Bridge-Scour Screening Methodology for New Zealand Bridges

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Bloxam, Burnett & Olliver employees, Ray Reeve, Glenn O'Connor, Charles Stokes, accompanied the project team for the field inspections.

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Executive Summary

Introduction

Currently (2000), effective management of public facilities within New Zealand is receiving strong emphasis in local and national government. Recognising the significance of scour (i.e. channel erosion, in all its forms) as a cause of bridge damage, a screening methodology appropriate to New Zealand conditions is presented in this report. It is to assess and rank bridges in regard to the dual criteria of susceptibility to scour and of the importance of the bridge to the roading network. The methodology, based on a review of national and international scour-screening methodologies and programmes, was refined during 1999–2000 by trials and peer reviews. The Screening Form and guidelines explaining the Forms are given in Appendices.

Methodology

The methodology comprises an office review of available information and a field review of the bridge(s) to be assessed. At the office review stage, bridges that are closed, scheduled for replacement, or not over a waterway, are excluded from further scour-screening analyses. For the remaining bridges, a bridge-significance rating (of high, medium or low) is assigned, based on the categorisation of the route.

Next, the vulnerability of a bridge to scour is assessed, and individual aspects of the bridge and waterway are rated as indicating high, unknown, medium, or low vulnerability to scour.

The individual aspect ratings are then combined to give ratings (of high, unknown, medium, or low) of vulnerability to scour in terms of aspect groupings of: catchment development and/or conditions, historical scour, degradation and contraction, aggradation, waterway adequacy, lateral channel changes, and bridge approaches, flow depths in bends and confluences, and local scour at piers and abutments.

An overall rating (high, unknown, medium, or low) of bridge vulnerability to scour is then assessed, based on an overview of the eight ratings for the combined groupings. A high rating for a combined grouping or for the bridge overall can be determined by a particular dominating aspect of the bridge or waterway (e.g. scour-induced foundation movement), or by a weight of the contributing ratings (e.g. notable degradation of the channel combined with increased flow depths at the outside of a channel bend influencing the bridge foundations).

Based on the bridge-significance rating and overall bridge-vulnerability rating, an overall scour-susceptibility rating (1 = highest susceptibility, 4 = lowest susceptibility) is then assigned. Possible remedial actions are subsequently identified for bridges indicated to be susceptible to scour.

The methodology has the particular advantage of using pictorial guides of conditions in conjunction with the data form to ensure consistency and completeness in reporting site information in the field. This aspect of the proposed guidelines is a particular improvement over existing guidelines worldwide.

The screening exercise is designed to be a "one-off" event to be carried out (possibly every 25 years) in a comprehensive and programmed manner, to produce a national priority list of waterway mitigation projects. Subsequent monitoring of sites identified as scour-susceptible would occur more often as required.

For the proposed Screening Form, the office review is anticipated to take about 1-1.5 hours, and the field review to take about 1 hour. The bridge inspection team is expected to consist of an experienced bridge designer, and bridge inspectors. Screening Forms can be filled out by hand in the field, and then entered into a computer database while in the field, to save time in generating reports back at the office. An electronic version of the Screening Form is on a floppy disc in the pocket inside the back cover of the report.

Advantages of the Proposed Methodology

Use of the proposed methodology for all bridges of a roading network will enable "at-risk" sites (of higher scour-susceptibility ratings) to be identified, thereby avoiding potential safety and asset risks. It will also enable scour risk to be consistently and rationally evaluated and ranked nationally, through comparison of the overall scour-susceptibility ratings for bridges across New Zealand.

Scour-related works can then similarly be prioritised nationally. For example, for each bridge identified by the screening procedures or subsequent more detailed analyses as requiring remedial work, remedial-work options will be determined. The costs of the remedial works can then be quantified along with the resulting benefits (based on Transfund New Zealand's Project Evaluation Procedures) in order to develop an economic ranking indicator (ERI).

Bridges requiring works can then be ranked nationwide based on ERI values and on the importance of the structure in the road network. Thus, bridges of higher ERI values and importance can progress to more detailed analyses and/or remedial works as funds permit. This process will rank the bridges in priority order on the basis of vulnerability, risk, and economic justification for remedial works, and will ensure that the large annual expenditure on scour-related works is consistently prioritised nationally.

Recommendations

Given the need for a degree of understanding of waterway processes and waterway–structure interaction processes in the assessment of bridge-scour susceptibility, the recommendation is that training of bridge inspection teams is undertaken to ensure that the scour-screening methodology can be understood and effectively implemented by the teams.

As indicated by the peer reviewers, a working party review before implementation of the methodology is recommended. To this end, further thorough trialling of the screening procedure supplied in the report is needed in order to improve the accuracy and usability of the proposed bridge-scour screening methodology.

After trialling the methodology has been completed, the recommendation is that bridge-scour screening is urgently carried out for bridges on New Zealand state highways.

Abstract

Recognising the significance of scour (i.e. channel erosion, in all its forms) as a cause of bridge damage, a screening methodology for assessing and ranking New Zealand bridges in terms of their susceptibility to scour is presented. The methodology trialled during 1999–2000 comprises an office review of available information, and a field review of the bridge(s). Based on ratings of bridge significance to the roading network and of bridge vulnerability to scour (as indicated by assessments of aspects of the bridge and the waterway), an overall scour-susceptibility rating (1 = highest susceptibility, 4 = lowest susceptibility) is assigned.

Use of the proposed methodology for all bridges of a roading network will enable "at-risk" sites (of higher scour-susceptibility ratings) to be identified, thereby avoiding potential safety and asset risks. It also enables scour risk to be consistently and rationally evaluated and ranked nationwide through comparison of the overall scour-susceptibility ratings for bridges on the New Zealand state highway network.

Recommendations are for training bridge inspection teams to use the methodology, for trialling and reviewing the proposed bridge-scour screening methodology before its implementation, and once it is implemented for bridge-scour screening to be urgently carried out for bridges on the New Zealand state highway network.

1. Bridge-Scour Screening Methodology for New Zealand Conditions

1.1 Background

Currently, effective management of public facilities within New Zealand is receiving strong emphasis in local and national government. For example Transit New Zealand has recently prepared a State Highway Bridge Assessment Management Plan, which highlights the need for a "lifelines" approach to risk management, whereby all risks and mitigation options are evaluated.

The major damage to bridges occurs during floods. Each year, floods inundate bridge crossings, and scour removes bridges from service, for the purposes of inspection or repair, for varying periods of time. Although the costs of repairing and replacing bridges are substantial, these costs often constitute only a fraction of the economic impact on the travelling public and the local community.

Flood-induced damage is caused by various mechanisms, the main mechanism being scour at bridge foundations, of piers and abutments. In New Zealand, at least one serious bridge failure each year (on average) can be attributed to scour at the bridge foundations.

A seismic-risk analysis (i.e. seismic screening) of all state highway bridges is also underway in 2000, for New Zealand. The development of a parallel bridge-scour screening methodology for New Zealand conditions is therefore logical and timely, given:

- the identified need for an assessment of bridge risk management in New Zealand;
- the significance of scour as a cause of bridge damage;
- the present state-of-the-art understanding of bridge scour as reflected in the recent completion of the benchmark document for bridge-scour design and analysis for New Zealand conditions, by Melville & Coleman (2000); and
- recent overseas initiatives at developing bridge-scour screening methodologies.

1.2 Study Objectives

The objective of the present study is thus to provide scour-assessment guidelines and an overall methodology for bridge-scour screening of bridges in New Zealand conditions. This methodology is designed to provide clear guidance to users of the process but not unnecessarily overburden these users. The methodology is to form the basis of a screening programme aimed to prioritise the bridges requiring remedial action arising from their vulnerability to potential scour damage. The bridge-scour-screening programme will increase the effectiveness of programmes aimed at ensuring the future continuity and safety of the New Zealand state highway network.

In particular, the proposed bridge-scour screening methodology will:

- identify "at-risk" sites and thereby avoid potential safety and asset risks;
- allow a consistent and rational evaluation of scour risk nationally;
- ensure that the large annual expenditure on scour-related works is consistently prioritised nationally; and
- allow expenditure on scour and other risks (e.g. seismic) to be compared, justified and prioritised in a rational manner.

1.3 Study Programme

The specific tasks carried out during 1999–2000 were:

1. A review of present international screening methodologies and programmes.
2. A review of data required for bridge-scour screening in New Zealand.
3. A review of appropriate data sources available to those carrying out bridge-scour screening in New Zealand.
4. Formulation of a bridge-scour screening methodology appropriate to New Zealand conditions.
5. Application of the proposed methodology to a number of New Zealand bridge sites as examples.
6. Submission of a Draft Final Report comprising the proposed bridge-scour screening guidelines, the overall bridge-scour screening methodology, and examples of application.
7. Peer review of the Draft Final Report.
8. Review and editing of the Draft Final Report by Transfund New Zealand (Transfund).
9. Submission of the Final Report incorporating review and editing comments as appropriate.

As a follow-up to these tasks, the methodology will need to be thoroughly trialled before it is implemented as the accepted system for bridges on New Zealand state highways.

Discussions were also held with consultants carrying out bridge inspections (e.g. Opus International Consultants Ltd, Greymouth; and Bloxam, Burnett & Olliver, Hamilton) to obtain feedback on the existing inspection procedures and also on proposed procedures.

In addition, to aid the formulation of screening procedures useful to those in the field, the project team accompanied Bloxam, Burnett & Olliver employees to carry out general inspections of seven bridges on State Highway (SH) 26 from Kopu to Paeroa, Hauraki Plains, North Island. The bridge inspections applied existing general inspection procedures.

2. Types of Scour

Bridge scour comprises all forms of channel erosion occurring at bridge foundations. The types of scour that can occur at a bridge crossing are typically referred to as general scour, contraction scour, and local scour. They can be classified as shown in Figure 1, and are defined as follows:

- ***Total scour*** refers to the total depth of scour at the particular bridge foundation, and includes *general scour* and *localised scour*.
- ***General scour*** is scour that occurs irrespective of the existence of the bridge, and includes *short-term general scour* and *long-term general scour*.
- ***Short-term general scour*** is scour that develops during a single or several closely spaced floods. It includes scour at a confluence; a shift in the channel thalweg; shifts in bends, braids or anabranches within the channel; and scour arising from bed-form migration.
- ***Long-term general scour*** is scour that occurs with a time scale of the order of several years or longer, and includes *progressive degradation* or *aggradation* and lateral bank erosion caused by channel widening or meander migration.
- ***Progressive degradation*** is the quasi-permanent general lowering of the river bed at the bridge site related to natural changes in the catchment (e.g. cut-off formation, landslides, mud flows, fire, climate change) or human activities (e.g. channel dredging, channel straightening, cut-off formation, stream-bed mining, dam construction, urbanisation, deforestation, agricultural activity).
- ***Progressive aggradation*** is the general raising of the river bed at the bridge site.
- ***Localised scour*** is scour that is directly attributable to the existence of the bridge, and includes *contraction scour* and *local scour*.
- ***Contraction scour*** is scour that occurs because the flow is constricted by the bridge foundations (including approaches).
- ***Local scour*** is scour caused by the interference of the bridge foundations with the flow, and includes *abutment scour* and *pier scour*.
- ***Abutment scour*** is scour caused by the interference of the abutments with the flow.
- ***Pier scour*** is scour caused by the interference of the piers with the flow.

At a particular bridge crossing, any or all of the different types of scour may occur simultaneously. It is necessary to ensure that the total scour for design includes an appropriate superposition of the scour due to all possible causes.

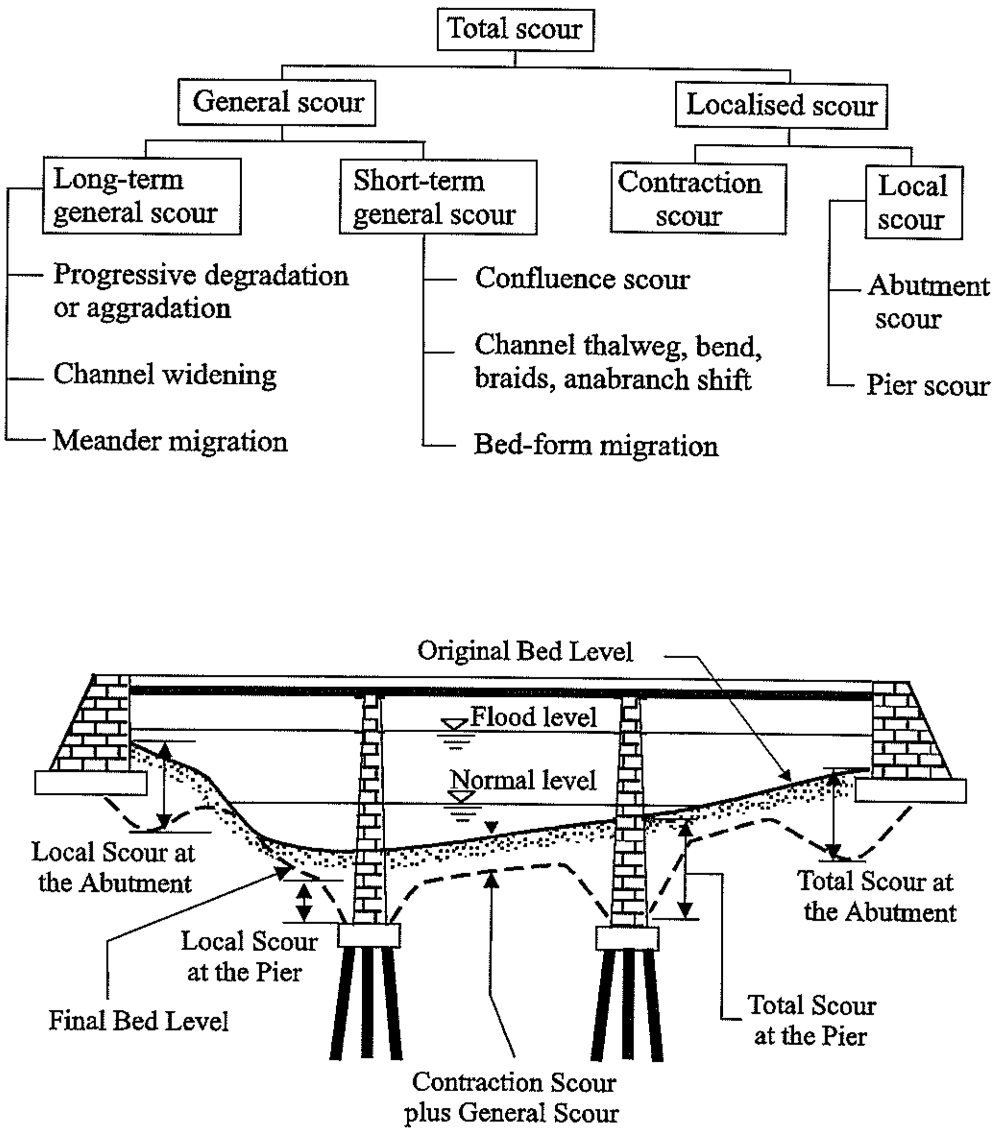

Figure 1 **The types of scour occurring at a bridge crossing (from Melville & Coleman 2000).**

3. Provisional Bridge-Scour Screening for New Zealand

3.1 Existing Bridge-Scour Screening Programmes

Existing New Zealand and overseas bridge-scour screening procedures and programmes are discussed and illustrated in Appendix G. In essence, present New Zealand bridge-scour screening is limited to the scour and waterway components of general inspection procedures. In contrast, relatively comprehensive stand-alone bridge-scour screening procedures, predominantly of US origin, are used overseas.

3.2 Provisional Procedures

To effectively use resources, bridge-scour inspection and screening can be undertaken in stages (e.g. Davis & Dee 1996), comprising:

- a primary less intensive screening process to quickly identify scour-susceptible bridges and to evaluate stream stability at such bridges; and
- a secondary more comprehensive screening process to assess and rate bridges found to be scour-susceptible.

In line with the above, the approach adopted for a provisional New Zealand bridge-scour screening programme consisted of:

- a first-stage bridge-scour screening process (using the form given in Appendix C), with a simple means of ranking bridge susceptibility to scour at the end of the process; and
- a second-stage advanced bridge-scour assessment (using two additional forms for data collection and bridge assessment respectively), with more sophisticated means of ranking bridge susceptibility to scour at the end of the process.

The principal references used in creating the three provisional forms include Melville & Coleman (2000), Minnesota Department of Transportation (Minnesota DOT 1991), Hunter et al. (1993), Robinson & Thompson (1993), Simon (1995), Simon & Downs (1995), Fischer (1996), Davis & Dee (1996), Palmer & Turkiyyah (1997), Palmer et al. (1999), and Johnson et al. (1999). The last of these bridge-scour assessment methods has been promoted in a draft revision of HEC-20 (US FHWA guidelines regarding stream stability at highway structures, Lagasse et al. 1995) to be released shortly.

Peer review comments focussed upon the provisional form for the first-stage bridge-scour screening. This provisional form, which has been subsequently modified to give the final proposed form for bridge-scour screening (given in Appendix A of this report), is presented and discussed in Appendix C. The respective forms for the advanced second-stage data collection and second-stage bridge assessment are not presented or discussed herein.

3.3 Peer Reviews

To evaluate the usefulness of the provisional bridge-scour screening procedures, the project team supplied the provisional form for the first-stage bridge-scour screening, along with explanations of the terms and illustrating figures to Opus International Consultants Ltd, Greymouth; Opus International Consultants Ltd, Dunedin; Bloxam, Burnett & Olliver, Hamilton; and Transit New Zealand, Dunedin. Opus International Consultants Ltd, Christchurch, and Transit New Zealand, Dunedin, also reviewed the draft final report, which contain the three provisional forms for first-stage bridge-scour screening, second-stage data collection, and second-stage bridge assessment respectively.

The review comments obtained are summarised in Appendix D. A sample application (by Opus International Consultants Ltd, Dunedin) of the provisional first-stage bridge-scour screening procedure to a New Zealand bridge site is given in Appendix E.

As a consequence of the review comments, the bridge-scour screening procedures were modified, resulting in the final proposed bridge-scour Screening Form (Appendix A) discussed in Section 4 of this report. Responses to the review comments are discussed briefly here:

1. The methodology, including the presentation of the procedures, has been simplified from that initially supplied as the provisional methodology.
2. The provisional second stage has been eliminated, and instead the single Screening Form of Appendix A now incorporates the more significant aspects of the earlier second-stage forms.
3. The procedures retain a simplified staged approach within the single form, with a preliminary elimination of the bridges for which scour screening is not applicable.
4. The proposed screening team and screening frequency have been modified as indicated in 6 below.
5. As suggested by the peer reviewers, entering Screening Form data into a computer database while in the field will save time when generating reports back at the office. For this an electronic version of the Screening Form is provided on the floppy disc in the pocket inside the back cover of this report.
6. The Screening Form has been modified, in particular to:
   a. clarify forms of scour that can occur at bridge crossings;
   b. clarify Screening Form terms and statements;
   c. allow for user interpretation of unknown conditions;
   d. include measurements at piers, abutments and centre spans;
   e. clarify the positions at which bed elevations are measured across the section for different aspects of scour;

f. clarify measures indicating degradation and contraction at a bridge site;

g. clarify measures indicating lateral channel movement and channel widening at a bridge site;

h. clarify means of allowing for effective foundation width (especially for piers);

i. estimate, rather than measure (which is often not possible), the influence on foundations of increased flow depths in bends and confluences;

j. distinguish between approach erosion/ failure and scour of foundations (owing to possible differences in scale of economics for possible remedial works);

k. include a transparent assessment of risk in terms of bridge significance and allowance for alternative routes, detours, and availability and timing of temporary bridges (e.g. Bailey bridges, etc.);

l. rate bridge significance in line with vehicle route importance categories given for waterway analyses in the Transit New Zealand Bridge Manual (Section 2. Design - General Requirements. Amendment No. 3: December 1999);

m. improve the combination of bridge significance and bridge vulnerability to scour ratings to give an overall scour-susceptibility rating;

n. include additional useful or necessary bridge and waterway details that are to be recorded, e.g. effects of catchment on reasons for scour at the bridge site, downstream hydraulic controls and their stability, bed material type and size, depth of bed material deposits, bank materials, the angle of flood flows to bridge foundations, quality of installed protection measures, the existence of relief bridges, channels, etc.

4. Proposed Bridge-Scour Screening for New Zealand

The proposed bridge-scour screening procedure for New Zealand bridges uses the Screening Form presented in Appendix A. To aid use of the bridge-scour Screening Form, explanations of the terms and statements of the Form and figures illustrating aspects of the Form are given in Appendix B.

4.1 Screening Process

The process of identifying and rating scour susceptibility for bridges involves a number of steps, and the Screening Form comprises six sections. According to the Form structure, an office review of available information will be carried out for a bridge, followed by a site visit.

Background Office Review

- Basic bridge details are entered.
- If the bridge is not over a waterway, is closed, or is scheduled for replacement, then the bulk of the Form is not filled in, and at the end of the Form the lowest scour-susceptibility rating of '4' is assigned. Otherwise, additional bridge and waterway details are entered.

Office Review of Bridge Significance (S)

- Basic road-use details are entered.
- A bridge significance rating (high, medium or low) is assigned, based upon categorisation of the route.

Bridge Vulnerability (V)

- Additional bridge and waterway details are entered, based on office and field reviews.
- Individual aspects of the bridge and waterway are rated as indicating high, unknown, medium, or low vulnerability to scour.
- Individual aspect ratings are combined to give ratings (high, unknown, medium, or low) of vulnerability to scour in groupings of:
    - catchment development/ conditions,
    - historical scour,
    - degradation and contraction,
    - aggradation,
    - waterway adequacy,
    - lateral channel changes and bridge approaches,
    - flow depths in bends and confluences, and
    - local scour at piers and abutments.
- An overall rating (high, unknown, medium, or low) of bridge vulnerability to scour is then assessed based on an overview of the eight ratings for the above combined groupings.

- Each assessment of vulnerability (in terms of individual aspects of the bridge and waterway, the combined groupings, and the overall rating) is subjective and relies on engineering judgement and experience for an appropriate rating.

  For example a high rating for a combined grouping or for the bridge overall can be determined by a particular dominating aspect of the bridge or waterway (e.g. scour-induced foundation movement), or by a weight of the contributing ratings (e.g. notable degradation of the channel combined with increased flow depths at the outside of a channel bend influencing the bridge foundations).

Overall Scour-Susceptibility Assessment

- Based on the bridge-significance and bridge-vulnerability ratings, an overall scour-susceptibility rating (1 = highest susceptibility, 4 = lowest susceptibility) is assigned.
- Possible remedial actions are identified for bridges with scour-susceptibility ratings of 1, 2 or 3.

Personnel

- For quality assurance purposes, the personnel carrying out the reviews and assessments are identified.

Visual Records, Notes and Comments

- Notes and comments are recorded as required.
- Standard photographs of the bridge and waterway are to be taken.

4.2 Screening Results

All bridges will be given overall scour-susceptibility ratings ranging from 1 (highest) to 4 (lowest), the ratings being based on the significance of the bridge and its vulnerability to scour. The above methodology will then:

- identify "at-risk" sites (of higher scour-susceptibility ratings) and thereby avoid potential safety and asset risks; and
- allow a consistent and rational evaluation and ranking of scour risk nationally, through comparison of the overall scour-susceptibility ratings for bridges throughout New Zealand. Scour-related works can then be prioritised nationally.

4.3 Benefits of Screening Procedures

The proposed methodology has the particular benefits of:

- using a single form to rank bridges in priority order on the basis of bridge vulnerability and bridge significance;
- being staged to quickly eliminate bridges that are clearly not scour-susceptible;
- having the bridge-scour Screening Form applicable to both bridges and culverts (of fixed inverts); and

- using pictorial guides of conditions in conjunction with the Screening Form to ensure consistency and completeness in reporting site information. This aspect of the proposed guidelines is a particular improvement over existing guidelines worldwide.

4.4 Screening Frequency

Recognising the high number of bridges on the New Zealand state highway network alone, and the potential cost of screening these structures as a group, peer reviewers have recommended (Appendix D) that the screening exercise be a "one-off" event to be carried out, possibly every 25 years, in a comprehensive and programmed manner. The aim is to produce a national priority list of bridge-scour mitigation projects. The assessment of waterway-related matters could continue on the present two-yearly inspection cycle which, despite its simplicity and shortfalls, has been largely successful in managing the risk associated with waterways in a cost-effective manner. Separate monitoring of sites identified as scour-susceptible would occur at higher frequencies as required.

4.5 Bridge Inspection Team, Equipment & Duration of Visit

Given the subjective nature of the interpretations of conditions to be made, the bridge inspection team is expected to have the technical insight of an experienced bridge designer, together with the site knowledge of the bridge inspectors. The Screening Form guidelines of Appendix B have accordingly been written assuming some understanding of catchment, bridge and scour mechanisms and terminology.

Recommended equipment for the field component of the bridge-scour screening inspection will be as for the existing general inspection: the bridge-scour Screening Form, a laptop, previous inspection forms, standard bridge description inventory forms, a steel tape measure, camera, slasher, waders, etc. Inspection forms can be filled out by hand in the field, then entered into a computer database while in the field. This is to save time in generating reports back at the office. For this an electronic version of the Screening Form is provided on the floppy disc in the pocket inside the back cover of this report.

Based on the experience of using the provisional first-stage Screening Form (Section 3.3, Appendices D and E for comments), the office review using the proposed Screening Form is anticipated to take about 1-1.5 hours, and the field review to take about 1 hour to complete. The estimated time to complete the site inspection is comparable with that required for US bridge-screening procedures (Appendix G2).

4.6 Training of Bridge Inspection Team

As reflected in the proposed bridge-scour Screening Form given in Appendix A, and also in the sample US bridge-scour Screening Forms given in Appendix G2, a degree of understanding of waterway processes and waterway-structure interaction processes is a recognised need in the assessment of bridge-scour susceptibility. Based on this requirement. and on similar US practice commented on in Appendix G2 (e.g. Lagasse et al. 1993b; Lagasse & Richardson 1996), the recommendation is that training of bridge inspection teams is undertaken to ensure that the scour-screening methodology can be understood and effectively utilised by the teams.

4.7 Review of Screening Procedures

As indicated by the peer reviewers, a working party review before implementation of the methodology is recommended. To this end, further thorough trialling of the screening procedure presented in Appendix A is needed to highlight any pitfalls. The results of such trial applications will be used to improve the accuracy and usability of the proposed bridge-scour screening methodology. Application of the methodology of Appendix A requires bridge inspectors to have spent time reading and understanding the explanatory material in Appendix B, before actually carrying out any bridge-scour inspections.

4.8 Data Sources

A review of sources of appropriate data that are available to those carrying out bridge-scour screening in New Zealand was made. Sources for data about bridges, streams and flood plains, hydrology or hydraulics, road use, and local and previous experience are listed in Appendix F.

5. Analyses of Results

5.1 Remedial Actions

For bridges with overall scour-susceptibility ratings of 1, 2, or 3, possible remedial actions are noted on the bridge-scour Screening Form, including:

- Monitoring of scour development at the bridge site. Commonly adopted monitoring frequencies include: routine (associated with the biannual scour-screening programme); seasonal (during or after seasons of high flows); storm-based (during or after the passage of floods); and fixed (instrument-based to give high frequency monitoring of scour levels).
- Detailed analyses of potential depths of scour components in accordance with the guidelines of Melville & Coleman (2000).
- Structural countermeasures and channel modifications (lists of countermeasures appropriate to the different scour types are given on the bridge-scour Screening Form; detailed guidance regarding countermeasures is given in Melville & Coleman 2000).
- Bridge replacement.
- Bridge closure.

5.2 Priority Ranking

For each bridge identified by the screening procedures or the subsequent more detailed analyses (Melville & Coleman 2000) as requiring remedial work, the remedial work options are to be determined. The costs of the remedial works are then to be quantified along with the resulting benefits (based on Transfund's Project Evaluation Procedures) to develop an economic ranking indicator (ERI).

Bridges requiring works nationwide are then ranked based on ERI values and the importance of the structure in the road network, with bridges of higher ERI values and importance progressing to more detailed analyses and/or remedial works as funds permit.

This process:

- ranks the bridges in priority order, on the basis of vulnerability, risk and economic justification for remedial works;
- ensures that the large annual expenditure on scour-related works is consistently prioritised nationally; and
- allows expenditure on scour and other risks (e.g. seismic) to be compared, justified and prioritised in a rational manner.

6. Recommendations

- As indicated by the peer reviewers, a working party review before implementation of the proposed bridge-scour screening methodology is recommended. To this end, further thorough trialling of the screening procedure, given in Appendix A, is needed to highlight any pitfalls. The results of such trial applications will be used to improve the accuracy and usability of the proposed bridge-scour screening methodology.

- Subsequent to completed trialling of the methodology, it is recommended that bridge-scour screening is urgently carried out for all bridges on the New Zealand State Highway network.

- A programme of educating the bridge inspection teams is recommended to ensure that the scour-screening methodology can be understood and effectively implemented by the teams.

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Appendix A

Bridge-Scour Screening Form

Background Office Review

[N=no, U=unknown, Y=yes]

Bridge authority/region:		
Highway:	Route position:	
Bridge name:		
Bridge not over a waterway		N U Y
Bridge closed		N U Y
Bridge scheduled for replacement		N U Y

If any of the above responses are 'Y', then go to the final scour-susceptibility assessment.

Regional Council:		
Feature (waterway) crossed:		
Year constructed:		
Plan/ drawing numbers:		
Foundations (identify: e.g. spread footings, piles, cylinders, other):		
Pier types (identify: e.g. none, walls or diaphragms, columns, inclined piers, piles with cap, spread footing, other):		
Abutment types (identify: e.g. vertical wall, wing wall, spill through (identify slope H:V), piled foundation, spread footing, other):		
Maximum distance (m) from bridge deck to channel bed at foundations at construction ('U' if unknown):		A
Minimum distance (m) from bridge deck to pier founding level ('U' if unknown):		B
Minimum distance (m) from bridge deck to abutment founding level ('U' if unknown):		C
Bed materials (identify: e.g. erosion-resistant bedrock, semi-resistant bedrock, erodible bedrock; boulders, cobbles, gravels, sands, silts, clays, unknown):		
Grading of sediment deposits (identify: e.g. narrow, wide, unknown):		
Depth (m) of sediment deposits ('U' if unknown):		
Historical scour at the bridge	N U Y	
Historical scour of the channel	N U Y	
Historical scour at surrounding bridges	N U Y	
Previous screening classification:		
Previous screening recommendations:		

Office Review of Bridge Significance (S)

Route traffic volume (vpd):	
Alternative routes; readily-available temporary bridges	N U Y
Utilities carried (identify: e.g. none, power, telephone, gas, sewer, water supply, irrigation, flushing, unknown, other):	

Vehicle route importance category	Rating	Optional rating[1]	Bridge rating (SH, SM, SL)
Routes carrying more than 2500 vpd; routes carrying or crossing motorways or railways; State Highways 1, 2, 3, 3A, 4, 5, 6, 8 or 8A	SH	SM	
Routes carrying between 250 and 2500 vpd; remaining State Highways	SM	SL	
Routes carrying less than 250 vpd; non permanent bridges	SL	SL	

1. For adequate alternative routes or readily-available replacement bridges, a lower bridge significance rating can optionally be adopted.

Bridge Name:

Bridge Vulnerability (V)

[Vulnerability: H=high, U=unknown, M=medium, L=low]

Office review of catchment developments/ conditions influencing the bridge site		**Bridge rating (H,U,M,L)**
Changes in catchment surface	H U M L	
Forestry operations	H U M L	
Sediment mining/ dredging or dumping	H U M L	
Channel straightening/ channelisation	H U M L	
Channel diversion	H U M L	
Catchment-wide bank instability owing to channel migration/ widening	H U M L	
Bridge on steep or active alluvial fan/ delta	H U M L	
Upstream or downstream check dam/ storage reservoir	H U M L	
Barrier beach control of the hydraulic regime at the bridge site	H U M L	
Sediment bar control of the hydraulic regime at the bridge site	H U M L	
Waterfall control of the hydraulic regime at the bridge site	H U M L	
Grade-control structure control of the hydraulic regime at the bridge site	H U M L	
Sea, lake or river level control of the hydraulic regime at the bridge site	H U M L	

Historical scour		**Bridge rating (H,U,M,L)**
Scour experienced over bridge life (office review)	H U M L	
Implementation of previous screening recommendations	H U M L (P)	

Degradation and contraction			
Average present distance (m) from bridge deck to channel bed ('U' if unknown):			D
Culvert of fixed invert	H U M L	**Bridge rating (H,U,M,L)**	
Recent degradation exposing bridge foundations across the channel to a distance below the bridge deck, D, approaching [A+(B-A)/2] or [A+(C-A)/2]	H U M L (P)		
Countermeasures present (identify: e.g. none, grade control structure, check dam, weir, channel lining, erosion-resistant bedrock):	H U M L (P)		
Countermeasures damaged/ ineffective	H U M L (P)		

Aggradation		**Bridge rating (H,U,M,L)**
Recent aggradation across the channel to a distance below the bridge deck, D, approaching [2A/3]	H U M L (P)	
Countermeasures present (identify: e.g. none, upstream check dam/ debris basin, controlled channel clearing/ mining, other):	H U M L (P)	
Countermeasures damaged/ ineffective	H U M L (P)	

Waterway adequacy		**Bridge rating (H,U,M,L)**
Culvert of fixed invert	H U M L	
Waterway significantly blocked (identify source: e.g. debris, bars, vegetation, foundations, guidebanks, scour countermeasures, other):	H U M L (P)	
High debris or flood marks	H U M L (P)	
Debris/ sediment on superstructure	H U M L (P)	
Countermeasures present (identify: e.g. none, relief/ overflow bridges/ channels, other):	H U M L (P)	
Countermeasures damaged/ ineffective	H U M L (P)	

Bridge Name:

Lateral channel movement, channel widening, bridge approaches		
Waterway bank materials (identify: e.g. erosion-resistant bedrock, semi-resistant bedrock, erodible bedrock, boulders, cobbles, gravels, sands, silts, clays, unknown):		
Grading of waterway bank materials (identify: e.g. narrow, wide, unknown):		
Bridge approach materials (identify: e.g. erosion-resistant bedrock, semi-resistant bedrock, erodible bedrock, boulders, cobbles, gravels, sands, silts, clays, unknown):		
Grading of bridge approach materials (identify: e.g. narrow, wide, unknown):		
Bank erosion/ failure influencing the factors of safety for the bridge foundations	H U M L (P)	**Bridge rating** **(H,U,M,L)**
Bank erosion/ failure influencing the factors of safety for the bridge approaches	H U M L (P)	
Flow concentration at a bridge approach (identify source:____________________) (identify point of concentration:____________________)	H U M L (P)	
Bridge approach toe erosion	H U M L (P)	
Bridge approach fill movement	H U M L (P)	
Countermeasures present (identify: e.g. none, riprap (note size), gabions, concrete blocks, tetrapods, used tires, planted vegetation, piles, jack or tetrahedron fields, groynes, spurs, dikes, other):	H U M L (P)	
Countermeasures damaged/ ineffective	H U M L (P)	

Flow depths in bends and confluences		**Bridge rating** **(H,U,M,L)**
Increased flow depths at the outside of a channel bend (up to 4 times the average depth in upstream cross-sections in straight reaches) influencing the factors of safety for the bridge foundations	H U M L (S)	
Increased flow depths in a channel confluence (up to 6 times the average depth in the upstream channel cross-sections) influencing the factors of safety for the bridge foundations	H U M L (S)	
Countermeasures present (identify: e.g. none, channel lining, erosion-resistant bedrock, other):	H U M L (P)	
Countermeasures damaged/ ineffective	H U M L (P)	

Local scour at piers and abutments	
Debris on the foundations or in the channel upstream H U M L (P)	
Angle of flood flow to pier centrelines:	
Angle of flood flow to abutment centrelines:	
Average approach flow depth (m) for design floods ('U' if unknown):	y
Maximum present distance (m) from bridge deck to channel bed ('U' if unknown):	D_m
Projected width perpendicular to flood flow of debris-laden pier (m) ('U' if unknown):	b_e
Approximate potential local pier scour (m) $D_{sp} = (D + 2.4b_e)$ ('U' if unknown):	D_{sp}
Projected length perpendicular to flood flow of debris-laden abutment (m) ('U' if unknown):	L_e
Approximate potential local abutment scour (m) D_{sa} = minimum of $(D + 2L_e)$ and $(D + 10y)$ ('U' if unknown):	D_{sa}

Bridge Name:

Local scour at piers and abutments - continued		Bridge rating (H,U,M,L)
Foundation tilt/ movement	H U M L (P)	
Maximum possible present local scour, D_m, approaching [A+(B-A)/2] or [A+(C-A)/2]	H U M L	
Potential local pier scour, D_{sp}, approaching [A+3(B-A)/4]	H U M L	
Potential local abutment scour, D_{sa}, approaching [A+3(C-A)/4]	H U M L	
Spill-through abutment toe erosion	H U M L (P)	
Spill-through abutment fill movement	H U M L (P)	
Flow concentration at a bridge foundation (identify source:________) (identify foundation:________)	H U M L (P)	
Countermeasures present (identify: e.g. none, channel lining, erosion-resistant bedrock, riprap (note size), gabions, concrete blocks, tetrapods, used tires, sacrificial piles, deflector vanes, collars, underpinning, jack or tetrahedron fields, groynes, spurs, dikes, other):	H U M L (P)	
Countermeasures damaged/ ineffective	H U M L (P)	

Overall bridge vulnerability rating (VH, VU, VM, VL)[1]	

1. Based on an assessment of the eight ratings (H, U, M, L) above for the combined vulnerability groupings.

Overall Scour-Susceptibility Assessment[1]

		Bridge Significance		
		SH	SM	SL
Bridge Vulnerability	VH	1	1	2
	VU	1	2	3
	VM	2	2	3
	VL	3	4	4
	N/A[2]	4		

Overall scour susceptibility (1, 2, 3, 4)	

1. Scour-susceptibility ratings: 1 = highest susceptibility, 4 = lowest susceptibility.
2. N/A = not applicable, the rating category for a bridge not over a waterway, a closed bridge, or a bridge scheduled for replacement.

Possible actions - for overall scour-susceptibility ratings of 1, 2 or 3	
Monitoring (suggested frequency:________)	☐
Detailed scour analyses	☐
Structural countermeasures (possible options:________)	☐
Channel modifications (possible options:________)	☐
Bridge replacement	☐
Bridge closure	☐
Other:________	☐

Bridge Name:

Personnel

Office review by:	Date:
Field inspection by:	Date:
Scour-susceptibility assessment by:	Date:
Checked by:	Date:

Visual Records, Notes and Comments

Standard photographs			
From bridge - looking upstream	☐	From bridge – looking downstream	☐
Looking downstream at bridge	☐	Looking upstream at bridge	☐

Notes and comments
(use channel plan/cross-section sketches as required)

[1] Note factors indicating scour susceptibility.
[2] Note individual foundations highlighted as scour susceptible.
[3] Note locations of channel/ foundation erosion influencing the assessment.

Bridge Name:

Appendix B

Bridge-Scour Screening Form Guidelines

Appendix B Bridge-Scour Screening Form Guidelines

The following guidelines have been written to aid assessment of bridge and waterway details in regard to rating the relative scour-susceptibility of bridges. The guidelines take the form of explanations of the terms and statements of the form, along with figures illustrating aspects of the form. The guidelines recognise the subjective nature of the interpretations of conditions to be made, and have been written assuming some understanding of catchment, bridge and scour mechanisms and terminology.

Screening-form terms/ statements	Guidelines
N, U, Y	No, unknown, yes.
SH, SM, SL	Significance rating: high, medium, low.
H, U, M, L	Vulnerability rating: high, unknown, medium, low.
VH, VU, VM, VL	Overall vulnerability rating: high, unknown, medium, low.
(P)	If the given aspect of the bridge or waterway is a significant factor in terms of assessing vulnerability to scour, then take photographic or video evidence. On each photograph, note the date, the bridge name, what is being viewed, and where from. When viewing the bridge from upstream (or downstream), note the distance upstream (or downstream) from the bridge. When viewing the channel from the bridge, note the position on the bridge from which the photo was taken.
(S)	If the given aspect of the bridge or waterway is a significant factor in terms of assessing vulnerability to scour, then sketch a plan view of the interaction between the channel(s) and the bridge (e.g. *Figures B18 and B19*).
Bridge authority/ region	e.g. Transit New Zealand
Highway, Route position, Bridge name	Summarised in the Bridge Descriptive Inventory, e.g. SH26, 85/8.29
Bridge not over waterway, Bridge closed, Bridge scheduled for replacement	If any of these conditions is satisfied, then scour-susceptibility analyses are not applicable and the overall scour susceptibility is rated as such.
Regional Council	Identify those overseeing the catchment and waterway, e.g. Environment BOP.
Feature (waterway) crossed	e.g. Waikato River.
Year constructed, Plan/ drawing numbers, Foundations, Pier type	Summarised in the Bridge Descriptive Inventory.

Screening-form terms/ statements	Guidelines
Distances (m) measured from the bridge deck to the channel bed and foundation levels	The bridge deck is chosen as a fixed point of reference elevation. It is assumed that any variation in levels along the bridge deck is negligible. If this is not the case, then the bridge deck at a particular foundation (identify the chosen foundation on the screening form, e.g. true-right abutment) is chosen as the fixed point of reference elevation.
Maximum distance (m) from bridge deck to channel bed at foundations at construction	The distance A on Figure B1. This distance is measured at foundations to reflect initial embedment lengths. The maximum relevant value of A is adopted to reflect minimum embedment lengths. (*Figure B1*)
Minimum distance (m) from bridge deck to pier (abutment) founding level	The distance B(C) on Figure B1. The minimum relevant value of B(C) is adopted to reflect minimum embedment lengths. (*Figure B1*)
Bed materials	These reflect the relative erodibility of the channel bed.
Erosion-resistant bedrock	e.g. not-highly broken or fractured: Granite, Basalt, Andesite, Gneiss, and Greywacke.
Semi-resistant bedrock	e.g. Slate, Argillite, Limestone, Ignimbrite, and Schist.
Erodible bedrock	e.g. Sandstone, Siltstone, Mudstone, Shale, and weathered bedrock.
Grading of sediment deposits (identify: e.g. narrow, wide, unknown)	Grading is range of sediment sizes. Sediments of a wide grading may armour to protect against erosion.
Depth (m) of sediment deposits	This reflects whether underlying bedrock may influence scour at the bridge site.
Historical scour at the bridge, Historical scour of the channel, Historical scour at surrounding bridges, Previous screening classification, Previous screening recommendations	Historical scour at the bridge foundations and approaches, scour away from the bridge foundations and approaches, scour at surrounding bridges. The existence of scour at surrounding bridges can indicate catchment development that may influence bed levels at the investigated bridge site. Refer bridge reports, local experience, engineering experience, Bridge Descriptive Inventory 'Condition' and 'Action recommended' codings, etc.
Route traffic volume (vpd)	This reflects the vehicle route importance (vpd = vehicles per day).

Screening-form terms/ statements	Guidelines
Alternative routes; readily available temporary bridges	These may reduce the significance rating for the bridge.
Alternative routes	Summarised in the Bridge Descriptive Inventory.
Utilities carried	Summarised in the Bridge Descriptive Inventory.
Bridge significance rating	This is assigned based on the traffic volume for the route, along with natures of the route and the bridge. For adequate alternative routes or readily-available replacement bridges, a lower bridge significance rating can optionally be adopted as indicated.
Catchment developments/ conditions	Aerial photos are a particularly valuable aid in assessing catchment-wide factors influencing channel erosion at the bridge site.
Changes in catchment surface, forestry operations	Degradation, aggradation, and lateral instability can result from the surface being exposed and loosened, or covered and sealed. Surface changes can be caused by land clearing, landslides, surface erosion, fire, urbanisation, changing vegetation cover, forestry operations, strip mining, agricultural activities, etc.
Sediment mining, dredging or dumping	Removal/ addition of sediment from/ to a channel can result in degradation/ aggradation and lateral instability.
Channel straightening/ channelisation	Degradation and lateral instability can occur upstream of channel straightening, whereas aggradation and lateral instability are possible downstream of channel straightening. Channelisation constraint of flows and sediment can result in degradation or aggradation, and lateral instability.
Channel diversion	Degradation and lateral instability can result from an increase in flow relative to sediment load in a channel. A decrease in flow relative to sediment load in a channel can cause aggradation and lateral instability.
Catchment-wide bank instability owing to channel migration/ widening	This reflects general lateral instability of the channel that may influence the bridge site.

Screening-form terms/ statements	Guidelines
Bridge on steep or active alluvial fan/ delta	Channels on steep or active alluvial fans are often characterised by significant degradation or aggradation, and episodes of significant lateral movement. This can be determined from site reconnaissance and an office review of maps and aerial photos. (*Figures B2 and B3*).
Upstream or downstream check dam/ storage reservoir	An upstream dam can cause degradation and lateral instability at a bridge site by inhibiting sediment migration along the channel. A downstream dam can similarly cause aggradation and lateral instability at a bridge site. The opposite effects will occur for the removal of a dam.
Barrier beach control of the hydraulic regime at the bridge site, Sediment bar control of the hydraulic regime at the bridge site	Removal of the hydraulic control (naturally during flooding) can result in degradation and lateral instability at the bridge site.
Waterfall control of the hydraulic regime at the bridge site	Upstream movement of the hydraulic control (naturally by erosion) can result in degradation and lateral instability at the bridge site.
Grade-control structure control of the hydraulic regime at the bridge site	Lowering of the hydraulic control can cause degradation and lateral instability at the bridge site. Aggradation and lateral instability can result from raising of the control.
Sea, lake or river level control of the hydraulic regime at the bridge site	Lowering of the level of the downstream receiving waters (sea, lake or converging river) can cause degradation and lateral instability at the bridge site. Aggradation and lateral instability can result from raising of the downstream controlling water level.
Scour experienced over bridge life, Implementation of previous screening recommendations	These are judged based upon an office review of bridge and waterway history (comments being recorded earlier in the screening form), and a field review of present conditions. Photograph previously noted scour deficiencies that have not been remedied.
Field inspection/ review	Transit expects that bridge inspectors look over both sides of the bridge from the bridge deck, particularly to identify debris build-up and local scour.

Screening-form terms/ statements	Guidelines
Average present distance (m) from bridge deck to channel bed	The distance D on Figure B1. This reflects the average bed level across the site for present conditions. (*Figure B1*)
Culvert of fixed invert: degradation and contraction scour	Owing to the fixed-level nature of the invert of such a bridge opening, degradation and contraction scour may be more significant for these bridge openings (particularly down-stream of the fixed invert).
Recent degradation exposing bridge foundations across the channel to a distance below the bridge deck, D, approaching [A+(B-A)/2] or [A+(C-A)/2]	Degradation across the bridge opening that approaches half of the initial embedment length [(B-A) or (C-A)] for any foundation. (*Figures B4 and B1*)
Scour countermeasures	Measures placed to prevent channel erosion. These measures vary according to the form of erosion occurring, appropriate measures being listed on the screening form for the different types of scour.
Countermeasures present (identify: e.g. none, grade control structure, check dam, weir, channel lining, erosion-resistant bedrock, other) Countermeasures damaged/ ineffective	The presence of such countermeasures may reduce the vulnerability of the bridge to degradation and contraction scour. This protection may be reduced, however, if the countermeasures are damaged, or if they are assessed in the field inspection to be ineffective. (*Figure B5*)
Recent aggradation across the channel to a distance below the bridge deck, D, approaching [2A/3]	Aggradation across the bridge opening that approaches one-third of the initial bridge opening depth (A) for any foundation. (*Figures B6 and B1*)
Countermeasures present (identify: e.g. none, upstream check dam/ debris basin, controlled channel clearing/ mining, other) Countermeasures damaged/ ineffective	The presence of such countermeasures may reduce the vulnerability of the bridge to aggradation. This protection may be reduced, however, if the countermeasures are damaged, or if they are assessed in the field inspection to be ineffective.
Waterway adequacy	For flood flows, waterway inadequacy can exacerbate scouring with high flow velocities, large flow depths, and undesirable flow paths (e.g. overtopping the bridge or an approach, attacking channel banks, etc.).

Screening-form terms/ statements	**Guidelines**
Culvert of fixed invert: waterway adequacy	Waterway adequacy considerations are more important for a bridge than a culvert, i.e. a degree of waterway inadequacy is generally permissible and not a significant concern for culverts of fixed inverts.
Waterway significantly blocked	This typically reflects a reduction in waterway capacity and may be indicative of waterway inadequacy. (*Figures B7 and B8*)
High debris or flood marks, Debris/ sediment on superstructure	These indicate the occurrence of large flow depths that may reflect waterway inadequacy. (*Figures B9 and B10*)
Countermeasures present (identify: e.g. none, relief/ overflow bridges/ channels, other), Countermeasures damaged/ ineffective	The presence of such countermeasures may reduce the vulnerability of the bridge to waterway inadequacy exacerbating scour. This protection may be reduced, however, if the countermeasures are damaged, or if they are assessed in the field inspection to be ineffective.
Waterway bank materials	These reflect the relative erodibility of the channel banks
Grading of waterway bank materials (identify: e.g. narrow, wide, unknown), Grading of bridge approach materials (identify: e.g. narrow, wide, unknown)	Grading is range of sediment sizes.
Bridge approach	A bridge approach is an embankment supporting the road leading to the bridge, the embankment being founded in the waterway.
Bridge approach materials	These reflect the relative erodibility of the bridge approaches.
Thalweg	The thalweg is the line of lowest bed elevation along a channel. (*Figure B14*)
Anabranches	Channel branches, similar to significant channel braids, that are relatively well-defined and stable.

Screening-form terms/ statements	Guidelines
Bank erosion/ failure influencing the factors of safety for the bridge foundations, Bank erosion/ failure influencing the factors of safety for the bridge approaches	Active bank failure/ erosion (especially along the toe or lower bank) can be evidenced by a number of symptoms: fresh vertical cut banks; (tension) cracks along the bank surface; irregular indentations in the bank surface; slump blocks; leaning or fallen vegetation along the bankline; vegetation, particularly live, in the flow; increased turbidity; newly formed bars immediately downstream; deflected flow patterns adjacent to the bankline; a deep scour pool adjacent to the toe of the bank; etc. Such symptoms (when significant, of notable rates, or influencing either foundations/ approaches directly or flows impacting the foundations/ approaches) can indicate increased vulnerability to scour for the bridge. Lateral movement is typically indicated by erosion/ failure occurring particularly along the outside banks of high curvature sections of the thalweg, bends, braids, and anabranches. In contrast, channel widening is typically indicated by erosion/ failure co-existing along both banks, even in regions not of high curvature in plan. Channel widening is commonly associated with ongoing vertical instability (aggradation or, more particularly, degradation). (*Figures B11, B12, and B13*)
Flow concentration at a bridge approach (identify source) (identify point of concentration)	A concentration of flow at a point on the approach can exacerbate scour at this point. Sources of flow concentration include flows in the thalweg; flows in a confluence; flows at the outside of a bend; deflected flows (e.g. by vegetation, debris, scour countermeasures, guidebanks, sediment bars, or adjacent bridge foundations); etc. Use a sketch to identify actual or potential significant flow concentrations for the approaches. (*Figure B15*)
Bridge approach toe erosion, Bridge approach fill movement	These reflect active scour of the bridge approach. (*Figures B16 and B17*)

Screening-form terms/ statements	Guidelines
Countermeasures present (identify: e.g. none, riprap (note size), gabions, concrete blocks, tetrapods, used tires, planted vegetation, piles, jack or tetrahedron fields, groynes, spurs, dikes, other) Countermeasures damaged/ ineffective	The presence of such countermeasures may reduce the vulnerability of the bridge to lateral channel movement, channel widening, or erosion of the bridge approaches. This protection may be reduced, however, if the countermeasures are damaged, or if they are assessed in the field inspection to be ineffective.
Increased flow depths at the outside of a channel bend (up to 4 times the average depth in upstream cross-sections in straight reaches) influencing the factors of safety for the bridge foundations	Secondary flows in channel bends can result in lowered bed levels, and increased flow depths, at the outsides of the bends (*Figure B18*). Such flow depths can be up to 4 times the average depth in upstream cross-sections in straight reaches. Any present or potential influence on bridge foundations during flooding of the presence of an upstream channel bend then needs to be assessed. (*Figure B18*)
Increased flow depths in a channel confluence (up to 6 times the average depth in the upstream channel cross-sections) influencing the factors of safety for the bridge foundations	The mixing of flows in a channel confluence results in lowered bed levels, and increased flow depths, in the confluence (*Figure B19*). Such flow depths can be up to 6 times the average depth in the upstream channel cross-sections. Any present or potential influence on bridge foundations of the presence of a channel confluence then needs to be assessed. (*Figure B19*)
Countermeasures present (identify: e.g. none, channel lining, erosion-resistant bedrock, other) Countermeasures damaged/ ineffective	The presence of such countermeasures may reduce the vulnerability of the bridge to scour in bends or confluences. This protection may be reduced, however, if the countermeasures are damaged, or if they are assessed in the field inspection to be ineffective.
Debris on the foundations or in the channel upstream	The occurrence of moderate-to-heavy debris accumulations on the foundations or in the channel upstream indicates that projected foundation widths perpendicular to flood flows may need to be increased to allow for debris accumulations. (*Figures B11, B20, B21*)

Screening-form terms/ statements	**Guidelines**
Angle of flood flow to pier centrelines	This is required in order to assess projected pier widths perpendicular to flood flows
Angle of flood flow to abutment centrelines	This is required in order to assess projected abutment lengths perpendicular to flood flows
Average approach flow depth (m) for design floods	This is required in order to assess potential scour depths at abutments
Maximum present distance (m) from bridge deck to channel bed	The distance D_m on Figure B1. The maximum value of D_m across the channel (independent of foundation positions) is adopted to reflect possible minimum embedment lengths for present conditions. (*Figure B1*)
Projected width perpendicular to flood flow of debris-laden pier (m)	Pier width inducing local scour allowing for debris accumulations and the angle of flood flow to pier centrelines
Approximate potential local pier scour (m) $D_{sp} = (D + 2.4b_e)$	The distance D_{sp} on Figure B1 (based on Melville & Coleman 2000). For piers socketed into erosion-resistant bed rock, potential local scour can be taken to be negligible, with $D_{sp} = D$. (*Figure B1*)
Projected length perpendicular to flood flow of debris-laden abutment (m)	Abutment length inducing local scour allowing for debris accumulations and the angle of flood flow to abutment centrelines
Approximate potential local abutment scour (m) D_{sa} = minimum of $(D+2L_e)$ and $(D+10y)$	The distance D_{sa} on Figure B1 (based on Melville & Coleman 2000, for alternate conditions). For abutments socketed into erosion-resistant bed rock, potential local scour can be taken to be negligible, with $D_{sa} = D$. (*Figure B1*)
Foundation tilt/ movement	Foundation tilt or movement, which can often be readily detected by sighting along bridge handrails, may reflect scour-induced foundation undermining. (*Figures B22, B23*)

Screening-form terms/ statements	Guidelines
Maximum possible present local scour, D_m, approaching [A+(B-A)/2] or [A+(C-A)/2]	Present maximum local bed-level lowering at the bridge site approaching half of the initial embedment length [(B-A) or (C-A)] for any foundation. This assessment allows for some infilling of local scour holes as floods recede. (*Figures B24, B25, B26, B1*)
Potential local pier scour, D_{sp}, approaching [A+3(B-A)/4]	Potential local bed-level lowering approaching three-quarters of the initial embedment length (B-A) for any pier. (*Figure B1*)
Potential local abutment scour, D_{sa}, approaching [A+3(C-A)/4]	Potential local bed-level lowering approaching three-quarters of the initial embedment length (C-A) for any abutment. (*Figure B1*)
Spill-through abutment toe erosion, Spill-through abutment fill movement	These reflect active scour of the spill-through abutment. (*Figures B16, B17*)
Flow concentration at a bridge foundation (identify source) (identify foundation)	A concentration of flow at a bridge foundation can exacerbate scour at this foundation. Sources of flow concentration include flows in the thalweg; flows in a confluence; flows at the outside of a bend; deflected flows (e.g. by vegetation, debris, scour countermeasures, guidebanks, sediment bars, or adjacent bridge foundations), etc. Identify foundations of actual or potential significant flow concentration and use a sketch to identify the concentration of flow for each such foundation. (*Figure B27*)
Countermeasures present (identify: e.g. none, channel lining, erosion-resistant bedrock, riprap (note size), gabions, concrete blocks, tetrapods, used tires, sacrificial piles, deflector vanes, collars, underpinning, jack or tetrahedron fields, groynes, spurs, dikes, other) Countermeasures damaged/ ineffective	The presence of such countermeasures may reduce the vulnerability of the bridge to local scour at piers and abutments. This protection may be reduced, however, if the countermeasures are damaged, or if they are assessed in the field inspection to be ineffective. (*Figure B28*)
Overall scour susceptibility (1, 2, 3, 4)	Assessed based on the bridge significance and overall bridge vulnerability ratings. Ratings of '1' and '4' indicate the highest and lowest susceptibilities respectively.

Screening-form terms/ statements	Guidelines
Possible actions	Possible remedial actions are noted for overall scour-susceptibility ratings of 1,2,or3. Possible actions include: monitoring of scour development at the bridge site (frequencies discussed below), detailed analyses of potential depths of scour components in accordance with the guidelines of Melville & Coleman (2000), structural countermeasures and channel modifications (lists of countermeasures for different scour types are given above), bridge replacement, bridge closure, etc. Indicate applicable options and give details where possible.
Scour-monitoring frequencies	Commonly adopted frequencies include: routine (associated with the biannual scour-screening programme); seasonal (during or after seasons regularly of high flows), storm-based (during or after the passage of floods), and fixed (instrument-based to give high frequency monitoring of scour levels).
Personnel	For quality assurance purposes, the personnel carrying out the reviews and assessments are identified, along with when the reviews and assessments were carried out.
Visual Records, Notes and Comments	These are recorded as required. Standard photographs (e.g. Figure B29) of the bridge and waterway are required to be taken. On each photograph taken, note the date, the bridge name, what is being viewed, and where from. When viewing the bridge from upstream (or downstream), note the distance upstream (or downstream) from the bridge. When viewing the channel from the bridge, note the position on the bridge from which the photo was taken. Supplementary video records are also useful for review of field conditions after the inspection. Note factors indicating susceptibility of the bridge to scour, individual foundations highlighted as scour-susceptible, and locations of channel/ foundation erosion influencing the assessment. (*Figure B29*)

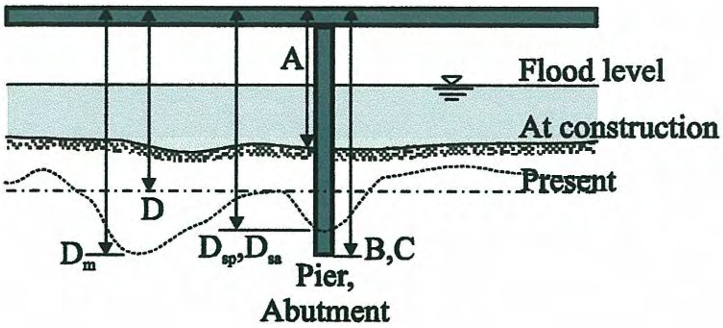


Figure B1. **Definition of distances from the bridge deck to the channel bed and the foundation founding levels.**

Figure B2. **Bridge across a stream on a steep alluvial fan; flow is to the right (from Melville & Coleman 2000).**

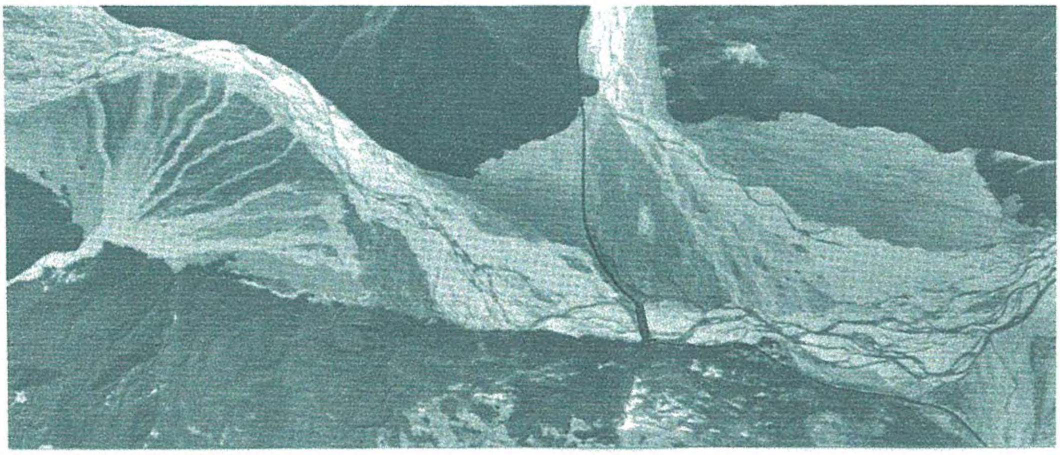


Figure B3. Aerial photo of a bridge with an abutment located on an active alluvial fan (the road and bridge are highlighted); flow is to the right.

Figure B4. Degradation across a bridge site; the bridge carries utilities; flow is to the left (from Melville & Coleman 2000).

Figure B5. **Undermining and lowering of a weir designed to control degradation at the upstream bridge; flow is to the right.**

Figure B6. **Sediment build-up filling the channel to the base of the bridge superstructure; flow is to the left (from Melville & Coleman 2000).**

Figure B7. Bridge waterway significantly blocked by vegetation; note also the fencing across the waterway that could potentially aid debris blockage of the channel; flow is away from the viewer.

Figure B8. Bridge waterway significantly blocked by fencing that could potentially aid debris blockage of the channel; flow is to the left.

Figure B9. Debris accumulations on the bridge superstructure.

Figure B10. Sediment deposits on the bridge superstructure (on top of a pier and immediately below the bridge deck).

Figure B11. Ongoing bank erosion/ failure at the bridge site, as indicated by a significant tension crack along the top of the near bank and the vegetation-free region of notable thickness along the base of the far bank. A significant debris accumulation has formed against the central pier. Flow is to the left.

Figure B12. Significant lower bank erosion leading to bank failures (with a recently-slumped section of bank evident in the foreground); flow is towards the viewer (from Melville & Coleman 2000).

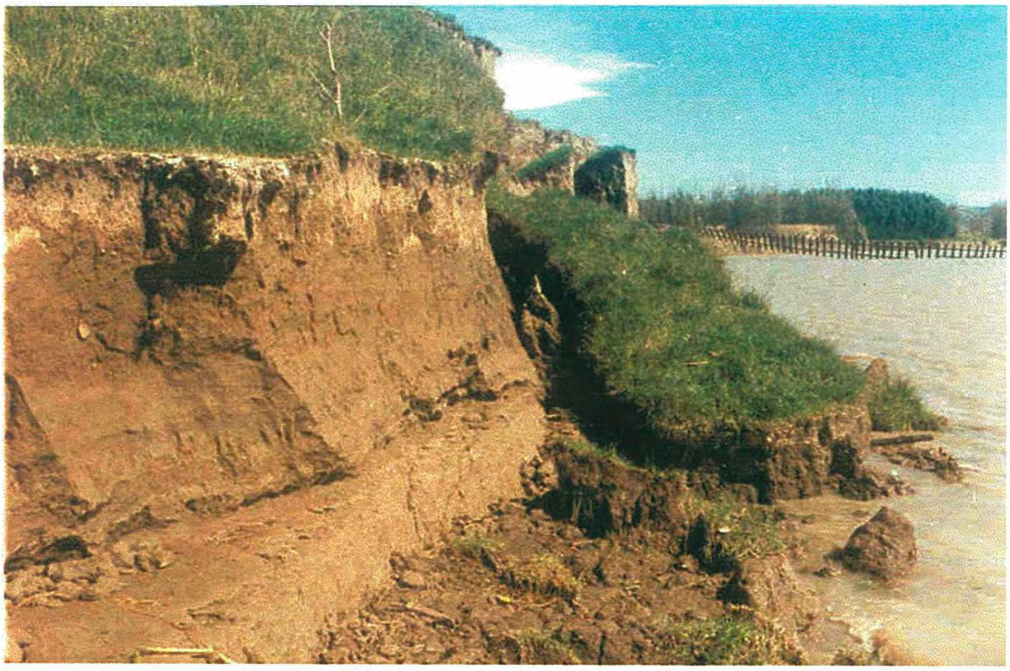
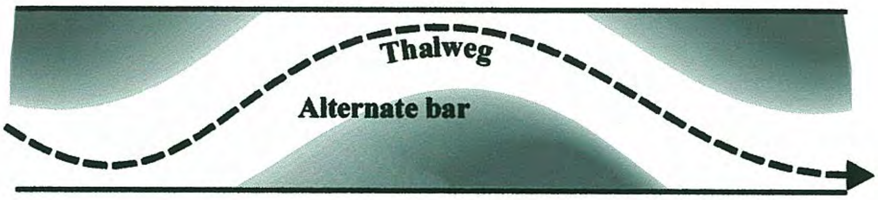
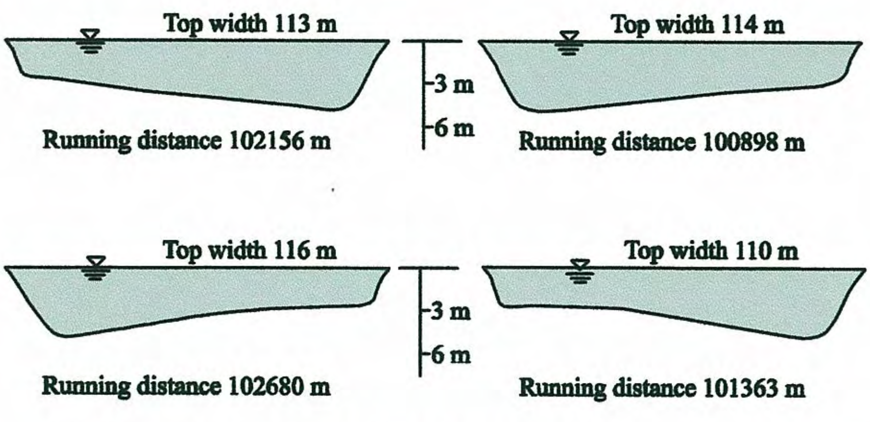


Figure B13. Significant lower bank erosion leading to bank failures (a recently-slumped section of bank being evident towards the centre of the picture); flow is towards the viewer.



(a) Schematic view of thalweg meandering in a straight channel



(b) Schematic representation of cross-sections measured on 6-14 December 1977 in the Qadirabad-Balloki Link Canal

Figure B14. Representation of relative flow depth in the thalweg along a channel. Note that as a thalweg migrates downstream, its position will vary across a bridge site (from Melville & Coleman 2000).

Figure B15. Flow concentration at the approach and abutment owing to the presence of a channel bend at the bridge site; flow is towards the viewer (from Melville & Coleman 2000).

Figure B16. Toe erosion and fill movement providing evidence of undermining of a spill-through abutment; equivalent evidence would be apparent for the undermining of a bridge approach. Note the associated damage to the existing countermeasures evident in the photo.

Figure B17. Toe erosion and fill movement providing evidence of undermining of a spill-through abutment; equivalent evidence would be apparent for the undermining of a bridge approach. Note the associated damage to the existing countermeasures evident in the photo.

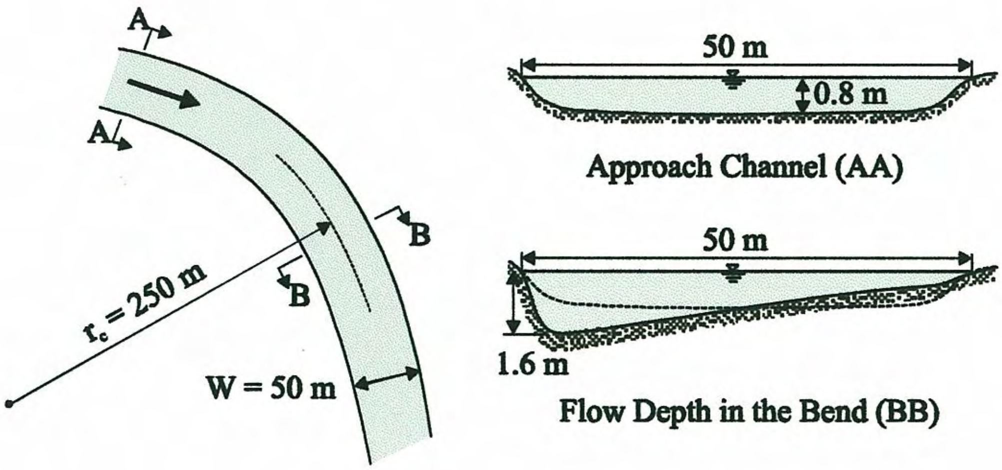


Figure B18. Representation of deeper flow depths occurring at the outside of a channel bend (after Melville & Coleman 2000).

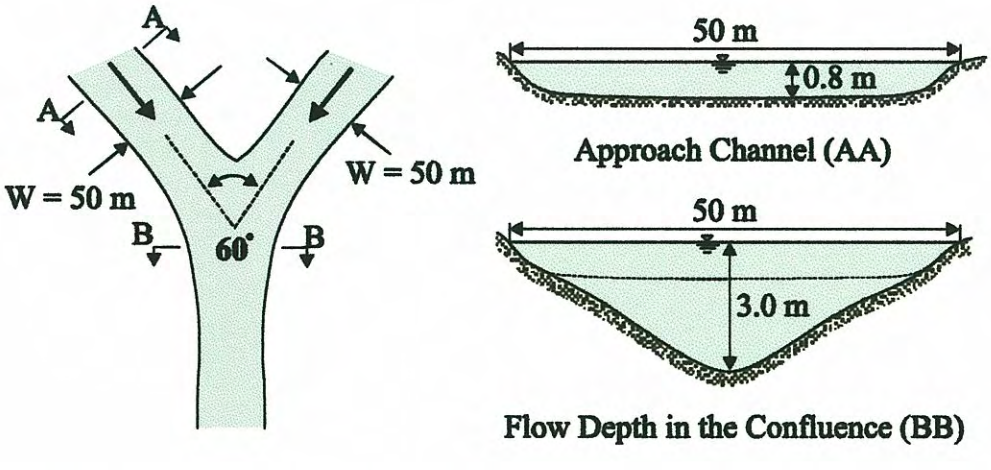


Figure B19. Representation of deeper flow depths occurring at a channel confluence (after Melville & Coleman 2000).

Figure B20. Debris accumulations on bridge foundations; flow is away from the viewer (from Melville & Coleman 2000).

Figure B21. Debris accumulations on bridge foundations; flow is to the right.

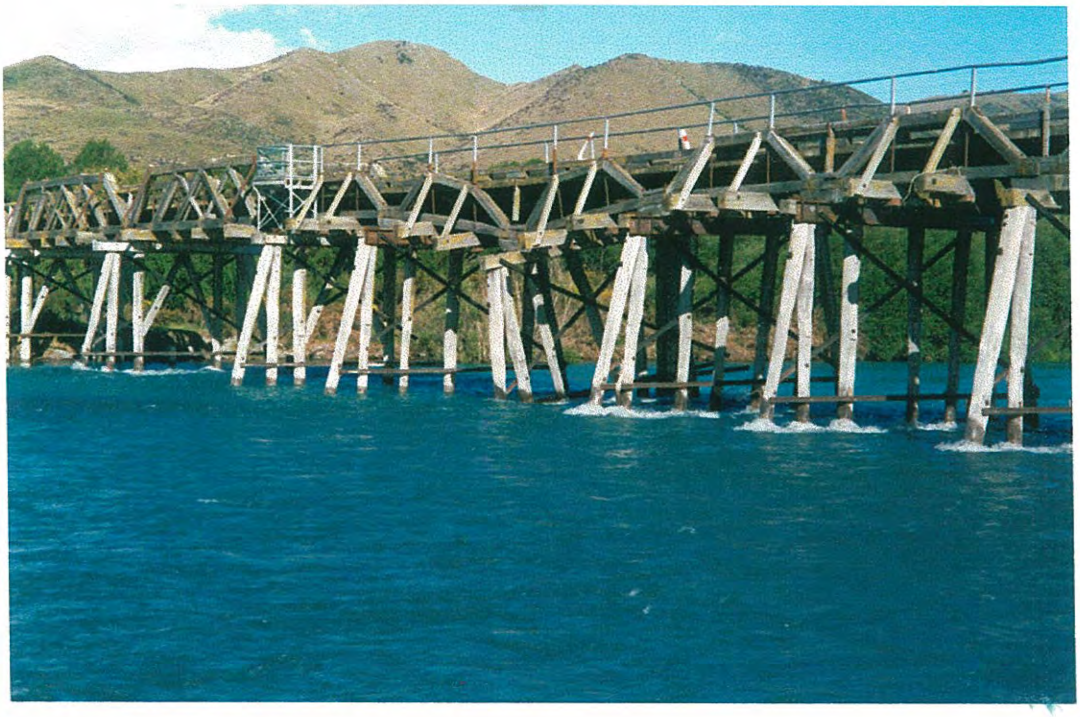


Figure B22. Tilt of an undermined pier for a bridge; flow is to the right (from Melville & Coleman 2000).

Figure B25. Local bed-level lowering at the scoured bridge abutment, approaching half of the initial embedment length.

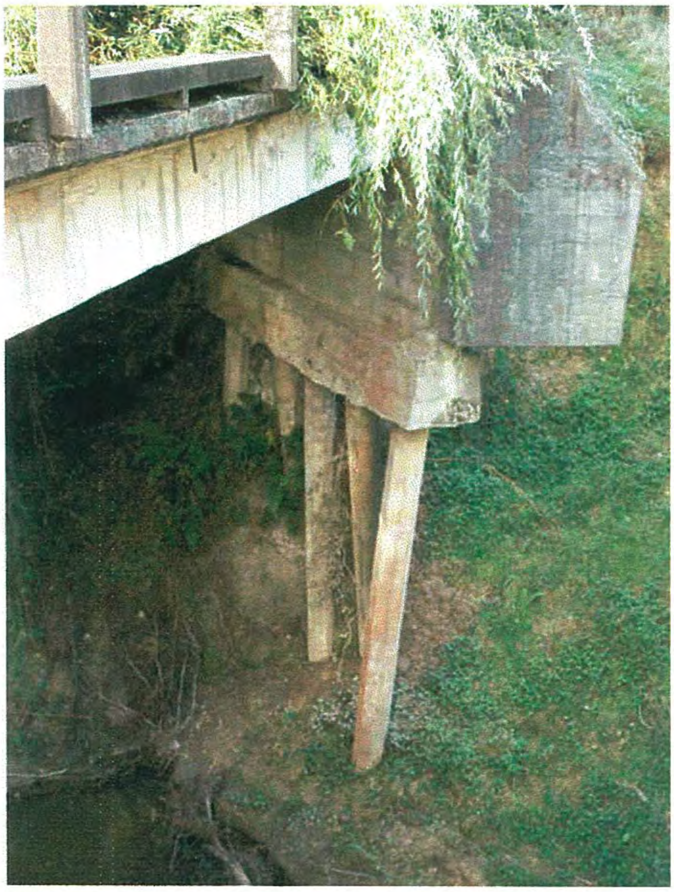


Figure B26. Local bed-level lowering at the scoured bridge abutment, approaching half of the initial embedment length.

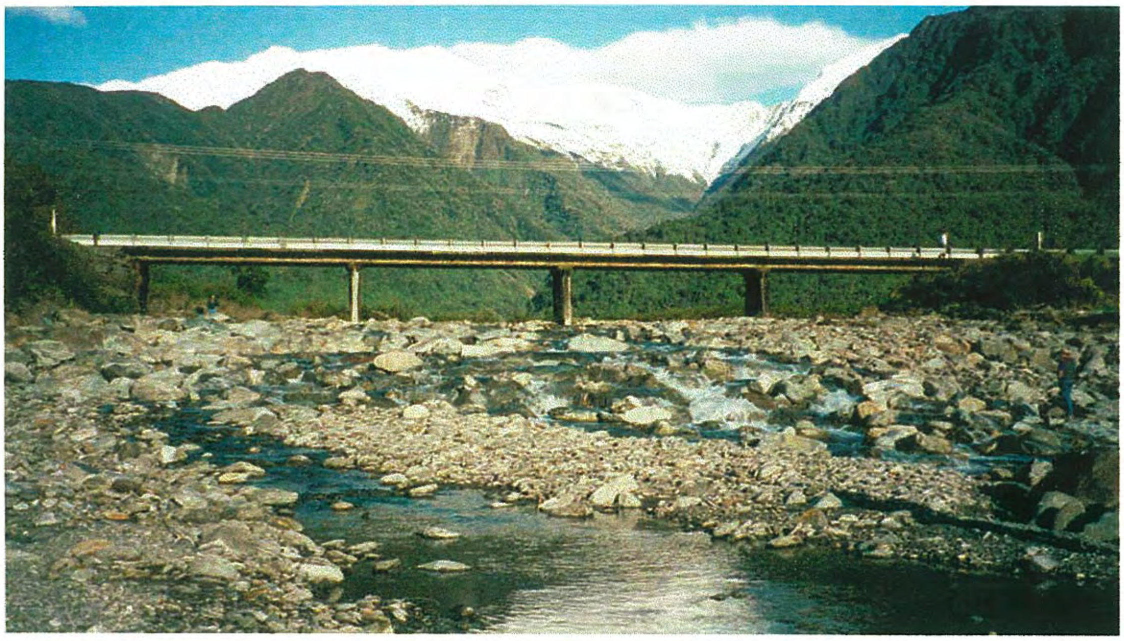


Figure B29. An example of a standard photograph of the complete bridge waterway (looking upstream at the bridge).

Appendix C

Provisional First-Stage Bridge-Scour Screening Form

Appendix C Provisional First-Stage Bridge-Scour Screening Form

The provisional form for the first-stage bridge-scour screening is given below. In order to aid use of the form, explanations of the terms of the form and figures illustrating aspects of the form were provided with the form. These explanations and figures are not included herein.

The field component of the bridge-scour screening inspection consisted of screening undertaken at the bridge-near-field and the bridge-far-field scales. Structuring the screening in this manner was designed to aid the inspectors by focussing the factors to be considered when inspecting the bridge site itself and when inspecting the surrounding channel. To this end, Robinson & Thompson (1993) found greater efficiency of data collection for US bridge-scour screening with variables grouped by order of collection ahead of type.

From the office review and the field inspection, "at-risk" sites were identified, the bridge was classified based on its vulnerability to scour and its significance, and remedial measures were recommended. For bridges identified as scour-susceptible, the second-stage advanced bridge-scour assessment analyses could be recommended (Section 3.2). Comparison of the vulnerability and significance classifications for bridges across New Zealand would enable scour risk for bridges to be consistently and rationally ranked nationally. Scour-related works could then similarly be prioritised nationally.

The proposed methodology had the advantages of:

- having the bridge-scour screening form being applicable to both bridges and culverts;
- recognising the different spatial scales (e.g. bridge near-field and bridge far-field) involved in the varying scour processes influencing bridge foundations; and
- utilising pictorial guides of conditions in conjunction with the data form in order to ensure consistency and completeness in reporting site information. This aspect of the proposed guidelines is a particular improvement of the guidelines over existing guidelines worldwide.

It was recommended that bridge-scour screening inspections be carried out every two years, in conjunction with general bridge inspections.

Office Review

Bridge authority/region:			
Highway:		Feature (waterway) crossed:	
Route position:			
Bridge over waterway	N U Y	Volume class:	
Bridge closed	N U Y	Motorway, urban, over 10,000 vpd	☐
Bridge scheduled for replacement	N U Y	4,000-10,000 vpd	☐
Engineering lifeline	N U Y	1,000-4,000 vpd	☐
Abutment founding depth	_____	less than 1,000 vpd	☐
Pier founding depth	_____	Heavy vehicle volume class:	
Historical scour at surrounding bridges	N U Y	over 600 heavy vpd	☐
		400-600 heavy vpd	☐
Historical scour of the channel	N U Y	200-400 heavy vpd	☐
Historical scour at the bridge	N U Y	less than 200 heavy vpd	☐
Previous screening classification:			
Previous screening recommendations:			

Field Inspection

Bridge Near-Field Scale			Bridge Far-Field Scale		
Bridge Location					
Bridge on steep or active alluvial fan *(office review at stream-section scale)*				N U Y	
Historical Scour					
Failure to implement previous screening recommendations				N U Y	(P)
Scour-Based Structural Damage					
Foundation tilt/ movement	N U Y	(P)	Present countermeasures damaged	N U Y	(P)
Degradation and Contraction			**Upstream and Downstream Lateral Movement or Channel Widening**		
Scour > 0.5 m since last inspection	N U Y	(P)	Bank vegetation tilted	N U L R	(P)
Exposed piles	N U Y	(P)	Significant root exposure on bank	N U L R	(P)
Exposed base of spread footing	N U Y	(P)	Notable vegetation-free bank zone	N U L R	(P)
Aggradation			Bank erosion	N U L R	(P)
Build-up>0.5m since last inspection	N U Y	(P)	Bank failure	N U L R	(P)
			Tension cracks	N U L R	(P)
Waterway Adequacy					
Debris/ sediment on superstructure	N U Y	(P)	High debris or flood marks	N U Y	
Waterway significantly blocked	N U Y	(P)			
Source ______________________					
Thalweg, Bend and Confluence					
			Thalweg below tolerable level	N U Y	
			Bend below tolerable level	N U Y	
			Confluence below tolerable level	N U Y	
Local Scour at Piers or Abutments					
Spill-through abut. toe erosion	N U Y	(P)	Flow concentration at foundations or approaches	N U Y	(P)
Spill-through abut. fill movement	N U Y	(P)			
Bridge approach toe erosion	N U Y	(P)	Source: ______________________		
Bridge approach fill movement	N U Y	(P)	Locations: ______________________		
Potential/ present scour > tolerable	N U Y		Debris on foundations or upstream	N U Y	(P)

Standard Photographs			
From Bridge - Looking Upstream	▯	From Bridge - Looking Downstream	▯
Looking Downstream at Bridge	▯	Looking Upstream at Bridge	▯

Notes and Comments
(use channel plan/cross-section sketches as required)

[1] Note factors indicating scour susceptibility.
[2] Note individual foundations highlighted as scour-susceptible.
[3] Note locations of channel/foundation erosion influencing the assessment.

Scour-Screening Classification

Scour Vulnerability		Bridge Significance	
Not over waterway	▯	Highest	▯
Scheduled for replacement	▯	High	▯
Low risk	▯	Medium	▯
Potentially scour susceptible/critical	▯	Low	▯
Scour susceptible/critical	▯		
Recommended Actions			
Advanced scour assessment	▯	Scour monitoring	▯
Advanced scour assessment–unknown	▯	Frequency:	
Detailed scour analyses	▯		
Replacement	▯	Bridge closure	▯
Structural countermeasures Details:	▯	Channel modifications Details:	▯

Personnel

Field Inspection By:	Date:
Office Review By:	Date:
Scour-Screening Classification By:	Date:
Checked By:	Date:

Appendix D

Peer Reviews of Provisional Procedures

Appendix D Peer Reviews of Provisional Procedures

Reviews were received from:

1. Mike O'Cain of Transit New Zealand, Dunedin;
2. John Reynolds of Opus International Consultants Ltd., Christchurch;
3. Dave Charters of Opus International Consultants Ltd., Dunedin (completed an example of proforma use, refer Appendix E);
4. Neville Higgs and Errol Russ of Opus International Consultants Ltd., Greymouth; and
5. Reece Burnett and Tony Mans of Bloxam Burnett and Olliver, Hamilton;

The material provided to the reviewers is summarised in Section 3.3. In particular, the detailed comments of Bloxam, Burnett & Olliver, Hamilton, are only made in respect to the provisional form for the first-stage bridge-scour screening (along with explanations of the terms and illustrating figures).

Transit New Zealand, Dunedin

1. A scour-screening programme is of significant value.
2. It is required that the methodology
   - produces clear guidance for users,
   - does not overburden users, and
   - identifies and prioritises remedial actions.
3. A two-stage screening programme as proposed is supported, i.e. coarse then fine screening steps is OK. It is noted that further work is recommended to refine the process.
4. From a practical point of view, the methodology is overly complicated.
5. The second stage appears too detailed, and an equally reliable result of scour susceptibility could well be arrived at by an experienced bridge/ waterway engineer.
6. Transit New Zealand's principal driver for prioritising any remedial works will be based on Transfund's Project Evaluation Procedures and the importance of maintaining the link for lifeline reasons. Hence it is expected that Transit would use the initial phase to identify scour susceptible bridges and then go through an evaluation of each bridge identified and decide on required action based on costs (Benefit/Cost Ratio), importance of the structure in the national network, and its importance as a lifeline linkage. If there are not a significant number of bridges susceptible to scour nationally, then the second phase may not be required.
7. Until the first phase is trialled, the need for the second stage will not be known.
8. It is expected that consultants will have a fair idea already of the scour susceptible bridges.

Opus International Consultants Ltd., Christchurch

(Comparisons were made with the Seismic Screening exercise, which has been found to be very successful)

1. A scour-screening exercise is required to better understand the network risk, and to better target funding of mitigation works.
2. Form 1 of Appendix G has been updated recently (since updated in this report).
3. The basics of the screening have been well done, and it is really a matter of how the screening methodology is packaged to suit the requirements of bridge owners (and bridge inspectors).
4. Screening frequency was initially recommended as every two years during bridge inspections. Instead it is recommended that the screening exercise be a "one-off" event to be carried out possibly every 25 years in a comprehensive and programmed manner, to produce a national priority list of waterway mitigation projects. The assessment of waterway-related matters could continue on the present two-yearly inspection cycle, this process, despite its simplicity and shortfalls, having been largely successful in managing the risk associated with waterways in a cost-effective manner. A reason for the reduced screening frequency is that there are 3300 large structures on the State Highway network alone, and the cost of screening every two years could not be justified.
5. It is expected that most bridge inspectors alone are unlikely to have the required knowledge to successfully complete the screening exercise. The inspection team is expected to also require the technical insight of an experienced bridge designer.
6. With economics being the key driver for ranking funding, it is important to distinguish between bridge/ approach scour/ failure, approach scour/ failure being usually cheap and quick to repair, in contrast to bridge scour/ failure.
7. The present separation of primary and detailed screening exercises is unsatisfactory in regard to the roading authority needing a result that ranks the bridges in priority order on the basis of vulnerability, risk and economic justification for remedial works.
8. The staged approach to screening is supported, although it is recommended to eliminate as many bridges as possible at an initial more fundamental screening level, e.g. bridges not over a waterway, bridges founded on deep piles/ foundations, bridges scheduled for replacement.
9. A three-stage screening approach is recommended:
   - Basic elimination of non-risk bridges.
   - Quantification of "risk" associated with remaining bridges.

   a) Vulnerability (V) = High (VH) or Low (VL)
   b) Significance (S) = High (SH) or Low (SL)
   c) Low Risk = [VL and SL]
   d) Medium Risk = [VH and SL] or [VL and SH]
   e) High Risk = [VH and SH]

- For High Risk bridges, identify remedial work options, and quantify the cost of the required remedial works and the resulting benefits to develop an economic ranking indicator (ERI). Bridges are then ranked based on ERI values, bridges of higher ERI values progressing to more detailed analyses/ remedial works as funds permit.

The present screening methodology can be considered as the "evaluation of risk" part of a comprehensive scour screening process (i.e. up to Stage 2 of the three-stage process).

10. The assessment of risk/ economics (for Stage 3, but possibly also for Stage 2) needs to address alternative routes, detours, availability and timing of temporary bridges (e.g. Bailey bridges etc.).
11. Inclusion of transparent assessment of risk for the first-stage bridge-scour screening form is queried.
12. Inclusion of assessment of economics for the advanced second-stage bridge-scour assessment form is queried.
13. There needs to be a thorough trialling of the screening procedure before it is implemented in order to highlight any pitfalls. A further working party review, prior to implementation, is common to projects such as this, involving clients in quite large expenditure on a national basis.

Opus International Consultants Ltd, Dunedin

1. Proforma report sheets ended up tatty after use.
2. The historical records asked for may not always be available.
3. The office work takes about an hour, but this would decrease if several bridges were to be surveyed.
4. The field work, excluding photographs, took about 20 minutes. An hour for the whole exercise, including measurements, would be reasonable.
5. The proforma does not have a space for the measurements at piers, abutments and centre spans. Surely this is the most important single bit of information.
6. The queries regarding depths in thalweg, bend and confluence can't always be assessed visually, e.g. for muddy/ dark coloured beds.
7. "Whilst I am not convinced that the level of detail is worthwhile, the real time taken for a scour survey is in the measurements and the questionnaire doesn't add significantly."
8. Whether the bridge approach toe erosion/ fill movement is on the road is queried.

Opus International Consultants Ltd, Greymouth

1. Photographs take time, especially for larger bridges and also more inaccessible bridges.
2. Otherwise, the material in the screening methodology is generally looked at anyway in present bridge screening.

Bloxam Burnett and Olliver, Hamilton

1. Some of the language will be confusing to bridge inspectors, e.g. thalweg. It is expected that 9/10 of bridge inspectors will not understand what is required in terms of thalweg, bend, and confluence considerations.
2. Any recommendation of an education programme for staff would be strongly supported.
3. An electronic version of the screening form would be great for field loading of data into a laptop.
4. Define scour up front: local scour, bank scour (different to bank stability arising from drawdown), etc.
5. Bridge scour could be better defined as bridge stability in the waterway (which would then include bridge overturning owing to flood conditions – a non-scour failure mode however).
6. In the office review, identify the appropriate Regional Council (useful for river details).
7. In the office review, identify the drawing/ plan numbers (useful for later reference).
8. Re-categorise "Scheduled for Replacement" as "Scheduled for Replacement in X years", X then providing a measure of the degree of risk in scour susceptibility.
9. Include an option of "Scheduled for Replacement Owing to Scour", this reflecting a high degree of risk in scour susceptibility for a bridge being replaced.
10. Bridge significance owing to a lifeline can in reality be a conflict of interest for the road owner Transit New Zealand, e.g. Telecom's need becomes Transit New Zealand's problem.
11. Bridge significance is not necessarily measured by AADT.
12. Transit has a system of definition for bridge/ road conduit significance.
13. In regard to the definition of abutment/ pier founding depth, define the reference bed elevation position (at the abutment/ pier and not in the thalweg).
14. In regard to the definition of abutment/ pier founding depths, if the depth is unknown then answer as unknown and don't insert a fictitious number.
15. Identify the bed material, e.g. rock, pumice, etc., as this may influence assessments of the adequacy of founding depths.
16. Bridge near-field and bridge far-field are not inspector-friendly terms.
17. In the field inspection section of the first-stage screening form, the first two questions are of general relevance and not specifically appropriate to the bridge near-field or bridge far-field.
18. Sight along the handrails to confirm foundation tilt/ movement.
19. Define countermeasures to look for, e.g. anything placed to stop erosion.
20. Identify the quality of installed protection measures, e.g. dumped concrete, or riprap of designed grading and underlying filters, etc.
21. Identify the bed material type and size (giving an indication of the flow-velocity regime, armouring-layer presence, etc.).

22. Identify depth of bed materials, e.g. gravel depths off design drawings, bore records, etc.
23. Identify bank materials, e.g. rock overlain by soil.
24. Identify if the channel is man-made, man-influenced (e.g. channelised), or natural (natural channels tending to be more stable, with more armouring).
25. Identify if the structure has a fixed invert, such structures of fixed reference levels requiring particular attention in regard to aggradation and degradation (particularly downstream of the fixed invert).
26. Emphasise the use of aerial photos to assess factors influencing channel stability (e.g. outflanking) at the bridge, e.g. upstream catchment amalgamation, changes in catchment surface, forestry operations, extent of sediment mining operations, catchment stability, bank stability, etc.
27. Identify catchment reasons for bridge activity, referencing the appropriate Regional Council as necessary, e.g. sediment extraction, artificial control of bed levels by a weir, etc.
28. Identify downstream hydraulic controls, and their stability, e.g. barrier beaches (controlling degradation), sediment bars, waterfalls, lakes, etc.
29. Identify proximity to the sea and tidal effects, affecting sediment deposition, velocities, etc.
30. The statements regarding exposed piles need to be rephrased in order to avoid silly answers, e.g. where the pile cap was initially constructed at the level of the water surface.
31. Waterway adequacy considerations are more important for a bridge than a culvert, reinforcing the above need to identify if the structure has a fixed invert.
32. Identify weir bridge approaches, these approaches acting as safety valves in terms of the waterway capacity.
33. Tree stability may reflect drawdown failure of banks and not necessarily channel widening or lateral channel movement.
34. In terms of channel widening or lateral movement, look for channel-caused bank undermining that influences or reduces the factor of safety of the bridge or the bridge approaches (outflanking).
35. Remove the vegetation comments and focus more on the channel beneath the bridge, and general things going on in the catchment.
36. Define the difference between spill-through abutments and approaches.
37. The procedure doesn't give enough weight to the effective foundation width (especially for piers), as determined by the pier type and the angle of flow to the foundation in flood.
38. Identify the angle of flow to the foundations at normal and flood flow stages.
39. In terms of visual records, inspectors typically take still photos as required by the client (with no telephoto in order to provide an undistorted view). For bridges of active scour, inspectors also video the upstream and downstream channels, and underneath the bridge in the direction of flow.

40. p.24. Replace level with elevation for thalweg, bend confluence etc., as level may imply that the elevation needs to be measured using a level.
41. p.25. Define erosion-resistant materials.
42. p.25. In regard to potential local scour, socketing does not protect against overturning.
43. Waterway adequacy analysis requires estimation of flood flow Q, e.g. from regionalisation techniques, and flood level for Q using field-estimated/ measured cross-section profile and channel roughness, and comparison of this level with historical levels and waterway capacity.
44. Analysis of overturning moment capacity requires measurement of pier height from drawings, determination of peak flood level, and estimation of debris-raft height.

Appendix E

Sample Completed Provisional First-Stage Screening Form

Bridge-Scour Screening Inspection 1

Bridge Name: POMAHAKA RIVER.

Office Review

Bridge authority/region: TRANSIT REGION 14.	
Highway: 90.	Feature (waterway) crossed:
Route position: 35/0.00	POMAHAKA RIVER.
Bridge over waterway N U (Y)	Volume class:
Bridge closed (N) U Y	Motorway, urban, over 10,000 vpd ☐
Bridge scheduled for replacement (N) U Y	4,000-10,000 vpd ☐
Engineering lifeline N U (Y)	1,000-4,000 vpd ☑
Abutment founding depth 5.	less than 1,000 vpd ☐
Pier founding depth 5.	Heavy vehicle volume class:
Historical scour at surrounding	over 600 heavy vpd ☐
bridges N (U) Y	400-600 heavy vpd ☐
Historical scour of the channel N U (Y)	200-400 heavy vpd ☐
Historical scour at the bridge N U (Y)	less than 200 heavy vpd ☑
Previous screening classification: Moderate risk.	
Previous screening recommendations: Monitor following floods and at 8 yearly intervals.	

Field Inspection

BRIDGE NEAR-FIELD SCALE	BRIDGE FAR-FIELD SCALE
Bridge Location	
Bridge on steep or active alluvial fan *(office review at stream-section scale)* (N) U Y	
Historical Scour	
Failure to implement previous screening recommendations (N) U Y (P)	
Scour-Based Structural Damage	
Foundation tilt/ movement (N) U Y (P)	Present countermeasures damaged (N) U Y (P)
Degradation and Contraction	**Upstream and Downstream Lateral Movement or Channel Widening**
Scour > 0.5 m since last inspection (N) U Y (P)*	Bank vegetation tilted N U (L R) (P)
Exposed piles N U (Y) (P)	Significant root exposure on bank N U (L R) (P)
Exposed base of spread footing (N) U Y (P)	Notable vegetation-free bank zone N U (L) R (P)
Aggradation	Bank erosion N U (L R) (P)
Build-up>0.5m since last inspection (N) U Y (P)*	Bank failure N U (L R) (P)
	Tension cracks N U (L R) (P)
Waterway Adequacy	
Debris/ sediment on superstructure N U (Y) (P)	High debris or flood marks N U (Y)
Waterway significantly blocked (N) U Y (P)	
Source	
Thalweg, Bend and Confluence	
	Thalweg below tolerable level N U Y } Can't
	Bend below tolerable level N U Y } assess
	Confluence below tolerable level N U Y } visually
Local Scour at Piers or Abutments	
Spill-through abut. toe erosion (N) U Y (P)	Flow concentration at foundations
Spill-through abut. fill movement (N) U Y (P)	or approaches N U (Y) (P)
on road } ? Bridge approach toe erosion (N) U Y (P)	Source: Build up of debris.
? Bridge approach fill movement (N) U Y (P)	Locations:
Potential/ present scour > tolerable (N) U Y	Debris on foundations or upstream N U (Y) (P)

Bridge-Scour Screening Inspection 2

Bridge Name:

Standard Photographs			
From Bridge - Looking Upstream	☐	From Bridge - Looking Downstream	☐
Looking Downstream at Bridge	☐	Looking Upstream at Bridge	☐

Notes and Comments
(use channel plan/cross-section sketches as required)

[1] Note factors indicating scour susceptibility.
[2] Note individual foundations highlighted as scour-susceptible.
[3] Note locations of channel/foundation erosion influencing the assessment.

Scour-Screening Classification

Scour Vulnerability		Bridge Significance	
Not over waterway	☐	Highest	☐
Scheduled for replacement	☐	High	☒
Low risk	☐	Medium	☐
Potentially scour susceptible/critical	☒	Low	☐
Scour susceptible/critical	☐		
Recommended Actions			
Detailed scour assessment	☐	Scour monitoring	☒
Detailed scour assessment–unknown	☐	Frequency:	
Detailed scour analyses	☐	After significant floods / 3-yearly.	
Replacement	☐	Bridge closure	☐
Structural countermeasures	☐	Channel modifications	☐
Details:		Details:	

Personnel

Field Inspection By:	Date:
Office Review By:	Date:
Scour-Screening Classification By:	Date:
Checked By:	Date:

Appendix F

Data Sources

Appendix F Data Sources

Sources of data about bridges, streams and flood plains, hydrology or hydraulics, road use, and local or previous experience are listed below.

Details	Data Sources
Bridge:	• Bridge design drawings, reports, records and experience • Bridge construction drawings, reports, records and experience • Bridge maintenance and inspection drawings, reports, records and experience • Survey data records • Foundation/ subsurface investigation reports and records (including bore logs, sediment-sample analyses, pebble-count analyses, soil surveys, pile records, etc.) • Field observations, measurements, and records • Maps (historic and existing): site, geologic, soils, etc.
Stream and floodplain:	• Historic and existing cross-sections and bed elevations throughout the reach • Records of changes (natural or man-made) in stream morphology • Colour infrared photography (indicating active bank erosion and increased turbidity) • Aerial photographs (historic and existing) • Photographs (historic and existing) • Field observations, measurements, and records • Maps (historic and existing): area, site, land use, geologic, soils, topographic, flood insurance, etc.
Hydrology/ hydraulics:	• Precipitation records • Flow and stage records • Tidal records • Records of changes (natural or man-made) in hydrology/ hydraulics • Field observations, measurements, and records • Maps (historic and existing): area, site, land use, topographic, flood insurance, etc.
Road usage:	• Maps (historic and existing): transportation, etc.
Experience:	• Local resident experience, photos and records • Engineering consultant experience, photos and records • Governing body experience, photos and records

Appendix G

Sample Bridge-Scour Screening Forms

G1. Present New Zealand Bridge-Scour Screening

G1.1 Bridge-Scour Screening

Present New Zealand bridge-scour screening is limited to the scour and waterway components of existing general inspection procedures (Section G1.2 and Form 1 below). The scour and waterway inspection categories are:

1. river aggrading (inspectors look for sediment levels increasing at foundations or along the channel invert, etc.);
2. river degrading (inspectors look for sediment levels decreasing at foundations or along the channel invert, moss growing at higher levels on foundations, etc.);
3. waterway adequate (inspectors look for debris levels upstream or at the bridge, the degree of growth in and constriction of the waterway, etc.);
4. erosion of abutments or approach;
5. embedment of foundations;
6. other erosion or scour risks.

Each component is assessed as: not inspected, satisfactory, monitor next inspection, routine maintenance, urgent maintenance, or not applicable. In addition, the condition of the foundations and substructure (including any settlement) is assessed.

Bridge inspectors note that in terms of scour and waterway assessment:

- scour/ waterway assessment is not observed in great detail, generally scour events being looked for (although these are noted to be difficult to pick up post-flood as scour holes are filled in); and
- the waterway invert is often difficult to see to assess the waterway beneath the water surface.

The existing procedures are limited in terms of bridge-scour screening. This is highlighted by the relatively comprehensive nature of overseas bridge-scour screening procedures, as discussed in Section G2 below.

G1.2 Transit NZ Standard S6:2000 – Bridge Inspection Policy

The following provides an overview of TNZ Standard S6:2000 (Bridge Inspection Policy) guidelines regarding types of inspections, who is to be involved, and reporting to be carried out.

1. ***Superficial Inspections*** identify any obvious defect which may affect the safety of highway users or anything else needing urgent attention, e.g. the build-up of flood debris, erosion damage, or approach settlement.

2. ***General Inspections*** shall be carried out at intervals not exceeding two years. During such an inspection, personnel shall verify that the data recorded in the Descriptive Inventory is correct, or note any necessary changes.

3. ***Detailed Inspections*** shall be carried out at intervals not exceeding six years. Inspection shall be carried out at close quarters of all external surfaces above water level and, where appropriate, all internal surfaces. In waterways where abrasion or impact damage is possible, sufficient underwater inspection shall be carried out to verify whether such damage has occurred. Where measurements indicate that significant scour has occurred, its extent shall be recorded and, if necessary, underwater inspection shall be carried out.

4. ***Special Inspections*** include Posted Bridge Inspections, Large or Complex Bridge Inspections, and Flood Inspections. Posted Bridge Inspections, carried out in lieu of General Inspections at frequencies to be determined by the Bridge Inspection Engineer, shall include close observation of deterioration at locations identified as susceptible to damage. Large or Complex Bridge Inspections are carried out for identified bridges in lieu of General or Detailed Inspections. Flood Inspections, carried out following a flood that is likely to have caused damage on all bridges at sites known to have a history of instability, shall be as for a General Inspection on the waterway and all members susceptible to flood damage, although the exact criteria and extent of inspection are site dependent.

5. ***General, Detailed and Special Inspections*** shall be carried out, typically by bridge inspectors, under the control of the Bridge Inspection Engineer.

6. ***General, Detailed and Special Inspections*** are to be reported on Form TNZ 801 (or 802 as appropriate), accompanied by a written report as necessary to describe specific defects. Form TNZ 801 is shown as Form 1 below. Maintenance work or further detailed investigations shall be recommended as appropriate.

G2 Overseas Bridge-Scour Screening Programmes

Parola et al. (1995) comment that literature on techniques for evaluating existing bridges for scour susceptibility is all of US origin as there apparently has been no emphasis by other countries on the evaluation of existing bridges. Certainly, no such bridge-scour screening methodology or programme has been developed for New Zealand conditions. Recent exceptions to the comment of Parola et al. (1995) are provided by the European works of Thorne (1998), Thorne et al. (1996), and the Environmental Agency (1998). These works centre on providing geomorphologic reconnaissance techniques and analyses in order to give a geomorphologic classification of a river system and permit a detailed investigation of form and process for critical reaches. Mitchell (1990) and Gordon et al. (1992) provide Australian works aimed at assessing waterway conditions.

Recognising that scour of bridge foundations during floods has resulted in more bridge failures than all other causes in recent history (Murillo 1987), the US Federal Highway Association (FHWA) recommended that " ... *every bridge over a stream, whether existing or under design, should be assessed as to its vulnerability to floods in order to determine prudent measures to be taken* " (Richardson et al. 1993). As part of the basis for the recommendation, the authors note that the "... *added cost of making a bridge less vulnerable to scour is small when compared to the total cost of a failure which can easily be two to ten times the cost of the bridge itself.*" Consequent to these recommendations for bridge assessment, US bridge owners were required to undertake bridge-scour-screening programmes.

The objectives of the US bridge-scour evaluation programme were:

1. to review all bridges over streams in the National Bridge Inventory to determine those foundations that are stable for estimated scour conditions and those that are not;
2. to provide interim scour protection for scour-critical bridges until adequate scour countermeasures are installed; and
3. to replace the bridge or install scour countermeasures in a timely manner, depending upon the perceived risk involved.

The FHWA subsequently recommended HEC-18 (e.g. Richardson & Davis 1995) and HEC-20 (e.g. Lagasse et al. 1995) as guidance for implementing the proposed bridge screening programme (Objective 1 above). These two documents were not specifically written to facilitate screening programmes, however. Many US States then developed State-specific guidelines based on these documents. Other States developed guidelines different from, but consistent with the intent and principles presented in the FHWA guidelines. The overall result has been a variety of bridge-screening programmes, e.g. Minnesota Department of Transportation (1991), Robinson & Thompson (1993), Hunter et al. (1993), Lagasse et al. (1993a), Simon & Downs (1995), Fischer (1996), Davis & Dee (1996), Bergendahl & Jordan (1996), and Johnson et al. (1999). These programmes incorporate different emphases dependent upon the bridge, river, hydrologic and geomorphologic characteristics that are deemed important in the particular state or region of study. The essence of US screening programmes is, however, outlined below:

- screening is based on history of scour problems at the site, geomorphic stability of the stream, streambed erodibility, complexity of flow conditions, design features of the bridge, and importance of the bridge lifeline;
- data to be considered include geologic conditions, catchment conditions, hydraulic conditions, riverine conditions (including geomorphological and channel evolution data), bridge site data; bridge design data (including any countermeasures), historical data on bridge or channel scour during floods, and community usage of the bridge;
- data is sourced from field inspections, aerial photographs, geologic records, stream records; flow records, bridge records, and reference to the community; and

- based upon an assessment of the data collected, bridges are screened into risk (or susceptibility) categories (for example, low risk, scour susceptible, and unknown foundations) and then into priority order (based on relative vulnerability to potential scour damage and relative importance of the bridge lifeline).

Examples of the more advanced US bridge-scour screening forms are given below. As a guideline of effort required to complete these forms, Simon & Downs (1995) estimate their site evaluation form (Form 3) to take about 1 to 1.5 hours for a (trained) person to complete for a bridge site. Forms of Robinson & Thompson (1993) and Simon & Downs (1995) are indicative of forms for bridge-scour screening data collection.

Earlier screening programmes and less-intensive programmes look for the presence or absence of critical factors as the basis for ranking bridge susceptibility to scour (e.g. the preliminary section of the form of Hunter et al. 1993, shown as Form 7). More comprehensive screening programmes rank bridge susceptibility to scour using formal weighted assessments of the data collected (e.g. forms of Minnesota Department of Transportation 1991; the latter section of Hunter et al. 1993; Simon & Downs 1995; and Johnson et al. 1999).

Much of the recent bridge-scour screening and evaluation technology is new to engineers and designers charged with completing scour evaluations and/ or designing new bridges. Recognising this, training programmes were set up and run to support implementation of the bridge-scour screening programmes in the US. Initially, a general three-day course was run for engineers, designers and inspectors covering stream stability and scour (Lagasse et al. 1993b). A one-day supplementary course was subsequently designed and run focussing on training particularly relevant to bridge inspectors in stream stability and scour (Lagasse & Richardson 1996).

Consequent to the screening analyses, plans of action can be formulated for those bridges identified as scour critical, such plans including interim plans of action to protect the public until the bridge can be replaced or scour countermeasures installed. Such bridges can, for example, be added to flood-watch or post-flood-inspection lists.

Based upon appropriate analyses, scour-critical foundations will then be evaluated in greater detail for scour susceptibility and vertical and lateral stability for design floods. The bridges evaluated as low risk can then be further evaluated after the more critical bridges have been attended to.

Form 1: Existing New Zealand General Inspection: Form TNZ 801

TNZ S6: 2000

TRANSIT NEW ZEALAND
ARARAU AOTEAROA

Bridge Inspection Report

Bridge Name: .... Highway: .... R.P: ....
Spans: .... Width Between Kerbs: .... Length: ....
Type of Bridge: .... Restrictions: ....
Inspected By: .... Date: /...../ Reviewed By: .... Date: / /
(Bridge Inspection Engineer)

Check List

General			**Superstructure Steel**		Main Member	Sec. Member	**Foundations and Substructure**				
1	Appearance										
2	Approach adequacy						26	Settlement			
3	Signs		15	Condition of Paint			27	Cracking			
4	Vibration		16	Corrosion			28	Spalling			
5	Bearings		17	Joints			29	Abrasion			
6	H.D Bolts and Linkages		18	Rivets and Bolts			30	Corrosion of Steel			
7	Expansion Joints		19	Other defects			31	Other defects			
8	Footways		**Superstructure Timber**				**Scour and Waterway**				
9	Road safety barriers and/or handrails										
10	Deck drainage		20	Decay			32	River aggrading			

Superstructure Concrete		Deck	Main Member	Sec. Member							
					21	Warping and Cracking			33	River degrading	
					22	Deck wear			34	Waterway adequate	
					23	Bolts and Spikes			35	Erosion of abuts/ approaches	
					24	Other defects			36	Embedment of foundations	
11	Cracking				25	Date of last boring			37	Other erosion or scour risks	
12	Spalling										
13	Reinf. Corrosion										
14	Other defects										

Marking Code

Not inspected	0	Routine maintenance *(provide comment)*	3
Satisfactory	1	Structural maintenance *(provide comment)*	4
Monitor next inspection	2	Not Applicable	N

Remedial work recommended last inspection has been completed: YES NO *(comment overleaf if answer is NO)*
Bridge Descriptive Inventory Changes Required YES NO *(describe change if answer is YES)*

(Continue over if required)

Comments and Recommendations for Maintenance/Repairs

Item	Brief Description of Fault and Recommendations for Repair and Urgency	Cost Estimate
	(Continue over if required)	

Comments and Recommendations Relating to Future Management (Transfer to Current Report)

Item	Defect/Strategy	Person (Bridge Inspection Engineer)	Date
	(Continue over if required)		

TNZ 801

Form 2: Robinson and Thompson (1993): Bridge-Scour Screening Data Collection

CHANNEL-INSTABILITY ASSESSMENT FORM

Problem: ____________
____
Followup: ____________
____________ Date: ______
Action Taken: ____________
____________ Date: ______
DOT QA: ______ Date: ______
USGS QA: ______ Date: ______
Data Input: ______ Date: ______
Report QA: ______ Date: ______

Plan View Sketch of Site

In the Vehicle

Bridge #: ____________ Inspector: ____________
Date: __________ Stream: ____________
County #: ____ Nearest Town: __________ Route #: ______
Total Bridge Length (ft): ________ Overflow Bridge: __ 0=No 1=Yes
Type of Structure: ____________ ADT x 100: ______

From the Roadway

of Overflow Bridges: L: ____ R: ____ Wadeable: ____ 0=No 1=Yes
Minimum Span Over Water (ft): ________
Surface Cover USLB: ___ USRB: ___ DSLB: ___ DSRB: ___ Overall: ___
1=>50% Paved 2=10%-50% Paved 3=Row crop 4=Pasture 5=Brush 6=Forest 7=Wetland

	Higher than Bridge Deck	Subject to Meander Impact	
Left Road Approach to Bridge:	___	___	0=No 1=Yes
Right Road Approach to Bridge:	___	___	0=No 1=Yes

High Flow Angle US/DS (degrees): ______ + = Pushes RB - = Pushes LB
Upstream Channel Profile: ____ 1 = Pool 2 = Riffle
Photograph from Bridge Looking Upstream
Roll #: ________ Frame #: ______ Standing: ____________ Bridge
Photograph from Bridge Looking Downstream
Roll #: ________ Frame #: ______ Standing: ____________ Bridge
Downstream Channel Profile: ____ 1 = Pool 2 = Riffle

In the Upstream Channel

Meander Impacts: (1) ____ Bank: ____ Distance: ______ (ft)
(2) ____ Bank: ____ Distance: ______ (ft)
0 = No 1 = Yes 1 = LB 2 = RB - = Downstream

(Beyond Bridge Right-of-Way for Bank and Channel Observations Only)

Bank Height (ft)		Bank Angle (degrees)		Veg Cover (%)		Bank Material		Bank Erosion	
LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
___	___	___	___	___	___	___	___	___	___
(nearest 0.5 ft)		(nearest 5) (degrees)		1=0-25% 2=26-50% 3=51-75% 4=76-100%		1 = Silt/Clay 2 = Sand 3 = Gravel 4 = Cbl/Boulder 5 = Bedrock 6 = Con/Steel		0 = None 1 = Mass Wasting 2 = Fluvial	

US Bankfull Channel Width: ______ (ft)

Photograph from Upstream Looking Downstream at Bridge
Roll #: ________ Frame #: ______ Standing: ____________ (ft US)

			Comments
Tributary #1: ___	Enters: _____ (ft)	On: ___	____________
Tributary #2: ___	Enters: _____ (ft)	On: ___	____________
Tributary #3: ___	Enters: _____ (ft)	On: ___	____________

0 = No 1 = Yes - = Downstream 1 = LB 2 = RB

In the Upstream Channel (cont)

Point Bar:___ Location at widest point:__% to __% Distance to widest point:____(ft)
0 = No 1 = Yes   0% = LB   100% = RB   - = Downstream

Cut Bank:____ Cut Bank Location:____ Distance to Mid Cut Bank:_____(ft)
0 = No 1 = Yes   1 = LB 2 = RB   - = Downstream

Sketch of Bridge Opening at Upstream Face of Bridge

Under the Bridge

Depth Required for Pressure Flow:_____(ft) (999 if > 35)   Water Depth at Thalweg:_____(ft)

Flow Deflected by Debris:___ Impact Point:___ Distance to Impact Point:_______(ft)
0 = No 1 = Yes   1 = LB 2 = RB   0 = At Bridge - = DS

Piers and Columns

Nose Shape	# of Columns (If Shape =) (4, 5, or 6)	Diagonal Member (If Shape =) (4, 5, or 6)	Attack Angle (degrees)	Location LFP	LTB	LB	MCL	MCM	MCR	RB	RTB	RFP	Scour Conditions
				(Circle Appropriate Choices Below)									
1-____	____	____	____	1	2	3	4	5	6	7	8	9	0 1 2 3
2-____	____	____	____	1	2	3	4	5	6	7	8	9	0 1 2 3
3-____	____	____	____	1	2	3	4	5	6	7	8	9	0 1 2 3
4-____	____	____	____	1	2	3	4	5	6	7	8	9	0 1 2 3
5-____	____	____	____	1	2	3	4	5	6	7	8	9	0 1 2 3
6-____	____	____	____	1	2	3	4	5	6	7	8	9	0 1 2 3
7-____	____	____	____	1	2	3	4	5	6	7	8	9	0 1 2 3
8-____	____	____	____	1	2	3	4	5	6	7	8	9	0 1 2 3
9-____	____	____	____	1	2	3	4	5	6	7	8	9	0 1 2 3

Shape
1 = Square
2 = Round
3 = Pointed
4 = Square Columns
5 = Round Columns
6 = Pointed Columns

0 = No
1 = Yes

Flow
+ = Pushes RB
- = Pushes LB

0 = None
1 = Local scour
2 = Footing Exposed
3 = Piles Exposed

Pier or Column Width:_______(ft)   Total Pier Length:_______(ft)

Under the Bridge (cont)

Abutments

	Attack Angle (degrees)	Abutment Location	Type of Abutment	Scour Conditions	Guide Banks	Upstream Wing Walls	Wing Wall Condition
Left Abut:	____	____(ft)	____	____	____	____	____
Right Abut:	____	____(ft)	____	____	____	____	____
	+ = Pushes RB - = Pushes LB	- = Past Bank into Stream 0 = Even w/ Bank + = Set Back from Bank	1 = Vertical If Sloping: 2 = Unhardened 3 = Hardened	0 = None 1 = Local scour 2 = Footing Exposed 3 = Piles Exposed	0 = No 1 = Yes	0 = Absent 1 = Present	1 = Good 2 = Fair 3 = Poor 4 = Failed

Rip Rap

	Presence	Cond. (If Presence = 1)
US LB:	____	____
US L WW:	____	____
L Bank:	____	____
DS L WW:	____	____
DS LB:	____	____
US RB:	____	____
US R WW:	____	____
R Bank:	____	____
DS R WW:	____	____
DS RB:	____	____
Bed:	____	____
	0 = Absent 1 = Present	2 = Good 3 = Partial 4 = Slumped

Bed Material

US:_ _ _ Under Bridge:_ _ _ DS:_ _ _
1 = Silt/Clay 2 = Sand 3 = Gravel
4 = Cbl/Boulder 5 = Bedrock 6 = Con/Stl

Under Bridge
Bankfull Channel Width:________(ft)

Debris

Accumulation:__ 0 = No 1 = Yes

Horizontal:_____% to _____%
0% = LB 100% = RB

Vertical: _____% to _____%
0% = Bed 100% = Low Steel

Type of Material:_____
1 = Brush 2 = Whole Trees
3 = Trash 4 = All Others

Debris Potential

Debris Potential:____
0 = Low 1 = Medium 2 = High

Scour Holes

Present	Stream Pos.	Channel Pos.	Width	Length	Depth
1-____	____(ft)	____%	____(ft)	____(ft)	____(ft)
2-____	____(ft)	____%	____(ft)	____(ft)	____(ft)
0 = Absent 1 = Present	+ = US 0 = Under Bridge - = DS	LB = 0% RB = 100%			

In the Downstream Channel

(Beyond Bridge Right-of-Way for Bank and Channel Observations Only)

Bank Height (ft) LB	Bank Height (ft) RB	Bank Angle (degrees) LB	Bank Angle (degrees) RB	Veg Cover (%) LB	Veg Cover (%) RB	Bank Material LB	Bank Material RB	Bank Erosion LB	Bank Erosion RB
____	____	____	____	____	____	_ _ _	_ _ _	____	____
(nearest 0.5 ft)		(nearest 5) (degrees)		1=0-25% 2=26-50% 3=51-75% 4=76-100		1 = Silt/Clay 2 = Sand 3 = Gravel 4 = Cbl/Boulder 5 = Bedrock 6 = Con/Steel		0 = None 1 = Mass Wasting 2 = Fluvial	

Stage of Reach Evolution:_____
1 = Undisturbed 2 = Constructed
3 = Degradation 4 = Aggradation
5 = Lateral Migration 6 = Stable

DS Bankfull Channel Width:______(ft)

Blow Hole:__ 0 = No 1 = Yes

Dist. DS to Middle of Blow Hole:_______(ft)

Blow Hole Width:______(ft)

Blow Hole Length:_____(ft)

Photograph from Downstream Looking Upstream at Bridge

Roll #:___________ Frame #:________ Standing:____________________(ft DS)

Additional Photographs

Roll #:___________ Frame #:________ Standing:______________ Looking At:__________________

Roll #:___________ Frame #:________ Standing:______________ Looking At:__________________

Roll #:___________ Frame #:________ Standing:______________ Looking At:__________________

Roll #:___________ Frame #:________ Standing:______________ Looking At:__________________

Form 3: Simon and Downs (1995): Bridge-Scour Screening Data Collection

• Site-evaluation form:

1) Intro: Date ________ Stream ____________________ Vicinity ____________ Inspector ____________
Land use _______, 1 = urban, 2 = row crop, 3 = pasture, 4 = forest.

2) Location: Route ___________ Cty ________ Hwy.Log-mile _____ TDOT reg _______ Bridge No. ________
Latitude________________ Longitude ____________Total bridge length ______________________
Max. span length __________ Channel protection ______________
Waterway adequacy __________ Sufficiency rating ______________
Number of overflow bridges: Left __________ Right ___________

3) Flow conditions: Baseflow ________ 0 = no, 1 = yes
Underclearance at thalweg _______ m. or *999* if > 12m.
Depth of flow _________ m.
High flow angle of approach __________ degrees (+ = toward right bank, - = toward left bank)
Deflected flow ______ 0 = no, 1 = yes; impact point ________ 1 = Left bank (LB), 2 = Right bank (RB)
Cause of deflection and affect on bridge crossing:
Capacity of bridge opening (qualitative), can the bridge handle all flow or is there some restriction for certain flow stages:
Capacity of channel (qualitative):
Observed High Water Marks (HWM) _________ m. above/below ___________(reference point)
Road overflow risk (qualitative):

4) Bank condition:

	Height from bed 1 LB	Height from bed 2 RB	Angle 1 LB	Angle 2 RB	Woody Veg. cover (%) 1 LB	Woody Veg. cover (%) 2 RB	Material type 1 LB	Material type 2 RB	Erosion type 1 LB	Erosion type 2 RB
1 U/S	___	___	___	___	___	___	___	___	___	___
2 D/S	___	___	___	___	___	___	___	___	___	___

Note: U/S = upstream, D/S = downstream
Bank angle sketch with heights and angles. Veg. type (woody or herbaceous), approx. age, species if recognized.
Material 1 = ML/CL 2 = sand 3 = bedrock 4 = gravel/cobble
Erosion 0 = none 1 = mass wasting 2 = fluvial erosion

5) Bed material characteristics: 1 = sand 2 = ml or cl 3 = gravel
4 = cobble/boulder 5 = bedrock 6 = alluvium (if can't tell others)
Armored? ______ 0 = no, 1 = yes
Estimated depth of gravel deposits _______ m. (enter *999* if not observed)

6) Channel profile: 1 upstream: 1 = pool, 2 = riffle, 3 = smooth
2 downstream: 1 = pool, 2 = riffle, 3 = smooth

7) Distance to upstream confluence if any: 0 = no, 1 = yes
________ m. 1 = left bank entry, 2 = right bank entry.
________ m. 1 = left bank entry, 2 = right bank entry.
________ m. 1 = left bank entry, 2 = right bank entry.

8) Piers: To be listed from left to right. Stop at first floodplain pier.

number		shape	skew	Loc: 1	2	3	4	5	6	7	8	9	Local scour
				(circle the appropriate choice below)									
B ____	____	shape ____	skew ____	Loc: lfp,	ltb,	lb,	mcl,	mcm,	mcr,	rb,	rtb,	rfp.	0 1 2 F P N
B ____	____	shape ____	skew ____	Loc: lfp,	ltb,	lb,	mcl,	mcm,	mcr,	rb,	rtb,	rfp.	0 1 2 F P N
B ____	____	shape ____	skew ____	Loc: lfp,	ltb,	lb,	mcl,	mcm,	mcr,	rb,	rtb,	rfp.	0 1 2 F P N
B ____	____	shape ____	skew ____	Loc: lfp,	ltb,	lb,	mcl,	mcm,	mcr,	rb,	rtb,	rfp.	0 1 2 F P N
B ____	____	shape ____	skew ____	Loc: lfp,	ltb,	lb,	mcl,	mcm,	mcr,	rb,	rtb,	rfp.	0 1 2 F P N
B ____	____	shape ____	skew ____	Loc: lfp,	ltb,	lb,	mcl,	mcm,	mcr,	rb,	rtb,	rfp.	0 1 2 F P N
B ____	____	shape ____	skew ____	Loc: lfp,	ltb,	lb,	mcl,	mcm,	mcr,	rb,	rtb,	rfp.	0 1 2 F P N
B ____	____	shape ____	skew ____	Loc: lfp,	ltb,	lb,	mcl,	mcm,	mcr,	rb,	rtb,	rfp.	0 1 2 F P N
B ____	____	shape ____	skew ____	Loc: lfp,	ltb,	lb,	mcl,	mcm,	mcr,	rb,	rtb,	rfp.	0 1 2 F P N
B ____	____	shape ____	skew ____	Loc: lfp,	ltb,	lb,	mcl,	mcm,	mcr,	rb,	rtb,	rfp.	0 1 2 F P N

Notes: B = bent; check only if applicable.
Shape is a standard: 1 = squared, 2 = rounded, 3 = pointed, 4 = square piles, 5 = round piles, 6 = pointed piles.
Skew will be from upstream to downstream based on high flow:
alignment: + = skew to right, - = skew to left.
Location: lfp = left floodplain, ltb = left top bank, lb = left bank, mcl = main channel left, mcm = main channel middle, mcr = main channel right, rb = right bank, rtb = right top bank, rfp = right floodplain
Local scour: 0 = none, 1 = observed, 2 = undefinable,
F = footing exposed, P = piling exposed, N = no exposure

9) Abutment: 1 = left; skew_______ Loc: 0, +______ m., - ______ m., sloping or vertical. 1 = yes, 2 = no
2 = right; skew_______ Loc: 0, +______ m., - ______ m., sloping or vertical. 1 = yes, 2 = no

Notes: Skew will be measured for high flow conditions as difference bewteen normal flow and abutment; + = right skew, - = left skew.
Loc: + indicates the abutment is set back from the bank, - indicates the abutment sits out into the stream, 0 indicates the abutment is even with the bank.

10) Debris accumulation: % of opening blocked; horizontal _____ to _____ %, vertical _____ to _____ %.
Type and size: _____ 1 = brush, 2 = whole trees, 3 = trash, 4 = all of others
Potential for debris (qualitative):

Obstructions (describe):

Notes: Left bank to right bank. 0 % = LB, 100% = RB, Bed to top of bank, 0% to 100%.
Take pictures, make notes.

11) Rip-rap on:
1 = U/S rt bank; 0 = absent, 1 = present, 2 = good cond., 3 = weathered to size smaller, 4 = slumped.
2 = U/S lf bank; 0 = absent, 1 = present, 2 = good cond., 3 = weathered to size smaller, 4 = slumped.
3 = at rt bank; 0 = absent, 1 = present, 2 = good cond., 3 = weathered to size smaller, 4 = slumped.
4 = at lf bank; 0 = absent, 1 = present, 2 = good cond., 3 = weathered to size smaller, 4 = slumped.
5 = D/S rt bank; 0 = absent, 1 = present, 2 = good cond., 3 = weathered to size smaller, 4 = slumped.
6 = D/S lf bank; 0 = absent, 1 = present, 2 = good cond., 3 = weathered to size smaller, 4 = slumped.
Type and size (qualitative):

If slumped, where and why:

7 = bed; 0 = absent, 1 = present, 2 = good cond., 3 = weathered to size smaller, 4 = slumped.
If moved, to what extent?

Type and size (qualitative):

8 = at rt abut. 0 = absent, 1 = present, 2 = good cond., 3 = weathered to size smaller, 4 = slumped.
9 = at lf abut. 0 = absent, 1 = present, 2 = good cond., 3 = weathered to size smaller, 4 = slumped.
Type and size (qualitative):

If slumped, where and why:

12) Channel width: U/S _______, at ______, D/S _______; blowhole _______ 0 = no, 1 = yes
_______ m. downstream, _______ m. wide, _______ m. long.

13) Meander characteristic in vicinity of bridge (impact points):

	1 Low flow		2 High flow	
	straight: 0 = no, 1 = yes		straight: 0 = no, 1 = yes	
	1 = LB	2 = RB	1 = LB	2 = RB
U/S (m.)	_____	_____	_____	_____
D/S (m.)	_____	_____	_____	_____
Meander wavelength	_____ m.		_____ m.	

Note: entry will be LB or RB and distance from bridge. 0 = impact at bridge

14) Point bar location: ________, 0 = absent, 1 = present
________ to ______ % (0% = LB, 100% = RB)
Distance U/S (+) _______ m. or D/S (-) _______ m.
Width at mid bar _______ m.

15) Alluvial fan in vicinity of bridge: 0 = no, 1 = yes, 2 = questionable. If questionable then describe:

16) Stage of reach evolution: 1 = undisturbed, 2 = new construction, 3 = degradational,
4 = degrdation and bank failure, 5 = aggradation or stable, with bank failure, 6 = fully recovered.

Form 4: Simon and Downs (1995): Weighted Rating of Bridge-Scour Susceptibility

1.	Bed material						
		bedrock	boulder/ cobble	gravel	sand	unknown alluvium	silt/clay
		0	1	2	3	3.5	4
2.	Bed protection						
		yes	no	(with)	1 bank	2 banks	
					protected		
		0	1		2	3	
3.	Stage of Channel Evolution						
		I	II	III	IV	V	VI
		0	1	2	4	3	1.5
4.	Percent of Channel Constriction						
		0-5	6-25	26-50	51-75	76-100	
		0	1	2	3	4	
5.	Number of Piers in Channel						
		0	1-2	>2			
		0	1	2			
6.	Percent of Blockage: horizontal (6), vertical (7), total (8)						
		0-5	6-25	26-50	51-75	76-100	(divide each
		0	1	2	3	4	value by three)
9.	Bank Erosion for Each Bank						
		none	fluvial	mass-wasting			
		0	1	2			
10.	Meander Impact Point From Bridge (in meters)						
		0-10	11-20	21-35	>35		
		3	2	1	0		
11.	Pier Skew for each Pier (sum for all piers in channel)						
		yes	no				
		1	0				
12.	Mass Wasting at Pier (calculated for each pier)						
		yes	no				
		3	0				
13.	High-Flow Angle of Approach (in degrees)						
		0-10	11-25	26-40	41-60	61-90	
		0	1	2	2.5	3	
14.	Percent Woody Vegetative Cover						
		0-15	16-30	31-60	61-99	100	
		3	2.5	2	1	0	

Form 5: Johnson et alia (1999): Weighted Rating of Bridge-Scour Susceptibility

Stability Indicators, Descriptions, and Ratings

Stability indicator (1)	Ratings: Excellent (1–3) (2)	Good (4–6) (3)	Fair (7–9) (4)	Poor (10–12) (5)
1. Bank soil texture and coherence	Clay and silty clay; cohesive material	Clay loam to sandy clay loam	Sandy clay to sandy loam	Loamy sand to sand; noncohesive material
2. Average bank slope angle (Pfankuch 1978)	Bank slopes <3H:1V (18° or 33%) on both sides.	Bank slopes up to 2H:1V (27° or 50%) on one or occasionally both banks.	Bank slopes to 1.7H:1V (31° or 60%) common on one or both banks.	Bank slopes over 60% common on one or both banks.
3. Vegetative bank protection (Pfankuch 1978; Thorne et al. 1996)	Wide band of woody vegetation with at least 90% density and cover. Primarily hard wood, leafy, deciduous trees with mature, healthy, and diverse vegetation located on the bank. Woody vegetation oriented vertically.	Medium band of woody vegetation with 70–90% plant density and cover. A majority of hard wood, leafy, deciduous trees with maturing, diverse vegetation located on the bank. Woody vegetation oriented 80–90° from horizontal with minimal root exposure.	Small band of woody vegetation with 50–70% plant density and cover. A majority of soft wood, piney, coniferous trees with young or old vegetation lacking in diversity located on or near the top of bank. Woody vegetation oriented at 70–80° from horizontal often with evident root exposure.	Woody vegetation band may vary depending on age and health with less than 50% plant density and cover. Primarily soft wood, piney, coniferous trees with very young, old and dying, and/or monostand vegetation located off of the bank. Woody vegetation oriented at less than 70° from horizontal with extensive root exposure.
4. Bank cutting (Pfankuch 1978)	Little or none evident. Infrequent raw banks less than 15 cm high generally.	Some intermittently along channel bends and at prominent constrictions. Raw banks may be up to 30 cm.	Significant and frequent. Cuts 30–60 cm high. Root mat overhangs.	Almost continuous cuts, some over 60 cm high. Undercutting, sod-root overhangs, and side failures frequent.
5. Mass wasting or bank failure (Pfankuch 1978)	No or little evidence of potential, or very small amounts of mass wasting. Uniform channel width over the entire reach.	Evidence of infrequent and/or minor mass wasting. Mostly healed over with vegetation. Relatively constant channel width and minimal scalloping of banks.	Evidence of frequent and/or significant occurrences of mass wasting that can be aggravated by higher flows, which may cause undercutting and mass wasting of unstable banks. Channel width quite irregular and scalloping of banks is evident.	Frequent and extensive mass wasting. The potential for bank failure, as evidenced by tension cracks, massive undercuttings, and bank slumping, is considerable. Channel width is highly irregular and banks are scalloped.
6. Bar development (Lagasse et al. 1995)	Bars are mature, narrow relative to stream width at low flow, well vegetated, and composed of coarse gravel to cobbles.	Bars may have vegetation and/or be composed of coarse gravel to cobbles, but minimal recent growth of bar evident by lack of vegetation on portions of the bar.	Bar widths tend to be wide and composed of newly deposited coarse sand to small cobbles and/or may be sparsely vegetated.	Bar widths are generally greater than 1/2 the stream width at low flow. Bars are composed of extensive deposits of fine particles up to coarse gravel with little to no vegetation.
7. Debris jam potential (Pfankuch 1978)	Debris or potential for debris in channel is negligible.	Small amounts of debris present. Small jams could be formed.	Noticeable accumulation of all sizes. Moderate downstream debris jam potential possible.	Moderate to heavy accumulations of various size debris present. Debris jam potential significant.
8. Obstructions, flow deflectors, and sediment traps (Pfankuch 1978)	Rare or not present.	Present, causing cross currents and minor bank and bottom erosion.	Moderately frequent and occasionally unstable obstructions, cause noticeable erosion of the channel. Considerable sediment accumulation behind obstructions.	Frequent and often unstable causing a continual shift of sediment and flow. Traps are easily filled causing channel to migrate and/or widen.
9. Channel bed material consolidation and armoring (Pfankuch 1978)	assorted sizes tightly packed, overlapping, and possibly imbricated. Most material >4 mm	Moderately packed with some overlapping. Very small amounts of material <4 mm	Loose assortment with no apparent overlap. Small to medium amounts of material <4 mm	Very loose assortment with no packing. Large amounts of material <4 mm
10. Shear stress ratio [Eqs. (3)–(4)]	$\tau_o/\tau_c < 1.0$	$1.0 \le \tau_o/\tau_c < 1.5$	$1.5 \le \tau_o/\tau_c < 2.5$	$\tau_o/\tau_c \ge 2.5$
11. High flow angle of approach to bridge or culvert (Simon and Downs 1995)[a]	$0° \le \alpha \le 5°$	$5° < \alpha \le 10°$	$10° < \alpha \le 30°$	$\alpha > 30°$
12. Bridge or culvert distance from meander impact point (Simon and Downs 1995)[b]	$D_m > 35$ m	$20 < D_m \le 35$ m	$10 < D_m \le 20$ m	$0 < D_m \le 10$ m
13. Percentage of channel constriction (Simon and Downs 1995)	0–5%	6–25%	26–50%	>50%

Note: Ranges of values in ratings columns provide possible rating values for each factor.
[a]α = approach flow angle to bridge or culvert.
[b]D_m = distance from bridge or culvert upstream to meander impact point.

Stability Indicators and Weights for Stability Assessment Scheme.[54]

Stability Indicator	Weight
1. Bank soil texture and coherence	0.6
2. Average bank slope angle	0.6
3. Vegetative bank protection	0.8
4. Bank cutting	0.4
5. Mass wasting or bank failure	0.8
6. Bar development	0.6
7. Debris jam potential	0.2
8. Obstructions, deflectors, and sediment traps	0.2
9. Bed material consolidation and armoring	0.8
10. Shear stress ratios	1.0
11. High flow angle of approach to bridge	0.8
12. Distance from meander impact point	0.8
13. Percentage of channel constriction	0.8

Overall Rating Ranges.

Description	Rating (R)
Excellent	$R < 32$
Good	$32 \le R < 55$
Fair	$55 \le R < 78$
Poor	$R \ge 78$

Form 6: Minnesota DOT (1991): Weighted Rating of Bridge-Scour Susceptibility

Date:________________
Name:________________
County:________________

MN/DOT BRIDGE SCOUR PRIORITIZATION WORKSHEET

CROSSING DATA:

Bridge #:________ Year Built:______ Route:_________ MP:__________

Stream:____________________________ Location: ________ (S,T,R) ADT:______

Descriptive Location:____

Bridge Plan:______ Hydraulic Data:______ Quad Map:______________

Scheduled Replacement/Repair Date:______________________________

This form is intended for prioritizing bridges for evaluation. The bridges should have been already screened, and determined to require an evaluation. The higher the total number of points, the higher the priority for evaluating that bridge. If you have bridges with known serious scour problems, they should be evaluated and/or repaired first.

For each numbered question, circle the answer that best describes the bridge. Then enter the number of points into the blank at the right. If more than one answer applies, use the answer with the highest number of points. Each question should be answered.

STRUCTURE:

			Points	
1. Category				
a.	Six:	single span, pile foundations	0	
b.	Five:	single span, spread or unknown footings	4	
c.	Four:	multi-span, piers on piling, continuous superstructure	4	
d.	Three:	multi-span, piers on piling, non-continuous superstructure	4	_____
e.	Two:	multi-span, piers on spread or unknown footings, continuous superstructure . .	8	
f.	One:	multi-span, piers on spread or unknown footings, non-continuous superstructure	8	

		Points	
2. Number of Piers in the Main Channel			
a.	No piers in main channel	0	
b.	One pier	1	_____
c.	Two or more piers	2	

Bridge Scour Prioritization Worksheet Page 2

Rock Erodibility Classification for Pier and Abutment Foundations

<u>Erosion Resistant Bedrock:</u>
Granite, basalt, gabbro, quartzite, gneiss. (if not highly broken or fractured)

<u>Semi-Resistant Bedrock:</u>
Slate, argillite, limestone, dolostone, schist.

<u>Erodible Bedrock:</u>
Sandstone, shale, siltstone.

Weathered bedrock (if highly altered) should be treated like a soil, even though it may act like erodible rock in some instances.

3. Pier Foundation

a. No piers, or all piers above flood flows . . . 0

b. Spread or unknown foundations
1. Spread on erosion resistant bedrock 0
2. Spread on semi-resistant bedrock 2
3. Spread on unknown or erodible rock 4
4. Unknown foundation type 5
5. Spread on soil . . . . 6 ______

c. Pile bents, footing/piling or caisson
Are piles driven to bedrock? . . . Yes-No-Unknown
1. Pile depth greater than 40' 0
2. Pile depth 20' to 40' 2
3. Unknown pile depth 3
4. Pile depth less than 20' 5

4. Abutment Foundation

a. Abutments located above flood flows 0

b. Spread or unknown foundations
1. Spread on erosion resistant bedrock 0
2. Spread on semi-resistant bedrock 1
3. Spread on unknown or erodible rock 2
4. Unknown foundation type 2
5. Spread on soil . . . . 3 ______

c. Pile bents, footing/piling or caisson
Are piles driven to bedrock? . . . Yes-No-Unknown
1. Pile depth greater than 40' 0
2. Pile depth 20' to 40' 1
3. Unknown pile depth 2
4. Pile depth less than 20' 2

5. Road Low Point Elev. vs. Low Member Submergence

Bridge Scour Prioritization Worksheet

a. Submergence of low member or overtopping of road low point is improbable 0

b. Low member elevation is above road low point, submergence possible . . . . 1 ______

c. Low member elevation is below road low point, submergence possible 4

HISTORY:

6. Measured Scour at Piers

a. No piers, or all piers above flood flows . . . 0

b. Spread or unknown foundations
   1. No scour hole 0
   2. Scour hole above top of footing 2
   3. Scour hole within limits of footing 8
   4. No measurement taken at piers 7

c. Footing/piling foundations
   1. No scour hole 0
   2. Scour hole above top of footing . . . . 2 ______
   3. Scour hole within limits of footing 4
   4. Piling exposed 6
   5. No measurement taken at piers 5

d. Pile bent foundations
   1. No scour hole 0
   2. Less than 5' of scour 2
   3. More than 5' of scour 4
   4. No measurement taken at piers 3

7. Abutment Type and Condition

a. Spill slope abutments 0

b. Vertical abutments ______
   1. Good condition, plumb 1
   2. Deterioration but plumb 2
   3. Evidence of movement 5

8. Abutment Protection
   a. Random riprap protection in good condition . . 0
   b. Other protection in good condition . . . . . . 1 ______
   c. Protection in poor condition 2
   d. No protection 3
   e. No information available 3

9. Observed Scour at Abutments
   a. No problems 0

Bridge Scour Prioritization Worksheet

b. Minor scour problems . . . . 2 ______
c. Major scour problems 4
d. No observations made 3

10. Observed Debris and Ice Lodged Against Bridge
a. Remote - less than once in 100 yrs 0
b. Slight to Occasional - every 3 - 100 yrs . . . 3 ______
c. Frequent - more than once every 3 yrs 6
d. No available information 4

STREAM GEOMORPHICS:

11. Average Degradation of Stream Bed Since Construction, Not Including Local Scour
a. Less than 1' or stream aggrading 0
b. 1' to 3' . . . . 2 ______
c. Greater than 3' 6
d. No Comparative cross-sections 4

12. Observed Lateral Movement of Stream
a. Stable 0
b. Movement, no threats to bridge . . . . 2 ______
c. Unstable, threatens bridge 6
d. No information available 4

13. Channel Bottom Material
a. Bedrock 0
b. Boulders and cobbles . . . . 2 ______
c. Gravel, Sand, Silt and Clay 4

SITE GEOMORPHICS:

14. Bridge over Mainstream, Tributary Nearby
a. No tributary nearby 0
b. Tributary downstream within 100 ft . . . . 1 ______
c. Tributary upstream within 1000 ft 4

15. Crossing on Bends
a. 0 to 15 degree bend 1
b. 15 to 45 degree bend . . . . 2 ______
c. 45 to 90 degree bend 3

16. Alignment of Piers to Flood Flows
a. No Piers, or all piers above flood flows 0
b. 0 to 5 degrees skew . . . . 1 ______
c. 5 to 10 degrees skew 3
d. 10 to 90 degrees skew 6

OTHER FACTORS:

Bridge Scour Prioritization Worksheet

17. Functional Classification of Road
    Is Bridge Federal Aid? . . . . Yes-No

    a. Rural Systems
        1. Local system 1
        2. Minor collector 2
        3. Major collector 3
        4. Minor arterial 4
        5. Principal arterial 5
        6. Interstate 6

    b. Urban Systems ______
        1. Local system 2
        2. Collector 4
        3. Minor arterial 5
        4. Principal arterial 6
        5. Interstate 7

18. Effect of Road Closure
    a. Detour less than 10 miles . . . . 1 ______
    b. Detour greater than 10 miles 3

TOTAL ______

Form 7: Hunter et alia (1993): Weighted Rating of Bridge-Scour Susceptibility

TABLE 1: SAMPLE PRIORITY EVALUATION SHEET

STREAM NAME RAMAPO RIVER MILE POST 31.78

INITIAL SCREENING

Bridge currently experiencing scour?	
Bridge over stream with erodible bed:	
Piers/abutments with spread footing?	
Superstructure with non-redundant support?	X
Bridge on aggressive stream:	
Active degradation?	
Significant lateral movement?	
Steep slope?	
Checks in any two categories, assign bridge high priority	YES /NO

CRITERION	RATING (1-5)*	WEIGHT**	WxR
Current Status			
Field Observations	3	3	9
Biennial Inspection Reports	3	3	9
Design Features			
Inadequate flood capacity	1	3	3
Channel contraction ratio	2	3	6
Type of foundation	3	3	9
Pier shape	4	2	8
Abutment type (Vertical/spill-thru)	2	2	4
Superstructure - lack of redundancy	5	2	10
Skew	4	2	8
Adequacy of protective measures (riprap etc.)	4	2	8
Channel Hydraulics			
Curvature at bridge	2	3	6
Channel bed (alluvial/rock)	2	3	6
Potential for debris blockage	1	3	3
Stream morphology (confined 1, braided 3, meandering 5)	3	2	6
Near confluence	1	2	2
Channel reach (upper/middle/lower)	3	1	3
Influence of adjacent structure	5	1	5
TOTAL SCORE			105

* LOWEST SCORE IS EXCELLENT CONDITION; HIGHEST SCORE IS CRITICAL CONDITION

** 1 IS LEAST IMPORTANT; 3 IS MOST IMPORTANT