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FLOODWAY INSPECTION AND MAINTENANCE FRAMEWORK

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Cover: Adelaide floods. Source: SA SES Flickr

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INTRODUCTION

Bridges, culverts, and floodways are vital road infrastructures for the operation of a road network. Their application may vary based on geographic and demographic features of the territory. Floodways are common in rural road networks as they provide economic and environmental friendly solutions over bridges and culverts. Floodways play a significant role in the economy of a country by connecting regional communities, farmlands and agricultural areas to city centers. For example, 48% of total agricultural production in Australia in 2006 had been produced from regional council areas, those covering only about 6.9% of Australia's population, 11% of total Australian land mass and 24% of roads in length [1]. Floodways are common in most of these rural road networks and, hence, play a vital role to distribute agricultural and farming products to highly populated city centers. Therefore, healthy operational levels of floodways are of paramount importance to maintain the continuous supply of essential commodities and the economic balance of Australia.

Floodways are different from bridges and culverts in the design and operational aspects. By definition, floodways are sections of roads which have been designed to be overtopped by floodwater during relatively low average recurrence interval (ARI) floods and are expected to return to fully serviceable level after the flood water recedes [2]. Although, floodways are designed to withstand at low flood levels, extreme natural disasters can damage these vital road infrastructures as evident from the 2011 and 2013 Queensland flood events. 58% of floodway structures in the Lockyer Valley Regional Council (LVRC) area in Queensland, Australia, were damaged during the 2013 Queensland flood event leading to operational failures in rural road networks. Floodway damage leads to isolating regional communities and hindering the supply of agricultural products to other regions. In a post-disaster period, the long-term impacts on the community and the economy of the country depend on the speed of re-establishing the fully operational level of those floodways.

FLOODWAY MAINTENANCE

The rehabilitation process of floodways during the post-disaster period includes several steps such as preliminary assessment, detailed evaluation, design and tendering process and reconstruction activities, similar to any other infrastructure. It is obvious that the preliminary and detailed assessment steps can cause an enormous impact on the subsequent operations. Underestimation of the extent of the damage often leads to subsequent failures of floodways during floods with lower recurrence intervals than that they are designed for. This situation can result in frequent repair and/or reconstruction activities causing operational failures in terms of extended travel times and/or distances. On the other hand, overestimation of damage results in overdesigning the structure and hence higher repair/reconstruction costs. In these situations, financial constraints should be thoroughly investigated, particularly in case of widespread natural disasters such as in the 2011 and 2013 Queensland flood events. In such cases, regional councils and government bodies can extend the time frame for the repair/reconstruction period, after prioritization of all activities through a detailed budget evaluation. Correct identification of the extent of the damage will avoid both situations highlighted above and will lead to right decision making in terms of prioritization and reconstruction of damaged floodways. Development of a method to estimate the extent of damage in terms of monetary requirements will assist the regional councils by enhancing the decision making and prioritization processes, considering both short term and long term benefits. Damage index method defined below evaluates repair and reconstruction needs in monetary terms.

DAMAGE INDEX

Nishijima and Faber [3] presented a damage index that is the ratio of the repair cost to the estimated replacement cost. This index measures the severity of damage in terms of the cost for the repair/reconstruction activities. Wahalathantri et al. [4] extended this method to quantify the extent of floodway damage. They divided the reconstruction work of a floodway into eight gross activities, namely: construction of temporary road; demolishing and removing existing structures; reconstruction of concrete roadway crossing; reconstruction of apron; placing geotextile fabric in conjunction with rock fill; construction of rock protection; replacing sign posts and clearing debris material. This categorization is based on the inspections reports for damaged floodways in Lockyer Valley region during 2013 flood event. For each of above eight activities, contribution factors were defined using Equation 1, in which, 'i' represents the i^{th} category from the above list.

$$\text{Contributing Factor for item 'i'} = \frac{\text{Repair Cost for item 'i'}}{\text{Estimated replacement cost}} \qquad \text{Equation (1)}$$

The damage index is then calculated using Equation 2 as given below.

$$\text{DI} = \sum \text{Contributing Factors for items 'i'} \qquad \text{Equation (2)}$$

Wahalathantri et al. [4] defined maximum contributing factors for these eight elements based on cost estimations for 27 floodways across the Left Hand Branch

Road in the LVRC. The extent of the damage is classified into five categories based on the calculated damage indices as below.

1. Complete damage – when the calculated damage index becomes 1 or above. Full replacement can be warranted based on site investigations.
2. Extreme damage – when the damage index is between 0.8 and 1. It is advisable to consider the long-term benefits of the full replacement, rather than considering repair works only.
3. Major damage – when the damage index is between 0.5-0.8. It is advisable to assess the vulnerability of areas that are severely damaged against possible extreme flood event in near future.
4. Moderate damage – when the damage index is between 0.1 and 0.5. Floodways with moderate damage can be easily rectified.
5. Minor damage – when the damage index is less than 0.1. Such incidents may have an insignificant impact on the operational level of the floodway.

The above method estimates the maximum damage index using maximum contributing factors. However, actual damage index can vary if the floodway components are not fully damaged. This discrepancy often leads to overestimation of the repair cost that may result in an extended time frame for reconstruction of damaged floodways. Extended time will cause partial operation for long periods of times, which will reduce the resilience of the community. Therefore, an accurate method to estimate the extent of the damage is an important field of study. Such a detailed method should include a detail inspection report to improve the quality of the assessment.

Although bridges do have an inspection framework/protocol to follow, same is not applicable for floodways. For an example, Queensland Transport and Main Roads do have the bridge inspection manual [5] which outlines inspection procedures, key components of bridges and general format of inspection forms for Queensland. Floodway inspection details received from the LVRC for the 2011 and 2013 flood events do not indicate the existence of such a detailed inspection report or framework for floodways. Similarly, other regional councils may also not utilize standard forms to inspect floodways. If any regional council has a standard framework to assess damage, it is worthwhile to bring this matter into a common discussion forum so that regional councils who own floodways can further discuss and improve the framework towards developing a locally, regionally and nationally accepted framework. Therefore, developing a floodway inspection framework is a timely topic for investigation.

CURRENT INSPECTION GUIDELINES FOR ROAD STRUCTURES

VicRoads, the Queensland Department of Transport and Main Roads (DTMR) and NSW Roads and Traffic Authority (RTA) are the main three road authorities on the east coast of Australia. Inspections of Road structures are a necessary and important part of asset management. By conducting inspections, it provides the information necessary to make current and future decision regarding the level of service required for a network of assets. Perhaps, considered one of the most important aspects of the inspection is the management of the risks [6]. Generally, if defects are identified, they are documented and submitted for further analysis against the perceived risk across the network of assets and the availability of funds. Inspections may also be audited depending on the level of deterioration documented in the previous inspection. This may result in more frequent inspection to monitor the deterioration. An accredited inspector is generally required by three main road authorities to undertake these inspections.

INSPECTION PROCESS

Each state road authority shares a common goal which aims to manage the risks associated with the network of assets. Although, the extent and type of information required differs from state to state. In each of these inspection manuals they generally aim to identify the similarity through tabulation of the data. The topics addressed are the structures each manual cover. The inspection levels considered are generally 1,2 and 3. However, in New South Wales inspection level 4 may be required. Similarities throughout each inspection manual are considered; the frequency of inspections, the scope of inspections, the data collection requirements and the condition state definitions and recommendation for treatment if defects are identified (Transport and Main Road 2016).

THE STRUCTURES COVERED

Vic Roads covers all significant road structures. It also provides relevant information regarding policy, procedure and condition ratings associated with any type of routine inspections [7]. Similarly, DTMR covers all bridge assets and large culverts which contains the necessary information regarding policies, deterioration mechanism and inspection procedure for all types of routine inspections [6]. RTA bridge inspections contain information relating to inspection procedures and condition rating for bridges and large culverts [8]. However, none of these gives a clear guidance on the inspection of floodways.

INSPECTION LEVELS

In general, three levels of inspections consist of a three-level ranking system involving routine maintenance, condition assessment and detailed engineering investigation (Table 1). The definition for each level of inspection is provided by Austroads [9], which is the same as those given in VicRoads and RTA inspection manuals.

Level 1 – Routine maintenance inspection consists of a visual inspection to check the general serviceability of the structure, particularly for the safety of road users, and identify any defects that may cause future problems

Level 2 – Bridge condition inspection consists of an inspection to visually assess and rate the condition of a structure including all components (as a basis for assessing the effectiveness of past maintenance treatments, identifying current maintenance needs, modelling and forecasting future changes in condition and

estimating future budget requirements) and to identify any significant damage or defects requiring urgent repair or replacement.
Level 3 – Detailed engineering inspections and analysis – are investigations intended to provide improved knowledge of the condition, load carrying capacity, in-service performance and other characteristics that are beyond the information obtained from visual only, Level 1 and Level 2 inspections. These inspections generally include a combination of theoretical analysis and field investigation and usually target a specific issue relevant to an individual structure or class of structure.

Inspection Level	State	Inspection type
Level 1	VicRoads (VIC) RTA (NSW) TMR (QLD)	Visual inspection for routine maintenance issues and further inspection pending inspection results.
Level 2	VicRoads (VIC) RTA (NSW) TMR (QLD)	Visual inspection to assess the condition rating of the structure and all its components/elements.
Level 3	VicRoads (VIC) RTA (NSW) TMR (QLD)	Detailed engineering inspection to target specific issues and assess load-carrying capacity of a structure or group of structures. Structural safety inspection of full structure or specific elements to identify and quantify structural issues. Detailed engineering inspection to identify and quantify deterioration and provide a load rating if required
Level 4	RTA (NSW)	Load capacity assessment to determine the load capacity of the bridge.

TABLE 1: INSPECTION LEVELS

FREQUENCY

Frequency of inspection according to VIC Roads technical service [10] '*the minimal period between inspections is six months and a maximum of one year*'. Transport and Main Road [6] also follows the same frequency of inspection. However, RTA inspection frequency is dependent on the observations made by inspector and only if any defects have been identified [8]. A summary of the frequency of inspections are shown in Table 2.

Inspection Level	State	Frequency
Level 1	VicRoads (VIC) RTA (NSW) TMR (QLD)	6 – 12 months maximum According to road maintenance 6 – 12 months maximum
Level 2	VicRoads (VIC) RTA (NSW) TMR (QLD)	2 years - (1 - 5 years) 2 years - (1 - 4 years) 2 years - (1 - 5 years)

Level 3 and 4	VicRoads (VIC) RTA (NSW) TMR (QLD)	When Required

TABLE 2: INSPECTION LEVELS

LEVEL 2 INSPECTIONS

Table 3 shows the common tasks relating the level 2 inspection of concrete road structures and waterways. These are the most relevant to floodway maintenance framework. However, the level 2 inspections can vary widely in the level of detail and documentation across state authorities [11].

Common tasks level 2 inspections	State
Condition rating of components	VicRoads (VIC) RTA (NSW) TMR (QLD)
Condition rating of whole structure	VicRoads (VIC) RTA (NSW) TMR (QLD)
Identify structural defects	VicRoads (VIC) RTA (NSW) TMR (QLD)
Identify structures/components for further inspection	VicRoads (VIC) RTA (NSW) TMR (QLD)
Identify structure/components	VicRoads (VIC) RTA (NSW) TMR (QLD)
Identify supplementary testing	VicRoads (VIC) RTA (NSW) TMR (QLD)
Obtain photographic record	VicRoads (VIC) RTA (NSW) TMR (QLD)
Sounding to measure waterway profile	TMR (QLD)
Underwater inspection	RTA (NSW) TMR (QLD)
Recommend maintenance/repairs	VicRoads (VIC) RTA (NSW) TMR (QLD)
Recommend timeframe for maintenance/repairs	VicRoads (VIC) RTA (NSW) TMR (QLD)

TABLE 3 SCOPE OF COMMON TASKS IN LEVEL 2 INSPECTION, AUSTRALIA

DATA COLLECTION REQUIREMENTS

The inspection procedure varies from state to state. The most significant factor is the scope of works required and the assets databases used by different state authorities.

Level 1 inspection in Queensland and Victoria follow similar procedures whereas New South Wales only reports on significant issue that need to be recorded. A trained inspector is required to make accurate assessments of the assets. Data

Collection consists of the basic information of the inspection and site and any previous documentation and safety equipment required. Reporting any structural integrity issues and document the different degrees of damage and deterioration to the structure component with photograph and detailed description of the impacts.

In Level 2 inspections, the data collection is more similar in Victoria and New South Wales. Queensland's data collection is more specific to each element in the structure. The inspector is required to record the GPS co-ordinates of the structure. Each state also requires photographs of the defects to the structure but that are only used in specific condition states. In Victoria, the inspector is required to take photographs of all condition state 3 and 4 defects whereas in Queensland photographs of condition state 4 defects only are required. In New South Wales, the inspector is not required to document and photograph the defects that maybe present in the existing structure.

In Level 3 and 4 inspections, the data recorded from level 1 and 2 are taken into consideration to carry out the detailed engineering investigation.

CONDITION RATING OF COMPONENTS

Assigning the condition ratings for component of road structures have some difference between each road authority. Below tables summarises the requirements.

Condition state	Description
1	Component is in good condition with little or no deterioration.
2	Component shows minor deterioration with primary supporting material showing the first signs of being affected. Intervention points for maintenance are generally as follows: Minor spalls or cracking of no real concern. Paintwork on steel components with spot rusting up to 5%.
3	Component shows advancing deterioration and loss of protection to the supporting material which is showing deterioration and minor loss of section. Intervention points for maintenance are generally as follows: Large spalls, medium cracking and defects should be programmed for repair works. Paintwork has spot rusting of up to 10%, which is the approximate limit for overcoating
4	Component shows advanced deterioration, loss of effective section to the primary supporting material, is not performing as designed or is showing signs of distress or overstress. Intervention points for maintenance are generally as follows: Very large spalls or heavy cracking and defects should be repaired within the next 12 months. Paintwork beyond repair requires blasting back to bright metal and recoating.

TABLE 4 :VICROADS - CONDITION RATING OF COMPONENTS AND DESCRIPTIONS

Condition state	Subjective rating	Description
1	GOOD ('as new')	Free of defects with little or no deterioration evident
2	FAIR	Free of defects affecting structural performance, integrity and durability. Deterioration of a minor nature in the protective coating and/or parent material is evident.
3	POOR	Defects affecting the durability/serviceability which may require monitoring and/or remedial action or inspection by a structural engineer. Component or element shows marked and advancing deterioration including loss of protective coating and minor loss of section from the parent material is evident. Intervention is normally required.

4	VERY POOR	Defects affecting the performance and structural integrity which require immediate intervention including an inspection by a structural engineer, if principal components are affected. Component or element shows advanced deterioration, loss of section from the parent material, signs of overstressing or evidence that it is acting differently to its intended design mode or function.
5	UNSAFE	This state is only intended to apply to the **overall structure rating.** Structural integrity is severely compromised and the structure **must** be taken out of service until a structural engineer has inspected the structure and recommended the required remedial action.

TABLE 5 :AUSTROADS- CONDITION RATING OF COMPONENTS AND DESCRIPTIONS

In Roads and Traffic Authority of New South Wales, for each element, the estimated quantities or percentages in each condition state are calculated by dividing the total quantity between three to five possible condition states.

Condition state	Description
1	The element shows no deterioration. There may be discolouration, efflorescence, and/or superficial cracking.
2	Minor cracks and spalls may be present but there is no exposed reinforcement or surface evidence of corrosion of reinforcement.
3	Some delamination's, significant cracks or spalls may be present, or some reinforcement may be exposed. Corrosion of reinforcement may be present but loss of section is minor and is not sufficient to warrant analysis to ascertain the impact on the strength and/or serviceability of either the element or the bridge.
4	Advanced deterioration. Corrosion of reinforcement and/or loss of concrete section is sufficient to warrant analysis to ascertain the impact on the strength and/or serviceability of either the element or the bridge.

TABLE 6 :RTA- NSW - CONDITION RATING OF COMPONENTS AND DESCRIPTIONS

Roads and traffic authority [8] have developed a procedure that is used for the maintenance inspection of all RTA bridges and bridge size culverts. The inspection procedure manual describes the steps involved when inspecting bridges and bridge size culverts. It also, aids with collecting consistent and objective measurable condition ratios for the bridge elements. A summary of the step involved are listed below:

- Divide the structure into elements (Elements are coded with descriptions)
- Calculate the total quantities of the elements
- Enter element data into the bridge information system (BIS)
- Prepare bridge inspection report at the bridge site (Level 1 and Level 2 inspections)
- Data input into BIS

COMPONENTS OF A FLOODWAY

The following components have been identified as the components of a floodway that need to be inspected.

Upstream

- Apron
- Rock protection
- Cut off(edge) wall
- Culvert entry
- Stream banks

Downstream

- Apron
- rock protection
- Cut off wall
- Culvert exits
- Stream banks

Roadway

- Road crossing
- Sub base
- Sub grade
- Culvert
- Road signs
- Flood level indicator

Peripheral area

- Approaches
- Approaches signs
- Flooded beyond the floodway extent
- Vegetation (upstream)
- Evidence of creek change.

DEFINING CONDITION STATES FOR EACH COMPONENT OF A FLOODWAY

It is important to investigate current inspection practices to decide how to define condition state for each component of a floodway. For this purpose, floodways in a case study region (Lockyer Valley Regional Council area) were selected. Inspection data for the floodways from 2008 were collected. A sample of the available data is shown in Figure 1.

_ID	RoadName	FloodwayDeckM	PipeMaterial	PipeSize	SlabLength_m	SlabWidth_m	Cells	CellLength_m	Condition	ConditionDate	ConstructionDate
5970	Heise Road	CONCRETE	RCP	300	0	6.8	1	7.32	2	13/10/15	01/01/70
7657	Minton Road	CONCRETE	RCBC	450X300	0	4	1	4.88	2	13/10/15	01/01/87
3790	Woolshed Creel	CONCRETE	NA	NA	0	4.3	0	0	3	13/10/15	01/01/66
7025	Hill Road	CONCRETE	RCP	375	0	4	4	7.5	3	17/08/16	01/01/87
5165	Becky Road	CONCRETE	NA	NA	0	3.8	0	0	4	16/08/16	01/01/91
3579	Douglas McInne	CONCRETE	RCBC	2400X900	0	5.7	6	7.7	2	15/08/16	02/01/00
5153	Beames Drive	CONCRETE	NA	NA	22.3	4.9	0	0	3	26/08/16	01/01/75
7677	Moonlight Parad	CONCRETE	RCBC	600X225	0	7.9	1	9.76	2	30/08/16	01/01/87
5284	Boland Lane	CONCRETE	NA	NA	0	3.6	0	0	3	31/08/16	01/01/87
7448	Lester Lane We	CONCRETE	RCP	225	0	3.5	1	7.32	3	31/08/16	01/01/87
0001	Red Gap Road	CONCRETE	NA	NA	0	2.8	0	0	2	31/08/16	02/01/00
0002	Taylor Road	CONCRETE	NA	NA	0	3.7	0	0	1	28/09/16	28/09/13
0003	Stoney Creek R	GRAVEL	RCP	300	0	0	1	5	2	11/10/16	02/01/00
5553	Dippel Road	CONCRETE	RCBC	1200X600	0	3.7	7	9.76	3	07/10/16	01/01/83
5561	Watkins drive	CONCRETE	TBD	1200X450	0	5	6	4.88	2	07/10/16	01/01/83
0004	Main Camp Cre	CONCRETE	RCBC	1200X600	0	4.8	8	5.3	2	07/10/16	02/01/00
3906	Main Camp Cre	CONCRETE	NA	NA	0	4.6	0	0	1	07/10/16	02/01/00
3538	Thornton Schoo	CONCRETE	NA	NA	0	4	0	0	3	05/10/16	01/01/73
3537	Thornton Schoo	CONCRETE	NA	NA	0	3.9	0	0	3	05/10/16	01/01/73
7280	Kowaltzke Road	SEAL	NA	NA	0	3.7	0	0	TBD	30/06/14	01/01/83
7945	Peters Road	CONCRETE	NA	NA	0	3.9	0	0	2	29/09/16	01/01/87
0005	Peters Road	CONCRETE	NA	NA	0	3.3	0	0	2	29/09/16	02/01/00
7723	Mount Berryman	CONCRETE	RCBC	1200X600	50	5	1	7.32	4	06/12/17	01/01/89

FIGURE 1: SAMPLE DATA FOR FLOODWAYS

Using the available data from 2005, inspections for each asset was identified using the GIS details and they are collated as shown in Figure 2.

_ID	Condition	ConditionDate	ConstructionDate							
005	2	02/08/17	01/01/12							
ue_ID	Valuation_Index	Residual_Value	Gross_Cost	Written_Down_Value	Depreciation_to_Date	Annual_Depreciation	Condition_Value	Original_Cost	Construction_Date	Longitude
	0	1	3636	1800	1836	36	2909	0	22282	429345.3842
_ID	Condition	ConditionDate	ConstructionDate							
007	3	02/08/17	01/01/41							
ue_ID	Valuation_Index	Residual_Value	Gross_Cost	Written_Down_Value	Depreciation_to_Date	Annual_Depreciation	Condition_Value	Original_Cost	Construction_Date	Longitude
	0	1	3552	1048	2504	36	1421	0	01/01/41	429714.7073
ue_ID	Valuation_Index	Residual_Value	Gross_Cost	Written_Down_Value	Depreciation_to_Date	Annual_Depreciation	Condition_Value	Original_Cost	Construction_Date	Longitude
	0	1	3552	1048	2504	36	1421	0	01/01/41	429714.7073
ue_ID	Valuation_Index	Residual_Value	Gross_Cost	Written_Down_Value	Depreciation_to_Date	Annual_Depreciation	Condition_Value	Original_Cost	Construction_Date	easting
	0	0	3552	1119	2415	36	1421	0	01/01/41	429715
)	Valuation_Index	Residual_Value	Gross_Cost	Written_Down_Value	Depreciation_to_Date	Annual_Depreciation	Condition_Value	Unique_ID	Original_Cost	Construction_Date
	0	0	3552	1119	2415	36	1421	0	0	01/01/41

FIGURE 2: DATA ANALYSIS

Using the inspection data for conditions and the available photos, it is proposed to develop a method to identify the condition state for each component of the floodway.

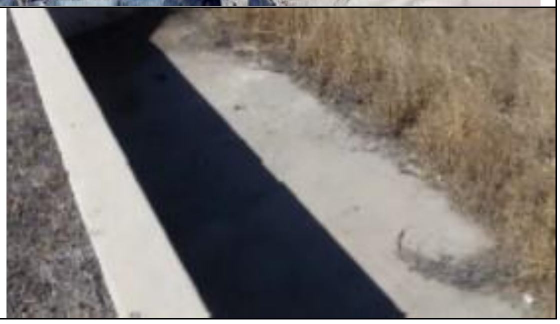
CONDITION STATE 1

VicRoads - Component is in good condition with little or no deterioration.
TMR - Free of defects with little or no deterioration evident
RTA - The element shows no deterioration. There may be discolouration, efflorescence, and/or superficial cracking.

Apron and Rock Protection (US)





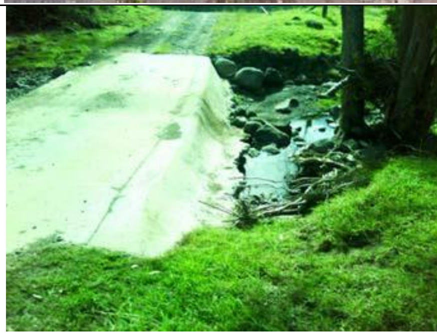
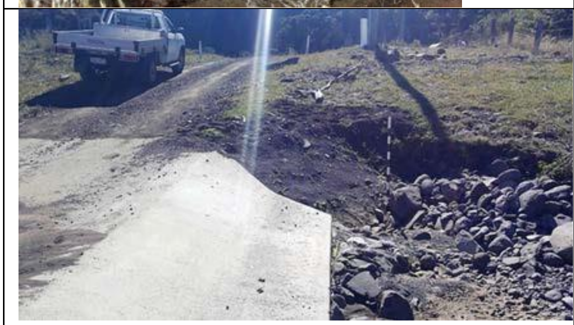



Culvert entry

Apron and Rock Protection (DS)






Culvert Exits





Culvert





Road crossing





Approaches

CONDITION STATE 2

VicRoads - Component shows minor deterioration with primary supporting material showing the first signs of being affected. Intervention points for maintenance are generally as follows: Minor spalls or cracking of no real concern. Paintwork on steel components with spot rusting up to 5%.

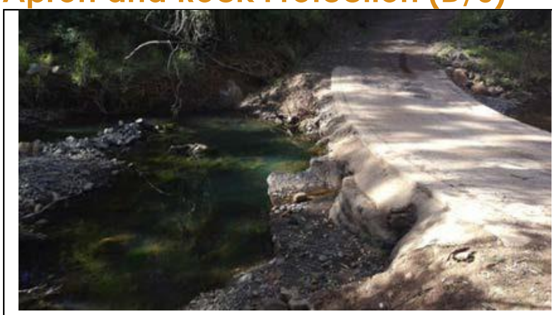
TMR - Free of defects affecting structural performance, integrity and durability.

Deterioration of a minor nature in the protective coating and/or parent material is evident.

RTA - Minor cracks and spalls may be present but there is no exposed reinforcement or surface evidence of corrosion of reinforcement.

Apron and Rock Protection (U/S)

Apron and Rock Protection (D/S)



Culvert exits

Culverts

Road crossing

Approaches

CONDITION STATE 3

VicRoads - Component shows advancing deterioration and loss of protection to the supporting material which is showing deterioration and minor loss of section. Intervention points for maintenance are generally as follows: Large spalls, medium cracking and defects should be programmed for repair works. Paintwork has spot rusting of up to 10%, which is the approximate limit for overcoating

TMR - Defects affecting the durability/serviceability which may require monitoring and/or remedial action or inspection by a structural engineer Component or element shows marked and advancing deterioration including loss of protective coating and minor loss of section from the parent material is evident Intervention is normally required

RTA - Some delamination's, significant cracks or spalls may be present, or some reinforcement may be exposed. Corrosion of reinforcement may be present, but loss of section is minor and is not sufficient to warrant analysis to ascertain the impact on the strength and/or serviceability of either the element or the bridge.

Apron and Rock Protection (U/S)

Culvert entry

Apron and Rock Protection (D/S)




Culvert exits





Road crossing





Culvert


Approaches

CONDITION STATE 4

VicRoads - Component shows advanced deterioration, loss of effective section to the primary supporting material, is not performing as designed or is showing signs of distress or overstress. Intervention points for maintenance are generally as follows: Very large spalls or heavy cracking and defects should be repaired within the next 12 months. Paintwork

TMR - Defects affecting the performance and structural integrity which require immediate intervention including an inspection by a structural engineer if principal components are affected. Component or element shows advanced

deterioration, loss of section from the parent material, signs of overstressing or evidence that it is acting differently to its intended design mode or function
RTA - Advanced deterioration. Corrosion of reinforcement and/or loss of concrete section is sufficient to warrant analysis to ascertain the impact on the strength and/or serviceability of either the element or the bridge.

Culvert exits

Culverts

Apron

Rock protection

Road crossing

FLOODWAY INSPECTION FRAMEWORK

The proposed floodway inspection framework consists of following key elements:

A. Basic information about floodway
B. Notes from previous inspection or repair/maintenance work
C. Basic details of current inspection
D. Inspection records
E. Condition report

BASIC INFORMATION

Contrasts to the other major road infrastructures, floodways do not require regular inspections, and, hence, they are often inspected infrequently or only after a major natural disaster. This inspection practice leads towards making assumptions about the floodway performance prior to a natural disaster. Also, it makes it difficult to distinguish between deterioration due to aging and damage due to a natural disaster. These factors can lead to more uncertainties in judgement or may require re-inspection after referring to the previous condition. The inclusion of basic information minimizes those uncertainties and any needs for re-inspections.

Basic information should facilitate asset identification, location, some design and construction details with suitable sketches or drawings as shown in Table 1. A01-A03 supports floodway identification in terms of asset number, suburb and road name. Type of floodway should be specified under A04. It is recommended to adopt the Austroads Guide [7] to define the floodway type. Austroads guide defines five types of floodways [7]. However, alternative floodway types or slightly modified versions from above five types have been attempted and constructed by regional councils in Australia. For an example, Allen and Rickards [8] presented alternative floodway types with the utilization of soil stabilization methods. Some of those types are being constructed and tested in the Central Local Government Region of South Australia. In such situations, a clear explanation should be given to the type of floodway with the correct reference. Alternatively, a comprehensive study should be performed to include those floodway types in a nationally accepted guideline such as Austroads guide [7]. A05-A11 provides design details of the floodway.

Basic Information	
A01. ID	
A02. Suburb & Road Name	
A03. Local Authority	
A04. Type	
A05. Constructed year	
A06. Design Life	
A07. Number of lanes and load limit	

A08. Construction material				
A09. Design Flood (AEP)	Trafficable		Maximum	
A10. Chainages/Coordinates	Start chainage (Latitude, Longitude)		End chainage (Latitude, Longitude)	
A11. Drawings & Details (dimensions, material)				

TABLE 7 SECTION A OF THE FLOODWAY INSPECTION FRAMEWORK

NOTES FROM PREVIOUS INSPECTION, REPAIR OR MAINTENANCE WORK

Summary of previous inspection reports, repair/reconstruction work will also be important in the decision-making process. This section can include pictures from last inspection to demonstrate the latest status of the floodway. Table 8 shows a general format for this task.

Notes from previous inspection, repair or maintenance work	
B01. Date of last inspection	
B02. Inspected by	
B03. Reason	
B04. Recommendations	
B05. Repair/reconstruction work	
B06. Pictures/sketches	

TABLE 8 SECTION B OF THE FLOODWAY INSPECTION FRAMEWORK

BASIC DETAILS OF CURRENT INSPECTION

Section C is to record current inspection records such as date, time, person/s inspecting and the reason for the inspection. The reason for the inspection can be due to regular inspection procedures, maintenance work or to assess the structure due to the damage caused by a natural disaster or an accident. In the latter case, the nature of the incident should also be included. For an example, flood level, period and annual exceedance probability can be included in the event of a flood event. Table 9 shows the general format for the element C.

Basic details of current inspection	
C01. Date of current inspection	
C02. Time	
C03. Inspected by	

C04. Reason	
C05. Nature of the incident (E.g., flood level, period, AEP in case of flood)	
C06. Pictures/sketches	

TABLE 9 SECTION C OF THE FLOODWAY INSPECTION FRAMEWORK

INSPECTION RECORDS

This section should include a detailed and methodological approach outlining each component of a floodway, failure mechanisms and extent of the damage. This step is the most important step to estimate the magnitude of the damage and hence decisions on repair/reconstruction needs. Therefore, attempts should be made to quantify the damage at all possible instances. A qualitative assessment can be performed if it is hard to undertake a quantitative evaluation.

Table 10 presents the framework to record inspection details according to floodway zones and elements in each of the four zones. Four floodway zones proposed by Allen and Rickards [8] are used in this table. Wahalathantri et al. [5] presented common floodway failure mechanisms and elements based on the inspection records from the LVRC area following the 2013 QLD flood event. These floodway zones and elements are therefore listed in Table 10.

D. Inspection records					
Element		Quantitative Assessement[1]		Qualitative assessment (See notes below)[2]	Notes (such as failure mode, source of damage, etc..) & reference to photos/sketches
		Location/ Dimension	Damage extent (%)	Quality Index	Notes
D01. Upstream Zone					
	Apron				
	Rock Protection				
	Cut-off Wall				
	Culvert entry				
	Stream banks				
D02. Downstream Zone					
	Apron				
	Rock Protection				
	Cut-off Wall				
	Culvert exit				
	Stream banks				
D03. Roadway Zone					
	Road crossing				
	Sub-base				
	Sub-grade				

	Culvert					
	Road signs					
	Flood level indicators					
D04. Peripheral Zone						
	Approaches					
	Approach signs					
	Flooded area beyond floodway extent					
	Vegetation - upstream					
	Vegetation - downstream					
	Evidence on creek changes					
D05. Photos						
Notes:	[1] Report extent and dimension, if the damage extent significantly varies at different sections for a given element					
	[2] Qualitative Assessment					
	Value	5	4	3	2	1
	Condition	Critical	Poor	Fair	Satisfactory	Good

Table 10 Section D of the Floodway Inspection Framework

Table 10 has a provision for both quantitative and qualitative assessments and a column to record any other notes or sketches or reference for photos. The qualitative assessment assigns a value to each element based on the state of the floodway at the time of inspection [9]. The value of 1 indicates that the element is In excellent condition with no significant damage or deficiency. Satisfactory condition means that the floodway is only subjected to minor damage, deterioration and/or misalignment with insignificant effect on the performance. Moderate damage/deterioration levels can be classified as the fair condition. Elements with major or multiple defects that can cause significant impact on the serviceability or the integrity of the floodway should be rated as poor condition. Any element that has failed or failure is imminent should be rated as in critical condition.

CONDITION REPORT

Last section includes a condition report prepared and signed by the person/s who inspect the floodway. Judgement on the extent of damage, repair/reconstruction needs should be outlined here. The method developed by Wahalathantri et al. [5] can be used to rank the repair/reconstruction needs. Maximum contributing factors defined by Wahalathantri et al. [5] should be modified based on the estimated percentage damage for each component.

E. Condition Report			
E01. Damage Index	Repair need as a fraction	Maximum factor for item	Adjusted Contribution factor
Need for temporary access		0.05	

Demolishing existing structures		0.10	
Reconstruction of roadway crossing		0.25	
Reconstruction of apron		0.50	
Placing Geo-textile		0.01	
Reconstruction of Rock Protection		0.05	
Replacing sign posts		0.02	
Cleaning and debris removal		0.02	
DI = Σ(Adjusted contribution factors)			

E02. Level of Damage	Complete DI =1	Extreme DI: 0.8 -1.0	Major DI: 0.5 – 0.8	Moderate DI: 0.1 – 0.5	Minor DI < 0.1
E03. Recommendation based on DI	Replace the structure	Perform a detail analysis considering design life	Critically assess components subject to major damage	Repair activities should perform as quickly as possible	Rectify the problem at the earliest possible time

E04. Other recommendations	
E05. Asset Number:	
E06. Date of inspection:	
E07. Prepared by (Name, Signature and Date):	

TABLE 10 SECTION E OF THE FLOODWAY INSPECTION FRAMEWORK

CASE STUDY

A case study was undertaken to compare the results of the above inspection framework and current condition state of a culvert.

The culvert was selected at random from any culvert that was not in condition state 1 or one of the 436 selected for the data analysis. The random selection and elimination of previously inspected culverts was to mitigate bias. Thereason that no culvert in condition state 1 was selected is that most of those are relatively new and would not demonstrate the validity of the inspection framework.

The following images were taken from a culvert in LVRC. The culvert identity has been withheld at the request from the governing body. The images being used for the case study include the upstream and downstream of:

- Endwall
- Left hand wingwall
- Right hand wingwall
- Left hand pipe
- Right hand pipe
- Apron.

FIGURE 2: IMAGES FOR THE CASE STUDY

Inspection Record				
Upstream	Location/ Dimension	Damage Extent (%)	Condition State	Notes
Pipe from Left to Right	In pipe note any debris, evidence of wildlife or anything noteworty.			
1	Internal	10	1	Minor debris in pipe.
2	Internal	25	2	Cracks in pipe. Evidence of plant life.
Endwall	External	10	1	Needs reseal. Not covering Pipe
Left Wingwall	External	50	2	Cracking throughout. Needs seal
Right Wingwall	External	100	5	Missing
Apron	External	25	2	Evidence of plant life
Toe	External	100	5	Missing
Riprap/Rock Protection	External	100	5	Missing
Scour/Erosion	External	0	1	None evident
Downstream	Location/ Dimension	Damage Extent (%)	Condition State	Notes
Pipe from Left to Right	In pipe note any debris, evidence of wildlife or anything noteworty.			
1	Internal	5	1	Needs reseal.
2	Internal	10	1	Minor debris in pipe.
Endwall	External	10	1	Needs reseal. Not covering Pipe

Left Wingwall	External	60	3	Part missing. Cracks throughout
Right Wingwall	External	60	3	Part missing. Cracks throughout
Apron	External	100	5	Missing
Toe	External	100	5	Missing
Riprap/Rock Protection	External	100	5	Missing
Scour/Erosion	External	0	1	None evident
Sundry				
Roadway	Good condition			
Upstream Vegitation	Ok 1/5			
Downstream Vegitation	Fair 2/5			
Signage	Ok 1/4			

TABLE 11: INSPECTION RECORD

Structure Condition State			
Element	Damage (%)	Factor	Adjusted Damage (%)
Average damage for pipes	12.5	0.4	5
Endwall	10	0.1	1
Average damage for wingwalls	67.5	0.08	5.4
Apron	62.5	0.1	6.25
Toe	100	0.02	2
Riprap/rock protection	100	0.1	10
Scour	0	0.2	0
Condition Damaged			29.65
Condition State	Damage (%)		
Condition State 1	0 - 20		
Condition State 2	21 - 40		
Condition State 3	41 - 60		
Condition State 4	61 - 80		

TABLE 12: CASE STUDY STRUCTURE CONDITION STATE

Damage index			
Repair Proceedure	Repair needed as a fraction	Factor	Adjusted Contribution Factor
Temporary Access	0.5	0.05	0.025
Demolishing of existing structure	0	0.1	0
Reconstruction of culvert	29.65	0.5	14.825
Reconstruction of roadway	0	0.25	0
Replacing geo-textile	100	0.01	1
Reconstruction of riprap	100	0.05	5
Replacing sign posts	0	0.02	0
Cleaning and debris removal	20	0.02	0.4
DI = Σ Adjusted Contribution Factors	MUST EQUAL 1	1	21.25

TABLE 13: CASE STUDY DAMAGE INDEX

Level of Damage	Complet e	Extreme	Major	Moderate	Minor
Damage Index	1	0.8 - 1	0.5 - 0.8	0.1 - 0.5	< 0.1

Recommendations based on the damage index	Replace the structure	Perform a detailed analysis considering the design life	Critically assess compon e nts subject to	Repair activities should perform as quickly as possible	rectify the proble m at the earliest
Other recommendations	Mowing of downstream not required with geotextile placement				
Asset ID	Withheld				
Date of Inspection	10-Sep-18				
Prepared by					
Name					
Id					
Signature					
Date					

TABLE 14: CASE STUDY RECOMMENDATIONS

The culvert featured in this case study received a condition state 2 rating from LVRC in 2015. This inspection framework also gave the culvert a condition state 2 but also gave it a damage index of 21.25. This damage index can be used to rate culverts against each other to determine maintenance priority.

SUMMARY

The following work has been completed as part of this maintenance framework for small structures.

- Conducted a comprehensive literature review on the available maintenance guidelines for road structures.
- Collected associated photos for each element of the floodways/ culverts under the four condition states.
- Used and expanded the already developed inspection framework to suit the small road structure maintenance.
- Demonstrated the developed framework using a case study.

RECOMMENDATIONS

It is recommended that further work be undertaken into creating more accurate values for the culvert element factor in determining the condition state of the structure.

Further work could also be completed in gathering further images of culverts and having the culvert elements rated. The more comprehensive the image library is of culvert elements the less room for error with diagnosing the condition state and damage index of culverts.

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