Esperance Culvert Rehabilitation

Assessment Report

South Coast NRM

12 October 2021

→ The Power of Commitment

GHD Pty Ltd | ABN 39 008 488 373
10 Victoria Street, 1st Floor
Bunbury, Western Australia 6230, Australia
T +61 8 9721 0700 | **F** +61 8 9721 0777 | **E** bunmail@ghd.com | **ghd.com**

Printed date	12/10/2021 10:48:00 AM
Last saved date	12 October 2021
File name	
Author	Lucy Ellis, Tauseef Hassan
Project manager	Erin Ashley
Client name	South Coast NRM
Project name	Esperance Culvert Rehabilitation
Document title	Esperance Culvert Rehabilitation | Assessment Report
Revision version	Rev 0
Project number	12555645

Document status

Status Code	Revision	Author	Reviewer		Approved for issue		
			Name	Signature	Name	Signature	Date
S4	0	Lucy Ellis, Tauseef Hassan	Nick Deeks	* On file	Jeff Foley	Jeff Foley 2021.10.12 13:49:34 +08'00'	

Executive summary

South Coast Natural Resource Management (NRM) has asked GHD to investigate engineering and management options to remediate erosion along Coobidge Creek, immediately downstream of the South Coast Highway culvert. Coobidge Creek flows into Lake Gore, a designated Wetland of International Importance. GHD's options assessment will be used to apply for National Resources Management Grant Applications to fund stabilisation of a 350 m reach downstream of the South Coast Highway.

GHD reviewed the available information regarding historic creek change, the creek response to the 2017 flood, and the current geomorphology and functioning of the creek. In 1970 (the earliest available aerial photograph), Coobidge Creek was heavily modified. Much of the riparian corridor had been removed due to agricultural clearance. Between 1970 and 2005, the creek narrowed from a broad, multi-thread system to a narrow, single-thread channel within a vegetated high-flow riparian system. Narrowing of the high flow and low flow creek channels continued, aided by agricultural clearance and the establishment of a densely vegetated riparian corridor, until a large flood in 2017.

The 2017 flood caused the creek to avulse into a new channel, leaving a remnant island of densely vegetated riparian corridor. The post-flood creek reverted to a broad, multi-thread channel, which was incised appreciably deeper than the pre-flood channel. The pre-flood channel flowed through resistant red duplex soils, whereas the post-flood channel has incised into deep uniform sands. During the flood, the vertical incision through the sandy soils occurred until a resistant weathered rock layer was encountered and lateral erosion predominated. The post-flood channel is approximately 50 m wide, with banks approximately 1.7 m high. It is estimated that over 17,000 m^2 of soil was lost to erosion. A 0.9 m scour hole has formed downstream of the highway culvert and upstream of a resistant natural cross-channel bar. Prior to 2017, the creek flowed sharply to the left (east), but now flows sharply to the right (west).

An assessment of peak flows and culvert capacity was carried out. Using a catchment area of 162 km^2, and using the Wheatbelt rational method for peak flow assessment, the 100 year return flood was calculated to be 308 m^3/s. Using a culvert blockage factor of 25% and HY-8 analysis, the maximum culvert discharge was calculated to be 163 m^3/s, somewhat lower than the maximum calculated peak flow.

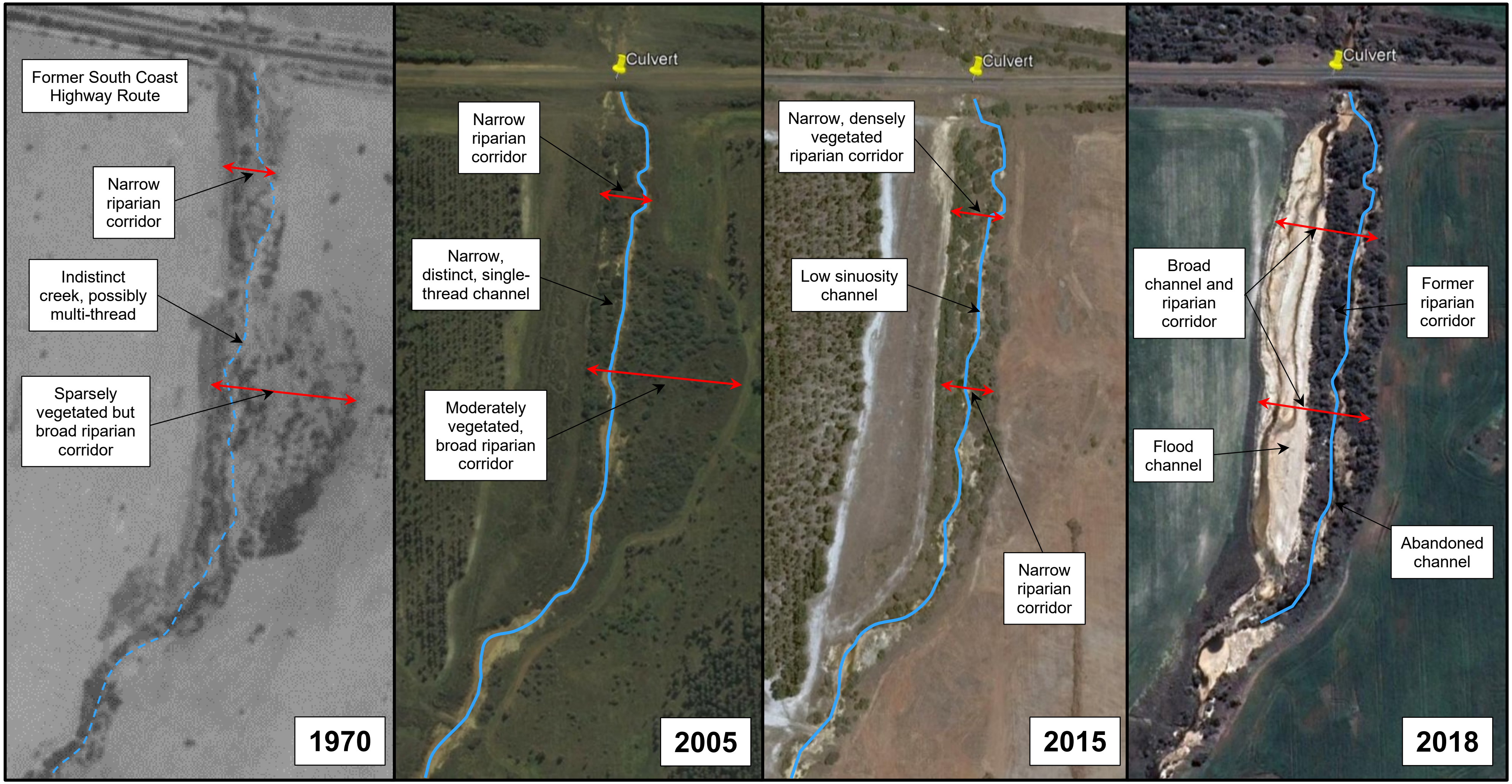
GHD considered the geomorphological functioning of Coobidge Creek and concerns raised by DWER to assess suitable options for flow and erosion control. Three options were reviewed:

- **Option 1**: installation of a flow diversion bund encouraging the creek to re-occupy the abandoned pre-flood channel. To be successful, this would require infilling of the post-flood channel, significant widening of the pre-flood channel and removal of riparian vegetation to prevent future avulsion.
- **Option 2**: stabilisation of the post-flood avulsion channel. This would accommodate the majority of flood flows, but the natural adjustability of the channel would be compromised by the installation of the right bank protection and the naturally resistant bed materials. Flow velocities and erosivity are likely to increase, and increased erosion of downstream reaches is likely. Imported material is likely to be required to stabilise the right bank.
- **Option 3**: the creation of a broad, quasi-stable channel through the removal of some of the pre-flood riparian corridor and 'soft' engineered stabilisation of the avulsion channel. This is GHD's preferred option as it would allow the natural character, morphology and geomorphic functioning of the creek to be re-established. This option unusually recommends the removal of part of the mature pre-flood riparian corridor, in order to accommodate the full range of anticipated flood flows and to remove acute meander bends downstream of the resistant sediment bar. The removal of existing vegetation would be offset by the establishment of a full riparian corridor along both banks and in-channel vegetation. The channel would be designed to allow net throughput of sediment once fully established (i.e. no significant erosion or deposition within reach).

In addition, it is recommended that the short section of the creek just downstream of the culvert is modified by infilling the scour hole, cutting a notch in the resistant bar and stabilising the banks to limit widening.

GHD has presented a draft management plan for the rehabilitation of the study reach. Initially, informal monitoring of right bank erosion could be considered, possibly through engagement with the landowner. A conceptual channel design, based on Option 3 is presented, with an indicative planform and cross-section. It is recommended that this is used as a guideline to inform applications for funding and as a basis for future detailed design. This concept design should not be used for construction. GHD's recommendations have been made in alignment with the DWER recommended resources *Water and River Commissions River Restoration Manual 10: Stream Stabilisation* (WRC RR10, 2000) and *Manual RR18: Stream Channel and Floodplain Erosion* (WRC RR18, 2002).

Further investigations would be required prior to progressing the concept design through to detailed design, including a full geomorphological assessment, a detailed site survey, a geotechnical investigation and hydrologic/hydraulic modelling. These investigations could then be used to progress the concept design through to a detailed channel rehabilitation design.



Comparison of Coobidge Creek study reach in 1970, 2005, 2015 and 2018 (NOTE: images are not orthorectified, and are not to scale)

Conceptual remediation design planform of Coobidge Creek

Contents

Table index

Figure index

Appendices

1. Introduction

1.1 Purpose of this Report

South Coast Natural Resource Management (NRM) has asked GHD to investigate engineering and management options to remediate erosion along Coobidge Creek, immediately downstream of the South Coast Highway culvert. Coobidge Creek flows into Lake Gore, a designated Wetland of International Importance. GHD has assessed the recent evolution of the channel, and the response to the 2017 flood, and proposed options for a sustainable creek alignment and morphology. Our assessment included a site visit and desk study of available information.

GHD understands that our advice will be used for Natural Resources Management (NRM) Grant Applications to fund stabilisation of this section of the creek. Our report has considered the Department of Water and Environmental Regulation (DWER) responses to the landowner's application to remove vegetation from the creek, and to 'train' the creek into a new wider, deeper channel (DWER, 10 October 2017).

1.2 Scope and Limitations

This report: has been prepared by GHD for South Coast NRM and may only be used and relied on by South Coast NRM for the purpose agreed between GHD and South Coast NRM.

GHD otherwise disclaims responsibility to any person other than South Coast NRM arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the proposal.

The opinions, conclusions, and recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

2. Site Background

2.1 Coobidge Creek and Locality

This report has assessed a 350m reach of the river, downstream of a culvert under the South Coast Highway, 46.7km west of Esperance. Prior to a large flood in 2017, the study reach of Coobidge Creek was narrow with a well-established, densely vegetated riparian corridor. The creek alignment veered sharply left immediately after the culvert, and was characterised by a narrow, relatively straight channel. During and after the flood, the creek avulsed (abandoned the old channel and formed a new one), bypassing the right bank riparian corridor and forming a new, broad, deep channel. This new channel is eroding laterally into agricultural land.

Coobidge Creek is one of two major tributaries flowing south through agricultural land into Lake Gore (see Figure 1). Lake Gore is a Ramsar site, and a designated Wetland of International Importance. The wetland system of Lake Gore provides habitat for a diverse range of waterbirds (including marine and migratory species). Therefore, any degradation of upstream tributaries and potential for eroded sediment to enter the lake system are of concern. Sedimentation and nutrient runoff from agricultural land has been identified as a primary threat to the wetland of Lake Gore.

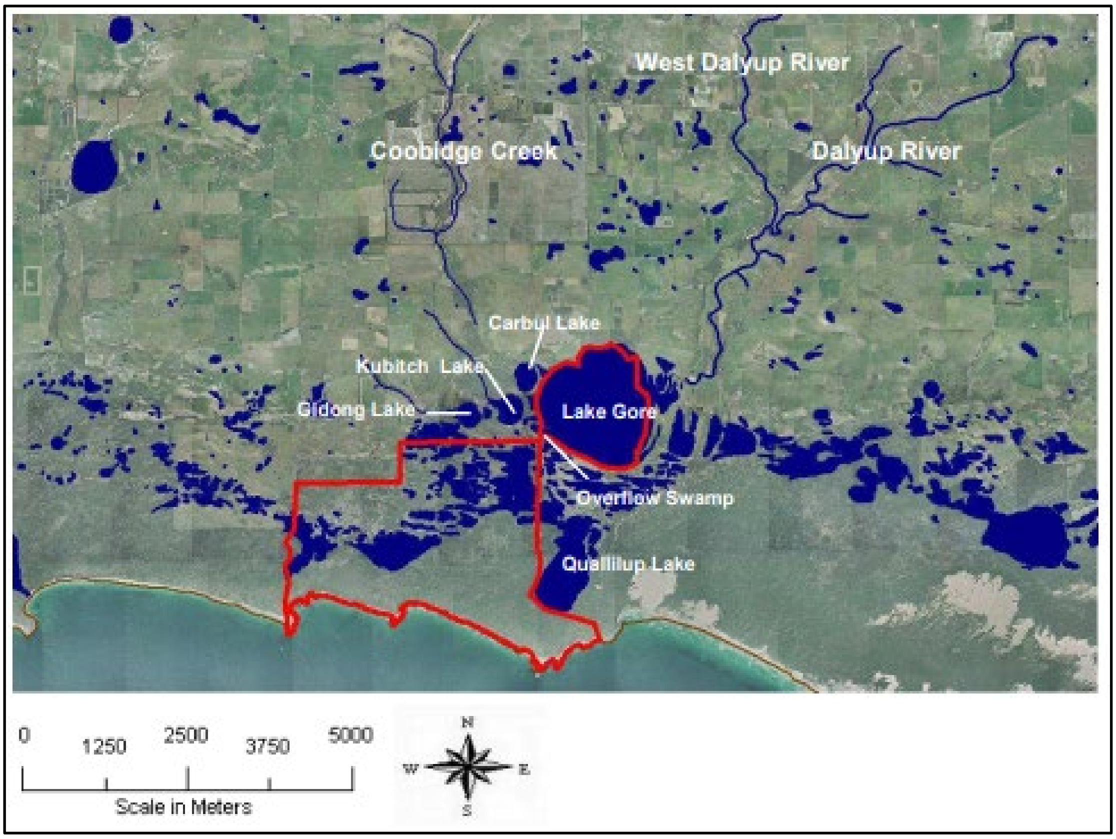


Figure 1 ***Coobidge Creek and the Lake Gore Ramsar site (shown in red; Source DEC, 2009[1]).***

[1] Department of Environment and Conservation (2009). Ecological Character Description of the Lake Gore Ramsar Site: A Report by the Department of Environment and Conservation. Prepared by G.Watkins, Department of Environment and Conservation, Perth, Western Australia.

2.2 Surface Geology and Soils

The study area is characterised by shallow, ancient granitic gneiss (a metamorphic granite). Rock outcrops downstream of the study reach. These outcrops form rounded, low-elevation hills, and constrain both agricultural development and the location of Coobidge Creek. The Esperance Land Resource Survey (Overheu *et al.*, 1993[2]), specifically covers the study reach, noting that the area is characteristic of the Young Land System, typified by deeply incised Dalyup River and Coobidge Creek systems. The valley floors are described as moderately saline with broad surface depressions. Gneiss outcrops regularly, forming bed elevation controls in the mid- to upper-reaches. The soils in the area are described as yellow duplex soils (soils which have a marked difference in texture between their topsoil and subsoils). These have shallow sandy topsoils with a blocky, columnar clay subsoil, which can be dispersive and prone to water erosion. Deep sandy soils are also found in places on the alluvial plains. Our assessment indicates that the pre-2017 channel probably flowed through red duplex soils (Y1 map unit), whereas the post-flood channel has incised into deep uniform sands (Y2 map unit). The incised channel intercepts a resistant layer, which is clay-rich and gravelly in places. This is thought to be highly weathered bedrock.

[2] Overheu, T D, Muller, P G, Gee, S T, and Moore, G A. (1993), Esperance land resource survey. Department of Agriculture and Food, Western Australia, Perth. Report 8.

3. Historic Creek Change

An assessment of available aerial imagery from 1970, 2005, 2012 and 2018 was assessed to examine morphological changes to over this period (see Figure 2).

The 1970 image shows that Coobidge Creek had already been heavily modified. The creek flows beneath the South Coast Highway, but the type of flow-conducting structure is not visible. Much of the riparian corridor had been removed during agricultural clearance, although some broader sections of sparse vegetation still remained. The creek itself was indistinct, and may have comprised several smaller channels (multi-thread or braided) in sections. The reaches up and downstream of the study reach also indicate similar characteristics. In some sections, the creek diverged into two or more entirely different channels (known as an anastomosing pattern). Creeks typically evolve multi-thread channels when the sediment inputs are high, for example, as a result of clearance of the protective cover of vegetation.

By 2005, the creek channel had become a distinct, single-thread channel. The riparian corridor is still broad in sections. Vegetation appears to be better established than in the earlier image. Between 1970 and 2005, the South Coast Highway had been realigned, and a new culvert constructed for Coobidge Creek. Downstream of the culvert, the creek bends acutely to the left (east), possibly to occupy a former channel. The planform morphology is unusually straight, indicating that some form of straightening or channelisation may have occurred. There is a possibility that this may have occurred naturally due to the narrowing of the riparian corridor or establishment of more dense riparian vegetation.

The 2015 image indicates that the narrowing of the riparian corridor has continued since 2005, as a result of agricultural encroachment. The creek appears slightly more sinuous, but the channel is still narrow and single thread. This may indicate development of a more naturally sinuous channel following straightening.

The 2017 flood was one of the largest in recorded history, resulting in closure of sections of the South Coast Highway. During this flood, as mentioned in the previous section, the pre-2017 channel of Coobidge Creek was abandoned, and the floodwaters occupied a new channel further west. This new channel is broad, with flows splitting into at least two low-flow channels. The avulsion left the densely vegetated former riparian corridor virtually intact.

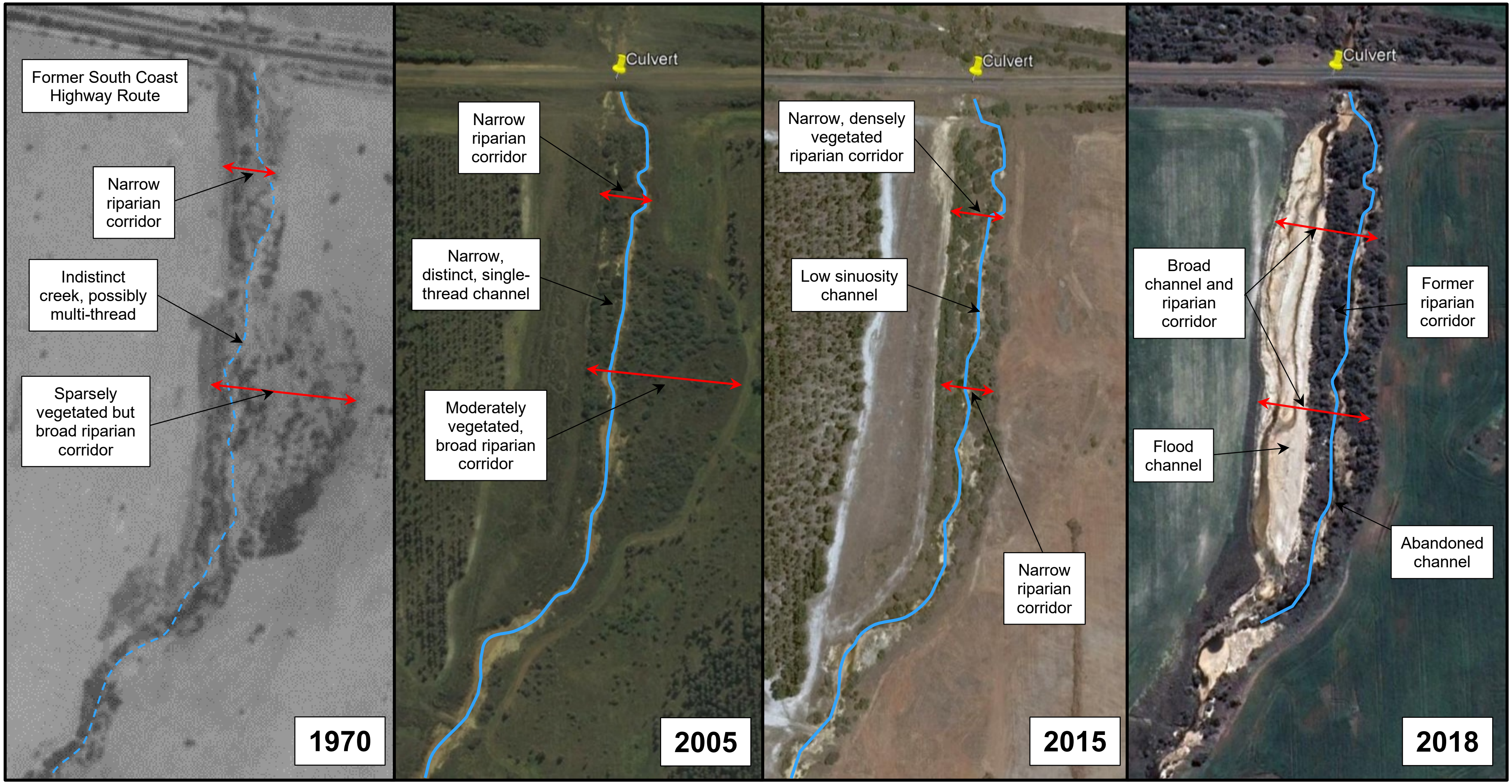


Figure 2 *Comparison of Coobidge Creek study reach in 1970, 2005, 2015 and 2018 (NOTE: images are not orthorectified, and are not to scale)*

4. Impact of the 2017 Flood

In 2017 a major flood occurred, causing an avulsion of the creek into a new channel to the west of the original. This new channel was approximately 50 m wide, encroaching on the adjacent agricultural land.

Channel Avulsion

The historic evolution assessment of Coobidge Creek indicates that the channel dimensions and character had adapted to narrowing of the riparian corridor and anthropomorphic alteration between 1970 and 2017. It is likely that the lack of large floods during this period enabled the creek to form a single-thread channel constricted by dense vegetation. However, this channel did not have sufficient capacity to accommodate the high flow discharge of the 2017 flood. In addition, during flood events, channel flows typically become less sinuous, adapting to the increased velocity and volume of water. Therefore, the acute meander bend in the pre-flood channel downstream of the culvert was bypassed, resulting in the channel avulsion. The dense vegetation of the (now mid-channel) riparian corridor may have acted almost as a levee or barrier. As the channel straightened, this vegetation diverted the flood flows further to the west. Fundamentally, during the 2017 flood, a combination of these factors resulted in the creek taking the path of least resistance and avulsing into the new channel.

Influence of Bed and Bank Material

A natural bed elevation control is present just downstream of the culvert (see Figure 5). This appears to have been responsible for diverting the low flow channel to the left prior to the 2017 flood. It is unclear whether this acute bend existed prior to the culvert construction, or developed following construction of the culvert. A deep scour hole formed upstream of the natural control, which is now approx. 0.9 m deep. The scour hole is typical of high velocity flows leaving a concrete lined apron and scouring the relatively more erodible natural bed materials. The avulsed post-flood channel takes an equally acute bend to the right (west) downstream of this natural bed control.

The pre-flood channel flowed through an incised channel with resistant bed and bank materials. The avulsion channel is characterised by highly erodible sandy banks, but has intersected resistant bed materials throughout the study reach, which act as bed elevation controls. During the flood, as the creek was unable to adjust vertically once it had incised to the resistant material, lateral erosion predominated. This resistant bed material is likely to affect future channel development, causing flows to preferentially erode laterally, rather than vertically.

Post-Flood Morphology

The channel of Coobidge Creek is now characterised by steep, high, sandy banks, with a bed comprising broad outcrops of resistant material incised by deep pools. Riling of the resistant material exposed at the base of the sandy banks indicates the possibility of dispersive clays. The resistant outcrops currently control the low-flow channel location, splitting the flow into at least two channels.

Broad, sandy, erodible bars have been deposited since the 2017 flood. These indicate a substantial quantity of material still passing through the system, possibly as a result of upstream erosion during the flood. Upstream, there are currently similar broad, unvegetated reaches that may also be temporary sediment stores. It may take some time for this sediment to move through the current system and a quasi-equilibrium channel form to be regained.

Since the flood, a berm (wedge) of collapsed material has accumulated along the base of the right bank. This has been stabilised by grassy vegetation. In-channel vegetation has also started to become established.

Figure 3 *Coobidge Creek during the 2017 flood, looking downstream into the avulsed channel from the South Coast Highway, with the former alignment within the dense vegetation to the left of the photograph*

Figure 4 *Post-flood channel of Coobidge Creek after 2017 floods, looking upstream towards the South Coast Highway culvert*

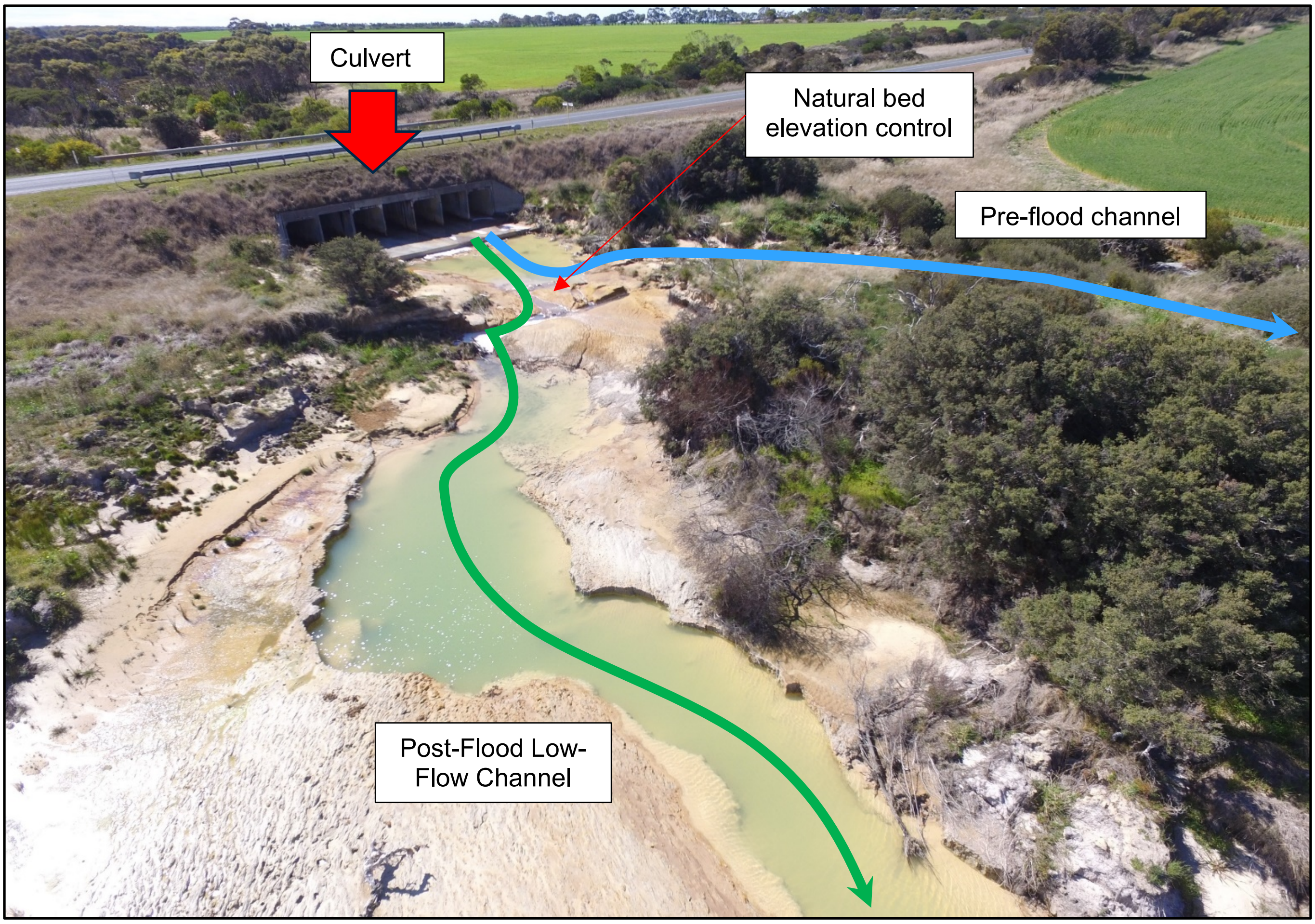


Figure 5 Aerial view of the original and flood channels

Figure 6 Post-flood avulsion channel in 2021, showing resistant bed elevation controls, multi-channel system and right bank protected by vegetated berm

Figure 7 *Incised bank of flood channel, with vegetation-stabilised berms protecting right bank. Person is standing on a resistant outcrop perched above the current low-flow channel*

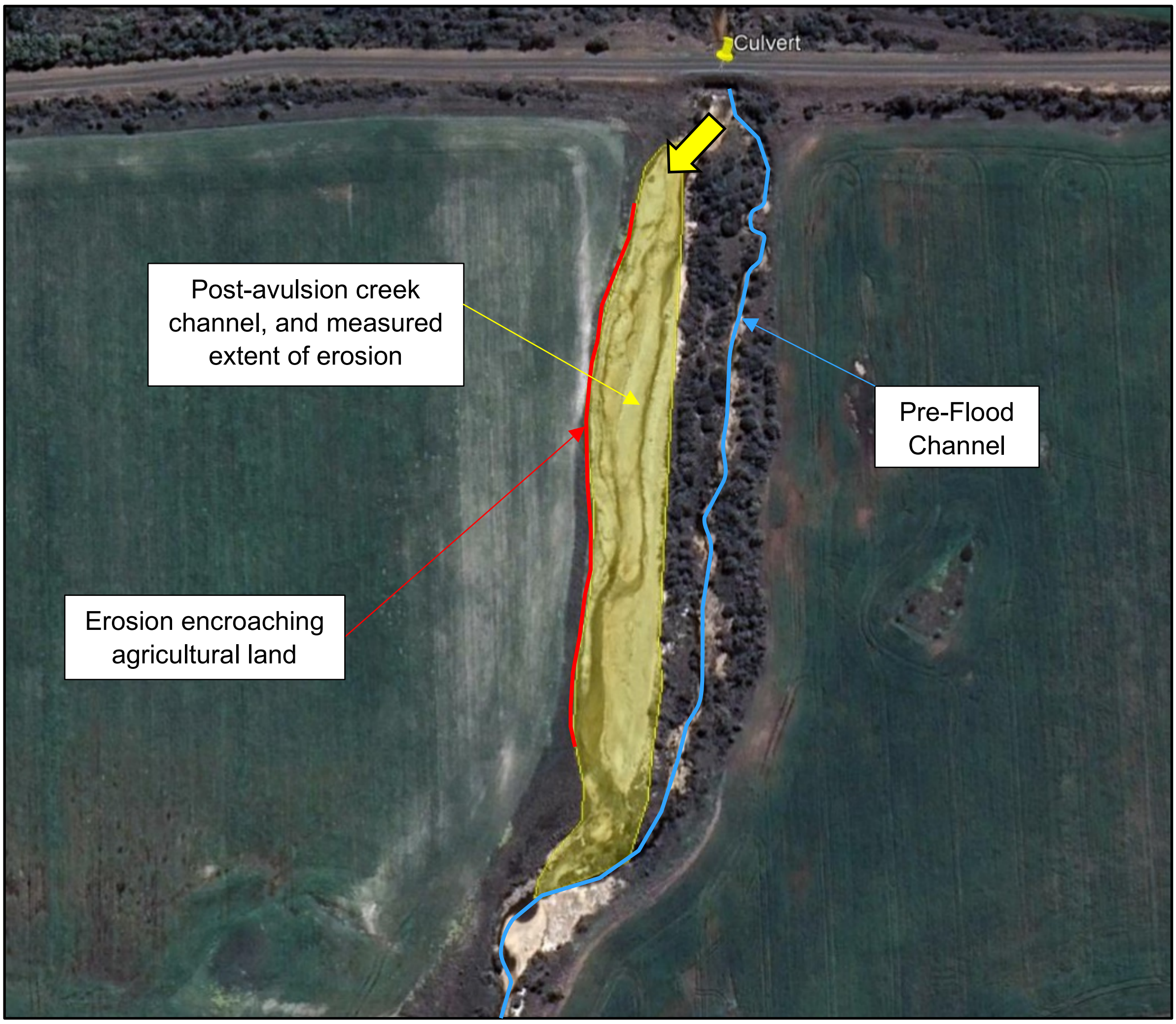


Figure 8 *Coobidge Creek avulsion and erosion during and after 2017 flood*

To date, more than 17,000 m^2 of land has been eroded due to the avulsion of Coobidge Creek. The agricultural land buffer has been completely eroded, in some cases, with lateral erosion beginning to encroach worked arable land. The volume of soil lost to erosion is approximated as follows:

– Eroded area over 17,000 m^2 (Figure 8)
– Depth of soil cover eroded up to 1.7 m (Figure 7)
– Total volume of erosion up to 30,000 m^3

Given the proximity to agricultural land, it is possible that the eroded sediment was contaminated by fertiliser. Both sediment and agricultural nutrients present a hazard to Lake Gore's ecological values.

5. Peak Flow and Culvert Capacity Assessment

The catchment delineation of the culvert is carried out using the DEM (Digital Elevation Model) from the SRTM database. The output of the hydrological analysis using ArcGIS is shown in Figure 9. The catchment area of the culvert is 162 km^2.

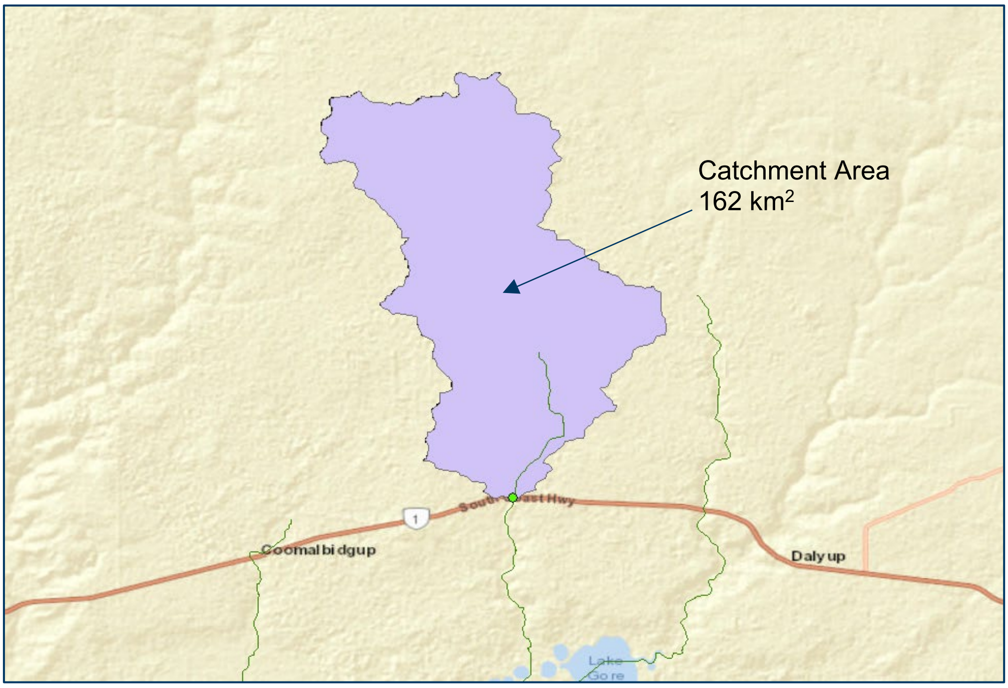


Figure 9 ***Coobidge Creek catchment***

The RFFE (Regional Flood Frequency Estimation) model for the Esperance area (and arid zone) is unavailable. Therefore, the peak flow assessment was carried out using the Wheatbelt rational method as below:

$Q_Y = 0.278 \times C_{10} \times (C_Y/C_{10}) \times I_{tc} \times A$

Catchment Area = A = 162 km^2 (as per Figure 9)

$t_c = 0.76\ ^{A0.38}$ $= 0.76 \times 162^{0.38} = 5.25$ hours

Therefore, the I_{tc} shall be based on 1% AEP (or 100 ARI) and time of concentration of 5.25 hours

I_{tc} = 14.7 mm/hr (see Appendix A)

L = Main stream length = 8.9 km

$C_{10} = 3.46 \times 10^{-1} \times L^{-0.42}$ $= 3.46 \times 10^{-1} \times 8.9^{-0.42} = 0.138$

$C_{100}/C_{10} = 3.37$

1% AEP Flow (100 Year ARI) = $Q_{100} = 0.278 \times 0.138 \times 3.37 \times 14.7$ mm/hr $\times$ 162 km^2

$Q_{1\%AEP} = 308.2\ m^3/s$

Using a culvert blockage factor of 25% (based on Australian Rainfall and Runoff Culvert Blockage Guidelines, 2015), and culvert dimensions of 17.7 m wide and 2.4 m high, the culvert carrying capacity was assessed using HY-8 Analysis. This indicated that the maximum culvert discharge was only 163 m^3/s, somewhat lower than the maximum calculated peak flow.

6. Creek Stabilisation Options Assessment

GHD has considered the geomorphological functioning of Coobidge Creek, as per the outcome of the field and desktop assessments, to develop suitable options for flow and erosion control. In our considered opinion, there are only three possible options, as follows:

- **Option 1**: Install a flow diversion bund to encourage the creek to re-occupy the abandoned channel
- **Option 2**: Install bank protection to encourage the creek to remain in its post-flood channel, and reduce the possibility of further right (west) bank retreat
- **Option 3**: Remove the vegetation between the former and current channels, establish a broad creek with a narrow low-flow channel and a wide high-flow channel.

These options will require further investigation to establish bed and bank material properties, and a careful detailed design that accommodates the full range of anticipated flows (from dry/very low to >300 m^3/s).

Shortly after the 2017 flood, local landowner, Mr Burnett, applied to clear the former riparian corridor dividing the pre-flood and post-flood channels. DWER refused this application on the grounds that this would present an unacceptable risk to biodiversity values, water quality and land degradation. Their concerns were as follows:

- Environmental impacts to Lake Gore Ramsar wetland downstream of the proposed clearing site. Clearing may increase existing levels of salinity, sedimentation and nutrients within Lake Gore and the associated seasonal wetlands. Sedimentation is a key threat to Lake Gore Ramsar Wetland.
- Risk of increased flooding across the property.
- Increased erosion on the property from removal of riparian vegetation from Coobidge Creek.
- Risk of further erosion and land degradation of the Coobidge Creek from subsequent stream channel instability from increased water velocity.
- Cumulative impacts of altered hydrology resulting from clearing in the catchment of Lake Gore Ramsar site.
- Climate change is predicted to increase the intensity of extreme rainfall events and the resulting flooding and erosion will be ongoing management concerns.

In addition, the following advice is presented:

- Removing the native vegetation and deepening and widening Coobidge Creek will reduce the stability and increase the flow velocity within the channel. This will likely result in increased erosion, bank undercutting and collapse.
- Removal of riparian vegetation and excavation of Coobidge Creek to make it deeper will not redirect future water flow. Future flood water will still take the path of least resistance and flow through the existing breakout area.
- Based on the above, the 'stream training' approach is unlikely to achieve [the] objective of reducing erosion and controlling future flood events.

6.1 Option 1: Reoccupation of Abandoned Channel

Option 1 proposes the installation of a flow-diversion bund and channel training works to encourage the creek to re-occupy the pre-flood abandoned channel. Typically, in cases where flows have avulsed from their natural location, it is desirable to reinstate this pre-migration course. However, in this case, there are several factors which mean that this course of action is not preferred:

Limitations

- The pre-flood channel was narrow, incised and laterally constrained by dense riparian vegetation. It lacks sufficient capacity to cope with high discharge floods. It is, therefore, likely that major event floodwaters would preferentially bypass the previous channel in favour of the avulsion channel, unless it is infilled.
- Whilst the diversion could be designed to cater for major event flows, the avulsion channel would require infilling with less-erodible, more well-compacted material than encountered by the pre-flood channel.

– This option would require the import of significant fill material to backfill the avulsion channel and removal of the densely vegetated riparian corridor for a successful outcome.

6.2 Option 2: Stabilisation of Flood Channel

Option 2 proposes to stabilise the post-flood channel configuration, encouraging flows to remain within the avulsion channel. Currently, the unprotected erodible right (west) bank is anticipated to continue eroding laterally during future floods, due to the presence of resistant bed material and resultant lack of vertical channel adjustability. This lateral erosion will both remove agricultural land and input potentially contaminated sediment into the system. Ultimately, this sediment will be transported downstream into Lake Gore. This option would therefore, require installation of bank protection to stabilise the bank. There are benefits and limitations associated with this option, as follows:

Benefits

– Coobidge Creek currently flows into the post-flood channel.

– The channel is wide and of sufficient capacity to accommodate any flows that the culvert is able to contain.

– Vegetation removal will not be required.

Limitations

– Naturally resistant material diverts flows at an acute angle into the broad post-flood channel. It is possible that during future flood events, a straighter course may be eroded.

– Installation of right (west) bank protection, combined with the dense former riparian corridor on the left (east) bank, will effectively constrain the creek laterally. As the channel is unable to adjust vertically, flow velocities and erosivity are likely to increase during flood events. Therefore, deep scour pools may be created where the bed materials are less resistant, and more erosion could occur in unprotected downstream reaches.

– A material source is required for the right (west) bank. This may come from re-profiling the bank (consuming more agricultural land), imported from elsewhere, or imported from the former channel (refer Option 3).

6.3 Option 3: Creation of Wide Combined Channel

Option 3 proposes the creation of a broad, quasi-stable channel through removal of some of the pre-flood riparian corridor and stabilisation of the post-flood avulsion channel. In the majority of cases, established, mature vegetation would never be removed from a creek corridor. However, in this instance, it is the preferred option. It is envisaged that ‘soft’ engineering channel controls (e.g. slope re-profiling, use of natural geotextiles, soil improvement and revegetation) would be used for this option. A conceptual design based on this option is included in Section 7.2. The opportunities and limitations associated with this option as follows:

Opportunities

– This option is likely to be the most successful, low maintenance long-term solution.

– It aims to use ‘soft’ engineering measures, rather than ‘hard’ engineering controls.

– The channel character and morphology can be designed based on the pre-agricultural constriction and alteration of Coobidge Creek. This will allow the creation of a channel which, as it considers the geomorphic creek functioning and is better adapted to cope with the variable flow and sediment inputs characteristic of the region. It can also consider the geomorphic functioning within artificial constraints (e.g. the upstream culvert) and natural constraints (such as the erodible banks and resistant bed material).

– Although mature vegetation would need to be removed, the design will allow for establishment of a broad riparian corridor (to stabilise the bank edges and near-bank area), and in-channel vegetation (to encourage sedimentation, increase channel roughness and retard flow velocities). Sufficient vegetation can be left to maintain the stability of the pre-flood channel. The vegetation removed can be placed within the channel to encourage sediment deposition along the right (west) bank and at strategic locations within the channel (often referred to as Large Woody Debris (LWD)).

– Consideration can also be made for sediment inputs, throughputs and outputs from the reach. Ideally, the channel should be able to transport sediment through the reach without significant further addition. Currently, this is only the case during low flows.

Limitations

– Requires movement of appreciable quantities of sediment during construction and temporary loss of mature vegetation.
– Channel works should be carried out during the dry season to limit the possibility of flooding while construction is occurring.
– There will be a vulnerable period while vegetation becomes re-established. However, standard erosion control measures could be incorporated into the design to reduce the possibility of adverse impacts.

6.4 Other Considerations

In the section of the creek downstream of the culvert apron, the existing bed control has resulted in a deep scour pool and acute downstream channel bends. Any design should consider ways to improve the channel morphology through this section. This is likely to require the following:

– Bank protection to reduce the possibility of further lateral erosion.
– Removal or lowering of the existing resistant material such that a more gradual bed slope is achieved. It is not recommended that the material is entirely removed, as this may result in widening and/or unwanted scour. It is envisaged that suitably-sized riprap would be placed downstream of the culvert apron to limit further scour, and that a notch is cut through the resistant material, such that a less-sinuous planform is achieved. Currently, this would direct flows towards the remnant riparian corridor. Removal of some or all of this vegetation is, therefore, recommended.

6.5 Options Appraisal

An appraisal of the three options, considering the comments and recommendations of DWER, is as follows:

Table 1 Appraisal of stabilisation options for Coobidge Creek

Considerations	Option 1	Option 2	Option 3
Planform Pattern	Single thread, low sinuosity	Broad, multi-thread, low-sinuosity	Very broad, multi-thread
Cross-section	Narrow, incised channel	Largely controlled by resistant bed material and in-channel sediment storage	Design should allow for in-channel features with allowance for resistant bed materials
Channel Capacity	Too small	Currently sufficient	Sufficient and designed with variable flows in mind
Channel Adjustability	Low	Preferentially lateral into erodible sandy sediments	Design should accommodate variable flow regime
Planform Alignment	Acute left bend downstream of culvert and natural bed control	Acute left bend downstream of culvert and natural bed control	Design should straighten alignment from culvert
Geomorphic Functioning	Good in low-flow conditions, not adapted for flood conditions. Creek not adjusted to likely range of flows. Flood flows will either re-occupy the avulsion channel (unless infilled) or erode a larger channel.	Still responding to effect of 2017 flood. Low flow channel controlled by resistant bed materials. Slow throughput of sediment. High flow channel prone to lateral erosion.	Design can short-cut natural stabilisation process, create a quasi-stable channel, improving geomorphic functioning.

Considerations	Option 1	Option 2	Option 3
DWER Concerns			
Downstream Impacts	Erosion of saline, nutrient-rich sediments and downstream deposition likely.	Continued lateral erosion of nutrient-rich agricultural land and downstream deposition likely.	Design should aim to reduce lateral erosion and encourage in-channel deposition and throughput
Increased Flooding Risk	High	Low	Low – design channel should accommodate full range of flows
Increased Erosion Risk	High	Moderate/High	Low
Risk of further erosion and land degradation	High	Moderate/High	Low
Cumulative impacts from increased water velocity	Flow velocities may be initially be retarded by dense riparian vegetation, but will increase if avulsion channel is reoccupied.	Currently little in-channel vegetation and significant geomorphic features (bars and benches). Flood flows are anticipated to be high velocity.	Design should aim to reduce flow velocities through the introduction of low flow channels within the high flow trench, in-channel geomorphic features, appropriate in-channel vegetation and a riparian corridor.
Climate Change	Ongoing management concern.	Ongoing management concern	Channel design can accommodate anticipated increased frequency of high flows. Maximum flows are constrained by the culvert size.
DWER Advice			
Reduction of stability and increased flow velocities	-	-	Design aims to improve channel stability and retard flow velocities
Flood water will still flow through existing breakout	-	-	Intention is not to prevent flows entering the existing avulsion, but to improve the functioning of the channel as a whole.

7. Preliminary Management Plan

GHD understands that South Coast NRM wishes to rehabilitate the study reach to reduce the likelihood of large quantities of eroded sediment being transported into Lake Gore. Our recommendations for a preliminary management plan involve short-term monitoring and eventual channel stabilisation, and are discussed in the following sections.

7.1 Short Term 'Quick Wins'

It is suggested that simple monitoring of right (west) bank erosion is considered, to assess the rate of retreat. One way would be to discuss placement of erosion monitoring stakes with the Landowner. These could be placed along the right bank a given distance (e.g. 10m) away from the current bank edge, and measurements taken at regular intervals (say, every 3-6 months). This information can be used to determine the urgency of remediation.

Currently, Coobidge Creek is becoming naturally stabilised following the 2017 flood. However, this could be reversed by the occurrence of a large flood event. If the monitoring (or visual observation) highlights sections of the right (west) bank that are particularly at risk of further lateral erosion, stability can be encouraged through placement of material (e.g. suitably sized riprap or LWD) at the base of the bank.

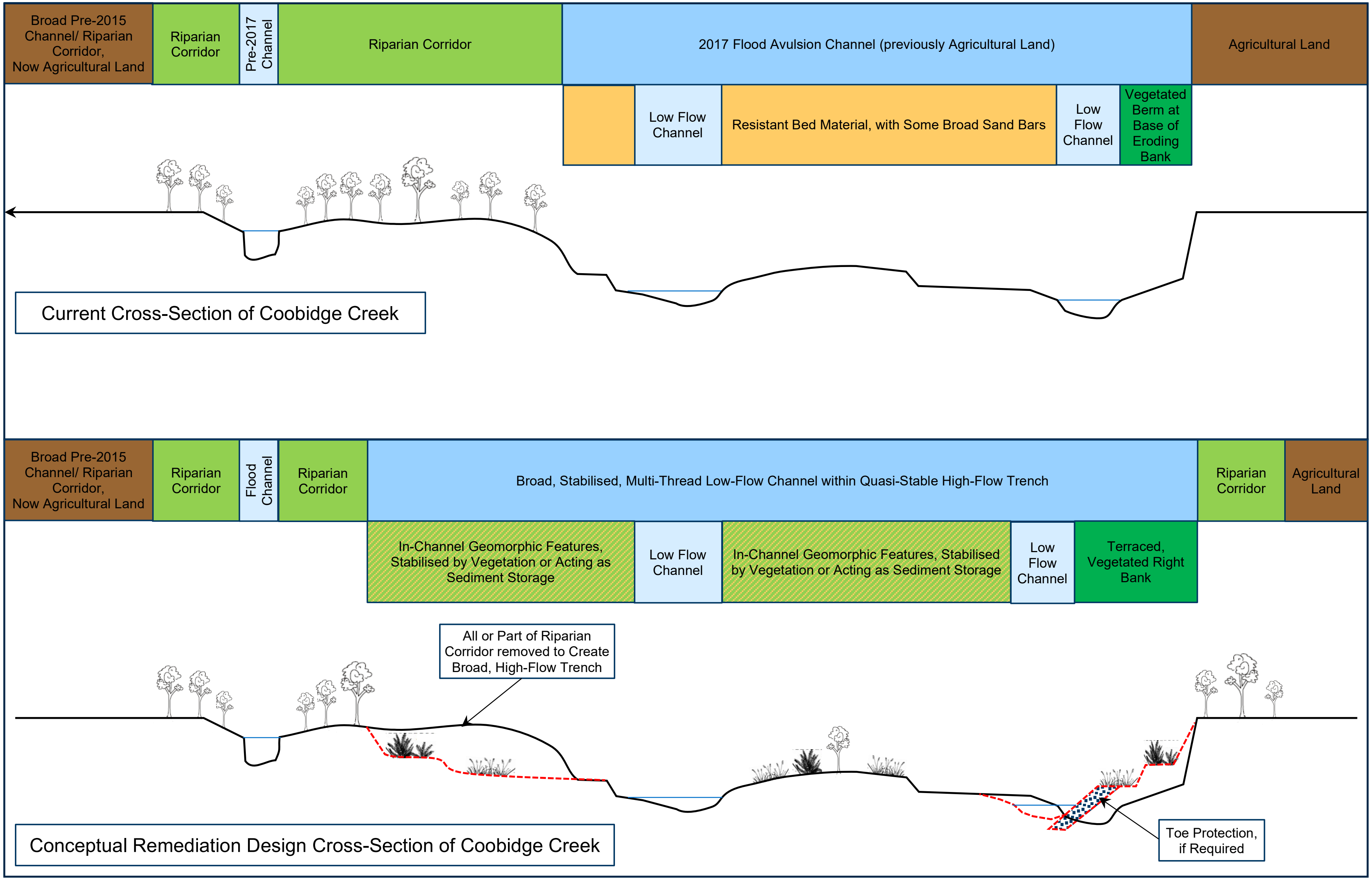
7.2 Conceptual Rehabilitation Design

GHD proposes a conceptual design based on Option 3, outlined above. At this stage, the concept is designed only to provide a guideline to inform applications for funding and as a basis for future detailed design. This concept design should not be used for construction. GHD's recommendations have been made in alignment with the DWER recommended resources *Water and River Commissions River Restoration Manual 10: Stream Stabilisation* (WRC RR10, 2000) and *Manual RR18: Stream Channel and Floodplain Erosion* (WRC RR18, 2002).

The design should consider, and seek approval for, the following:

– Removal of part of the mid-channel riparian corridor to create a broad high-flow trench.
– Establishment of a more sinuous low-flow channel to mimic the pre-disturbance creek. It is noted that there are frequent reaches where there are two or more low-flow channels. Existing pools and shallower areas can be used to redevelop this sinuosity. Since the post-flood avulsion channel has naturally split into two or more channels, a multi-thread planform is recommended.
– Creation of armoured bars and riffles using existing LWD and resistant bed material (broken into suitable-sized boulders).
– Creation of a terraced, vegetated right (west) bank with riprap toe protection (if required). The slope and elevation of the terraces should be designed based on the bank material properties and elevation of in-channel vegetated benches The riprap may be able to be sourced from resistant material excavated from within the channel and broken into suitable-sized boulders. LWD obtained from removal of the mid-channel riparian corridor can be used to encourage deposition along the base of the right bank, particularly at the apexes of bends (both macro and low-flow channel scale).
– The use of LWD provides potential habitat, as well as encouraging sediment deposition.
– The compatibility of stabilisting vegetation with the existing soil conditions should be carefully considered to reduce the possibility that it does not thrive.
– Construction will require rapid establishment of stabilising vegetation. While vegetation is being established, natural geofabrics (e.g. jute mesh) may be required to protect bare surfaces.
– Construction should ideally take place at the start of the dry season, to reduce the likelihood of floods occurring while the channel is vulnerable to erosion.

Figure 10 ***Conceptual remediation design planform of Coobidge Creek***



NOTE: Sketches are not to scale, vertically exaggerated and for visualisation purposes only.

Figure 11 ***Sketch of current creek morphology and conceptual remediation design***

7.3 Geomorphological Assessment, Survey and Geotechnical Investigation

Prior to more precise channel design, additional information is required, as follows:

Detailed Site Survey

A detailed site survey will be required for accurate assessment of the volume of soil relocation, detailed design and hydrologic and hydraulic modelling of the final design. The survey should include sufficient information to assess the current low and high flow channel dimensions, alignment and longitudinal profile.

Geotechnical Investigation

A geotechnical investigation to assess the characteristics of the bed, bank and near-channel agricultural ground will be required. It will be important to establish:

- The characteristics, location and extent of resistant and erodible bed material (including extent of rock outcropping, relative permeability of bed material and shear strength of bank material)
- The characteristics, layering and stability of the existing banks (including the left (east) bank)
- The presence of erodible materials such as dispersive clays or loose sands which may require specific stabilisation measures.

Geomorphological Assessment

GHD has carried out a brief walkover and desktop study of the site. It is recommended that our fluvial geomorphologist conducts a more detailed assessment of geomorphic functioning, flow and sediment dynamic; flow connectivity between neighbouring land and the channel; and the likely impact of the proposed design. It is envisaged that this assessment would be conducted in association with the site survey and geotechnical investigation. Establishment of pre-disturbance channel dimensions and morphology would also be a critical element of this section.

Hydrologic and Hydraulic Modelling

Further hydrologic and hydraulic modelling is needed to assess the anticipated flow velocities, shear stress and scour depths in order to refine the channel design.

7.4 Detailed Channel Rehabilitation Design

Once sufficient information has been gathered, this would be used to inform and refine the conceptual design. GHD's recommendations have been made in alignment with the DWER recommended resources *Water and River Commissions River Restoration Manual 10: Stream Stabilisation* (WRC RR10, 2000)' and *Manual RR18: Stream Channel and Floodplain Erosion* (WRC RR18, 2002).

It is envisaged that the 'soft' stabilisation measures proposed could be used to stabilise other eroded sections of the creek (such as that further downstream).

8. Conclusion

GHD was engaged to investigate engineering and management options to remediate erosion along Coobidge Creek, downstream of the South Coast Highway culvert. A flood in 2017 caused avulsion of the creek from a narrow, single-thread, incised channel flowing through resistant material, to a broad, multi-thread, more deeply-incised channel cut into erodible sandy material. The post-flood channel is characterised by a resistant channel bed and erodible sandy banks. Lateral erosion, therefore, predominates in the post-flood channel.

GHD's calculations have indicated that the South Coast Highway culvert has a maximum discharge of 163 m^3/s, somewhat lower than the maximum calculated peak flow of 308 m^3/s. Downstream of the culvert, bed scour has formed a 0.9 m deep scour hole. Downstream of the scour hole, an outcrop of resistant material forms a bed elevation control. Downstream of this control, the channel previously turned along an acute left bend, but now flows acutely right, leaving an island of former riparian corridor isolated between the pre- and post-flood channels.

GHD has assessed three remediation options, based on the geomorphic functioning of the creek and DWER concerns and advice. Options to 'train' the creek back into its pre-flood channel or to stabilise the right (west) bank of the post-flood channel were considered to be unfeasible both from a practical perspective (i.e. they required large quantities of imported material, or had a high chance of failure) and in addressing DWER's concerns. The preferred option is to carry out the following works:

– Downstream of the South Coast Highway culvert:
  - Infill the scour hole with appropriately-sized riprap
  - Cut a notch through the resistant bar of material downstream of the scour hole
  - Install bank protection to reduce the possibility of lateral erosion
– Create a broad, quasi-stable channel along the post-flood channel course. This would require:
  - Removal of part of the pre-flood riparian corridor to remove the acute bend downstream of the resistant bar and create a channel that can accommodate the entire range of expected flows and sediment volumes. While the removal of riparian vegetation from a creek corridor is usually never recommended, in this case, it allows for channel widening, a reduction in the likelihood of potentially contaminated agricultural sediment and re-use of on-site materials
  - Stabilisation of the right bank using 'soft' engineering measures and materials obtained from the left bank
  - Encouraging in-channel habitat and sediment deposition through the use of Large Woody Debris
  - Establishment of a broad riparian corridor and in-channel vegetation.

The preferred option addresses DWER's concerns by allowing for increased flood discharge due to climate change, stabilising the channel, encouraging floodwaters to flow in a defined channel, and encouraging in-channel sediment deposition. These measures aim to reduce adverse impacts due to downstream sedimentation of Lake Gore from this reach.

GHD recommends that simple monitoring of the post-flood right (west) bank is implemented to assess the rate of retreat and urgency of remediation. Our preferred option provides a conceptual design that can be used to inform applications for funding and that can be used as a basis for detailed design. Recommendations for further investigations required to progress the concept through to detailed design have been provided, including a full geomorphological assessment, a detailed site survey, a geotechnical investigation and hydrologic/hydraulic modelling.

Appendix A

IFD DATA

Australian Government
Bureau of Meteorology

Location

Label: Esperance

Latitude: -33.6949 [Nearest grid cell: 33.6875 (S)]

Longitude: 121.4787 [Nearest grid cell: 121.4875 (E)]

IFD Design Rainfall Intensity (mm/h)

Issued: 08 August 2021

Rainfall intensity for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	80.2	90.5	125	151	178	217	248
2 min	69.9	79.4	111	133	157	189	215
3 min	62.1	70.4	98.1	118	139	168	192
4 min	56.0	63.4	88.1	106	125	152	173
5 min	51.0	57.7	80.1	96.6	114	138	158
10 min	36.3	40.9	56.6	68.2	80.4	97.9	112
15 min	28.8	32.5	44.9	54.1	63.8	77.6	89.0
20 min	24.2	27.3	37.8	45.5	53.7	65.2	74.8
25 min	21.1	23.8	32.9	39.7	46.8	56.9	65.2
30 min	18.8	21.2	29.4	35.5	41.8	50.8	58.1
45 min	14.5	16.4	22.8	27.5	32.5	39.4	45.1
1 hour	12.1	13.7	19.1	23.0	27.2	33.0	37.8
1.5 hour	9.34	10.6	14.8	18.0	21.2	25.8	29.6
2 hour	7.79	8.86	12.4	15.1	17.8	21.8	25.1
3 hour	6.05	6.89	9.73	11.8	14.1	17.3	19.9
4.5 hour	4.71	5.37	7.62	9.32	11.1	13.7	16.0
5.25 hour	4.29	4.89	6.94	8.50	10.2	12.6	14.7
6 hour	3.95	4.50	6.40	7.85	9.41	11.7	13.6
9 hour	3.06	3.49	4.99	6.15	7.41	9.27	10.9
12 hour	2.54	2.90	4.15	5.14	6.22	7.81	9.18
18 hour	1.94	2.21	3.17	3.95	4.81	6.05	7.13

Note:
The 50% AEP IFD **does not** correspond to the 2 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.
* The 20% AEP IFD **does not** correspond to the 5 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

ghd.com

→ The Power of Commitment