maximum Contraction Scour Depth (ft)	4.3	5.9
Maximum Pier Scour Depth (ft)	9.5	11.8
South Abutment Scour Depth (ft)	3.9	5.2
North Abutment Scour Depth (ft)	14.6	18.7
Contraction Scour + Pier Scour (ft)	**13.8**	**17.7**

[A] The 100-year flood applies unless overtopping occurs at a lower event and the worst case up to the 100-year flood applies.

[B] The 500-year flood is a check for those cases where flows are contained to the bridge waterway at the 500-year flood event, or use the worst case frequency greater than the 100-year event when overtopping occurs before the 500-year flood.

*Q_{OT} = Frequency at which water begins to overtop the highway.

Figure 6.3-B — SCOUR DEPTH RECOMMENDATIONS (Sample Passage)

We have reviewed the deck drainage for the 119′-0″ continuous concrete bridge with 12-ft travel lanes and 4-ft shoulders. To contain the design water spread within the allowable 4-ft shoulder width, provide four bridge deck drains for each bridge lane. To meet the hydraulic design criteria, it is recommended that the drains be placed approximately 8 ft ahead of Abutment No. 1 and Bent No. 2 and 8 ft back of Bent No. 3 and Abutment No. 4. The bridge deck drains used for these calculations are 4-in scuppers (PVC pipe) depressed 0.5 in into the deck.

Standard drop inlets should be placed in both shoulders at the east end of the bridge. Type D inlets are typically used at the ends of bridges.

Figure 6.3-C — BRIDGE DECK DRAINAGE RECOMMENDATIONS

(Sample Passage)

- drainage area map, if used (see Section 6.3.7);
- design flows (see Section 6.3.7);
- stream profile and cross sections;
- cross section(s) used in the design water surface determinations and their locations;
- roughness coefficient ("n" value) assignments;
- roadway geometry (plan and profile) (see Section 6.3.6.2);
- information on the method used for design water surface determinations;
- magnitude and frequency of overtopping flood;
- water surface profiles through the reach for the 2-year, design, 100-year and any historical floods;
- stage-discharge curves for the 2-year, design, 100-year and any historical water surface elevation(s);
- channel velocity estimates and locations for 2-year, design, 100-year, 500-year and any historical water surface elevation(s);
- a summary of the hydraulic calculations for the waterway opening, documenting the optimum;
- design or analysis of materials proposed for the channel bed and banks;
- energy dissipation calculations and designs;
- copies of applicable computer analyses;
- floodway consistency determination or support for and approval of floodway revision; and
- risk assessment.

6.3.9 SDDOT Hydraulic Data Sheet

The SDDOT Hydraulic Data Sheet is the centerpiece of the Hydraulic Design Report. The Data Sheet provides a single source of information that summarizes and documents a significant portion of the basic hydraulic design data. SDDOT has developed three Hydraulic Data Sheets as follows:

- State projects completed in-house,
- State projects completed by Consultants, and
- Local Transportation Program projects.

See Appendix 6.A.

6.4 RECORDS AND FILES

At the completion of every project, the hydraulic engineer should compile a comprehensive Hydraulic Project File as a permanent record. The Hydraulic Project File should contain a General File, Hydraulic Site File(s) and a Permit File. The Hydraulic Project File will serve as a resource for:

- retrieving project or site information,
- any future litigation,
- any future work in the vicinity of the project by SDDOT or others,
- any future work at the structure site(s), and
- maintenance personnel.

6.4.1 General File

The General File should contain important project information that is not included in an individual Hydraulic Site File. The information should be logically segregated and, within each section, the information should be organized chronologically as seen fit. The contents of the General File include, but are not limited to:

- Preliminary and Final Drainage Memo,
- general correspondence,
- inspection reports,
- computation sheets and check notes for drainage areas and basin slopes,
- drainage maps,
- environmental reports/studies/impact statements,
- construction plans/cross sections, and
- original plans.

6.4.2 Hydraulic Site File

6.4.2.1 Responsibilities

The hydraulic engineer should create and maintain a Hydraulic Site File for each large crossing or waterway encroachment on the project with a drainage area of 1000 acres or more or as needed for drainage areas less than 1000 acres, depending on the criticality.

6.4.2.2 Contents

6.4.2.2.1 General

Documentation and calculations related to hydrologic and hydraulic design should be retained in the Hydraulic Site File. Similar general project information may be filed in the General File and need not be repeated in each Hydraulic Site File.

In the Hydraulic Site File, the information should be logically segregated and, within each section, the information should be organized chronologically as seen fit. The key contents of the Hydraulic Site File are as follows:

- Hydraulic Design Report,
- design computations, and
- site-specific correspondence.

6.4.2.2.2 Design Computations

Hydrologic and hydraulic design computations are an important part of the Hydraulic Site File. The design computations should be maintained for permanent reference during and after construction. They provide a permanent record of design analysis methods, materials used and structure dimensions. The design computations should be in sufficient detail so that others can duplicate the original design.

Arrange the hydrologic and hydraulic design computations so that they can be easily followed by others. The title sheet of the computations should include the project number, project name, county name, station of structure, initials of those who prepared the computations and the date of preparation. Each sheet of the design computations should be thoroughly checked and initialed by the designer and the design checker.

When unconventional methods or formulas are used in the hydrologic or hydraulic design, list the sources of the methods or formulas. When different considerations for economic purposes have been used, include all quantities and calculations substantiating these considerations. When computations are made by a computer, identify the program used (including software version) and include the computer input and output values with an explanation of the terms, assumptions and computations used. Provide a sketch with an explanation of all abbreviations and symbols used with the input and output sheets of the program. When using a spreadsheet application, there should be supporting documentation defining the spreadsheet in the file or referenced in the file. See Chapter 18 “Hydraulic Software” for a discussion on hydraulic software.

Design computations may include the following:

- Preliminary Hydraulic Data Sheet,
- Final Hydraulic Data Sheet,
- hand computations,
- hydrologic computations,
- computer output for “existing condition,”
- computer output for “proposed condition,”
- erosion protection computations,
- bridge scour and countermeasure computations,
- bridge deck drainage computations,
- channel stabilization computations,
- bank protection computations,
- site contour plot,
- channel profile plot,
- road plan and profile plot,
- road cross section plots, and
- miscellaneous other trial computer outputs (upon completion of the project construction, these may be discarded).

Some of these items will be included in the Hydraulic Design Report, as previously described.

6.4.2.2.3 Site-Specific Correspondence

The correspondence portion of the Hydraulic Site File provides a source location for administrative information on the site and a history of the site development. The following correspondence is typically located in the Hydraulic Site File:

1. Agreements. Include copies of any agreements related to the hydraulic design of the site (e.g., for cost sharing of storm sewer infrastructure improvements).

2. FHWA Correspondence. Include all correspondence sent or received from FHWA on hydraulic issues specific to the site.

3. Internal Department Memoranda. The correspondence file should contain all site-related hydraulic correspondence.

4. Email. Include a hard copy of applicable site-related hydraulic emails.

Similar general project correspondence may be filed in the General File and need not be repeated here. When correspondence refers to a small portion of the sites, either file the correspondence in the General File or place copies in each relevant Site File.

6.4.2.2.4 Hydraulic Site File Checklist

Figure 6.4-A presents a checklist that may be used to compile the Hydraulic Site File. The items listed establish a minimum requirement consistent with the hydraulic design procedures as outlined in this *Manual*. If circumstances are such that the drainage facility is sized by other than normal procedures, or if the size of the facility is governed by factors other than hydrologic or hydraulic factors (e.g., the need for farm equipment access), a narrative summary detailing the basis for design should be included in the file. Additionally, the hydraulic engineer should include additional items not listed but that are useful in understanding the analysis, design, findings and final recommendations.

6.4.3 Permits

The Permit File should include all water-related permit information, including the permit application, its disposition and all relevant back-up data. Chapter 17 "Permits/Certifications" provides a discussion on water-related permits, which should be used for guidance to identify the contents of this Permit File.

The following presents the recommended contents specifically for the US Army Corps of Engineers Section 404 Permit File.

6.4.3.1 Section 404 Permit (Typical Project)

For applicable projects, the following documentation should be included in the Section 404 Permit File for a typical project:

- a copy of the USACE's certification form from the Area Office upon completion of the project;
- a copy of the transmittal memo transferring the Section 404 permit to the Area Office at the time of letting;

HYDROLOGY	REPORTS
Discharge Calculations: Rational Formula HEC-HMS NRCS WMS Regional Analysis Regression Equations Area-Discharge Curves USGS Gaging Data Log-Pearson Type III Gage Rating **Computer Programs:** USGS NSS USGS Peak FQ USGS NWISWeb USGS StreamStats NRCS WinTR-55 WinTR-20 HEC-HMS WMS **Highwater Elevations:** Survey External Sources Internal Sources Personal Reconnaissance **Flood History:** External Sources Personal Reconnaissance Maintenance Records Photographs	**Data Reports:** Hydraulic Design Report Construction Inspection Reports

Figure 6.4-A — HYDRAULIC SITE FILE CHECKLIST

REFERENCE DATA	HYDRAULIC DESIGN
Maps: USGS Quad: Scale: Date: USGS Other Local Zoning Maps Flood Hazard Delineation Floodplain Delineation (NFIP) Local Land Use Soils Maps Geologic Maps Aerial Photos: Scale: Date: **Studies By External Agencies:** USACE Floodplain Information Report NRCS Watershed Studies Local Watershed Management USGS Gages and Studies Interim Floodplain Studies Water Resource Data Regional Planning Data US Forest Service Utility Company Plans District Drainage Records Flood Records (Highwater, Newspaper) **Studies By Internal Sources:** Office of Bridge/Road Design	**Calibration of Highwater Data:** Discharge and Frequency of HW Elevation Influences Responsible for HW Elevation Analyze Hydraulic Performance of Existing Facility for Minimum Flow through 100-year Flow Analyze Hydraulic Performance of Proposed Facility for Minimum Flow through 100-year Flow **Drainage Appurtenances:** Bridges Culverts Storm Drains Storage Dissipators Bank Protection Channel Stabilization Erosion and Sediment Control Wetlands **Technical Aids:** SDDOT Drainage Manual SDDOT and FHWA Directives FHWA Hydraulic Engineering Publications USACE Hydraulic Engineering Publications **Computer Programs:** HY8 (FHWA Culvert Analysis) HEC-RAS (Water Surface Profile) SMS (Surface Water Modeling System) InRoads PondPack FHWA Hydraulic Toolbox SAMwin (Hydraulic Design Package for Channels) SRH (Sedimentation and River Hydraulics)

Figure 6.4-A — HYDRAULIC SITE FILE CHECKLIST
(Continued)

- a copy of the notice to Operations Support upon receipt of the Section 404 permit from USACE;
- the permit letter and conditions from USACE;
- a copy of the cover letter to USACE with the Section 404 permit application;
- a copy of the Section 404 permit application;
- FHWA Environmental Classification (EC) checklist or copy of Environmental Assessment (EA);
- a spreadsheet showing project quantities by site, if used;
- a copy of the quadrangle map for the project site;
- wetland list and wetland mitigation plan;
- copies of environmental correspondence for the project if EC or EA is not available;
- a list of plan sheets submitted with the Section 404 permit application; and
- the plan sheets.

6.4.3.2 Section 404 Permit (Maintenance Project)

For a maintenance project, the Section 404 Permit File should contain the following:

- a copy of USACE's certification form from the Area Office upon completion of the project;
- a copy of the transmittal memo transferring the Section 404 permit application to the Area Office;
- the permit letter and conditions from USACE;
- a copy of the cover letter to USACE with the Section 404 permit application;
- a copy of the Section 404 permit application;
- a copy of the quadrangle map for the project site;
- a copy of all environmental correspondence for the project; and
- the plan sheets.

For small maintenance projects, the correspondence and design computations may be filed together in the Permit File.

6.4.4 Maintenance of Files

The Hydraulic Project File and all of its contents should be readily available to SDDOT personnel for use during construction, for defense of litigation and for future improvements. Hydrologic/hydraulic documentation should be retained permanently even after the drainage facility is totally replaced or modified as a result of a new drainage study.

In general, a scanned electronic copy of the Hydraulic Project File is retained in the Office of Bridge Design; the hard copies are destroyed approximately one year after construction has been completed. The SDDOT Records Management Section also retains a scanned electronic copy of the Hydraulic Project File.

6.5 ROAD DESIGN HYDRAULIC DESIGN DOCUMENTATION

6.5.1 General

The Office of Road Design provides the design for roadway drainage appurtenances with drainage areas of less than 1000 acres. Other chapters in this *Manual* present the hydrologic and hydraulic techniques and methodologies that will be used to design the roadway drainage appurtenances. Grading designers provide documentation in several forms to summarize the design information and decision-making process involved in these smaller drainage areas and for urban storm drainage systems.

Road Design personnel document drainage components made by the public in summaries of public hearings and in formal notes collected during individual landowner meetings. Following preliminary and final design field inspections, the grading designer includes drainage observations in the inspection summary letters. Design information also is captured in computer software input and output.

6.5.2 Rural Drainage

After receiving the Final Drainage Memo from the Hydraulic Section, the grading designer collects the data for designing the culverts. Details that lead to the size and length of culverts are documented on the Hydraulic Analysis of Culverts form. This form is also used to record methods used, recommendations and reasons for the design decisions.

6.5.3 Storm Drainage Systems

The hydraulic design of storm drainage systems will be based on Chapter 12 "Storm Drainage Systems." The following items should be included in the Road Design documentation for storm drainage systems:

- computations for drainage areas, inlets and storm drains, including hydraulic gradelines;
- copies of the standard computation sheets;
- complete drainage area map;
- design frequency;
- information concerning outfalls, existing storm drains and other design considerations; and
- a schematic illustrating the storm drainage system layout.

Appendix 6.A

HYDRAULIC DATA SHEET/LAYOUT

This Appendix presents the following Hydraulic Data Sheets:

- State projects completed in-house
- State projects completed by Consultants
- Local Transportation Program projects

Following the three Hydraulic Data Sheets are instructions for completing the Sheets. A Preliminary and a Final Hydraulic Data Sheet are completed for each crossing site with a drainage area of 1000 acres or more. For the Preliminary Hydraulic Data Sheet, the hydraulic engineer will complete only the first side of the Sheet; for the Final Hydraulic Data Sheet, the hydraulic engineer will update the first side of the Sheet as necessary and also complete the second side of the Sheet.

Where a site involves a proposed bridge, a sketch of the Preliminary Hydraulic Data Layout should be included in the Hydraulic Design Report as an attachment to the Preliminary Hydraulic Data Sheet; the sketch must be an attachment to the Final Hydraulic Data Sheet only if revisions were made. Following the Hydraulic Data Sheets and their instructions is a generic sample for the Preliminary Hydraulic Data Layout (Figure 6.A-A).

For State Projects Completed In-House

SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION
HYDRAULIC DATA SHEET

County 1 Project No. 1 PCN 1 Sec. 2 Township 2 Range 2
Existing Station 3 Over 4 Drainage Area 5 Direction of Flow (N S E W) 6
Preliminary 7 Final 7 Q-Design Yr. Frequency 8 Observed H.W. Elev. 9
BRIDGE NO. 10 LOCATION 11

Cross Section	Q_d cfs	W.W. Area sq ft	V fps	S_o ft/ft	Bottom		H.W. ft	d_n ft	C.L. FL Elev	D.H.W. Elev.		Ch Ch	Degree Skew
					Structure	Ch				Culv. Inlet	Bridge		
Trapezoid 12 S:S	13	14	15	16	17	18	19	20	21	22	23	24	25
Rectangle													
Round													
Arch													

Type: 26
Size: 27
Proposed Location: 28
Notes or Remarks: 29

Distribution 30
Hydraulics
Bridge
Bridge Maint.
Rd. Design
Foundations
Environmental
Right-of-Way
FHWA
City
County
Region
Area Engineer
Checked
Reviewed
PIC

For additional hydraulic design supporting information, the full Hydraulic Design Report for this site may be obtained from the Hydraulic Engineer.

Vertical Datum Used: **NAVD 88:** 31 **NGVD 29:** 31 **Unknown:** 31
Topeka Shiner Stream: Yes 32 No 32 **404 Permit:** Yes 33 No 33
Community participating in NFIP: Yes 34a No 34a **OHW Elev. =** 35
Site in Identified NFIP Floodplain: Yes 34b No 34b
In-Place Structure: 36
100-Year DHW Elev. (existing): 37

Signed by: 38
Bridge Hydraulic Engineer

Revision No. 39 Date:
Supplement No. 39 Date:
Date:

For State Projects Completed In-House

HYDRAULIC SUMMARY FOR PLAN SHEET

Data Element	Alternative 1		Alternative 2	
Q_d	40	cfs		cfs
A_d	41	sq ft		sq ft
V_d	42	fps		fps
Q_F	43	cfs		cfs
Q_{100}	44	cfs		cfs
Q_{OT}	45	cfs		cfs
V_{max}	46	fps		fps

Q_d = design discharge for the proposed culvert or bridge based on ____ year frequency. El. _____.

Q_{OT} = overtopping discharge and frequency _____ year recurrence interval. El. _____.
Location_____.

Q_F = designated peak discharge for the basin approaching proposed project based on _____ year frequency.

Q_{100} = computed discharge for the basin approaching proposed project based on 100-year frequency. El. ____ ____.

V_{max} = maximum computed outlet velocity for the proposed culvert or bridge, based on a _____ year frequency.

The hydraulic data contained in these plans is valid only if the overflow section is maintained. Alteration of the overflow section will require re-analysis of the hydraulics at this site to determine its effect on public safety.

HYDRAULIC DATA TO BE INCLUDED ON ROADWAY PROFILE SHEET

Flow					Elevation
Q_d =				cfs	
Q_{100} =				cfs	
Q_{OT} = Q		=		cfs	

For State Projects Completed By Consultants

SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION
HYDRAULIC DATA SHEET

County 1 Project No. 1 PCN 1 Sec. 2 Township 2 Range 2
Existing Station 3 Over 4 Drainage Area 5 Direction of Flow (N S E W) 6
Preliminary 7 Final 7 Q-Design Yr. Frequency 8 Observed H.W. Elev. 9
BRIDGE NO. 10 LOCATION 11

Cross Section	Q_d cfs	W.W. Area sq ft	V fps	S_o ft/ft	Bottom		H.W. ft	d_n ft	C.L. FL Elev	D.H.W. Elev.		Ch Ch	Degree Skew
					Structure	Ch				Culv. Inlet	Bridge		
Trapezoid 12 S:S	13	14	15	16	17	18	19	20	21	22	23	24	25
Rectangle													
Round													
Arch													

Type: 26
Size: 27
Proposed Location: 28
Notes or Remarks: 29

Distribution 30
Hydraulics
Bridge
Bridge Maint.
Rd. Design
Foundations
Environmental
Right-of-Way
FHWA
City
County
Region
Area Engineer
Checked
PIC

Vertical Datum Used: **NAVD 88:** 31 **NGVD 29:** 31 **Unknown:** 31
Topeka Shiner Stream: Yes 32 No 32 **404 Permit:** Yes 33 No 33
Community participating in NFIP: Yes 34a No 34a **OHW Elev. =** 35
Site in Identified NFIP Floodplain: Yes 34b No 34b
In-Place Structure: 36
100-Year DHW Elev (existing): 37

Revision No. 39 Date:
Supplement No. 39 Date: Prepared By: 38
Hydraulic Engineer

Date:

Reviewed By: 38
SDDOT Bridge Hydraulic Engineer

Date:

For State Projects Completed By Consultants

HYDRAULIC SUMMARY FOR PLAN SHEET

Data Element	Alternative 1		Alternative 2	
Q_d	40	cfs		cfs
A_d	41	sq ft		sq ft
V_d	42	fps		fps
Q_F	43	cfs		cfs
Q_{100}	44	cfs		cfs
Q_{OT}	45	cfs		cfs
V_{max}	46	fps		fps

Q_d = design discharge for the proposed culvert or bridge based on ____ year frequency. El. _____.

Q_{OT} = overtopping discharge and frequency _____ year recurrence interval. El. _____.
Location_____.

Q_F = designated peak discharge for the basin approaching proposed project based on _____ year frequency.

Q_{100} = computed discharge for the basin approaching proposed project based on 100-year frequency. El. ____ ____.

V_{max} = maximum computed outlet velocity for the proposed culvert or bridge, based on a _____ year frequency.

The hydraulic data contained in these plans is valid only if the overflow section is maintained. Alteration of the overflow section will require re-analysis of the hydraulics at this site to determine its effect on public safety.

HYDRAULIC DATA TO BE INCLUDED ON ROADWAY PROFILE SHEET

Flow					Elevation
Q_d =				cfs	
Q_{100} =				cfs	
Q_{OT} = Q		=		cfs	

For Local Transportation Program Projects

SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION
HYDRAULIC DATA SHEET

County 1 Project No. 1 PCN 1 Sec. 2 Township 2 Range 2
Existing Station 3 Over 4 Drainage Area 5 Direction of Flow (N S E W) 6
Preliminary 7 Final 7 Q-Design Yr. Frequency 8 Observed H.W. Elev. 9
BRIDGE NO. 10 LOCATION 11

Cross Section	Q_d cfs	W.W. Area sq ft	V fps	S_o ft/ft	Bottom		H.W. ft	d_n ft	C.L. FL Elev	D.H.W. Elev.		Ch Ch	Degree Skew
					Structure	Ch				Culv. Inlet	Bridge		
Trapezoid 12 S:S	13	14	15	16	17	18	19	20	21	22	23	24	25
Rectangle													
Round													
Arch													

Type: 26
Size: 27
Proposed Location: 28
Notes or Remarks: 29

Distribution 30
Hydraulics
Bridge
Foundations
Environmental
Right-of-Way
FHWA
Secondary
Urban System
City
County
Region
Area Engineer
Checked

Vertical Datum Used: **NAVD 88:** 31 **NGVD 29:** 31 **Unknown:** 31
Topeka Shiner Stream: Yes 32 No 32 **404 Permit:** Yes 33 No 33
Community participating in NFIP: Yes 34a No 34a **OHW Elev. =** 35
Site in identified NFIP Floodplain: Yes 34b No 34b
In-Place Structure: 36
100-Year DHW Elev. (existing): 37

Revision No. 39 Date:
Supplement No. 39 Date:

Prepared by: 38
Hydraulic Engineer
Date:

Reviewed By: 38
SDDOT Engineer
Date:

HYDRAULIC SUMMARY FOR PLAN SHEET

Data Element	Alternative 1		Alternative 2	
Q_d	40	cfs		cfs
A_d	41	sq ft		sq ft
V_d	42	fps		fps
Q_F	43	cfs		cfs
Q_{100}	44	cfs		cfs
Q_{OT}	45	cfs		cfs
V_{max}	46	fps		fps

Q_d = design discharge for the proposed culvert or bridge based on ____ year frequency. El. _____.

Q_{OT} = overtopping discharge and frequency _____ year recurrence interval. El. _____.
Location_____.

Q_F = designated peak discharge for the basin approaching proposed project based on _____ year frequency.

Q_{100} = computed discharge for the basin approaching proposed project based on 100-year frequency. El. ____ ____.

V_{max} = maximum computed outlet velocity for the proposed culvert or bridge, based on a _____ year frequency.

The hydraulic data contained in these plans is valid only if the overflow section is maintained. Alteration of the overflow section will require re-analysis of the hydraulics at this site to determine its effect on public safety.

HYDRAULIC DATA TO BE INCLUDED ON ROADWAY PROFILE SHEET

Flow					Elevation
Q_d =				cfs	
Q_{100} =				cfs	
Q_{OT} = Q		=		cfs	

GUIDE FOR COMPLETION OF THE HYDRAULIC DATA SHEET

The Hydraulic Data Sheet is used for both preliminary hydraulic recommendations (complete the front side only) and for the final selected structure (revise the front side and complete the back side; see entry #7). To ensure consistency for all users of this document, explanations for each blank on the form are as follows:

1. "County, Project No. and PCN" are as identified in the program.

2. "Section, Township and Range" define the project location. If the location falls on the divide between two units, show section numbers, townships and ranges for both sides of the line.

3. "Existing Station" is the location of the existing structure centerline in reference to the proposed highway centerline (based on the stationing shown in the Drainage Memo).

4. "Over" is the name of the river, creek, draw or lake as shown on the USGS Quadrangle Map. If there is no name for the stream on the quadrangle map, use creek, draw or tributary to a "named stream."

5. "Drainage Area" is the total drainage area of the basin. If a portion of the basin is noncontributing, use a letter or asterisk footnote to indicate the contributing area in the "Notes or Remarks" section of the Data Sheet. For areas $\geq$ 1000 acres, show the area in square miles. For drainage areas < 1000 acres, show the area in acres.

6. "Direction of Flow" is the flow direction from upstream to downstream. If the direction is north and east, for example, underline both "N" and "E."

7. "Preliminary" or "Final" defines whether the Data Sheet is preliminary or final by placing an "X" in the appropriate box. The "Preliminary" Hydraulic Data Sheet is distributed at the completion of the Preliminary Hydraulic Design and prior to the Preliminary Structure Site Inspection. The "Final" Hydraulic Data Sheet is distributed following the distribution of the Preliminary Structure Site Inspection letter and the subsequent final hydraulic computations have been performed.

8. "Q-Design Year Frequency" is the designated design discharge frequency. This is based upon the appropriate frequency for the class of highway, or upon the level of urbanization or development.

9. "Observed Highwater Elevation" is as reported by the project survey, the Region or Area Office, Bridge Maintenance File or other source. Indicate "Not Provided" if information is not available. Use a letter or asterisk footnote to provide the source of the information and the date of the highwater in the "Notes or Remarks" section of the Data Sheet, or to report which sources were reviewed when no results were located.

10. "BRIDGE NO." is the SDDOT structure number assigned to the drainage crossing based on the NBIS system. The first number represents the county, and the other two numbers represent mileage coordinates in miles and tenths of a mile easterly and southerly from the extreme northwest corner of the county. Any new structure number should be reviewed by the Bridge Maintenance personnel to ensure that the number does not conflict with a previously assigned structure. If the proposed location is moved from the current location or if the existing number is found to be in error, this number may change from the existing to proposed.

11. "LOCATION" is a descriptive statement used to define the site location referenced to a community or road intersection (e.g., US 83, 5 miles S. of Selby).

12. "Trapezoid ___ S:S." is the berm slope (horizontal:vertical) for a berm type bridge. The slope is perpendicular to the flow direction.

13. "Q_d" is the design flow for the design flood frequency (cfs), or the flow which is flowing through the structure when flood routing is used if overtopping occurs. Record as a whole number. Report to three significant numbers, similar to the method the USGS uses to report flows.

14. "W.W. Area" is the waterway area of the structure that is used (sq ft), recorded as a whole number. For bridges, this is the area through the bridge opening. For culverts, it is the area at the culvert outlet (Area = Discharge/Velocity).

15. "V" is the average computed design velocity in the bridge opening or at the culvert outlet (fps).

16. "S_o" is the longitudinal slope of the surveyed channel for a bridge and the culvert slope for a culvert (ft/ft). Record to 4 places to the right of the decimal.

17. "Bottom — Structure" is recorded as the [number of barrels or openings (1, 2, 3, etc.)] × [individual type of opening (D = pipe diameter, S = arch pipe span, B = box culvert barrel width)] = total width in feet. For example, 4D = 10 ft.

18. "Bottom — Ch." is a bridge entry only. If there will be no low water channel disturbance, enter "Natural." If a geometric shape is specified, enter the bottom width of the channel.

19. "H.W." is the computed design headwater depth at the upstream end of a culvert (ft). Leave this entry blank if the structure is a bridge. The headwater will depend on the inlet or outlet control depth conditions in HY8; use whichever is greater and, therefore, controls. For HEC-RAS models, use the upstream cross section W.S. Elev. and subtract the culvert inlet invert elevation to get your H.W.

20. "d_n" is the water depth in a bridge opening or at the outlet of a culvert (use culvert outlet depth) (ft).

21. "C.L. FL Elev." is the design centerline flowline elevation of the culvert or bridge (ft). The centerline location is referenced to the centerline of the highway. The elevation is referenced to the channel bed inside the bridge or culvert. For culvert flowlines depressed 1 ft below the ground surface for fish passage, provide an explanation in the "Notes or Remarks" section of the Data Sheet, referenced by a letter or asterisk footnote.

22. "Culv. Inlet D.H.W. Elev." is the culvert design highwater elevation for design flow at the upstream end of the culvert (ft). This is the value used to determine the equivalency of culvert options. For HEC-RAS models, use the upstream cross section W.S. Elev. and verify with the water profile plot.

23. "Bridge D.H.W. Elev." is the design highwater surface elevation for the design flow at the upstream cross section before the drawdown to the bridge opening (ft).

24. "Ch. Ch." is for channel change; mark "Yes" or "No." If "Yes," follow with a letter or asterisk footnote and provide explanatory comments in the "Notes or Remarks" section of the Data Sheet as to the limits of the recommended channel change, the size of the channel, and any other information needed to implement the design. Minor channel cleanout is not considered to be a channel change but, if needed, a note should be provided on the Data Sheet. It is generally assumed that the contractor will provide a smooth channel alignment within the work limits of the culvert site.

25. "Degree Skew" is the recommended degree of skew for the structure crossing installation. If a square crossing is proposed, show zero degrees in the entry box. If skewed, specify LHF or RHF (left-hand forward or right-hand forward) skew.

26. "Type" defines the type of proposed structure opening (bridge or culvert) and special considerations, such as wingwall flares, cutoff walls, extensions, drop inlets, broken-back or dog-legged crossings, chutes, etc. For a bridge, enter "Berm-type bridge" or "Vertical Abutment," because it is ultimately up to the structural designer to determine the specific type. For box culverts, list cast-in-place options first and then precast options. Typically, the cast-in-place option will have flared wingwalls at the inlet and 0^o flared wingwalls at the outlet. The precast option will have 0^o flared wingwalls at the inlet and the outlet.

27. "Size" defines the size of the structure. For a culvert, show the number of barrels followed by the culvert span times the culvert rise (e.g., 2 — 11′ × 10'). For a bridge structure, indicate "See proposed location entry." Do not enter a bridge length because there are a number of combinations of bridge types and road grades for a given crossing, which will determine the bridge length. It will be up to the structural designer to determine the final bridge length.

28. "Proposed Location" is the centerline station for the proposed culvert installation. For a bridge, it is the definition of the bridge berms along centerline by station and elevation of berm toes or a point on the berm slope.

29. "Notes or Remarks" is a location used to identify any supporting information, including:

    a. computed flows other than the design flow
    b. 2-year and 100-year water surface elevations for each structure option
    c. maximum velocity up to the 100-year flow
    d. the overtopping elevation, flow, frequency, and location of existing and proposed options

e. the method used to determine the design flows
f. special definition of the drainage area if it cannot be fully defined in entry #5
g. the sources of information and, if located, the date of the observed highwater elevation listed in entry #9
h. the explanation for a depressed culvert flowline, such as for fish passage, if listed in entry #21
i. any information that is needed to implement a channel change, as listed in entry #24, or whether minor channel cleanout only is required
j. for the Final Data Sheet, include preliminary scour estimate, erosion control recommendations, and temporary traffic diversion size estimate, if possible
k. any information documenting community participation in the NFIP program and floodplain status, which would expand upon entry #34.

30. "Distribution" list shows the intended recipients of the Data Sheet by placing an "X" in the list for those that are to receive the distribution and include the initials of the project designer, checker and reviewer.

31. "Vertical Datum Used" records the datum that the hydraulic data is based upon. New SDDOT projects should be using the NAVD (19)88 datum. Old projects were normally based upon the NGVD (19)29 datum, and a few projects may be based upon an unknown datum. This datum is a very valuable source of information for both pre and post construction, used for comparing with previous information at the site.

32. "Topeka Shiner Stream" is to identify whether the stream is a Topeka Shiner habitat. These locations are located in the East River area of South Dakota.

33. "404 Permit" is a Clean Water Act Permit for the placement of fill within the "Waters of the United States." Check the entry as "Yes" if the site has wetlands identified on a wetlands map, or (in SD) a stream is identified on the quadrangle map with a blue line at the project site. The permit will require knowing the ordinary highwater mark (OHW = Q_2 flood) and/or the acres of wetlands impacted. The permit application will require the quantities of fill, concrete, riprap, etc., to be placed.

34a. "Community Participating in NFIP" indicates whether the community (city and/or county) is participating in the National Flood Insurance Program, according to the FEMA listing. If marked "Yes," follow with a letter or asterisk footnote and provide a comment in the "Notes or Remarks" section of the Data Sheet that identifies the community that is participating

34b. "Site in Identified Floodplain" is to indicate whether or not the site is in an identified floodplain on the FIRM (Flood Insurance Rate Map). If marked "Yes," follow with a letter or asterisk footnote and provide comments in the "Notes or Remarks" section of the Data Sheet as to the type of floodplain zone, whether or not the site has been studied and provide base flood elevations, if established, and the year in which the FIRM was established. If marked "No," follow with a letter or asterisk footnote and provide one of the following explanatory comments in the "Notes or Remarks" section: 1) The area is not mapped and is considered NSFHA (No Special Flood Hazard Area), or 2) The area is mapped, and the site is shown as not being in an identified floodplain. See Section 17.3 of the *South Dakota Drainage Manual*.

35. "OHW Elev." is the ordinary highwater elevation for the site (ft). This elevation is based upon the existing conditions at the inlet of the existing culvert or bridge. If the elevation is not known or available, use the Q_2 flood depth.

36. "In-Place Structure" is the size and type of the existing drainage structure that is presently serving the crossing. If there is more than one structure, enter both. Check to see if the survey size matches with the structure size shown on the original highway plans. If this is a new location, state "New location."

37. "100-year Design Headwater Elev. (existing)" is the computed 100-year upstream elevation for the existing structure (ft).

38. "Signed By" for State projects designed in-house is for the signature of the Bridge Hydraulic Engineer. "Prepared By" for Local Transportation Program projects and State projects designed by consultants should be the signature of the consultant hydraulic engineer, a PE. "Reviewed By" for State projects designed by consultants is for the signature of the SDDOT Bridge Hydraulic Engineer. "Reviewed By" for Local Transportation Program projects is for the signature of the responsible SDDOT engineer.

39. "Revision No." or "Supplement No." is used to identify the version number of revised (correcting data) Data Sheets, or Data Sheets offering supplemental options for the structure site.

SECOND PAGE OF FORM (Provide Information for Each Alternative):

40. "Q_d" is the design flow for the design flood frequency (cfs), or the flow that is flowing through the structure when flood routing is used if overtopping occurs (see entry #13).

41. "A_d" is the waterway area of the structure that is used (sq ft) (see entry #14).

42. "V_d" is the average computed design velocity in the bridge opening or at the culvert outlet (fps) (see entry #15).

43. "Q_F" is the peak discharge based on the design frequency of flow for the contributing drainage basin (cfs). This is usually the same as Q_d (design flow — see entry #13) unless storage routing analysis is performed or the culvert cannot handle the entire drainage.

44. "Q_{100}" is the 100-year peak flow discharge for the basin (cfs) (a 1% chance of flood occurrence for any given year) (see entry #29-a.).

45. "Q_{OT}" is the overtopping discharge (cfs) (see entry #29-d.).

46. "V_{max}" is the maximum computed outlet velocity for the proposed culvert or bridge (fps) (see entry #29-c.).

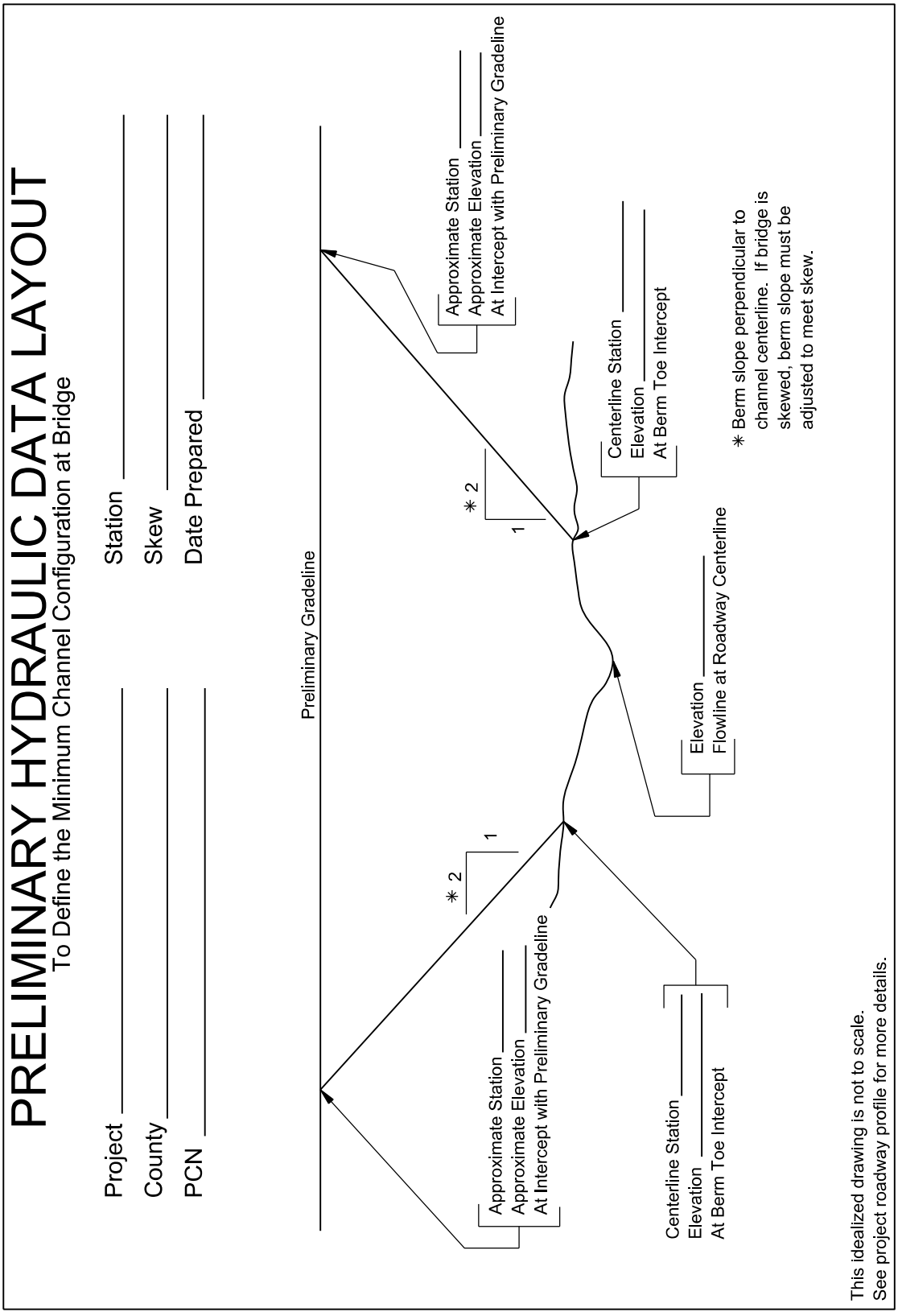

Figure 6.A-A — PRELIMINARY HYDRAULIC DATA LAYOUT

Appendix 6.B

DOCUMENTATION OF FLOOD EVENTS (Highwater)

This guidance has been prepared for use in recording highwater data that will form a permanent hydraulic inventory database.

Experienced personnel should be assigned to identify and evaluate highwater marks for SDDOT's permanent records. This information should be obtained at a time of unusual highwater or as may be available from a reliable source. The elevations can be recorded by level reading, by measurement from the bridge floor, relative to a house, above the roadbed or any other dependable and clear benchmark.

Figure 6.B-A, Flood Information Form, should be used to record highwater information. The documentation should also pictorially show pertinent information (e.g., sketch of roadway, structures, buildings, location of highwater marks). This Form should be forwarded to the Bridge Hydraulic Engineer, Office of Bridge Design, upon completion for the permanent record. The Form will provide historical information for the structures and roadway within the area of interest for any future use by SDDOT.

Reliable highwater data can be invaluable information for establishing the stage and discharge of past floods, for locating existing hydraulic controls and for establishing highway profiles.

Experienced personnel should be used in identifying and evaluating highwater marks. Highwater marks should be flagged and surveyed as soon as possible after a flood because they may disappear within weeks in heavily vegetated areas, or additional rainfall may wash away the evidence.

It is also important to obtain and record highwater information at culverts with spans 20 ft or greater. Also, highwater marks should be recorded for inundated roadways that are isolated from hydraulic structures.

Information on highwater elevations can usually be obtained by observing seed and mud lines on tree trunks and bridge abutments, wash lines and fine-debris lines on tree trunks and bridge approach fills, grass or hay lodged in tree limbs and fences and evidence of erosion and scour. Interviews with residents, commercial and school bus drivers, mail carriers, law enforcement officers, railroad maintenance personnel and others who may have had the opportunity to observe any floods can also yield additional information.

IDENTIFICATION

1) Region/Area _____ 2) County _____ 3) Route _____

4) Section _____ Township _____ Range _____

5) MRM _____ 6) Structure Number _____

7) Name of Stream _____

PERTINENT DATA

8) Date flood occurred _____

9) Date highwater flagged _____ By _____

10) Date highwater surveyed _____ By _____

11) Overtopping highwater _____ 12) Upstream highwater _____

13) Downstream highwater _____

14) Bridge deck elevation (lowest point) _____

15) Describe point surveyed under Item 14 _____

_____

16) Approximate duration of overtopping flood _____

17) Approximate 24-hour rainfall _____

GENERAL

18) Highwater mark obtained from ☐ actual water ☐ drift ☐ local resident

☐ Government Agency – Name _____

☐ Other _____

19) Location of Marks (briefly describe, attach sketch).

19 a) For Item 11 _____

19 b) For Item12 _____

19 c) For Item 13 _____

20) Description of marks; e.g., seed and mud lines on tree trunks and bridge abutments, wash lines and fine-debris lines on banks and bridge approach fills, wisps of grass or hay lodged in tree limbs and fences, evidence of erosion and scour, etc.

20 a) For Item 11 _____

20 b) For Item 12 _____

20 c) For Item 13 _____

Figure 6.B-A — FLOOD INFORMATION FORM

STATED INFORMATION

21) Name of Observer _____

22) Address _____

23) Stage of observation (distance above low point in highway, distance below bridge deck, distance above floor elevation of house, etc.) _____

24) Location of observer _____

25) Observed frequency of occurrence (e.g., every two years or some estimated interval) _____

REMARKS

26) Include brief description of flood damage, unusual circumstances that contributed to flood, and any other remarks relative to flood action _____

_____

_____

_____

_____

TO BE COMPLETED BY THE HYDRAULIC ENGINEER

27) Rainfall _____

28) Information from rainfall recording station located at _____

29) Rainfall frequency_____30) Stage from USGS gaging station _____

31) Discharge _____ cfs

FORM SUBMITTED BY _____ DATE _____

Note: Attach a sketch of referenced highwater locations.

Figure 6.B-A — FLOOD INFORMATION FORM
(Continued)

COMMENTS ON FLOOD INFORMATION FORM

Item 9: Highwater marks tend to disappear rapidly after the flood peak. For this reason, the work of surveying should begin as soon as possible. If a survey party is not available, locating the highwater marks at the site before surveys is a necessity. Identify the marks by means of stakes, cloth tags, flagging, paint, paint sticks, nails or crayon. Make field sketches showing the approximate locations of these marks for the benefit of the survey party. Enter the date and name of person who flagged the marks.

Item 10: Enter the date and name of party chief who surveyed the marks. Because it is difficult to flag sufficient marks as described under Item 9, the field party should attempt to survey all additional marks necessary to define the profiles well.

An assumed level datum, referenced to the bridge type structure, may be used if necessary.

Item 11: If the bridge, culvert and/or roadway was overtopped (inundated), enter maximum stage elevation. If overtopping did not occur, enter N/A and proceed to Items 12 and 13.

Item 12: Enter the upstream water surface level resulting from the contraction of the stream by bridge type structures. This elevation should be defined by highwater marks along each bank of the stream or the upstream face of the embankment.

Item 13: Enter the downstream water surface elevation. This is obtained on the downstream side of the embankment adjacent to the bridge type structure.

Item 14: Enter the elevation of the lowest point of the bridge deck. Normally, this point should be surveyed at the center of bridge except in superelevated sections. Then, the lowest point next to the bridge curb should be used.

Item 15: Briefly describe the location of the point surveyed and include in sketch with the Form.

Item 16: Enter estimated time of overtopping flood. This information may be obtained from a local resident, and it will be helpful to rate stated information as “excellent,” “good,” “fair” or “poor.”

Figure 6.B-A — FLOOD INFORMATION FORM
(Continued)

Item 17: Enter the approximate 24-hour rainfall received during the day of "unusual" highwater. This information is not necessary but, if an estimate is available from local people or news sources, please enter.

Item 18: This item is self-explanatory.

Item 19: Describe briefly the location of marks used for setting elevations for Items 11, 12 and 13.

Items 20-25: These items are self-explanatory.

Item 26: Enter any information that will clarify the recorded information. Describe any circumstance (in your opinion) that contributed to the flooding other than intense rainfall. You cannot make too many remarks.

Items 27-31: To be completed by the Hydraulic Engineer.

Upon completion, the form should be forwarded to:

Office of Bridge Design
Attention: Hydraulic Engineer
Becker-Hansen Building
700 E. Broadway Avenue
Pierre, South Dakota 57501

A copy of the form should also be sent to the Bridge Maintenance Engineer, who is in the same office and building as the Hydraulic Engineer.

Figure 6.B-A — FLOOD INFORMATION FORM
(Continued)