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2.8 WATERWAYS

2.8.1 Introduction

For any structure crossing a waterway, scour, flooding, and debris buildup can affect the stability. Scour is defined as the removal of streambed material due to stream flow. Scour can cause pier/abutment instability and bridge failures. Flooding can cause failures due to erosion of the embankment or lateral water flow pressures on the bridge. Debris buildup/aggradation can cause loading on substructure elements for which they were not designed, as well as create conditions causing scour and flooding.

The most common cause of bridge failures is water flow. For most of these failures, scour of the substructure is the failure mechanism. Part of every Routine Inspection is rating the channel and channel protection according to the Federal Highway Administration (FHWA) General Appraisal Rating Guidelines. In addition, a waterway adequacy appraisal is also required.

2.8.2 Channel and Channel Protection, NBI Condition Rating

A complete discussion of channel types, waterway changes, and scour is beyond the scope of this manual. However, main points will be addressed. Complete treatment of these topics may be found in *the Manual for Bridge Evaluation* and in the *Safety Inspection of In-Service Bridges Participant Workbook*.

The channel condition does not influence the physical condition of any bridge component. However, there are three reasons to perform waterway inspections. The first is to identify critical damage to the bridge caused by the waterway. Damage is usually settlement caused by scour and exposure/deterioration of substructure elements. The second reason is to record and monitor the channel conditions for any changes caused by natural or manmade circumstances. The final reason to perform waterway inspections is to establish the scour potential of a particular bridge site.

2.8.2.1 Scour and Channel Protection

Scour is the removal of material from the streambed or embankment as a result of the erosive action of stream flow. It is important for the inspector to recognize that there are four types of scour that can affect a bridge and channel. These are:

General scour – occurs whether there is a bridge crossing or not. It includes natural streambed movements and natural river lateral movements over time.

Contraction scour – caused by an increase in water flow velocity as a result of channel constriction. Building a bridge over a waterway will often cause this. Contraction scour will cause a lowering of the streambed across the entire channel width.

Local scour – occurs around an obstruction within the waterway, such as a bridge pier or abutment. The obstructions cause water turbulence, which stirs up the streambed material and allows it to be removed. Local scour is more severe when



substructures do not line up with the flow of the stream or when blunt shapes (squared off pier ends) are used instead of streamlined shapes (round or tapered pier ends).

Lateral Stream Migration – caused by stream meandering, channel widening or man-made channel changes. It affects abutments, wingwalls, and approach embankments.

Several factors affect a waterway's potential for scouring. Conditions which are more likely to lead to scour include high stream flow velocities, loose or granular streambed materials, a stream flow direction that is skewed relative to the bridge substructure units, and wide floodplains constricted to a narrow hydraulic opening at the bridge site.

To guard against the erosive effects of scour, the channel banks must be protected and the stream must be controlled. Channel protection and hydraulic control structures cover both natural and man-made features. Natural channel protection includes banks with well established vegetation, and streambeds consisting of bedrock, boulders, etc. Man-made control structures and channel protection include the following:

Riprap – large stones/boulders placed along the bank or substructure units that rely upon their mass for stability against the flow of water. Riprap may be natural or man-made. It is usually placed on a geotextile fabric to prevent erosion of the soil underneath. The size of the rip rap is typically determined by design calculations.

Channel lining – a layer of concrete across part of or the entire channel to virtually eliminate scour risk. Channel linings also increase the flow rate of the stream to drain the upstream region more quickly.

Gabions – large baskets of stone contained by a wire mesh. The baskets are normally tied together and anchored to the bank. They may be placed on steeper slopes.

Slope stabilization – treatment of the existing bank with plantings, geotextile or wire mesh to prevent erosion.

Footing aprons – a protective concrete layer that surrounds the structural footing of a pier, abutment or wingwall.

Guide banks/wing dams – devices that direct/control natural stream flows to prevent meandering.

Spur dikes – devices constructed to redirect flood flows smoothly through the bridge waterway opening protecting the embankments.



Figure 2.8.2.1-1: Well-Vegetated, Stable Natural Channel.



Figure 2.8.2.1-2: Riprap Channel Protection.



Figure 2.8.2.1-3: Concrete Channel Lining Protection.

2.8.2.2 Inspection

A channel condition rating covers the areas upstream, downstream, and directly under the bridge. The type of waterway has a significant influence on the condition of a channel. Fast-flowing streams and rivers may result in channel changes and a greater likelihood of scour. Waterways can be very difficult to control with man-made devices. Slow-flowing streams and rivers may result in channel obstructions due to debris and ice build-ups and slowly changing channel locations. Lake channels are subject to location changes due to aggradation, and can create ice pressures on the substructure units.

Channel inspection can be broken down into three parts: channel condition upstream, channel condition at the bridge, and channel condition downstream. Channel inspection upstream of the bridge should include the following items:

- Looking for stable banks. Stable banks will be gradually sloped and well vegetated.
- Checking to make sure any artificial slope stabilization measures are in place and intact.
- Looking for evidence of bank instability, such as sloughing due to scour and lateral stream movements.
- Looking for debris or aggradation that could redirect the stream flow.
- Looking for signs of streambed degradation.
- Noting any signs of lateral stream movement. General waterway alignment should normally be centered under the structure. Sketches or photographs should be taken during each inspection to monitor upstream alignment.



- Checking for other unusual obstructions to stream flow such as cattle guards and fences. These can trap debris, resulting in possible sediment buildup and redirection of the stream flow.
- Checking for evidence of stream flow within the floodplain.
- Noting changes within the floodplain, such as trees, houses, newly paved areas, etc. These affect main channel stream flow during floods.

Channel inspection under the bridge and at the bridge should include the following items:

- Checking for evidence of structure settlement, such as substructure tipping or superstructure vertical misalignments. A plumb bob or sighting along the bridge railing will often help in making this determination.
- Probing around the substructure units with a rod to check for areas of local scour.
- Checking the condition of channel protection devices (riprap, aprons, channel lining, levees, guide banks, and spur dikes). Riprap should be firmly in place on the banks and not scattered throughout the channel. Aprons and channel linings should not be undermined. Levees, guide banks and spur dikes should not be washed out.
- Checking if stream flow is impinging behind protective devices. For example, stream flow should not be pooling on the upstream side of a wingwall.
- Looking for evidence of overtopping by floodwaters. This evidence may include damaged girders or truss bottom chords; debris lodged between girders, cross frames, bearing areas, etc.; scrape or water marks on surrounding trees or bearings exhibiting transverse displacements.
- Noting if the superstructure or approaches are located within the flood plain.
- Looking for debris or sediment buildup that could redirect the stream flow.
- Looking for debris caught on the upstream end of piers or between pier columns. This can create localized increased water velocities.
- Looking for signs of degradation of the streambed.
- Noting if the hydraulic opening is sufficient to allow flood waters to pass without constriction, scour or damage to the superstructure.

Channel inspection downstream of the bridge should include the following items:

- Looking for stable banks. Stable banks will be gradually sloped and well vegetated.
- Checking to make sure any artificial slope stabilization measures are in place and intact.

- Looking for evidence of bank instability, such as sloughing due to scour and lateral stream movements.
- Looking for debris or sediment buildup that could redirect the stream flow and affect “getaway” flow conditions.
- Looking for signs of streambed degradation.
- Noting any signs of lateral stream movement. General waterway alignment should normally be centered under the structure. Sketches or photographs should be taken during each inspection to monitor downstream alignment.
- Checking for other unusual obstructions to stream flow such as cattle guards and fences. These can trap debris, resulting in possible sediment buildup and increasing tail water depths.
- Noting obstructions within the floodplain, such as trees, houses, etc.



Figure 2.8.2.2-1: Stable Upstream Channel.



Figure 2.8.2.2-2: Aggradation in Front of Abutment and Debris Buildup in Front of Pier.



Figure 2.8.2.2-3: Heavily Vegetated Downstream Channel.

2.8.2.3 Rating

Channel and channel protection condition ratings are concerned with water flow, channel protection, channel damage due to flow, and waterway stability. Damage to the substructure, superstructure or culvert should be reflected in their appropriate National Bridge Inventory (NBI) condition ratings.



Rating the channel and channel protection is done according to the Federal Highway Administration (FHWA) General Condition Rating Guidelines. The numeric condition ratings of these guidelines describe existing channel and channel protection devices compared to their as-built condition. Ratings range from 9 to 0, with 9 describing components in excellent condition and 0 describing failed devices.

Because only a single number is used to rate the channel and its protection, the rating must characterize its overall general condition. The rating should not be used to describe local areas of deterioration, such as an isolated area of washed-out riprap or an old tire discarded in the river upstream. However, widespread riprap washouts or large quantities of trash/debris located within the channel would certainly influence the rating. A proper rating will therefore consider deterioration severity plus the extent to which it affects the channel condition and performance. The FHWA channel and channel protection general condition ratings are as follows:

Code (Rating) Description

- N** **NOT APPLICABLE** – use only when bridge is not over a waterway (channel).

- 9** **EXCELLENT CONDITION** – there are no noticeable or noteworthy deficiencies which affect the condition of the channel.

- 8** **VERY GOOD CONDITION** – banks are protected or well vegetated. River control devices such as spur dikes and embankment protection are not required or are in a stable state.

- 7** **GOOD CONDITION** – bank protection is in need of minor repairs. River control devices and embankment protection have a little minor damage. Banks and/or channel have minor amounts of drift.

- 6** **SATISFACTORY CONDITION** – bank is beginning to slump. River control devices and embankment protection have widespread minor damage. There is minor streambed movement evident. Debris is restricting the channel slightly.

- 5** **FAIR CONDITION** – bank protection is being eroded. River control devices and/or embankment have major damage. Trees and brush restrict the channel.



- 4 **POOR CONDITION** – bank and embankment protection is severely undermined. River control devices have severe damage. Large deposits of debris are in the channel.

- 3 **SERIOUS CONDITION** – bank protection has failed. River control devices have been destroyed. Streambed aggradation, degradation or lateral movement has changed the channel to now threaten the bridge and/or approach roadway.

- 2 **CRITICAL CONDITION** – the channel has changed to the extent the bridge is near a state of collapse.

- 1 **“IMMINENT” FAILURE CONDITION** – bridge is closed because of channel failure. Corrective action may put it back in light service.

- 0 **FAILED CONDITION** – bridge closed because of channel. Replacement is necessary.

One suggested method for establishing the channel and channel protection rating is to identify phrases within the general condition guideline language that describes a condition more severe than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

For example, suppose the channel has extensive sloughing upstream, plus small amounts of debris within the channel. The sloughing has caused the stream to begin pooling behind one of the wingwalls, but there is no evidence of scour/undermining. Condition rating 5 indicates that bank protection is being eroded, and that the embankment has major damage. Trees and brush also restrict the channel. Condition rating 4 indicates that bank and bank protection is severely undermined. River control devices have severe damage, and large deposits of debris are in the channel. Using the method described above, Condition rating 4 describes a situation more severe than what actually exists within the channel. Therefore, a rating of 5 would be appropriate.

2.8.3 Waterway Adequacy National Bridge Inventory (NBI) Appraisal Rating

Waterway adequacy is an appraisal of the existing hydraulic opening and its ability to handle the water flowing through it. It compares the existing condition to the desirable condition of no roadway overtopping during a flood. The hydraulic opening is the opening available for water to pass under the bridge. It is essentially an area bounded by the streambed, abutment faces, and the underside of the bridge superstructure.



The waterway adequacy appraisal considers overtopping frequency as well as the significance of traffic delays caused by overtopping. When overtopping frequency information is available, the descriptions given in the table for chance of overtopping mean the following:

1. **Remote** – greater than 100 years.
2. **Slight** – 11 to 100 years.
3. **Occasional** – 3 to 10 years.
4. **Frequent** – less than 3 years.

Adjectives describing traffic delays mean the following:

1. **Insignificant** – minor inconvenience. Highway passable in a matter of hours.
2. **Significant** – traffic delays of up to several days.
3. **Severe** – long term delays to traffic with resulting hardship.

Points of concern regarding waterway adequacy include sediment/debris accumulation or vegetation growth that may block or partially block the hydraulic opening. The inspector should also note any newly paved areas or developments that would increase the amount of runoff into the stream and high water marks on the bridge or surrounding terrain. Local residents are often excellent sources of information regarding high water. With this said, the waterway adequacy appraisal rating is established during the Initial Inspection, and it should not be changed unless it has been reviewed and approved by the Inspection Program Manager.

The Federal Highway Administration (FHWA) waterway adequacy appraisal ratings are as follows:



Functional Classification			
Principal Arterials – Interstates, Freeways, or Expressways			
Other Principal and Minor Arterials and Major Collectors			
Minor Collectors, Locals			
Code		Description	
N	N	N	Bridge not over a waterway
9	9	9	Bridge deck and roadway approaches above flood water elevations (high water). Chance of overtopping is remote.
8	8	8	Bridge deck above roadway approaches. Slight chance of overtopping roadway approaches.
6	6	7	Slight chance of overtopping bridge deck and roadway approaches.
4	5	6	Bridge deck above roadway approaches. Occasional overtopping of roadway approaches with insignificant traffic delays.
3	4	5	Bridge deck above roadway approaches. Occasional overtopping of roadway approaches with significant traffic delays.
2	3	4	Occasional overtopping of the bridge deck and roadway approaches with significant traffic delays.
2	2	3	Frequent overtopping of the bridge deck and roadway approaches with significant traffic delays.
2	2	2	Occasional or frequent overtopping of the bridge deck and roadway approaches with severe traffic delays.
0	0	0	Bridge is closed.