1 Introduction
This technical note is intended for use by those who are responsible for the management of bridges over watercourses that are susceptible to damage or destabilising effects as a result of flood events. This note supplements, and must be read in conjunction with, the requirements for Level 1 – Routine Maintenance Inspection stated in the VicRoads Road Structures Inspection Manual. It provides additional requirements for inspection procedures and reporting which are intended to assist with the identification and management of critical damage to bridges after flooding.

2 Inspections and Assessment
2.1 General
The requirement to inspect after flood events is stated in Section 750 – Routine Maintenance of the VicRoads Standard Specification for Roadworks and Bridgeworks which refers to Section 1.2.4 of the VicRoads Road Structures Inspection Manual. In addition to completing Table 750.D021 – Bridge and Major Culvert Routine Maintenance and Inspection Report, a supplementary report sheet for use during post flood inspections only must also be completed. This report is intended to ensure that critical defects caused by flooding are identified, inspected, recorded and reported. A sample Post Flooding Bridge Inspection Report is included in the Appendix.

Where the term ‘experienced bridge engineer’ is used in this document, this shall be either a bridge engineer employed by VicRoads Technical Consulting Structures or a bridge engineer who is pre-qualified in accordance with VicRoads pre-qualification scheme at the Structures Complex or Proof Engineering level. Bridge Inspectors must have appropriate experience and be capable of making a reliable assessment of a flood-affected bridge.

2.2 Initial Post Flooding Inspection
Structures over severely flood-affected watercourses and those with known vulnerability to flood-damage are to be given priority. An inspection is to be conducted as soon as safe access to the structure is possible. The inspector should perform an initial visual inspection from a safe position. If the structure is under water and invisible, this must be reported and the structure, together with its approach roads, should be closed. Other than monitoring, no further action should be taken until the water-level has subsided and the whole of the structure – i.e. the superstructure and substructure including the piles - is visible.

If the structure is accessible, the inspector should carefully assess the immediate approaches to the structure and the visible parts of the bridge as follows:

- Bridge Approaches (voids in surface, settlement, slippage of embankment)
- Barriers (missing, misaligned, foundation washed away)
- Abutments (displaced, damaged, unsupported, voids)
- Deck/Beams (holes, missing beams, misalignment)
- Kerbs (misalignment, settlement)
- Movement Joints (missing, displaced)
- Crossheads (displaced, damaged, unsupported)
- Piles (missing, displaced, damaged)
- Pile-caps (displaced, damaged, unsupported)
- Changes in river bed (alignment, depth, profile) and visible scouring under bridge foundations
- Debris (accumulation on superstructure, lodged in substructure)

2.3 Initial Actions and Reporting
If there is any doubt regarding the stability of the structure or the adjacent road embankments, the road must be closed immediately.

Any irregularities in the structure, signs of distress or scour damage must be reported to the Principal Bridge Engineer as soon as possible. An initial structural inspection by an experienced bridge engineer must be arranged as soon as practicable in order to determine if the load capacity of the bridge has been affected and the necessary course(s) of action.

A Post Flooding Bridge Inspection Report is included in the appendices to this technical note. The
inspector should photograph the structure, giving particular attention to any irregularities, signs of distress or scour. Copies of the inspection report and the photographs must be sent to:

- The Region
- The Principal Bridge Engineer for the attention of the Manager Bridge Vehicle Loads
- The Manager Regional Services Road User Services Statewide Permits

If the whole of the structure can be inspected, it is clearly undamaged and its load-carrying capacity is unaffected, it can be re-opened to traffic. If the bridge barriers are damaged it may be necessary to provide temporary barriers. Accumulations of debris on or against a bridge must be removed. Care must be taken during removal of debris to ensure that the structure remains stable. If an underwater inspection is required to determine the condition of the foundations and the nature and extent of any damage, it will be necessary to engage a suitably qualified and experienced commercial diver to conduct the inspection. The diver’s qualifications and diving procedures must comply with AS2299 *Occupational diving operations*. The diver must be fully briefed by an experienced bridge engineer regarding the specific requirements for the inspection.

### 2.4 Weight Restrictions

If there is any uncertainty about the serviceability of the bridge following a flood event, the Principal Bridge Engineer may impose one of the following temporary restrictions pending a structural inspection and a formal load assessment:

- Lane closure
- Closure to all vehicles and pedestrians
- Pedestrians only
- Pedestrians and cars only
- Pedestrians, cars and light commercial vehicle only
- All legal vehicles excluding permit vehicles

On completion of the structural inspection and load assessment, the Principal Bridge Engineer may confirm or amend the weight restriction pending repairs or other remedial action. If the Principal Bridge Engineer determines that a weight restriction is not required, the bridge may be opened to all vehicles.

### 2.5 Level 3 Detailed Engineering Inspection and Analysis

A Level 3 Detailed Engineering Inspection is recommended where signs of damage or structural distress are evident. The Level 3 inspection may include a geotechnical investigation and an underwater inspection. Under-water inspections must be conducted as described in clause 2.3.

### 2.6 Load Assessment

On the advice of the Principal Bridge Engineer, a load-rating assessment may be required to determine the capacity of the structure. This shall be based on the post-flooding condition of the structure. Load rating shall be conducted in accordance with AS5100 Part 7: Rating of Existing Bridges.

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*Bridge Technical Notes are subject to periodic review and may be superseded*
Appendix

Background

Scour is the term used to describe erosion of a river-bed by flowing water. Scour may occur rapidly during a single severe flood event. It may also develop gradually over a number of flood events or over a long period of normal flows. Scour at or near to a bridge may undermine bridge foundations and severely affect stability and load capacity. The shape, size and orientation of bridge foundations may amplify the natural turbulence associated with flood conditions. Scour may occur at the bridge or, alternatively, it may commence downstream of the bridge and migrate upstream to eventually affect the bridge foundations. Another effect associated with flooding is deposition of upstream material adjacent to and against a bridge leading to an increase in river-bed level. This is called aggradation and may result in high lateral loads which can also damage the structure. Aggradation may also reduce the freeboard and waterway area under a bridge leading to a heightened risk of inundation and overloading from flowing water and debris.

Bridges and culverts may be damaged by impact from floating debris such as trees and other large objects. Debris may restrict the flow at a bridge or it may accumulate on the structure and impede or endanger traffic and also cause damage through overloading.

Bridge approach embankments may act as barriers to flow in flood conditions, accelerating and channelling the flow of water away from the normal river channel. For example, in flood conditions the highest velocity and the greatest damage may occur under a side-span adjacent to an abutment and not in the main low-flow channel.

Loss of river-bed and fill materials

Bridges that have foundations located in flood-affected water-courses are at risk of scour-related damage. The degree of risk depends on the intensity and frequency of flood-events and on the type of river-bed soils.

The river-bed surrounding piles, pile caps and abutments may be either partly or wholly eroded by scour action. Fill surrounding abutments or Buried Corrugated Metal Structures and the road above may be washed-away resulting in voids in the carriageway adjacent to the structure.

Rates of scour vary with the type of soil in the river-bed. For example, sand and silt may be eroded at flow-velocities under 0.3m/s whereas beaching can resist flow-velocities as high as 5m/s.

River-bed level and channel alignment may undergo significant changes during a flood-event. Visual inspection of the river-bed and submerged parts of a structure may not be possible in the immediate days following a flood-event due to the depth and turbidity of the water.

Scour-related damage may develop slowly over time or may occur as a result of a single high-intensity event. The river-bed profile near at-risk structures should be measured routinely.

Stability

The overall stability of a scour-damaged structure may be compromised leading to a risk of collapse or deformation. Certain older structural forms are more vulnerable to instability as a result of loss of material from around piles. For example, bridges supported by pile bents may have pin-joints where the pile is attached to the cross-head. Piles of this type may rotate at the pin joint if the pile becomes unrestrained as a result of scour.

Load Capacity

The capacity of the structure may be substantially reduced. Pile capacity depends on the presence of the surrounding and underlying soil. Following a recent flood event, several piles were found to be completely exposed and were hanging from the bridge superstructure which had dropped locally as the piles rotated sideways under the effect of water pressure. Piles are very slender and, when exposed in this way, may deflect laterally or may break if hit by debris.

Vulnerable Bridges

Slender piles of small cross-section and certain types of foundation (e.g. shallow spread foundations) are more vulnerable to undermining by scour damage.

Timber bridges and concrete beam bridges without overlays are more vulnerable to damage due to the higher deterioration rate of the these materials. Timber piles in water should be checked below the water level to ensure the pile condition is adequate.

Waterway profile and changes in direction can influence the degree of scour. Bridges on or near to river bends in waterways are more vulnerable to scour damage than those on straight sections.

Buried Corrugated Metal Structures (BCMS) may also be vulnerable to damage as a result of flooding. If the invert of the BCMS is corroded or if the upstream endwall is absent or deficient, flood-waters can flow around the BCMS and wash-away the backfill material. BCMS have been completely washed away in these circumstances leading to an extremely hazardous void in the carriageway. This type of damage can also develop slowly over a period of moderate flow with the final collapse occurring in flood conditions.

Inspection and Risk Assessment

Post-flood inspections must be completed at the earliest safe opportunity.

If there is any doubt about the severity of damage to a structure and its stability, the assessment must be completed by an experienced bridge engineer.

Reporting and Communication

Early identification of flood-damaged structures is essential to road-safety and to the continuity of the road network. The freight and crane industries, in particular, continue to make permit applications for the movement of heavy vehicles during flood events. Both industries may also be involved in flood-recovery activities so it is vital that the safety of movement across a structure is assessed as early as possible. In order to enable permit applications to be processed, inspection of affected structures must be completed as soon as practicable and reports must be submitted to the Principal Bridge Engineer, the Manager Bridge Vehicle Loads and to Road User Services permit officers at the earliest opportunity.

Restricted Access or Closure

It may be necessary to close a lane, close the structure or to impose a load limit. Signs and barriers must be provided on the bridge approaches.
Photographs illustrating typical pile defects

- Bridge deck, mis-aligned due to loss of support from damaged and displaced piles
- Displaced piles, unrestrained after loss of all river-bed material due to scour
- Broken pile and debris

Yackandandah Bridge December 2010

Kiewa Valley Highway Bridge December 2010
Appendix

POST FLOODING BRIDGE INSPECTION REPORT

Road Name: ____________________  Road Number: ____________

Bridge: _______________________

Structure Number: SN___________

Inspection Date: _____/____/_____  Time of inspection: _____:_____  Inspector: ______________________________________

<table>
<thead>
<tr>
<th>Element</th>
<th>Describe problem/Comment or tick NA (not applicable)</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge Approaches (voids in surface, settlement, slippage of embankment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barriers (missing, misaligned, foundation washed away)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kerbs (misalignment, settlement)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck/Beams (holes, missing beams, misalignment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Movement Joints (missing, displaced)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abutments (displaced, damaged, unsupported)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crossheads (displaced, damaged, unsupported)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piles (missing, displaced, damaged)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilecaps (displaced, damaged, unsupported)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changes in River Bed (alignment, depth, profile)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debris (accumulation on superstructure, lodged in substructure)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waterway - comparison of river-bed level to the original design drawings - estimate degree of scour over the life of the structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood level relative to the level of an easily identified datum. e.g. 400 mm below beam soffit.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photos:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other Comments:

Table 1 Post-flooding Inspection Report
<table>
<thead>
<tr>
<th>Element</th>
<th>Inspect for</th>
<th>Action if found</th>
<th>Report to</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach embankments and road surface</td>
<td>Voids, settlement, slippage of embankment, saturated pavement</td>
<td>Lane or Road-closure. May require advice from Geotechnical Engineer.</td>
<td>Region, TCS, RUS</td>
<td>The approach embankments and road surface may contain voids which, on their own, may necessitate road-closure.</td>
</tr>
<tr>
<td>Barriers</td>
<td>Missing, misaligned, foundation washed away</td>
<td>Temporary barrier, Lane or Road-closure.</td>
<td>Region, TCS</td>
<td>May be possible to maintain vehicle movement if temporary barriers, demarcation, speed restriction can be provided.</td>
</tr>
<tr>
<td>Bridge deck and road surface over structure</td>
<td>Missing beams or entire spans or other components</td>
<td>Road-closure followed by assessment by experienced bridge engineer.</td>
<td>Region, TCS, RUS</td>
<td>Extremely hazardous situation. Bridge is unstable.</td>
</tr>
<tr>
<td></td>
<td>Irregularities, depressions or sagging</td>
<td>Lane or Road-closure subject to assessment by experienced bridge engineer.</td>
<td>Region, TCS, RUS</td>
<td>Extremely hazardous situation. Bridge is potentially unstable. Deviations from line and level may indicate that the bridge foundations have been undermined or damaged.</td>
</tr>
<tr>
<td>Debris</td>
<td>Debris which may be wedged against the structure or may accumulate on the structure</td>
<td>Must be removed at the earliest safe opportunity. Possible lane or road closure. Inspect for damage. Arrange assessment by experienced bridge engineer.</td>
<td>Region, TCS, RUS</td>
<td>May continue to overload and damage the structure.</td>
</tr>
<tr>
<td>Piers, abutments, crossheads</td>
<td>Missing, displaced or damaged components</td>
<td>Lane or Road-closure subject to assessment by experienced bridge engineer.</td>
<td>Region, TCS, RUS</td>
<td>If visible. May be displaced, damaged or missing. Irregularities in the road surface or deck over the structure may be evident if piles or sub-structures have been damaged by impact or undermined by scour. Small irregularities may indicate serious structural damage.</td>
</tr>
<tr>
<td>Piles and pile-caps</td>
<td>Broken, deformed or misaligned piles</td>
<td>Lane or Road-closure subject to assessment by experienced bridge engineer.</td>
<td>Region, TCS, RUS</td>
<td>Inspect only if flood-waters have subsided sufficiently. Inspectors must not place themselves at risk of falling into rapidly flowing or deep water. Scour may be visible as voids under pile caps or as exposed piles. Underwater inspection by diver may be required.</td>
</tr>
<tr>
<td>River-bed</td>
<td>Line and level Scour Aggradation</td>
<td>Report. Assessment by experienced bridge engineer. May require advice from Geotechnical Engineer.</td>
<td>Region, TCS</td>
<td>Pile-caps and abutments may be undermined by scour. The river channel may have shifted horizontally – possibly outside of the limits of the structure. The river may have deposited material against and under the structure (aggradation). This may overload the structure laterally may completely block the watercourse under the structure. Underwater inspection by diver may be required.</td>
</tr>
<tr>
<td>Culverts</td>
<td>Voids in road, missing culvert components, loss of fill surrounding culvert. Partial or complete blockage with debris.</td>
<td>Lane or Road-closure subject to assessment by experienced bridge engineer.</td>
<td>Region, TCS, RUS</td>
<td>The fill may be washed away or, in the case of metal culverts, the culvert itself may be washed away. Culverts may be partially or wholly blocked with debris leading to heightened risk of flooding upstream or of over-topping of the road. Poor flow through the culvert may result in erosion of fill surrounding the culvert and potentially to failure of the road surface. Underwater inspection by diver may be required.</td>
</tr>
</tbody>
</table>

Table 2 Advice on the items to be inspected and courses of action that may be required

**Abbreviations:** TCS – Technical Consulting Structures Group; RUS – Regional Services Road User Services