Nebraska Dept. of Roads
Bridge Division – Hydraulics
1500 Highway 2
Lincoln, Nebraska 69502

NDOR HYDRAULIC ANALYSIS GUIDELINES
and
HYDRAULIC FORMS

2009

The hydraulic analysis will satisfy requirements of the FEDERAL–AID POLICY GUIDE, 23 CFR 650A (Location and Hydraulic Design of Encroachments on Flood Plains) and Federal Highway Administration Publication No. FHWA–IP–90–017 (Hydraulic Engineering Circular No. 18, Evaluating Scour at Bridges)

The hydraulic Engineer is required to define the most practical design for all hydraulic related issues. The analysis process evaluates, assesses and documents the impacts and consequences an encroachment has on the floodplain environment. The proposed design, countermeasure design and hydraulic related design parameters are defined by considering hydraulic constraints, cost, risks, regulatory requirements, channel behavior, environmental impacts, engineering requirements and social concerns.

Structure sizing is based on hydraulic requirements for floods up to Q_{100}. High Risk sites may require sizing based on Q_{500} floods. The proposed structure is selected by hydraulically assessing NATURAL, EXISTING and ALTERNATE conditions.

Bridge foundation designs are checked for scour to verify the structure has a reasonable chance of surviving a Q_{500} flood.

The hydraulic study is based on surveyed cross-sections that define the 100-year floodplain. Normally, a minimum of one upstream cross-section, one downstream cross-section and one encroachment (bridge opening/road grade) cross-section is required. For minor action projects with minimal hydraulic risks, such as culvert extensions, approximate hydraulic calculations based on preliminary road survey data is acceptable. High risk, very complex sites may require the use of additional floodplain cross-sections and/or total station survey data.

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1. Existing Hydrologic and Hydraulic Data

Research, collect and document previous, current and historic data that is relevant to the performance of the existing and proposed structures.

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2. Hydrologic Analysis

Develop flood flow magnitude–frequency relationships and/or flood hydrographs that shows flood flows the encroachment is required to convey.

Typically, the hydrologic evaluation is based on discharges up to Q_{100}. For bridge scour evaluations and high-risk areas (i.e. urban areas) discharges up to Q_{500} are required.

A partial list of hydrologic methods follows:

A. USGS Regression Equations
B. UNL Regression Equations
C. Rational Method
D. TR-55, Urban Hydrology for Small Watersheds (SCS)
E. Gaging Station Records (Log Pearson III Analysis)
F. Other Agency Data (C of E, FEMA, NRCS, etc.)

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3. Typical Hydraulic Survey

Typical floodplain cross-sections are surveyed as looking left to right downstream and extend out to the 100-year flood limits. The cross-sections are located along a line normal to the high-water floodplain and low water channel.

Locate the immediate upstream cross-section approximately one bridge length upstream from the bridge. Use a minimum upstream distance of 100 ft. and a maximum distance of 500 ft.

Locate the bridge-opening cross-section at the immediate downstream side of bridge from left abutment to right abutment. Include low structure elevation and existing bridge deck grade elevations at both abutments. For new alignments, obtain a channel cross-section at project centerline extending up to high bank.

Locate the downstream cross-section approximately one-half floodplain width downstream from the upstream cross-section. Use a minimum distance, downstream of the bridge, of 300 ft. and a maximum distance of 1500 ft.

Hydraulic controlling features such as natural contractions, downstream confluent streams, railroad structures, adjacent hydraulic structures, head cuts, and other obstructions have a variety of survey requirements. Obtain the appropriate data to hydraulically evaluate obstruction impacts.

For complex floodplain analysis obtain additional cross-sections and/or total station survey.

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4. Typical Hydraulic Analysis

A hydraulic analysis looks at the impacts and consequences a structure and its approaches have on the floodplain environment. A Hydraulic Computer Model is utilized to evaluate the floodplain over a range of flows. Natural, Existing, Alternate and Proposed conditions are analyzed to evaluate flood hazards, determine flood risks and to select a practical cost effective design.

The analysis addresses:

A. Type, size, elevation and location of the structure
B. Road grade elevation requirements across the floodplain
C. Backwater
D. Flood distribution
E. Freeboard relative to low structure, low road and high bank
F. Channel Geology and Geomorphology
G. Scour parameters that effect the bridge foundation and channel stability
H. Channel geometry, modification, training and stabilization
I. Sediment transport
J. Debris and Ice
K. Ice Jams and relief requirements
L. Flood wave storage and duration
M. Construction parameters that are Hydraulically related
N. Floodplain permit requirements and impacts
O. Environmental changes and wetland impacts
P. Subsurface water impacts
Q. Historic flood data

Hydraulic study limits are site specific. The floodplain study reach extends upstream and downstream sufficiently to analyze impacts of the encroachment. A step-backwater analysis based on Manning's and Bernoulli's equations define hydraulic impacts.

HEC-2, WSPRO, HEC-RAS, FESWMS and SMS are nationally recognized computer models for hydraulic analysis. HEC-RAS is the preferred bridge hydraulic analysis program.

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5. Bridge Scour

A bridge scour analysis defines bridge design requirements for the following:

- Superstructure elevation
- Span requirements
- Structure location
- Abutment design parameters
- Pier/bent design parameters
- Low road elevations

Bridge contraction scour, local pier/bent scour and abutment scour are analyzed per publication no. FHWA-IP-90-017, Hydraulic Engineering Circular No. 18, EVALUATING SCOUR AT BRIDGES.

Assess the impacts of channel geomorphology, aggradation and degradation on scour potential per publication no. FHWA-NHI-01-002, Hydraulic Engineering Circular No. 20, STREAM STABILITY AT HIGHWAY STRUCTURES.

Perform a scour analysis of the existing structure in conjunction with an assessment of maintenance history to define deficiencies. Utilize this data to assess the proposed design requirements and provide assurance the selected design is practical.

A proposed new design scour analysis is required to withstand the effects of scour to a Q500 flood with little risk of failing. Q_{500} scour elevation is based on calculation, debris impact assessment, long term aggradation/degradation, ice jam impacts, attack angle variations and channel behavior.

Minimum Q_{100} general scour, used for bridge design, is 3 ft. for cohesive soils and 6 ft. for sand bed streams. Minimum Q_{500} scour elevation is 6 ft. below flowline for cohesive soils and 12 ft. below flowline for sand bed streams.

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6. Structure Requirements

A. Superstructure

1. Bridge Length – Typically, the minimal bridge length spans the natural channel plus 5 ft. berms. Hydraulics, scour, channel behavior, backwater, road grade requirements, debris transport and design constraints define the proposed length requirements.
2. Bridge Low Superstructure – Typically the superstructure is above the Q_{100} flood elevation. When constraints are not an issue, 1 ft. of backwater is considered normal. Submerging a bridge must be justified. Freeboard requirements are defined by an assessment of the risks associated with the structure. When ice jams are an issue, up to 4 ft. of freeboard may be necessary.
3. Spans – A single span bridge should be used when practical. Multi-span structures are necessary when bridge length exceeds single span design requirements. Consult a Bridge Design Engineer for structural design requirements.

4. Stationing – Typically the structure is centered over the channel. Actual stationing is determined by hydraulic and design requirement.

B. Substructure
   1. Abutment – Typically sheet pile wall abutments are preferred. Concrete wall abutments are acceptable if they meet the Q_{500} scour requirements. Define critical berm elevation requirements for final abutment design. (Critical berm elevation is the soil line at the abutment after considering Q_{100} scour and channel behavior.) For concrete wall abutments the bottom of concrete elevation is the critical berm elevation. For sheet pile walls, estimate the bottom of wall elevation and verify that Q_{500} scour elevation is above the bottom. Typical abutment design has the critical berm elevation about 5 ft. below the berm and 14 – 15 ft. below bridge grade. (Maximum economical concrete wall depth is 15 ft. and maximum economical sheet pile length is about 30 ft.).
   2. Pier/Bent - Use concrete encased piers or bents when debris is significant, to protect piling from rust or for un-braced piling length requirements. Typically, low concrete is at stream flowline that included channel degradation. For Piers the low concrete is defined as top of footing. Define special pier/bent designs when necessary for debris or ice.

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7. Countermeasures

Design countermeasures as necessary to prevent bridge failure from channel behavior, contraction scour and local scour.

Countermeasures for abutment protection:

A. Proper alignment of channel and floodplain to minimize scour.
B. Armor berm, adjacent to abutment wall. Stabilize the berm from eddying flow along the irregular surface of the sheet pile walls. Normally a minimum 5 ft. width is adequate.
C. Construct an artificial berm (berm above normal high bank) to stabilize the abutment wall and minimize the probability of voids forming behind abutment due to repeated inundation. Minimum berm width is 5 ft. with a 2H to 1V slope to natural high bank. Protect artificial berms with armoring and extend/transition around road fill to end of wings.
D. Use guide banks (spur dikes) at abutments to transition flow smoothly through the bridge opening, to minimize scour, when flow depth and volume is excessive.
E. Stabilize the channel bank location as necessary to prevent the channel from shifting/meandering into the abutment. Do not encroach into the natural stable channel. (NOTE: Abutments located within the channel are subject to excessive abutment scour.)
F. When appropriate, utilize high bank buffer areas to minimize velocities at the abutment and reduce abutment scour.
G. Use relief structures on wide or skewed floodplains to reduce flow through the main bridge when practical.

H. Channel change is allowed only when there is no other practical alternative. Channel change limits and length changes shall be minimized and designed to be the least environmentally damaging practical solution.

Countermeasures for pier/bent:

A. Align pier/bent with flow to minimize local scour.
B. Use encased piers/bents to prevent debris from collecting in water way area. Typically encasement is to stream flowline.
C. Design ice breaker pier/bent when channel has ice effects.
D. Channels with excessive debris may require a tapered pier/bent at upstream side that causes debris to ride up and thereby reduces local scour.

Countermeasures for drip line protection on open rail bridges:

A. Armor unprotected areas, outboard of the channel, to prevent rutting. Typically, armor an 8 ft. wide strip, centered at drip line, when distance to ground is less than 10 ft. Use a 10 ft. wide strip when distance to ground exceeds 10 ft. Bury armoring to top of ground to prevent reduction of water way area.

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8. Road Grade Elevation Requirements

Flood overtopping of roadways for proposed conditions is acceptable if the action is reasonable and prudent. Determine preliminary road design requirements and then co-ordinate the proposed design with the road design engineer.

Minimum overtopping standards as follows:

A. Overtopping of all roads from floods less than the Q_{100} flood will require justification by hydraulic computations that consider existing conditions, constraints, risks associated with the action, road design requirements and economics.
B. Four lane interstate highways will be designed for minimum Q_{50} overtopping. Six lane interstate highways will be designed for minimum Q_{100} overtopping. When practical, expressways will be designed to the same standards as interstate highways.
C. Typically, highways are designed for minimum Q_{50} overtopping. Coordination with road design is required when it is not practical to meet the minimum.

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9. Channel Behavior

The process of selecting the most practical bridge design requires an assessment of channel behavior. Channels are dynamic and naturally adjust to changes in climate and changes imposed by man. Channel adjustments usually occur very slowly when reacting to natural environmental change. When the channel is subjected to man made alterations, such as dredging or straightening, changes can occur rapidly.

The dominant parameters that influence channel adjustments are water discharge, channel slope, sediment transport and the average size of channel bed material. A change in any of these four parameters causes the channel to readjust.

Six stages for **CHANNEL EVOLUTION** are used to understand how a channel adjusts when it is subjected to alterations.

STAGE I is the **PREMODIFIED** natural state. When the channel is in this stage it is relatively stable and properly designed bridges experience few channel behavior scour problems.

STAGE II is the **CONSTRUCTED** phase. This phase identifies channels recently modified by channel straightening. This phase usually has a short duration. After a major runoff event, major channel readjustments to an unstable, artificial channel cross-section are evident.

STAGE III is the **DEGRADATION** process. During this phase of channel evolution, degrading progresses in an upstream direction with a progression of headcuts. Bank heights increase and bank slopes become steeper.

STAGE IV is the **THRESHOLD** time. Degradation is ending, headcuts are not visible, alternate bars start to form and channel widening by mass wasting is the dominant channel shaping process.

STAGE V is the **AGGRADATION** phase. Stream meandering occurs and the flowline elevation aggrades.

STAGE VI is **RESTABILIZATION**. Channel equilibrium is reestablished, channel capacity is reduced and rates of channel readjustments are dramatically reduced.

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10. Risk Assessment

The hydraulic analysis detail requirement is based on the risk associated with the encroachment, economics, engineering requirements, social concerns and environmental issues.

Typically the design of a bridge is based on an assessment of the flood hazards to the natural and beneficial flood-plain values, regulatory requirements, economics and other hydraulic consequences associated with the encroachment. (A risk analysis is necessary when a risk assessment is inadequate to define the most practical encroachment design.)

Some areas of consideration are: Traffic requirements, Types of flooding, Flood duration, Channel behavior, Scour, Debris, Ice effects/jams, Structural impacts, Countermeasures, Constraints, Environmental impacts, Construction process and Economics.

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11. Hydraulic Assessment Categories

The hydraulic stability of bridges is determined by assessing c*hannel behavior*, *scouring of the bridge waterway area*, and *structural design parameters.* Field observations and hydraulic analyses of these factors are used to evaluate how floods will impact structures.

Structures are then separated into five categories: *stable, low risk, scour susceptible, scour vulnerable, and scour critical*.

Each structure assessed is unique. In some cases a single hydraulic concern will place the structure into a specific category. For others one must consider a combination of hydraulic problems.

Hydraulic Assessment Categories

Channel Behavior –

- Meander belt stability
- Channel reach stability
- High bank buffer
- Channel depths
- Channel vegetation
- Debris transport
- Countermeasure adequacy
- Degradation
- Aggradation

Scour –

- Contraction scour
- Local scour
- Abutment
- Pier/bent
- Berm stability
- Proper height/width
- Abutment wall turbulence

Structural Features –

- Bridge spans
- Bridge low steel
- Bridge alignment
- Abutment location
- Pier/bent type and location
- Abutment design
- Pier/bent design

Hydraulic Assessment Process

Stable

Bridge should survive a Q_{500} flood. A Q_{100} flood will have minimum impact to berm stability, substructure stability, and approach integrity. Requirement for new designs.

- **Channel Behavior -** Bridge is not at risk
- **Scour -** Minimal impact
- **Structural -** Designed to withstand hydraulic concerns

Low Risk

Bridge will survive a Q_{100} flood. Scour damage is within design limits and will not impact substructure and/or approach integrity. Scour at berm will not impact abutment stability.

- **Channel Behavior -** No significant risk to the bridge (Monitor during routine bridge inspections.)
- **Scour –** Within design limits
- **Structural** - Bridge foundations have minimal concerns

Scour Susceptible

Calculations indicate bridge failure probable from major floods (50 yr). Effective non-structural countermeasures may be necessary if major change in channel behavior occurs.

- **Channel Behavior** - Long-term risks for bridge foundations (Monitor during routine bridge inspections.)
- **Scour –** Design scour limits at risk
- **Structural** - Foundations are at risk from major floods

Scour Vulnerable

Calculations indicate critical berm will be exposed. Bridge failure probable from a moderate flood (25 yr) will occur. Monitoring, structure replacement, substructure modifications, or channel countermeasures are required to minimize scour risks, if channel behavior change occurs.

- **Channel Behavior** - Foundations or approaches at risk (Monitor during routine bridge inspections.)
- **Scour –** Exceeds design limits
- **Structural -** Foundations are at risk from a moderate flood

Scour Critical

Bridge failure is imminent from minor floods. Plan of Action (POA) required.

- **Channel Behavior -** Bridge near failure
- **Scour –** Excessive
- **Structural -** Bridge foundations near failure

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12. Permit Requirements

A. Nebraska law requires a flood easement, from the land owner, if the Q_{100} flood elevation is raised more than 1 ft. at any location.
B. The CLEAN WATER ACT requires a Corps of Engineers 404 permit. It is required for the placement of fill material into the waters of the United States.
C. Construction in a FEMA Zone "A" floodplain requires a Certification of Compliance, from a licensed Engineer, verifying that the Q_{100} flood elevation was not raised more than 1 ft. at any location. For major action projects (New Construction), a copy of the hydraulic analysis for the existing and proposed conditions will be provided with the certification.
D. Construction in a defined FEMA Floodway requires a Certification of Compliance, from a licensed Engineer, verifying there has been a no rise to the Q_{100} floodway elevation. A copy of the existing/effective FEMA model and the modified model will be provided with the certification.

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13. Shoo-fly Design

Hydraulic design of shoofly structures are typically based on the $Q_{2.33}$ flood without adverse effects. Reducing the design to a Q_1 flood is acceptable when the structure for the $Q_{2.33}$ flood is unreasonably large and risks allow the more frequent road overtopping.

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14. Ditch Drop Structures

The hydraulic design of ditch drop structures is the responsibility of road design. The bridge Hydraulic Engineer should notify road design if a ditch drop structure may be necessary.

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15. Documentation

Minimum content in the preliminary structure design recommendation report to include location information, hydrology data, hydraulic survey requirements, immediate area contour plot, existing hydraulic study, proposed hydraulic study, FEMA information, summary information, field inspection photographs and preliminary data sheet.

A. Bridge location
   1. USGS topographic map – site location identified
   2. Aerial photograph – typical scale at 1 inch per 500 feet
B. Hydrology data
   1. Frequency distribution plot to Q_{500}

C. Hydraulic survey requirement
   1. Cross-sections location sketch – Aerial photograph to scale
   2. Detailed contour plot of existing conditions
      a. Extend plot to right-of-way limits upstream and downstream (minimum).
      b. Extend plot 100 ft. outside of each abutment (minimum).

D. Hydraulic study – existing
   1. Water surfaces & flowline profile plot
   2. Rating curve for immediate downstream side of structure
   3. Computation input
   4. Computation output
   5. Cross-section plots – to common scale
   6. Scour computations

E. Assessment of hydraulic alternates
   1. Consider alternate hydraulic structure
      (Document in Project Summary Sheet – Risk Assessment)

F. Hydraulic study – proposed
   1. Cross-section plots – to common scale
   2. Cross-section plot of bridge opening – include grade, low structure, abutment data and pier/bent location
   3. Computation input
   4. Computation output
   5. Scour computations
   6. Water surfaces & flowline profile plot
   7. Detailed contour plot of the proposed conditions (reference C).
   8. Rating curve for immediate downstream side of structure

G. Backwater Assessment
   1. Assessment of upstream risks associated with the maximum desirable rise in floodplain elevations. Document in Project Summary Sheet – Risk Assessment.
   2. A flood easement is required when backwater exceeds one ft. Typically backwater for existing and proposed conditions is assessed using the existing and proposed water surface profiles. A hydraulic study of natural conditions is needed when the water surface profiles are not adequate to verify backwater requirements.

H. FEMA information
   1. FEMA map of site –
   2. Table comparing existing and proposed
   3. Computer model data for existing and proposed
   4. Certification of Compliance

I. Summary of Hydraulic Data
   1. Existing structure information
   2. Proposed structure information
   3. Hydrology – Hydraulic information
   4. Risk assessment documentation

J. Field inspection photographs
   1. Bridge opening - identify if looking upstream or downstream
   2. Upstream channel view
   3. Downstream channel view

K. Preliminary Data Sheet
L. Plan and Profile across floodplain

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16. Field Inspection

A field review of the site, early in the hydraulic design process, to become familiar with existing conditions and assess the hydraulic risks may improve design efficiency. Typically, a field inspection is conducted after the office evaluations are completed and a detailed design is defined. At this time the hydraulic engineer is very familiar with the specific details and can make a thorough review of the proposed design.

Field Inspect and verify the following:

A. Bridge locations – centerline, abutments, piers/bents, skew, channel alignment
B. Flood calculations by visualizing flood height, limits, and flow distribution
C. Hydraulic Coefficients
D. Berm and flowline elevations
E. Bed and bank material
F. Check upstream buffer effectiveness
G. Observe channel geomorphology and expected impacts to structure
H. Countermeasure requirements, location and limits
I. Ditch drop requirements
J. Photograph existing bridge opening
K. Photograph upstream and downstream channel
L. Photograph and assess flood risks

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17. Preliminary Data Sheet

The preliminary data sheet summarizes the hydraulic related design requirements.

The following information is included:

A. Project identification (project number, control number, project name, structure number, and location.)
B. Brief description of project location and project disposition.
C. Existing structure information (original plan number, current project station, bridge type, length, width, skew, span lengths, and low structure elevation.)
D. Proposed structure requirements (station location, length, width, skew, span lengths, water-way area, freeboard, low structure elevation, curb type, foundation type, bottom of encasement, and the abutments critical berm elevation.)
E. Proposed grade requirements (bridge grade and road grade across floodplain)
F. Hydraulic data (stream name, drainage area, base flood, bridge base flood, overtopping flood, highwater elevation, flowline elevation, low road elevation, Q_{100} general scour, Q_{100} local scour and Q_{500} scour elevation, ordinary high water and ordinary high water elevation.)

G. Channel modifications and training works required (typical channel shaping of bridge opening, riprap requirements, details of channel change, excavation quantities, embankment quantities, drip line protection and riprap quantities.)
H. Traffic handling selection (detour, shoo-fly or under traffic.) Define shoo-fly requirements and briefly explain selection process.
I. Permit requirements (404, local, FEMA floodplain or FEMA floodway.)
J. TS&L sketch required (yes or no.) Major action projects require a bridge designer generated TS&L sketch.
K. USGS datum used (1929 or 1988)
L. Plan and/or profile view sketch (graphically show typical shaping of bridge opening, rip-rap placement, channel change details and stabilization requirements.)

Submit the preliminary data sheet to the Bridge Engineer for review and approval.

Distribution of the preliminary data sheet

A. For state projects
   1. Road Design Engineer for review and comments
   2. cc: District Engineer, Structural Engineer, Geotechnical Engineer, Noise/Air Studies/Utilities Engineer and Environmental Project Engineer, bridge hydraulic file and bridge file clerk.

   (Note: Bridge Design incorporates the preliminary data sheet information into the final bridge data sheet.)
B. For county consultant projects
   1. Original data sheet to Government Affairs
   2. cc: Geotechnical Engineer, bridge hydraulic file, and bridge correspondence file. Distribute blue copy to bridge file clerk.

   (Note: Preliminary data sheet is not submitted to the Bridge Engineer for review and approval.)

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18. Type, Size and Location of Structure

Bridge designers will develop the Type, Size and Location (TS&L) plan based on the approved preliminary data sheet information.

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19. Culvert Data Sheet

Prepare a final design Culvert Data Sheet for bridge size culverts.

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20. Quality Assurance Review

Verify the hydraulic report satisfies NDOR Hydraulic Analysis Guidelines and the Federal Aid Policy Guide 23 CFR 650 A.

Review Categories

A. Project identification and location
   1. Current project identification (Project, Structure and Control Number)
   2. Location map (County or Topographic map showing proper location.)
B. Hydrologic data
   1. Drainage Area verification
   2. Frequency Distribution Plot (appropriate methods, hydrologic justified)
C. Hydraulic survey data
   1. Hydraulic Cross-section location sketch (Length and location acceptable)
   2. Detailed contour plot of proposed conditions, covering the sufficient area.
   3. USGS datum identified (1929 or 1988)
D. Existing hydraulic analysis
   1. Cross-section plot to appropriate scale (No obvious survey errors)
   2. Input data (Verify reach lengths, “n” values and natural channel slope.)
   3. Output data (Includes necessary information)
   4. Water Surface profile plot (Reasonable profile data)
   5. Bridge Scour assessment (Compare natural channel velocity with scoured Water Way Area velocity. WWA velocity)
   6. Hydraulic category identification (hydraulic data assessed correctly.)
E. Proposed hydraulic analysis – appropriate method
   1. Cross-section plots to appropriate scale (no obvious survey errors)
   2. Channel cross-section plots (Verify typical channel shape and WWA.)
   3. Input data (Verify reach lengths, “n” values and natural channel slope.)
   4. Output data (Includes necessary information.)
   5. Water Surface profile plot [assess flowline, Q2, Q100, Q (low road) and Q (ordinary high water)].
   6. Bridge Scour analysis (Compare existing with proposed)
F. Design parameters
   1. Structure length (Satisfies minimum channel and berm requirements)
   2. Superstructure (Appropriate type and depth)
   3. Low Structure (Justifiable freeboard – Q100, Low Road, high bank)
   4. Design flood (Justifiable overtopping frequency and flood distribution)
   5. Abutment Type (Critical Berm / bottom of wall satisfies Q100 and Q500 requirements)
   6. Pier/Bent Type (Appropriate span arrangement, type and bottom of encasement).
   7. Bridge WWA (Correct channel cross-section)
   8. Countermeasures, berm and drip line protection (Risk and Cost analysis justification)
   9. Channel changes are justified and minimal
G. Alternate hydraulic design (Summary of hydraulic, economic and risk comparison)
H. Constructability (Structure, countermeasures and traffic handling are practical).
I. Information sheets (Appropriate details - Risk assessment justifies design)

J. Final Hydraulic Report (Verify content, data sequence and permit/certification)
K. Preliminary Data Sheet (Details: Hydrologic, Hydraulic, structure parameters, road grades, appropriate sketches, countermeasures, traffic handling, permits)
L. Plan and profile
M. TS&L (Adequately represents Preliminary Data Sheet.)

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21. Bridge Scour Inspection and Analysis

The bridge scour inspection and analysis procedure assesses the vulnerability of existing bridge size structures from failure due to flood events. It provides hydraulic data that is used in conjunction with structural data to manage bridges in an efficient, effective, flexible and continuous manner to provide safe public travel. Trained bridge inspectors, Para-professional bridge personnel and bridge engineers combine their special skills to prioritize and inspect bridges, assess channel behavior and evaluate the structures for scour.

Visual screening of bridges is done by National Bridge Inspection Standards (NBIS) trained personnel. They make scour related observations to monitor and document hydraulic changes for bridges over waterways as part of their normal, typical two-year inspection cycle. The BRIDGE INSPECTOR SCOUR OBSERVATION procedure addresses items that identify scour problems.

BRIDGE INSPECTOR SCOUR OBSERVATION

The screening process uses the Nebraska Department of Roads Bridge Inspection Manual and Coding Guide 300 SERIES SCOUR CRITICAL ITEMS and knowledge of channel behavior to determine scour items.

300 SERIES SCOUR CRITICAL ITEMS

344	Abutment walls undermined	Y – N
344a	Approach settles/washes out	Y – N
346	Is stream bed degraded	Y – N
347	Contracted stream/abut. inside high bank	Y – N
348	Scour at: A (abut), B (bent/pier), C (other), N (none)	_____
349	Is bank erosion in progress	Y – N
350	Stream shifted from bridge center	Y – N
351	Floodwater reaches low structure	Y – N
351a	Low road elevation below low structure	Y – N
352	Flood overtops road/bridge relief	Y – N
353	Potential debris upstream	Y – N
354	Bents/Piers in channel	Y – N
355	Bridge alignment with flow (9 – 0)	_____
356	Debris blocking channel at bridge	Y – N
357	Drop from upstream deck to ground Abut-1 (__), Flowline (__), Abut-2 (__)	
358	OPINION SCOUR PROBLEM	Y – N
358a	Significant flood in last two yrs. A=Over road, B=Not over road, C=No	____
358b	Scour increased in last two years	Y – N

Document hydraulic observations with digital photos that show; bridge deck relative to low road grade, upstream & downstream channel views, bridge profile showing waterway area, wings, abutment walls, berms, natural banks, piers/bents, countermeasures, scour related problems, and recent high water marks.

INTERDISCIPLINARY SCOUR ASSESSMENT TEAM (ISAT) PROCESS

Bridge scour assessment requires multidisciplinary inputs. Hydraulic engineers involve structural and geotechnical engineers in the evaluation process. An Interdisciplinary Scour Assessment Team (ISAT) determines if a bridge is vulnerable to scour failure during flood events. (ISAT conducts scour evaluation under the supervision of a licensed Engineer.)

A five-step evaluation/calculation process is used by ISAT to assess bridges for scour.

STEP 1. Hydraulic data and Hydrologic analysis

Assemble existing hydraulic related information for the specific bridge. Reference the available hydraulic data from the immediate region.

Perform a hydrologic analysis for the bridge site. Develop flood frequency data for discharges up through Q_{500}. Base the hydrologic analysis on regression equations and available regional data.

Utilize Bridge Scour Report. (DR Form 385)

STEP 2. Field inspect bridge site

Collect and document scour and channel behavior data. (DR Form 385, DR Form 385B)

A. Identify voids and undermining of abutment/approaches (sounding/probing)
B. Establish depth of abutment backwalls. (plans/probing)
C. Probe for evidence of scour immediately upstream of piers/bents
D. Categorize bed material: granular, cohesive or non-erodible
E. Categorize bank material: granular, cohesive or non-erodible
F. Assess channel behavior and determine channel evolution stage.
G. Assess the NBIS 300-series items.
H. Perform a structure inspection to assess structure reaction to scour and channel behavior.
I. Document hydraulic observations and provide digital photos that show:
    i. bridge deck relative to low Road grade,
    ii. Upstream & downstream channel views,
    iii. Bridge profile showing waterway area,
    iv. Wings, abutment walls, berms, natural banks,
    v. Piers/bents,
    vi. Countermeasures, scour related problems and recent high water marks.
J. Wings, abutment walls, berms, natural banks, piers/bents, countermeasures, scour related
K. Problems and recent high water marks.
L. When bridge foundations have extensive scour evident the NBIS Item 113 coding is definitely a 2.

NOTE: Report, to bridge owner, any critical condition that requires immediate action.

STEP 3. Field survey for Scour Calculations

Obtain a bridge opening cross section, low road profile and a typical floodplain cross section.

A. Reference the elevations to USGS 1988 NAVD datum. (For remote areas, approximate USGS datum is acceptable. Use a bridge benchmark or approximate datum based on topographic map data)
B. Cross-section typical flood plain as viewed looking downstream (Minimum of 1 required)
C. Cross-section at downstream side of bridge opening as viewed looking downstream (Identify bridge grade at abutment 1 and abutment 2. Also identify low superstructure.)
D. Obtain road overflow profile relative to bridge.

STEP 4. Hydraulically evaluate/assess the bridge site for scour

Calculate bridge scour based on a hydraulic analysis (HEC-RAS), using floodplain cross-sections, bridge cross-section and road overflow profile.

A. Use the following HEC-RAS input data identification format:
   1. NEW PROJECT TITLE - use <u>Structure Number</u> Scour Study
   2. FILE NAME - use <u>Structure Number</u>.prj
   3. Reference the cross sections river stations to bridge centerline. (Typically the river station of the bridge is 1000.)
   4. Reference the river cross section stations to bridge centerline in the DESCRIPTION data. (e.g.: 100 ft upstream. 30 ft upstream, 30 ft downstream, 400 ft downstream)
   5. Combine the field information and hydraulic analysis to make an assessment of channel behavior and scour impacts on the bridge.
B. Assess the 300 series scour critical items and document on form (DR Form 385).
C. Assign the proposed Item 113 code on forms (DR Form 385, DR Form 385B).
D. Document the scour study in a report (Hard copy and Electronic) that includes the following:
   1. USGS contour map showing bridge site encircled
   2. Bridge site photographs
   3. Hydraulic data forms (DR Form 385, DR Form 385B)
   4. Cross-section location sketch on an air photo
   5. Cross-section plot of downstream bridge opening. Show bottom of abutment backwalls, low steel, deck elevation, bents/piers and calculated scour.
   6. Rating curve for the immediate downstream flood plain cross section.
   7. Flow line and Water surface profile plots for Q (2, 10, 25, 50, 100, 500 and overtopping).
   8. HEC-RAS input data referenced to structure number.
   9. HEC-RAS output (Q total, W.S. elev, Vel Chnl, Q left, Q Chnl, Q right, Top Width, Top Width Chnl, Flow Area, Flow Area Chnl, Conv. Total, Froude # Chnl).
   10. Flood plain cross-section plots showing "n" values, Q2 elevation, Q100 elevation and Q overtopping elevation if less than Q100.
   11. Scour calculation output.

STEP 5. Perform a Quality Control check to verify evaluation/report adequacy.

STEP 6. Plan of Action (POA) Requirements

Federal memorandum dated July 24, 2003 requires preparation of a "*Plan of Action*" (POA) for each structure rated "*Scour Critical*". A POA (*DR Form 385C*) is a written document prepared by the bridge owner. It communicates the planned actions necessary to provide for public safety when there is a risk of structure failure caused by scour. It documents the procedures that are enacted to address the scour risk.

A "*Scour Critical*" bridge is a structure which is rated 3 or lower under "*Item 113-Scour Critical Bridges*" as defined by the *NDOR Bridge Inspection "Manual & Coding Guide"*. The Item 113 rating is assigned by the Interdisciplinary Scour Assessment Team (ISAT) following inspection, calculation and assessment.

The Interdisciplinary Scour Assessment Team (ISAT) reports scour critical findings to the bridge owners for development of a POA. The bridge owner is given a copy of the scour study report and a POA form. The data in the report provides hydraulic and scour details the owner utilizes for developing the POA.

The POA may require increased inspections, periodic monitoring, installation of scour countermeasures, conditional closure, and/or bridge replacement. An acceptable POA includes a schedule for implementation of the various actions prescribed. Guidance for POA preparation is contained in *FHWA Hydraulic Engineering Circular (HEC) 18, 20 & 23*. Details for monitoring, maintenance and areas of responsibility are identified.

The frequency of NBIS inspections and the supplemental hydraulic inspections between/during/after flood events are identified. NBIS inspectors monitor the site during routine inspections. Additional NBIS inspections are specified as deemed necessary. Supplemental routine/special inspections by hydraulic inspectors are normally required. A high risk site requires an inspector to be at the site prior to flood arrival. Prestorm parameters are identified to define when to initiate an onsite visit. A low risk of failure site is visited during the flood event and/or post flood. A visit to the site is defined by rainfall parameters, flooding information and road overflow reports.

A closure plan and detour route is required. The plan defines equipment needs, instructions on how to close the road and defines a detour route. The agencies/people that may be immediately notified after a closure are identified. The general criteria and authorizing inspector for the reopening the bridge is specified.

Maintenance that is planned to minimize scour related failure risk is defined. The maintenance time schedule is documented.

Persons responsible for defining the Plan of Action requirements are identified.

The POA shall be submitted to NDOR Bridge Division within 30 days of the date when the bridge owner is notified that a bridge is scour critical. Direct questions regarding the POA request to NDOR Bridge Division - Hydraulics: Interdisciplinary Scour Assessment Team.

Bridge owner shall maintain a log that documents events required by the POA.

NDOR Bridge Division monitors and quality controls the POA and its requirements. Scour studies/ratings are updated as conditions warrant.

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22. Hydraulic Forms

NDOR Hydraulic Forms

Description	Name
Project Information	DR Form 14A
Bridge Plan Information	DR Form 14B
Hydrology and Hydraulics	DR Form 14C
Reference Information	DR Form 14D
Risk Assessment	DR Form 14E
Bridge Scour Information	DR Form 14F
Culvert Information	DR Form 14G
Preliminary Data Sheet	DR Form 359A
Data Sheet (CBC) (*Culvert to Culvert)*	DR Form 359B
Data Sheet (CBC) (*Bridge to Culvert)*	DR Form 359C
FEMA Certification and Compliance	DR Form 366
Bridge Scour Report	DR Form 385
Bridge Scour Assessment	DR Form 385B
Bridge Scour Plan of Action	DR Form 385C
Bridge Scour Worksheet	DR Form 385D

Print or Download Forms

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