

APPENDIX H

Geomorphology Report

Part 2 of 2

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

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Appendix F Baseline field inspection site records and photos

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Appendix F

Baseline field inspection site records and photos

Note site type, EP = erosion potential site, BL = baseline field work.

See Appendix A Drawing Set D for locations.

Coordinates									Erosion Potential (sites with existing infrastructure)		Channel					Material		Floodplain			
Site ID	Type	Watercourse Type	Floodplain Type	Catchment name	Soil Type ASC Regional	Soil Type ASC - Site (Aurecon 2022)	Easting	Northing	Infrastructure	Geomorphic change at existing infrastructure	Channel Type	Geometry	Features	Vegetation	Geomorphic Processes	Bed	Bank	Features	Vegetation	Behaviour	Notes
EP1a	EP	Local- poorly developed channel		Gowrie Creek	vertosols	ferrosols	386118	6958498	Rail bridge, retaining wall on right bank	Erosion on both banks, erosion and failure behind retaining wall. Deposition of silty sand material on inside of bends. Localised gravel dropout on inside of bend downstream of bridge on right	Meandering	Channel approx. 10-15m wide. Main channel 1.5-3m deep (from top of water level). Steep/subvertical banks. Approx. 5-6m from water level to underside of bridge.	In channel bars.	Grass on banks	Bank erosion downstream of bridge. Silty fine overbank deposits on both bends.	Silt/sand with minor gravels	Dark, silt/clay. Some ~400mm diameter boulders in grass on left bank deposited.	NA	NA	NA	Indications of water flow to approx. 0.5m below underside of rail bridge (flattened grass).
EP1b	EP	Local- poorly developed channel		Gowrie Creek	vertosols	ferrosols	385947	6958461	Ford/culverts: 3 culverts, box, 1.5x2.5m approx. Large broken concrete slabs in river, maybe from previous flood event and ford replaced?	Upstream and downstream of ford are volcanic rock outcrops. Deposition of fine silt on both banks. Tree uprooted on channel bank.	Low sinuosity section of a meandering channel	Shallow vegetated banks	Lateral bars	Grass on banks	Channel appears narrower upstream of the ford. Channel likely rock controlled in the ford area based on outcrop. Deposition on inside of channel bend, and erosion on outside of bend.	sand/silt/clay with volcanic rock outcrops and some gravels	Some dumping on bank, less erosion than at bridge site.	NA	NA	NA	Water has exceeded channel height.
6/EP2	Both	Local - well developed channel	C1	Dry Creek	vertosols	no data	379928	6954140	Concrete culverted causeway. One round approx. 450mm diameter culvert.	Erosion at interface between concreted section and natural river bed causing undercutting at downstream side. Erosion in channel downstream of culvert. Ponding upstream of culvert	Low sinuosity channel	2-3 m wide downstream	Channel artificially straightened at this site.	Vegetation in channel bank. Vegetation is tall grass, no trees.	Some erosion of rocks on left bank downstream. Water benched up on upstream side of causeway. Fine sediment deposited in grass as overland flow. River has flowed overland to right of causeway, flattened grass and eroded soil, re-joins main channel after concrete section ~15m downstream.	Mud	Downstream left bank is weathered and eroded basalt Approx. 50m downstream from causeway L bank changes to subvertical, dark soil. Some slumping into river channel. Right bank in shallow dipping, soil and vegetated with grasses and some small shrubs.	NA	NA	NA	Water flow level approx. 1.5m above causeway inferred from flattened grass.
EP3a	EP	Local - well developed channel	C1	Westbrook Creek	vertosols	no data	379662	6952297	2-lane concrete and asphalt bridge.	Covering of silt, indicates overtopping during flood. Bank slumping on the downstream true left bank. Minor cracking in seal on downstream side of left abutment, not major.	Low sinuosity channel, chain of ponds	Bridge crosses' over 'pond' overall channel width to outer banks approx. 30m wide immediately downstream of road bridge, narrowing to an indistinct grassy channel to approx. 15m 30 m downstream.	In channel bench on upstream right bank	Grass with sparse trees on bank	Slight erosion noted on downstream banks. Some fines deposition in grass on fairway immediately upstream of bridge.	NA (underwater)	Dark, silt/clay with grass cover	NA	NA	NA	No obvious signs of significant overland flow on flood plain. Barriers on bridge have covering of silt, may indicate overtopping during flood.
14/ EP3b	Both	Local - poorly developed channel	C1	Four Mile Gully	vertosols	vertosols	378803	6952245	Small concrete bridge approx. 12-15m span with concrete uprights.	Indications bridge was overtopped from grass debris. Bank slumping upstream of bridge and sediment deposited at and downstream of bridge.	Non channelised valley floor. Low sinuosity channel sections.	Shallow vegetated channel approx. 20m wide, with active channel approx. 5-10m wide.	Approx. 1.5m deep channel at alignment crossing. Minor slumping on right side of bank downstream of bridge.	Grass with minor exposed soil in pool	Deposition occurring at and downstream of bridge. Erosion occurring at bridge and site upstream of bridge (may be related to road crossing). Minor slumping on right side of bank downstream of bridge. Section of steep bank with exposed soil upstream of site caused by recent erosion, possibly near road crossing	Mud	Dark soil, possibly vertosol..	Flat, difficult to discern features as vegetated	Grass	Appears stable	
EP4	EP	Local - developed channel sections	C1	One Mile Creek	vertosols	no data	376863	6948296	Causeway, concrete with approx. 2mx1.5m culvert. Concrete weir downstream of causeway. Elevation from culvert outflow down to current river level approx. 2.5-3m	Ponding upstream, some bank erosion downstream	Low sinuosity channel downstream of causeway, upstream channel indistinct	Upstream channel indistinct. Overall fairway approx. 80m wide. Downstream channel is approx. 15m wide and 3-4m deep,	Multiple small discontinuous channels and ponds in fairway . Low sinuosity channel approx. 1.5m to 3 m deep.	Upstream channel vegetated with long grass.	Dark silt and clay with some sand deposited in vegetation and on road right side of causeway. Signs of overland flow above banks not obvious on downstream side. Slumping at downstream right bank into channel. Low sinuosity channel may have developed due to local scour downstream of causeway. Channel deepening and widening occurring downstream o Berghafer road.	Silt/clay	Dark silt and clay with some sand and gravel with grass cover.	NA	NA	NA	Water inferred to have been 30 cm deep across top of causeway from height of vegetation detritus on fence and depth gauge.
9	BL	Headwater		OC 4	vertosols	no data	377423	6945847	NA	NA	Non channelised valley floor/wash slope	Broad flat watercourse	Poorly defined vegetated channel, no distinct features.	Grass	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	NA (vegetated, very gentle slope)	NA	NA	NA	
EP5	EP	Local poorly developed		NC1	vertosols	ferrosols/vertosols	376319	6942653	Culvert. Pond formed on east of road embankment	Could not see culvert from road. Watercourse not flowing.	Non channelised valley floor/wash slope	NA	NA	Grass	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	Grass cover	NA	NA	NA	No safe pullover spot. Photo taken from up road to SW looking back at site.
EP6	EP	Headwater		NC2	vertosols/dermosols	ferrosols/vertosols	375475	6941988	Concrete culvert approx. 2.5x3m. Concrete wing walls with metal grate over culvert. Downstream side has concrete base on outflow.	Some erosion and undercutting at transition to natural bed. Ponding downstream of culvert. Minor erosion on true right bank downstream of culvert	Non channelised valley floor/wash slope with short low sinuosity channel sections	Downstream channel approx. 7m wide at base, 15 wide at top of bank, approx. 1.5-2m deep. Upstream channel much narrower. 1m-2m wide with flatter banks.	Single channel with some ponding downstream.	Grass with some trees	Change in channel width after culvert, widens into pond area. Minor erosion on downstream banks.	Silt/sand with minor gravels	Brown silt and sand with some grass cover downstream, grass covered upstream.	NA	NA	NA	

Coordinates									Erosion Potential (sites with existing infrastructure)		Channel					Material		Floodplain			
Site ID	Type	Watercourse Type	Floodplain Type	Catchment name	Soil Type ASC Regional	Soil Type ASC - Site (Aurecon 2022)	Easting	Northing	Infrastructure	Geomorphic change at existing infrastructure	Channel Type	Geometry	Features	Vegetation	Geomorphic Processes	Bed	Bank	Features	Vegetation	Behaviour	Notes
11/ EP7	Both	Local - poorly developed channel		NC3	dermosols	vertosols/dermosols	374473	6941233	3 box culverts, 2.5x2m each, with wingwalls, road embankment over top approx. 4m thick. Concrete base. Damaged and closed old bridge structure (immediately downstream of culverts), has wingwalls base in rock and concrete.	No sign of damage or major deposition at base. Some silt in bed of culverts, shows ripples. Scour hole at transition with natural channel	Low sinuosity channel	Approx. 7m wide. Banks of downstream channel are gradual and not steep. Upstream has steep bank on right side, almost flat on left side	Approx. 30m downstream appears to be gravel in channel bed. Origin unclear. Small pools within channel	Grass with some trees	Minor deposition.	Sandy silt with some gravel. Rock, boulders, bricks, rubble in base.	Vegetated, slope gentle	NA	NA	NA	
EP8	EP				vertosols	no data	373703	6939693	Culvert, couldn't safely observe, approx. 3.5m tall.	Pool/pond at outflow of culvert, low flow.	Upstream channel is low sinuosity, downstream channel becomes non channelised valley floor.	Downstream channel is approx. 20m wide, shallow sides. Upstream channel approx. 1 - 2 m wide.	Upstream poorly defined vegetated channel, no distinct features. Downstream minor ponding, no distinct features	Downstream vegetated with long grass and reeds. Channel visible due to change in vegetation	Change in channel type at culvert, downstream non channelised valley floor, upstream low sinuosity channel	NA	Grass cover	NA	NA	NA	
EP11	EP	Headwater		NC9	vertosols/rudosols	vertosols	364423	6934440	Culvert under road, approx. 600mm diameter.	Culvert appears to be performing with little to no impact on the watercourse	Non channelised valley floor to wash slope	Channel approx. 10m wide and 2m deep.	Poorly defined vegetated channel, no distinct features.	Very overgrown with long grass and sparse trees.	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	Grass cover	NA	NA	NA	
1h/ EP16a	Both	Main stem	C2	Condamine River	vertosols	no data	347327	6920022	Weir structure with road bridge downstream.	Weir under water during site visit, but can be seen forming ripples on surface.	Meandering to low sinuosity channel	Water is full width of channel, approx. 40-50m.	Not observed as water level high	Not observed as water level high	Not observed	NA (high water level)	Banks are low angle. Grass with sparse trees	NA	NA	NA	Silt/clay deposited on road indicates water level was approx. 3m higher and 30m wider at peak.
EP17	EP	Local - well developed channel	C2	Grasstree Creek	vertosols	no data	341659	6914807	Ford	Ponding directly upstream of the ford, channel is narrower directly downstream - may be due to natural chain of ponds channel type	Meandering with higher flows, chain of ponds with lower flows	Width of active channel 15-20m. Fairway width 60 m, ~3m deep. Banks on either side approx. 2m above river level. Very shallow slope on banks.	Single channel with chain of ponds in low flows. Shallow vegetated banks.	Long grass and some trees.	Minor deposition, no obvious erosion.	NA (underwater)	Grass with some trees	NA	Grass and some trees	NA	Debris in fence shows stream shows water was at least 1.5m higher and 15-20m wider.
EP19	EP	Local - developed channel sections	C1	SC2	sodosols	vertosols	329222	6911695	Culvert/bridge with 3 piers, approx. 12m wide total. Concrete and block wingwalls with rock lined backfill.		Chain of ponds in meandering planform.	Channel is approx. 15m wide, 1.5m deep to top of water. Downstream of bridge channel narrows to 2m wide.	Difficult to confirm due to high water level	Grass with some trees	Water ponding. No obvious erosion.	NA (underwater)	NA (vegetated, very gentle slope)	NA	NA	NA	Debris in fence across stream shows water was 1m higher than current level. Some evidence of water flow from flattened grass 0.5m below bank crest.
8/ EP21	Both	Headwater		SC5	vertosols	vertosols	326189	6907384	5 span box culverts, approx. 10m total width.	Some water in depression upstream and downstream of culvert. Vegetation blocking culvert, may have filled culvert, but doesn't appear to have overtopped. Culvert overgrown and likely has sediment deposition in bottom.	Non channelised valley floor/wash slope	Upstream channel widens to 3m, very shallow. Downstream channel only discernible from some bent grass, approx. 40cm wide. Once this enters long/tall grass it is completely lost.	Other than the local culvert impacts, no distinct features.	Grass	Culvert has concentrated flow and resulted in local erosion/deposition. Natural watercourse appears stable	Mud	Vegetated, very low angle.	NA	NA	NA	
EP22	EP	Local - poorly developed channel	B3	SC7	vertosols	no data	326501	6905744	Road. To the SE side water controlled by makeshift sluice gate and stone wall.	Water ponding on road. Road acts as embankment across watercourse	Non channelised valley floor		Poorly defined vegetated channel, no distinct features.	Grass with sparse trees on bank	Road acts as embankment across watercourse, ponding occurs adjacent to road.	NA (underwater/vegetated)	NA (vegetated, natural slopes very gentle slope)	NA	NA	NA	
EP23	EP	Local - developed channel sections	C1	Back Creek 1	vertosols	no data	326420	6904210	17 culverts, natural soil base 2m x 1.5m laid 45 degrees to road. Connecting walls at ends, road embankment approx. 1.5m above top of culverts.	~15m of low sinuosity channel directly upstream from culverts in non channelised valley floor. Multiple man made ponds near site along watercourse. Heavily modified. Standing water at outfall of culvert, approx. 10cm deep. Slight depression and wet area noted from vegetation, maybe 30m wide, bounded on both sides by grassy banks.	Non channelised valley floor, 15 m upstream from culverts, very short meandering channel	Meandering channel 2m wide, 1.5m-0.5m deep with vertical banks. Bank on right upstream from culvert is 3m tall and grass covered. Bank on left side is 3m tall artificial earth berm. Downstream grassy banks, very shallow slope and 2m tall on right, steeper, approx. 40 degrees, and 2.5m tall on left	Single very short section of meandering channel. Downstream poorly defined vegetated channel, no distinct features.	Grass on banks	Fed from small pond upstream. Some bank erosion occurring directly upstream of culverts in valley floor. Minor damage to banks from cattle. Minor deposition at culverts	NA (vegetated). Meandering channel bed appears silt/clay	NA (vegetated, natural slopes very gentle slope)	NA	NA	NA	
EP23a	EP	Local - developed channel sections	C1	Back Creek 1	vertosols	no data	325696	6903442	Road acts as embankment to watercourse	Watercourse highly modified, multiple man made ponds near site, as well as road embankment. No sign of watercourse at road site	Non channelised valley floor with multiple man made ponds	NA (site highly modified)	Poorly defined vegetated channel, no distinct features.	Grass	Minimal processes occurring, no evidence of bedload. Appears stable. No longer functions as a watercourse at this site.	NA (vegetated)	NA (vegetated)	NA	NA	NA	
EP24	EP	Headwater		C Ck 2	vertosols	no data	324573	6901783	Culvert under road. 2m x 1.5m overgrown so can't see base.	Watercourse not flowing during visit, and no evidence of recent activity.	Non channelised valley floor	Upstream approx. 1m wide and 0.5m deep, less clear on downstream side	Poorly defined vegetated channel, no distinct features.	Channel grassed with some trees	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	NA (vegetated)	NA	NA	NA	
EP24a	EP	Headwater			vertosols	no data	324079	6901266	4 span culverts under road, each approx. 1.5m x 1m	Small ponding area directly downstream of culverts.	Non channelised valley floor flow		Poorly defined vegetated channel, no distinct features.	Grass and some trees	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	NA (vegetated)	NA	NA	NA	
EP25	EP	Local - poorly developed channel			vertosols	no data	323570	6898886	Single culvert under road, 1.5m x 1m.	Culvert heavily overgrown with long grass. Water ponded on both sides.	Non channelised valley floor flow	Approx. 30m wide, 2-3m deep.	Water ponded on both sides of culvert	Grass and some trees	Small ponds at both ends of culvert, likely some minor erosion.	NA (vegetated)	NA (vegetated)	NA	NA	NA	
EP26	EP	Local - poorly developed channel			vertosols	no data	323341	6897019	Large culvert under road. 4 chambers 2 x 1.8m with concrete wing walls.	Water ponded at both upstream and downstream of culverts. Man made ponds directly upstream and downstream of site, highly modified watercourse	Non channelised valley floor with minor sections of low sinuosity channel, multiple man made ponds	Upstream a thin channel is visible approx. 1.5m wide 0.5m deep. Fairway gentle side slopes, approx. 40m wide left bank 3m high, but difficult to see clearly. Downstream channel much less distinct.	Poorly defined vegetated channel, no distinct features.	Channel grassed with some trees	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	NA (vegetated, right slope very gentle)	NA	NA	NA	
EP27	EP	Local - poorly developed channel			vertosols	no data	323103	6895137	Culvert under road 4 x 1.5 x 1.5m concrete base and large concrete apron approx. 4x10m. Concrete wingwalls.	Channel adjacent to culvert appears stable. Man made pond directly upstream of site, ponds downstream also. Some erosion of bench can be seen towards outfall of pond.	Non channelised valley floor flow	Upstream channel approx. 10m wide very shallow banks. Approx. 150-200m upstream may be banked channel but too far away to see clearly. Downstream flows towards detention pond .	Poorly defined vegetated channel, no distinct features.	Channel grassed with some trees	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	NA (vegetated)	NA	NA	NA	

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3a/ EP28	Both	Local - developed channel sections	B3	Nicol Creek	sodosols	no data	322720	6892020	Culverts under road. 4 2 x 2m box culverts, can't see concrete at base. Concrete wing walls. Upstream banks of road embankment reinforced with a concrete type matting. Downstream embankment banks have riprap.	Ponding of water upstream of culvert. Channel width narrows downstream of culvert	Chain of ponds in meandering planform.	Upstream of culvert channel is approx. 12m wide, 2.5m deep. Downstream channel is approx. 8m wide and 1m deep. Current flow only occupies 1-3m of channel upstream, approx. 0.1m deep.	Ponds with small channel/non channelised valley floor between. Channel depth approx. 0.5m. Minimal processes occurring, no evidence of bedload.	Grass with some trees	Culverts causing ponding on upstream side. Downstream erosion on banks. Flow has occupied whole channel downstream from flattened grass. Very minor deposition of silt/clay in base of channel	NA (vegetated). Mud in pond areas	Not easily assessed from road, appears fine material where not vegetated.	NA	NA	NA	
5/ EP29	Both	Local - well developed channel	B3	Bringalily Creek (and Nicol Ck)	sodosols	sodosols/dermosols	322066	6887288	Road bridge with 3 piers, approx. 20m total length has concrete wing walls outside of main channel.	Some bank erosion and development of a ponding area downstream of the bridge. Bank at upstream left abutment shows slight surface erosion from water flowing from road verge into river.	Chain of ponds in meandering planform.	Water in channel is approx. 8m wide upstream widening to 12m just before bridge. Downstream channel is 12m wide but quickly narrows to 1m wide. Where river narrows downstream fairway is 15m wide and 3.5-4m deep. Downstream Left bank is steep and becomes subvertical with slumped bench where river narrows.	Vegetated in-channel sand and gravel bar on right side causes channel to narrow downstream. Gully formed on left bank from surface flow from field.	Vegetated in channel bars, channel bed bare soil.	Bank erosion and slumping occurring downstream. Bridge has caused channel to widen both upstream and downstream.	Silt/sand/clay with minor gravel	Light brown silt/sand.	NA	NA	NA	
EP30	EP	Local - poorly developed channel	B3	Back Creek 2	sodosols	vertosols	321924	6884356	Row of 14 1m x 0.75m tall culverts with concrete base, no wing wall. Total span approx. 16m. Downstream has 1m wide concrete apron on base.	No obvious erosion or deposition. No water at site during visit, but flattened grass shows recent flows occurred. Man made pond ~130m upstream.	Non channelised valley floor		Channel grassed, no obvious features. Channel approx. 0.5m deep.	Grass	Channel grassed, minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	NA (vegetated, natural slopes very gentle slope)	NA	NA	NA	Hasn't been overtopped in flooding but evidence of flow in grass upstream and water has just reached edge of chip seal.
10/ EP31	Both	Local - poorly developed channel	B3-C1	Native Dog Creek	sodosols	no data	321120	6881107	Large road bridge approx. 8m tall, 4 piers shotcrete spill through and grass embankments.	Underneath bridge standing water in channel and long grass.	Non channelised valley floor	Overall channel is 80m wide and 3-4m deep, shallow sloping bank. Channel widens downstream.	Channel grassed, no obvious features. Channel approx. 0.5m deep.	Grass and trees	Local areas of very minor erosion. Downstream some localised sections of flattened grass and grass debris caught on trees. In very isolated areas these localised flow pathways have stripped <0.3m wide zone of vegetation along a length of <5m.	Sand, silt and minor gravel	Vegetated, slope gentle	NA	NA	NA	
EP32	EP	Headwater		C Ck 10	sodosols	sodosols	319683	6879629	1m x 40cm box culvert under road, concrete base no wing walls.	No obvious erosion or deposition. No water at site during visit or evidence of recent flow. Man made pond 40m downstream.	Non channelised valley floor		Pond visible 40m from culvert on downstream side but no channel linking.	Grass and trees	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	NA (vegetated)	NA	NA	NA	
EP33	EP	Local - poorly developed channel		C Ck 11	sodosols	sodosols	319421	6878457	Nine 1.6 x 0.8m culverts under road. Concrete on base, no wingwalls. Total span approx. 16m. Road level approx. 1m above base.	No obvious erosion or deposition. No water at site during visit or evidence of recent flow.	Non channelised valley floor		Poorly defined vegetated channel, no distinct features.	Trees with grass	Minimal processes occurring, no evidence of bedload. Appears stable. Appears to have minimal flow.	NA (vegetated)	NA (vegetated)	NA	NA	NA	
2/ EP34	Both	Local - developed channel sections	B3	Cattle Creek	sodosols	sodosols	318911	6875964	Approx. 6m tall bridge, 5 piers, total span approx. 45m, shotcrete spill through and grass embankments. Downstream side of bridge has old road surface.	Low point of watercourse under bridge, downstream channel incised into valley floor	Low sinuosity channel, non channelised valley floor	Non channelised valley floor ~70 m wide and 4m deep upstream of bridge. Downstream channel incised in valley floor to form a channel 2.5m wide 0.5m deep with a flat to concave bottom..	Broad vegetated channel with short section of low sinuosity channel with no flow at time of visit. Some woody debris and coarse gravel / boulders in channel downstream.	Grass	Bridge has restricted non channelised valley floor flow and resulted in minor erosion/incision of a small channel downstream	Mostly vegetated. Sand and silt with gravel and cobbles	Sandy and gravelly soil.	NA	NA	NA	
EP36	EP	Headwater		C Ck 14	sodosols	sodosols	320057	6870313	Culverts under road , 5 round culverts, 400mm diameter each	No obvious erosion or deposition. Damp at outflow but no flow, maybe 5cm standing water in thick grass. Pipe quite overgrown, road level approx. 50cm above top of pipes.	Non channelised valley floor		Poorly defined vegetated channel, no distinct features.	Bush and trees with grass	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	NA (vegetated)	NA	NA	NA	
EP37	EP	Headwater		C Ck 15	sodosols	sodosols	319646	6867010	1.2m diameter culvert under road, concrete, masonry wing walls. Road level is 80 cm above top of pipe. Downstream, culvert has 1m concrete apron.	Slight ponding downstream of culvert, indicating erosion, after apron water has scoured a pool 4m wide 10m long, 30cm deep.	Non channelised valley floor with some small ponds visible upstream and low sinuosity channel downstream	Low sinuosity channel 1m wide 30-90cm deep, vertical walls, flat bottom. Channel continuing to widen and deepen downstream. By 30m downstream is 5m wide, 1.5m deep.	Possible small gully on left bank downstream from water flowing from adjacent field, no obvious other features.	Grass and trees	Approx. 85m wide channel approx. 0.5m deep. Slight ponding downstream of culvert at EP37, indicating erosion, after apron water has scoured a pool 4m wide 10m long, 30cm deep.	Downstream channel gravel with some sand.	Downstream banks sand and silt w/ some gravel. Vegetation on banks is sparse grass and small trees.	NA	NA	NA	
EP38	EP	Local - poorly developed channel		C Ck 16	sodosols	vertosols	318201	6862392	Double culvert under road, 1.6m diameter. Masonry wing walls.	Slight ponding at culvert outflow indicating minor erosion.	Gully	15m downstream becomes low sinuosity channel, 0.8m wide, 0.2m deep, vertical sides. 0.4m wide and 0.1m deep multi channel threads occur also within the valley floor downstream	Non channelised valley floor grassed, no obvious features other than slight ponding at downstream end of culvert.	Grass and trees	Minor gully erosion downstream of culvert. Change in channel type 15m downstream of culvert. No bank erosion observed	Non channelised valley floor NA (vegetated). Low sinuosity channel sand/silt and gravel	Non channelised valley floor NA (vegetated). Low sinuosity channel sand/silt and gravel	NA	NA	NA	
4/ EP40	Both	Local - well developed channel	B3	Pariagara Creek	sodosols	dermosols	314010	6860035	Gravel/cobble Ford	Some erosion and deposition of gravel/cobbles placed for ford. Ponding of flow upstream. Channel is narrower with wider in channel bars downstream.	Low sinuosity channel	Channel is 3-4m deep, banks are 35-50 degrees, channel has flat bottom. Channel 10-15m at base, 15-25m at crest.	In-channel bars and benches with ripple formations at edges.	Some sparse grass on larger in channel bars. Channel bare soil	Significant in-channel deposition of sand and silty sand (mostly sand). Ford causes flow to pond upstream and increase deposition downstream. Downstream localised bank erosion and steepening.	Sand with some silt		NA	NA	NA	

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EP41	EP	Local - developed channel sections		C Ck 20	sodosols	no data	311368	6858944	Natural ford (no engineering structure). Road is sand. Stormwater diversion channel has been dug on upstream side of road on south side.	Sand road shows erosion channels. Some evidence of erosion in small shallow roadside 'channel'.	Non channelised valley floor	40 to 20m wide with undulating flat bottom, banks 2-4m tall, 30 degree slope.	Poorly defined vegetated channel, no distinct features.	Grass and trees	Some increased sediment from erosion of road surface. Watercourse appears stable.	NA (vegetated)	NA (vegetated)	NA	NA	NA	
EP42	EP	Main Stem	B3b	Macintyre Brook	dermosols	no data	302718	6851714	Concrete bridge, 13 0.7x0.7m box culverts with central 2.5mx0.7m box. Large concrete apron on downstream side. Concrete convex spill overs on both sides.	River channel narrows downstream bridge, no obvious erosion of banks, minor deposition downstream. Some localised slumping on downstream right bank. Upstream banks steeper, up to 55/60 degrees.	Meandering	35-45m wide, banks 6m high, approx. 40 degrees. At time of visit, flowing channel approximately 20m wide	One in-channel grassed bench on upstream right side.	Grass and trees	Minor deposition and bank erosion (right bank) downstream of the bridge, otherwise appears stable.	NA (underwater), displaced riprap downstream. Silt deposited downstream	Silt/sand with some gravels (?) partially vegetated	NA	NA	NA	Debris up to 7m above water level in trees.
EP43	EP	Main stem	B3b/ C2	Macintyre River	sodosols	no data	237740	6838204	Two bridges in a row. First larger bridge (northern) over the Macintyre River. Second bridge, likely for flood channel.	No safe place to pull over. No obvious erosion/deposition observed during drive by.	Meandering	Macintyre River ~50m wide.	Not observed as water level high	Grass and trees	No obvious erosion/deposition, however were not able to pull over and water level was high.	NA (water level high)	NA (vegetated)	NA	NA	NA	
EP44	EP	Whalan Creek		Whalan Creek arm	chromosols/ vertosols	no data	252252	6825845	Road bridge approx. 17m span, single pier, concrete wingwalls on grassed abutments, concrete vertical spillway through bridge approx. 5m tail. Possible remnant concrete ford further upstream. Remnants of old wooden bridge visible underneath right abutment.	Immediately before bridge/under bridge river has scoured out two ponded areas approx. 1m deep, 3-7m wide. Slight scour visible at both abutment bases.	Non channelised valley floor to chain of ponds - unsure if man made or natural	Short connecting channel between Whalan Creek and a channel ~170m north. Larger pond ~40m upstream 12m wide, other ponds 3-7m in size.	Upstream is series of ponds, Downstream is indistinct grassed channel, no distinct features	Grass with sparse trees	Erosion evident at bridge and upstream. Channel changes to non channelised valley floor flow downstream of bridge.	Upstream, grass with some sand/silt/gravel exposed. Downstream, grass.	NA (vegetated)	NA	NA	NA	Debris indicates water may have reached bridge level but difficult to confirm.
EP44a	EP	Whalan Creek		Whalan Creek	vertosols	no data	253664	6824920	Ford/low point on sandy gravel road, no structure.	Road may act as embankment between two perpendicular channels of Whalan creek	Non channelised valley floor	Upstream 35m wide channel with very shallow sloping banks 2.5m high. Downstream undulating valley floor channel with pond 20m wide.	Channel grassed, no obvious features other than pond downstream. Site occurs where Whalan Creek connects at right angles with a meander cut off (occupied during flood events) of the Macintyre River (also called Whalan Creek)	Grass and trees	Appears stable, road may act as embankment	NA (vegetated)	NA (vegetated)	NA	NA	NA	
EP45	EP	Local - well developed channel		Whalan Creek	vertosols	no data	247382	6824843	Ford and old rail bridge. Bridge ~100m long, 6-7m tall with large concrete piers. Railway on large embankment to span channel, but further along flood plain embankment is 0.5m-1m tall. Road level at ford is ~1m above ground on either side.	Ford acts as embankment, low sinuosity channel upstream, downstream channel becomes chain of ponds.	Chain of ponds to low sinuosity channel	Water channel on upstream side, approx. 10m wide, bank on left side 1-1.5m tall, right side 3m tall. Pond on the downstream side of the ford. Approx. 10m wide, 20m long.	Downstream is series of ponds, minor evidence of erosion in pond banks. Upstream is low sinuosity channel, banks appear stable	Grass with sparse trees	Appears stable, road acts as embankment and channel type changes at road	Silty sand with some gravel where visible.	Silty sand banks downstream with some cobble sized material (possibly riprap from bridge).	NA	NA	NA	Debris in trees shows water was 1.8m above road. Grass lodged in trees on upstream side of bridge shows water may have reached close to underside of bridge.
1a	BL	Local - well developed channel	C2	Condamine North Branch	vertosols	no data	344072	6929272	Concrete culvert with perpendicular wing walls, 2 channels, and central pier, each approx. 2m wide x 1.5m tall.	Erosion on upstream bank (~8m) and deposition of dark blackish brown silt/clay on downstream sides.	Meandering	Channel approx. 8m wide.	Not observed as water level high	Trees and grass	Erosion on upstream true left bank, deposition downstream	Silt/clay	Silt deposits on banks.	NA	NA	NA	Detritus up to 1.5m above current water level.
1d/ EP16	Both	Main stem	C2	Condamine River	vertosols	no data	338742	6922932	Multiple culverts and bridge along 200m stretch of road. Bridge ~35m span. Water flowing through under road at two main box culverts. Culvert site 1 is approx. 40m south of bridge, small wing walls, span approx. 8m. Culvert 2 site approx. 100m south of bridge. Span approx. 22m. One more culvert site approx. 50m downstream from culvert 2. Similar size and style to culvert 1.	Scour leading to bank failures approx. 20-30 m long both upstream and downstream of the bridge, channel appears narrower upstream of bridge.	Meandering	Banks are 35-45 degrees close to bridge, becoming less steep further away. Banks approx. 4m tall.	Failure in right bank on outside of slight left bend approx. 100m up river from bridge. Failure is full height of bank, approx. 20-30m long. Downstream on right bank, outside of slight bend, 40-50m from bridge 3 bank failures observed 7-15m long, subvertical backscarp, scalloped failure.		Erosion occurring on bends both upstream and downstream of bridge, deposition on banks/adjacent floodplain.	Dark silt/clay	Silt deposits on river banks. Lower banks are slightly bare, but not obviously over steepened or eroded.	NA	NA	NA	Field to south of main watercourse totally flooded. Large tree trunks lodged between bridge and pipe flow. Bridge was overtopped. Revisited site later in week at lower flows. Online data 11/03 @ 3pm, river level at 3.23m, last observed on Tues 08/03 @ 8am water level was 5.7m. Peak on 04/03 was 6.75m.
1b	BL	Local - well developed channel	C2	Condamine North Branch	vertosols	no data	345280	6925402	Double culvert, concrete, each approx. 2.5x1.5m. Very small wing walls. Downstream wall of culvert have larger wing walls and gabion on right bank.	Erosion in boulder fill at abutments, and minor erosion in natural banks. Banks at culvert are still partially inundated.	Low sinuosity channel but has been artificially straightened		Water level still high, natural banks are inundated., Large artificial berm forms right bank.	Grass with sparse trees	Minor local erosion and deposition at channel bends. Minor-moderate bank erosion observed.	Dark silt/clay	Dark silt/clay.	NA	NA	NA	Marks on depth gauge indicate water is at '0.65' but unclear what this is relevant to, currently at '0.3'. Detritus from flooding observed up to 2m up the bank from current water level.
3b	BL	Local - developed channel sections	B3	Nicol Creek	sodosols	no data	324234	6889362	Ford in road, concrete.	Water flowing across ford 5cm deep. Moss on ford, must flow regularly. Ponding upstream.	Low sinuosity channel with ponding caused by ford upstream	Overall channel 5m wide but wider just before ford. Downstream channel 2 m wide. Upstream shallow sloping banks steeper at water edge	Water level still high unable to see any in channel features.	Grass and sparse trees	Some minor out of bank deposition of fines in grass downstream. Minor steepening and erosion downstream of ford.	Silt/sand with minor gravel. Vegetated in places	Mostly vegetated	NA	NA	NA	

Coordinates									Erosion Potential (sites with existing infrastructure)		Channel					Material		Floodplain			
Site ID	Type	Watercourse Type	Floodplain Type	Catchment name	Soil Type ASC Regional	Soil Type ASC - Site (Aurecon 2022)	Easting	Northing	Infrastructure	Geomorphic change at existing infrastructure	Channel Type	Geometry	Features	Vegetation	Geomorphic Processes	Bed	Bank	Features	Vegetation	Behaviour	Notes
7a	BL	Headwater		SC 6	vertosols	no data	326392	6906693	Culvert approx. 8m wide.	Culvert structure has been totally infilled with sandy silt. Ponding upstream has resulted in deposition of sand/silt. Minor deposition/erosion occurring downstream.	Non channelised valley floor, very short sections (2m) of low sinuosity channel	Low sinuosity channel 2m wide, very shallow.	As flow dropped, it has transported some of the sediment deposited downstream.	Downstream side, long grass and some trees and brush.	Culvert has sedimented up and now restricts watercourse such that deposition occurs upstream. Sediment deposition at this site indicates erosion upstream.	Sand/silt	Vegetated, very low angle.	NA	NA	NA	
12	BL	Local - poorly developed channel		MB 5	kandosols	kurosols	306284	6857235	NA	NA	Short section of low sinuosity channel with gullies forming	3.5m wide, up to 0.4m deep. Vertical sides where eroded, gentle sloping sides where eroded material has been deposited downstream. Gully's are up to 2.5m deep.	Small gully's have formed up to 2.5 m deep. Some sand in grass on downstream roadside but no obvious sign of channel or water flow.	Bare channel in low sinuosity section, otherwise grass and tress with some sand deposited.	Gully erosion and deposition of sand	Sand with minor gravel .	Sand with layers of orange clay/silt on top.	NA	Grass and trees	NA	
15a	BL	n/a	B3b	Macintyre Brook	dermosols	no data	307473	6855661	Inglewood bridge	NA	NA	NA	NA	NA	NA	NA	NA	Difficult to distinguish due to the vegetation. Some paleochannels evident, subparallel to current channel.	Grass with some trees	Paleochannels occupied during flood events.	Township flooded and water reached bridge. Bridge is ~8m above the river. Flooding caused by large storm coinciding with water being release from Coolmunda dam. Debris visible at site 7-8m above current river level probably from this event.
16	BL	n/a	B3b	Canning Creek	sodosols	dermosols	313955	6859662	NA	NA	NA	NA	NA	NA	NA	NA	NA	Difficult to distinguish due to the vegetation. Flat to slightly undulating. Small ponds in depressions on west side of road.	Grass with some trees	Small ponds/backswamps in paleochannels	Photos facing south along road, east to field, west to field, north along road. Photos looking west at ponds and artificial channel.
EP17a	EP	Local - well developed channel	C2	Grasstree Creek	sodosols/vertosols	no data	344541	6912612	Concrete bridge approx. 15m wide with 4 piers and concrete wing wall. Water just below bridge surface during inspections	Difficult to tell if erosion/deposition occurring due to water level. Aerial imagery shows a vegetated meandering channel upstream of the bridge, and a 20m wide water filled meandering channel downstream which forms a chain of ponds.	Chain of ponds in meandering planform.	Current width approx. 20m, normal (lower flow) width maybe 15m. Very shallow slope on banks. Bank level only 0.5-0.75m above current water level.	Single channel with chain of ponds in low flows. Underwater during field visit.	Grass and trees on banks. Trees in main channel during inspection, so normal flow channel must be much smaller.	Difficult to confirm due to high water level. Aerial imagery shows change in channel type above and below bridge.	NA (underwater)	NA (vegetated, very gentle slope)	NA	Grass with trees along bank	NA	
EP18	Both	Local - developed channel sections	C1	Back Creek 1	sodosols	no data	330215	6913902	9 box culverts, each approx. 2.5m wide x 2m tall. Large vertical concrete wingwalls. Concrete wingwalls on upstream side much smaller.	Difficult to tell if erosion/deposition occurring due to high water level. Ponding upstream of bridge	Chain of ponds in meandering planform, appears meandering during site visit due to high water level.	River approx. 15m wide.	Not observed as water level high	Grass and trees	Difficult to confirm due to high water level. No sign of damage or overtopping downstream. No sign of sediment deposition or erosion.	NA (underwater)	NA (under water)	NA	NA	NA	Flattened grass shows water was approx. 0.5m higher but didn't reach top of bank.
19	BL	Headwater		NC 15	vertosols	no data	356540	6933606	NA	NA	Wash slope/non channelised valley floor	~30m wide	Poorly defined vegetated channel, no distinct features.	Grass	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetated)	NA (vegetated, very gentle slope)	NA	NA	NA	
21	BL	n/a	B3b/C2	Macintyre River	vertosols	no data	247636	6818170	NA	NA	NA	NA	NA	NA	NA	NA	NA	Area is very flat, paleochannels evident in aerial imagery	Grass and sparse trees.	Aerial imagery shows many paleochannels	
22	BL	Local - poorly developed channel		PC 1	sodosols	no data	323681	6919219	Further NE along road is a ford. Upstream sides of ford are concrete and riprap, natural material in soil. Downstream side of ford rock lined with wire restraint and some concrete, then loose rock riprap.	On upstream side water level is high. At transition to natural channel, flow has undercut concrete. Erosion occurring.	Non channelised valley floor upstream of ford, low sinuosity channel downstream	8-15m wide, 2-3 m deep. Ford concentrates channel to 1-2 m wide, widening to 5m wide downstream.	In channel vegetated bar downstream of ford.	Grass upstream of ponded area upstream of the ford, bare channel downstream	Ford changes channel form and behaviour, upstream ponding, downstream some erosion. Minor deposition of silt/sand on road and channel/floodplain	Silt/sand	Grass and trees upstream, downstream sand/silt	NA	Grass and trees	NA	
EP22a	EP	Headwater		C Ck 2	vertosols	no data	324573	6901783	Concrete pipe/culvert under road.	pipe/culvert heavily overgrown with long grass and scrub. No flow during site visit, likely flows only rarely	Non channelised valley floor		Poorly defined vegetated channel, no distinct features.	Grass	Minimal processes occurring, no evidence of bedload. Appears stable.	NA (vegetation)	NA (vegetated, very gentle slope)	NA	NA	NA	

Baseline Field Work Accompanying Images



F. 1 Site 1a photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 2 Site 1b photographs. River upstream of culvert (top left), culvert upstream detail (top right), culvert upstream (bottom left), culvert downstream detail (bottom right)



F. 3 Site 1d/EP16 photographs. Downstream failures (top left), bridge from downstream side (top right), from upstream left bank (bottom left), true left upstream (culverts underwater) (bottom right)



F. 4 Site 1h/EP16a photographs. From right bank (top left), right bank detail (top right), across channel towards true left bank (bottom left), Looking upstream towards the weir (under water) from right bank (bottom right)



F. 5 Site 2/EP34 photographs. Upstream (top left), downstream (top right), downstream detail 1 (bottom left), downstream detail 2 (bottom right).



F. 6 Site 3a/EP28 photographs. Upstream overview 1 (top left), culvert detail 1 (top right), culvert detail 2 (bottom left), upstream overview 2 (bottom right)



F. 7 Site 3b photographs. Upstream overview (top left), upstream detail (top right), carriageway (bottom left), downstream (bottom right).



F. 8 Site 5/EP29 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 9 Site 6/EP2 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right)



F. 10 Site 7a photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right)



F. 11 Site 9 photographs. Corner of Athol School facing west (left), and south (right).



F. 12 Site 10/EP31 photographs. Downstream, from road verge (road surface in lower part of the photo) (top left), downstream detail (top right), upstream (bottom left), upstream detail (bottom right)



F. 13 Site 11/EP7 photographs. Upstream (top left), upstream opposing side of carriageway (top right), downstream (bottom).



F. 14 Site 12 photographs. 4WD track (top left), uphill (top right), further uphill detail (bottom left), downstream side of road (bottom right).



F. 15 Site 14/EP3b photographs. Upstream from right bank (top left), upstream detail (top right), downstream (bottom left), downstream culvert (bottom right).



F. 16 Site 15a photographs. River from road (top left), debris detail (top left), downstream (bottom left), downstream detail (bottom right).



F. 17 Site 16 photographs. South along road (top left), field to east (top right), field to west (bottom left), road to north (bottom right).



F. 18 Site 17/EP39 photographs. Field to east (top left), road facing north (top right), road detail (bottom left), artificial channel (bottom right).



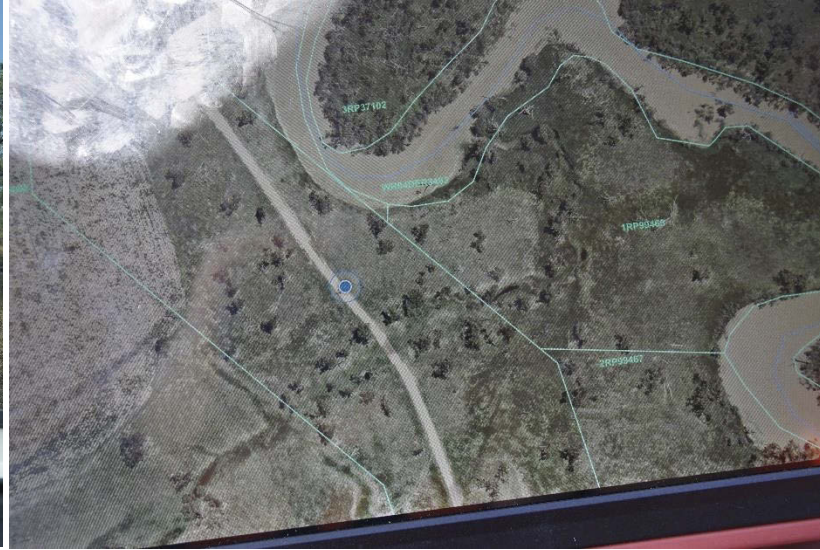
F. 19 Site 19 photographs. View down road (top left) and either side of road (top right and bottom).



F. 20 Site 21 photographs. Panorama facing northeast towards the Macintyre River Floodplain (top), panorama facing southwest (bottom)



F. 21 Site 22 photographs. Upstream of ford (top left), downstream (top right), downstream detail 1 (bottom left), downstream detail 2 (bottom right).



F. 22 *Photograph and location of chainage 139600 (land package 2RP99465).*



F. 23 EP1a photographs. Looking upstream towards the true right bank from left bank (top left), upstream detail of right bank (top right), across channel detail looking towards true right bank (bottom left), looking downstream (bottom right).



F. 24 EP1b photographs. Looking upstream (top left), ford/culvert looking downstream left bank (bottom left), right bank (bottom right).



F. 25 EP3a photographs. Downstream (top left), downstream detail (top right), upstream (bottom left), upstream detail (bottom right).



F. 26 EP4 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 27 EP5 photographs. SW of site looking back 1 (top left), SW of site looking back 2 (top right). View looking northwest from google earth, green line is proposed rail alignment (bottom).



F. 28 EP6 photographs. Upstream 1 (top left), upstream 2 (top right), downstream 1 (bottom left), downstream right (bottom right).



F. 29 EP8 photographs. Downstream (left), upstream (right).



F. 30 EP11 photographs. Facing SSW (left), facing NNE (right).



F. 31 EP17 photographs. From right bank (top left), detail 1 (top right), detail 2 (bottom).



F. 32 EP17a photographs. Upstream 1 (top left), upstream 2 (top right), downstream 1 (bottom left), downstream 2 (bottom right).



F. 33 EP18 photographs. Upstream (top), downstream 1 (bottom left), downstream 2 (bottom right).



F. 34 EP19 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 35 Site 8/EP21 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 36 EP22 photographs. Facing NW (left), facing SE (right).



F. 37 *EP22a photographs.*



F. 38 EP23 photographs. Upstream detail 1 (top left), upstream detail 2 (top right), downstream (bottom).



F. 39 EP23a photographs. Upstream (top left), upstream detail (top right), downstream (bottom).



F. 40 EP24 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 41 EP24a photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 42 EP25 photographs. Downstream (top left), downstream detail (top right), upstream (bottom left), downstream detail (bottom right).



F. 43 EP26 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 44 *EP27 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).*



F. 45 EP30 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 46 EP32 photographs. Upstream (top left), culvert upstream end (top right), downstream (bottom left), downstream 2 (bottom right).



F. 47 EP33 photographs. Panorama upstream (top), panorama downstream (middle), upstream detail (bottom left), downstream detail (bottom right).



F. 48 EP36 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 49 EP37 photographs. Upstream (top left), upstream detail (top right), downstream detail 1 (bottom left), downstream detail 2 (bottom right).



F. 50 EP38 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 51 4/EP40 photographs. Upstream (top left), ford (top right), Downstream (bottom left) downstream detail of scour in banks (bottom right).



F. 52 EP41 photographs. Upstream (top left), downstream (top right), sand on road (bottom left and right).



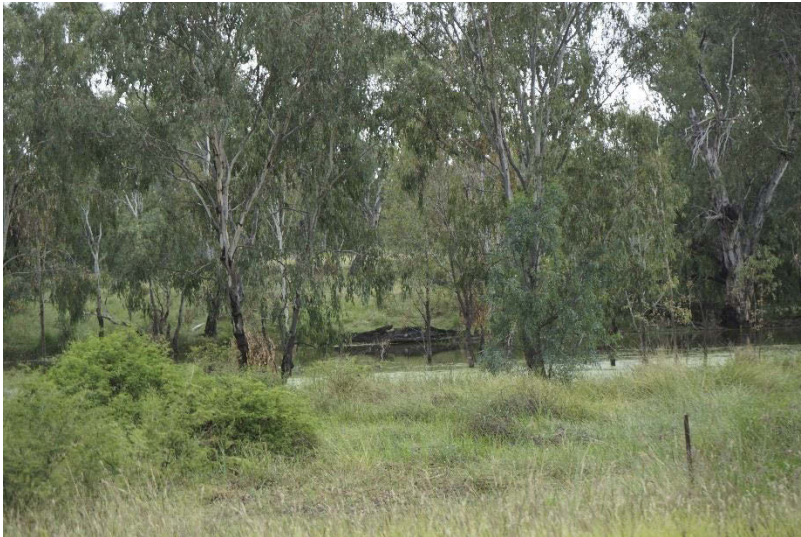
F. 53 EP42 photographs. Downstream (top left), downstream detail (top right), upstream (bottom left), upstream detail (bottom right).



F. 54 EP43 photographs. Downstream northern bridge (top left), upstream northern bridge (top right), downstream southern bridge (bottom left)



F. 55 EP44 photographs. Upstream (top left), upstream detail (top right), downstream detail (bottom left), downstream (bottom right).



F. 56 EP44a photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



F. 57 EP45 photographs. Upstream (top left), upstream detail (top right), downstream (bottom left), downstream detail (bottom right).



Geomorphology Report

Appendix G Watercourse sub-reach classification

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

CH (km)	Watercourse ID	Associated field checking site	Watercourse type	Channel type ⁶	Valley Setting	Valley setting notes	Tributaries ¹	Planform	Sinuosity	Channel Gradient (rise/run)	Channel planform at alignment	Channel processes ⁶	Local humanmade hydraulic controls	Change since earliest aerial image	Existing case sensitivity to change ²	ASC - Regional	ASC - Site (Aurecon 2022)
30.6	MB10	n/a	Local - poorly developed channel	Non-Channelised Valley Floor	unconfined		5060 m d/s converges	Sinuuous	1.18	0.010	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	Existing rail line Farm track 250m d/s Humanmade pond 250m u/s	Channel has become more defined downstream of existing road, possibly due to increased erosion. Channel appears to have widened u/s of ford.	4	Dermosols	Dermosols
43.212	MB 9	n/a	Local - poorly developed channel	Washslope to Non-Channelised Valley Floor	semi confined	Semi-confined to the north-east (250m to peak) - 4m elevation change	1045 m d/s converges with Macintyre Brook	Straight to sinuous	1.05	0.010	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	Existing rail line 1050m d/s constructed channel	Appears unchanged. Constructed channel across flow path 1050m d/s.	1	Dermosols	Dermosols
48.396	MB 8	n/a	Local - poorly developed channel	Non-Channelised Valley Floor	unconfined		1260 m u/s true left 890 m d/s converges with Macintyre Brook	Straight	1.03	0.020	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	50m u/s new road ford 800m d/s humanmade pond	Appears unchanged other than increase in vegetation d/s. 50m u/s new road ford constructed and 800m d/s humanmade pond.	2	Kandosols/ Chromosols	Kandosols/ Chromosols
52.599	MB 7	n/a	Local - poorly developed channel	Low sinuosity channel	unconfined		800m d/s converges Macintyre Brook	Sinuuous	1.07	0.006	Bend	Minimal processes occurring. Appears stable.	300 m d/s existing road	Appears unchanged, slightly more riparian vegetation.	1	Dermosols	Sodosols/ Dermosol
55.619	MB 6	n/a	Local - poorly developed channel	Non-Channelised Valley Floor with short section of low sinuosity channel	semi confined		840 m u/s true right 2300m u/s true left 2300 m d/s converges with Macintyre Brook	Sinuuous	1.11	0.003	Straight/bend	Minimal processes occurring. Appears stable.	Channel is approximately 0.5m deep and 1.5m wide in an otherwise relatively flat area. Bushy vegetation and anthropogenic constraints of crop circles, and fence lines. Moderate vegetation on bank edges.	Appears unchanged	2	Sodosols	Kurosols
60.465	MB 5	12	Local - poorly developed channel	Non-Channelised Valley Floor with short section of low sinuosity channel	semi confined		Multiple tributaries 100m u/s true right 130m u/s true left 1560m d/s converges with Macintyre Brook	Straight	1.04	0.024	Straight	Approximately 200 m upstream of the alignment, gully's, up to 2.5 m deep, have formed and eroded depositing sand on the road near the watercourse. Some sand in grass on downstream of roadside but no obvious sign of channel or water flow. Channel downstream and at the alignment is non channelised valley floor flow with sections of low sinuosity channel	190 m u/s Bybera Road	Vegetated and difficult to confirm if gully is present in earlier imagery. Planform appears unchanged, some man made ponds constructed upstream.	5	Kandosols	Kurosols
61.59	MB 4	n/a	Headwater	Washslope to Non-Channelised Valley Floor	confined	Confined to northeast (300m to peak) 6m elevation change. Confined to southwest (400m to peak) 30m elevation change	66m d/s true right MBs 1 457 m d/s converges with MB 3	Straight	1.04	0.030	Straight/bend	Minimal processes occurring, no evidence of bedload. Appears stable.	1500m u/s road ford	Appears unchanged, slightly more riparian vegetation.	1	Kandosols	Kurosols
61.9	MB 3	n/a	Local - developed channel sections	Low sinuosity channel	semi confined		Multiple tributaries 180m u/s true left 290m u/s true left 540m u/s true left and true right (2 tributaries join) 800m u/s true left 2800m d/s converges with Macintyre Brook	Sinuuous	1.06	0.024	Straight	Minimal processes occurring. Appears stable.	Moderately defined channel with approx. 0.5-1m depression. No visible continuous water.	Appears unchanged, less riparian vegetation.	1	Kandosols	Kurosols
62.911	MB 2	n/a	Headwater	Non-Channelised Valley Floor	unconfined		1000m d/s true right MB3 3000m d/s converges with Macintyre Brook	Straight	1.01	0.046	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	None nearby	Appears unchanged	1	Kandosols	Kurosols
63.148	MB 1	n/a	Headwater	Non-Channelised Valley Floor	unconfined		6500m d/s converges with Macintyre Brook	Sinuuous	1.18	0.018	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	None nearby	Appears unchanged	1	Kandosols	Kurosols
66.225	C Ck 20	EP41	Local - developed channel sections	Non-Channelised Valley Floor with short section of low sinuosity channel	unconfined	40 to 20m wide with undulating flat bottom, banks 2-4m tall, 30 degree slope.	420m u/s true left 620m u/s true left 2058m u/s true left 2558m u/s true right 542m d/s converges with Pariagara Creek	Sinuuous	1.23	0.007	Straight	Minimal processes occurring. Some increased sediment from erosion of road surface. Appears stable.	515 m d/s farmers track	Channel planform unchanged, riparian planting around channel increased.	2	Sodosols	Kurosols
66.811	C Ck 19	n/a	Headwater	Wash slope, becoming chain of ponds downstream	unconfined		730m d/s converges with Pariagara Creek	Sinuuous	1.19	0.009	Straight	Minimal processes occurring. Appears stable.	350 m d/s existing farmers pond (175 m x 76 m)	Appears unchanged	2	Sodosols	Vertosol/ Rudosol
67.209	C Ck 18	n/a	Headwater	Washslope to Non-Channelised Valley Floor	unconfined		140m d/s converges with Pariagara Creek 120m u/s true right	Straight	1.03	0.007	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	None nearby	Channel has become more defined, vegetation has increased.	3	Sodosols	Rudosols
67.328	Pariagara Creek	4/ EP40	Local - well developed channel	Low sinuosity channel	unconfined		220m d/s true right C Ck 18 140m u/s	Straight to sinuous	1.05	0.004	Straight	In-channel bars and benches with ripple formations at edges. Downstream localised bank erosion and steepening. Significant in-channel deposition of sand and silty sand (mostly sand). Channel is 3-4m deep, banks are 35-50 degrees. Channel 10-15m at base, 15-25m at crest.	None nearby	Channel appears largely unchanged, small local planform changes at bends. More riparian vegetation along channel.	3	Sodosols	Dermosols
68.734	C Ck 17	n/a	Headwater	Non-Channelised Valley Floor with short section of low sinuosity channel	unconfined		515m d/s converges with Pariagara Creek	Straight to sinuous	1.06	0.003	Straight	Minimal processes occurring. Appears stable.	60 m d/s existing road	Channel location unchanged, patches with less vegetation.	2	Sodosols	Dermosols
73.363	CCs 22	n/a	Headwater	Gully	unconfined		340 m d/s converges with Canning Creek	Sinuuous	1.09	0.019	Straight	Active gully erosion	None nearby	Channel was visibly smaller and ~210 m shorter in aerial imagery for 1959, vegetation cleared.	5	Sodosols	Sodosols
73.529	CCs 21a	n/a	Headwater	Gully	unconfined		150m d/s converges with C Ck 16	Straight to sinuous	1.05	0.031	Straight	Active gully erosion	None nearby	Channel was visibly narrower and shorter in aerial imagery, vegetation cleared.	5	Sodosols	Sodosols
73.531	CCs 21	n/a	Headwater	Gully	unconfined		115m d/s converges with C Ck 16	Straight	1.02	0.026	Straight	Active gully erosion	None nearby	Channel was visibly narrower and shorter in aerial imagery, vegetation cleared.	5	Sodosols	Sodosols
73.614	C Ck 16a	n/a	Headwater	Gully	unconfined		116m d/s converges with C Ck 16 620 m d/s converges with Canning Creek	Moderate meandering	1.48	0.015	Straight	Actively eroding channels, visible scour from aerial imagery. Not present in 1959 imagery.	None nearby	Channel was visibly narrower and shorter in aerial imagery, vegetation cleared.	5	Sodosols	Sodosol/ Vertosols

CH (km)	Watercourse ID	Associated field checking site	Watercourse type	Channel type ⁵	Valley Setting	Valley setting notes	Tributaries ¹	Planform	Sinuosity	Channel Gradient (rise/run)	Channel planform at alignment	Channel processes ⁶	Local humanmade hydraulic controls	Change since earliest aerial image	Existing case sensitivity to change ²	ASC - Regional	ASC - Site (Aurecon 2022)
73.682	C Ck 16	EP38	Local - poorly developed channel	Gully	unconfined		530m d/s converges with Canning creek 154m u/s true left 270m u/s true left CCs 20 260m u/s true right 45m d/s true right 225m d/s CCs 21	Sinuous	1.23	0.009	Bend	Active gully erosion	None nearby	Channel was visibly narrower and shorter in aerial imagery, vegetation cleared.	5	Sodosols	Vertosol
74.969	CCs 19	n/a	Headwater	Gully	unconfined		1280 m d/s true right Approx. 1400 m d/s true right Approx. 1800 d/s converges with Canning Creek	Sinuous	1.21	0.001	Straight	Active gully erosion	None nearby	Bush has been cleared. Gully's have developed and widened the watercourse, but do not appear to have migrated headward upstream along the channel very far. Man made pond constructed 450 m downstream of the alignment crossing.	5	Sodosols	Sodosol/ Vertosols
78.997	C Ck 15	EP37	Headwater	Non-Channelised Valley Floor with low sinuosity channel downstream	unconfined	~2m elevation gain approx.	1423m d/s converges with Canning Creek	Sinuous	1.06	0.009	Straight	Approx. 85m wide channel approx. 0.5m deep. Slight ponding downstream of culvert at EP37, indicating erosion, after apron water has scoured a pool 4m wide 10m long, 30cm deep.	73 m d/s existing road	Channel planform unchanged, downstream less vegetation.	4	Sodosols	Sodosols
82.348	C Ck 14	EP36	Headwater	Non-Channelised Valley Floor	unconfined		Approx. 1700m d/s converges with Canning Creek	Straight	1.04	0.010	Bend	Minimal processes occurring, no evidence of bedload. Appears stable.	Existing road adjacent to alignment which appears to modify the flow.	Channel planform appears unchanged, dense vegetation upstream, vegetation cleared downstream.	2	Sodosols	Sodosols
84.385	C Ck 13	n/a	Headwater	Low sinuosity channel	unconfined		1190 m d/s converges with CCs 16	Sinuous	1.14	0.009	Straight/bend	Minimal processes occurring. Appears stable.	50m u/s road culvert 150m d/s farm track ford	Appears unchanged Road 50m u/s upgraded	2	Sodosols	Sodosols
87.37	C Ck 12	n/a	Headwater	Low sinuosity, possible some non-channelised valley floor	unconfined		170m d/s true right CCs 15 670 m converges with Cattle Creek	Sinuous	1.11	0.015	Straight/bend	Minimal processes occurring. Appears stable.	100m u/s ponding u/s of existing road and farm track.	Ponding has developed u/s of road (100 m u/s of alignment). Ponding is up to 15 m wide and extends 150m u/s. Channel appears unchanged, downstream of road.	4	Sodosols	Sodosols
88.241	Cattle Creek	2/ EP34	Local - developed channel sections	Non-Channelised Valley Floor with short section of low sinuosity channel	semi confined	Semi-confined to the north-east (50m to peak) 6m elevation change	1993m d/s converges with Canning Creek 211m u/s true left 1404m u/s true left	Moderate meandering	1.39	0.005	Straight	Low point of watercourse under bridge, downstream channel incised into valley floor.	Existing road bridge	Appears unchanged	2	Sodosols	Sodosols
90.961	C Ck 11	EP33	Local - poorly developed channel	Non-Channelised Valley Floor	unconfined		600 m u/s true right 1580 m d/s converges with unnamed watercourse	Sinuous	1.13	0.006	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	43 m u/s existing road	Appears unchanged	2	Sodosols	Sodosols
92.064	C Ck 10	EP32	Headwater	Washslope, non channelised Valley Floor, short sections of channel may be present	unconfined		3290 m d/s converges with C Ck 11	Sinuous	1.20	0.023	Straight	Minimal processes occurring. Appears stable.	10m u/s humanmade pond	Less riparian vegetation 10m u/s humanmade pond constructed in channel, likely reduces d/s flow, however channel form downstream appears unchanged.	4	Sodosols	Sodosols
93.652	Native Dog Creek	10/ EP31	Local - poorly developed channel	Non-Channelised Valley Floor with some sections of low sinuosity channels	unconfined		1640m d/s converges with Canning Creek	Sinuous to moderate meandering	1.33	0.004	Straight	Local areas of very minor erosion visible.	Channel depression of approx. 0.5m. No clear channel visible, except some patchy vegetation.	Appears unchanged	2	Sodosols	No data
97.638	Back Creek 2	EP30	Local - poorly developed channel	Non-Channelised Valley Floor with some sections of low sinuosity channels	semi confined	Confined to the SW (300m from crossing) 5m elevation Confined to the NE (75m from crossing) 5m elevation	85m d/s Bringalily	Sinuous	1.26	0.005	Bend	Channel approx. 0.5m deep. Appears slightly more sinuous upstream and becomes straighter downstream. Area of ponding at the convergence between Back creek 2 and Bringalily creek. Minimal processes occurring.	Manmade pond approx. 390m upstream of alignment (approx. 50m wide).	Multiple man made ponds developed. Channel planform appears unchanged, increased riparian vegetation.	2	Sodosols	Vertosol
100.598	Bringalily	5/ EP29	Local - well developed channel	Chain of ponds with either narrow low sinuosity channel or in rare cases, non-channelised valley floor between ponds.	semi confined	Confined to the SW by 4m elevation change approx. 75m from alignment.	100m u/s true left 400m d/s true left Nicol Creek	Meandering	1.71	0.002	Straight to slight bend	Bank erosion and slumping occurring downstream. Bridge has caused channel to widen both upstream and downstream.	Road bridge with pond beneath (65m by 25m).	Man made pond upstream developed. Channel planform appears unchanged, increased riparian vegetation.	2	Sodosols	Dermosols / Sodosols
104.429	Nicol Creek	EP28/ 3a	Local - developed channel sections	Chain of ponds in meandering planform.	semi confined	Semi-confined to the SW by 7m elevation change approx. 125m from alignment.	1680m u/s true left 1642m d/s true left	Moderate meandering	1.47	0.004	Bend	Cut off channel visible south of current meandering planform. Channel depth approx. 0.5m. Minimal processes occurring.	30m u/s alignment there is a pond approx. 25m wide. 900 m u/s culvert with upstream ponding and downstream erosion. 2000m downstream, ford with downstream erosion.	Appears unchanged	2	Vertosol/ Sodosol	No data
107.212	C Ck 9	n/a	Headwater	Washslope to Non-Channelised Valley Floor	unconfined		170 m d/s true left	Sinuous	1.13	0.027	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	300m d/s humanmade pond 850m u/s road ford 950m u/s humanmade pond	Channel appears unchanged, vegetation has increased slightly. Surrounding land terraced. 950m u/s humanmade pond constructed.	4	Vertosol	Sodosols
109.437	C Ck 8	n/a	Local - poorly developed channel	Washslope to Non-Channelised Valley Floor	semi confined	Semi-confined to the northwest (200m from crossing) 10m elevation change	315 m u/s true right 1690 m d/s true right	Straight	1.01	0.013	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	1260m d/s road culvert 1130m d/s humanmade pond 470m d/s humanmade pond 1250m u/s humanmade ponds	Channel appears unchanged. Surrounding land terraced.	2	Vertosol	Sodosols
113.069	C Ck 7	n/a	Headwater	Non-Channelised Valley Floor with some sections of low sinuosity channels	unconfined		882m d/s converges tributary to Nicol Creek 115m d/s true left converges CCs 6	Straight/ sinuous	1.06	0.024	Straight	Minimal processes occurring. Appears stable.	Small pond approx. 125m u/s (28m by 15m). Pond 710m d/s (30m by 55m).	Appears straightened between farmers paddocks.	4	Vertosol	No Data
113.289	C Ck 6	n/a	Headwater	Non-channelised Valley floor	unconfined		240m d/s converges tributary to Nicol Creek	Sinuous	1.10	0.033	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	Pond 236m d/s (68m by 55m), and second pond 365m d/s (80m x 100m).	Appears unchanged	2	Vertosol	No Data
113.513	C Ck 5	n/a	Headwater	Non-Channelised Valley Floor with some sections of low sinuosity channels	unconfined		164m d/s converges tributary to Nicol Creek	Straight	1.04	0.039	Straight	Minimal processes occurring. Appears stable.	None nearby	Channel planform appears unchanged, upstream vegetation removed.	2	Vertosol	No Data

CH (km)	Watercourse ID	Associated field checking site	Watercourse type	Channel type ⁵	Valley Setting	Valley setting notes	Tributaries ¹	Planform	Sinuosity	Channel Gradient (rise/run)	Channel planform at alignment	Channel processes ⁶	Local humanmade hydraulic controls	Change since earliest aerial image	Existing case sensitivity to change ²	ASC - Regional	ASC - Site (Aurecon 2022)
113.768	C Ck 4	n/a	Headwater	Wash slope, Non-channelised Valley floor with sections of low sinuosity channel.	unconfined		262m d/s converges tributary to Nicol Creek	Sinuuous	1.06	0.048	Straight	Minimal processes occurring. Appears stable.	None nearby	Channel planform appears unchanged, upstream vegetation removed.	4	Vertosol	No Data
114.42	C Ck 3	n/a	Local - poorly developed channel	Non-Channelised Valley Floor, some visible low sinuosity channel features in places.	unconfined	Approx. 180m wide non channelised valley floor, before elevation gradually increases	100m d/s true right 530m d/s true left CCs 5	Sinuuous	1.09	0.016	Bend	Minimal processes occurring. Appears stable.	Pond 80m u/s (110m by 80m).	Channel planform appears unchanged, increase size of pond in flow path.	4	Vertosol	No Data
115.511	C CK 2	EP24/ EP22a	Headwater	Non-Channelised Valley Floor, some visible low sinuosity channel features in places.	unconfined		143m d/s C CK 1 220m d/s 510m d/s CCs 1	Sinuuous	1.10	0.029	Straight	Minimal processes occurring. Appears stable.	Pond 480m u/s (50m by 70m). Existing road crossing and culvert.	Appears unchanged	4	Vertosol	No Data
115.623	C CK 1	n/a	Headwater	Washslope to Non-Channelised Valley Floor	unconfined to semi-confined	True left confined by exiting road 95m away.	144m d/s converges with C Ck 2 222m d/s converges with tributary to Nicol Creek 520m d/s true left CCs 1	Straight	1.03	0.023	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	85 m southeast of watercourse crossing is existing road.	Appears unchanged	2	Vertosol	No Data
117.489	SC 11	n/a	Headwater	Non-Channelised Valley Floor with some sections of low sinuosity channels	unconfined		238m d/s SC10 true left 125m u/s true left 433m u/s true left 590m u/s true left	Sinuuous	1.06	0.016	Straight converges with SC10 236m d/s alignment	Minimal processes occurring. Appears stable.	65m downstream Pond (70m by 60m). Pond 850m u/s (60m by 50m).	Channel planform appears unchanged, slightly more riparian vegetation.	4	Vertosol	Vertosol
117.605	SC 10	n/a	Headwater	Non-Channelised Valley Floor	unconfined		118m d/s SC11 true right	Sinuuous	1.12	0.021	Straight converges with SC11 118m d/s alignment	Minimal processes occurring, no evidence of bedload. Appears stable.	Man made ponds along flow path. 972m d/s pond at convergence with SC9.	Appears unchanged	2	Vertosol	Vertosol
118.421	SC 9	n/a	Headwater	Non-Channelised Valley Floor with some sections of low sinuosity channels	unconfined		578m d/s 775m u/s true right	Sinuuous	1.16	0.018	Straight.	Minimal processes occurring. Appears stable.	437m u/s Pond (110m by 95m). Pond 575m d/s convergence with SC10 (80m by 30m).	Appears unchanged	2	Vertosol	Vertosol
119.377	SC 8	n/a	Headwater	Non-Channelised Valley Floor with short section of low sinuosity channel	unconfined		1456m d/s	Sinuuous	1.08	0.018	Straight.	Minimal processes occurring. Appears stable.	Pond 630m u/s (60m by 70m), Pond 820m u/s (40m by 45m), Pond 1670 m u/s (60m by 40m), Pond 830m d/s (120m by 20m), Pond 1075m d/s (113m by 20m), Pond 1455m d/s (160m by 60m)..	Appears unchanged	4	Vertosol	Vertosol
120.333	SC 7	EP22/ EP22a	Local - poorly developed channel	Non-Channelised Valley Floor with short section of low sinuosity channel	unconfined	Semi confined approx. 1500 m downstream due to existing road.	1249m u/s	Sinuuous	1.20	0.012	Straight.	Minimal processes occurring. Appears stable. Road acts as embankment across watercourse, ponding occurs adjacent to road.	Human made ponds 150 m u/s (70 m by 70 m), 1120 m u/s (50 m by 25 m), 1373 m u/s (100 m by 50 m). Initial high risk field site, refer to detailed assessment.	Scour downstream of man made pond has occurred over the last 10 years, the pond was enlarged and now has effectively cut off the natural watercourse.	5	Vertosol	No data
120.756	SC 6	n/a	Headwater	Non-Channelised Valley Floor, very short sections (2m) of low sinuosity channel.	unconfined		554m d/s converges with SC 5	Straight	1.04	0.019	Straight.	Minimal processes occurring. Appears stable.	Man made ponds along flow path. Pond 516m u/s (78m by 50m).	Appears unchanged	2	Vertosol	Vertosol
121.442	SC 5	8/ EP21	Headwater	Non-Channelised Valley Floor with short section of low sinuosity channel	unconfined		870m d/s converges SC6	Straight	1.04	0.032	Straight.	Culvert has concentrated flow and resulted in local erosion/deposition. Natural watercourse appears stable.	Existing road bridge 50m d/s. Man made ponds 53m u/s (43m by 35m). Pond 520m d/s (100m by 40m). Upstream channel widens to 3m. Downstream channel only discernible from some bent grass, approx. 40cm wide. Other than the local culvert impacts, no discernible fluvial geomorphology occurring at this site.	Channel planform appears unchanged, new pond downstream.	2	Vertosol	Vertosol
124.372	SC 4	n/a	Headwater	Non-channelised Valley floor	unconfined		450m d/s	Straight	1.05	0.009	Straight.	Minimal processes occurring, no evidence of bedload. Appears stable.	Man made ponds along flow path	Appears unchanged.	2	Vertosol	Vertosol
125.479	SC 3	n/a	Headwater	Non-channelised Valley floor with sections of low sinuosity channels, no channel downstream of man made ponds in flow path	unconfined		1024 m d/s converges SC 3	Sinuuous	1.24	0.042	Straight/bend	Minimal processes occurring. Appears stable.	250m u/s humanmade pond 250m d/s farm track ford 450m d/s humanmade pond	Surrounding land terraced Increased vegetation (riparian margin not cropped). Minimal change to channel planform. 250m u/s humanmade pond 250m d/s farm track ford 450m d/s humanmade pond	2	Vertosol	Vertosol
126.96	SC 2	EP19	Local - developed channel sections	Chain of ponds with low sinuosity channel between	unconfined	Manmade pond located within floodplain (approx. 70 m by 40 m)	390m d/s converges with Back Creek 1	Moderate meandering	1.40	0.006	Bend	Water ponding. No obvious erosion.	Bridge encroachment at meander bend, not actively eroding, modified channel at bend. Initial high risk field site, refer to detailed assessment.	Channel planform appears unchanged, increased vegetation.	2	Sodosols	Vertosol
128.017	Back Creek 1	EP23a/ EP23	Local - developed channel sections	Non-Channelised Valley Floor to chain of ponds in meandering planform	unconfined		1380m d/s SC2	Meandering form	1.87	0.002	Bend	Some minor bank erosion occurring directly upstream of culverts in valley floor. Minor damage to banks from cattle. Minor deposition at culverts.	Channel approximately 15 m wide, with multiple man made ponds.	Channel planform appears unchanged, increased vegetation.	2	Vertosol	No data
130.182	SC 1	n/a	Headwater	Washslope to Non-Channelised Valley Floor	unconfined	Manmade pond at crossing point (approx. 260 m by 180 m)	None	Straight	1.03	0.008	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	290m u/s humanmade pond 250m u/s road ford 25m d/s farm track form 130m d/s dam 360m d/s farm track form 420m d/s humanmade pond 1290m d/s humanmade pond	Channel appears unchanged 150m d/s humanmade pond enlarged	2	Vertosol	Vertosol
139.851	Grasstree Creek	EP17/ EP17a	Local - well developed channel	Chain of ponds in meandering planform.	semi confined	Confined to the east by 3m elevation change (approx. 150m away).	2800m d/s Grasstree Creek	Meandering form	1.51	0.000	Slight bend	Single channel with chain of ponds in low flows. Shallow vegetated banks. Minor deposition, no obvious erosion.	Semi-confined at the edge of a floodplain. Aerial imagery shows a vegetated meandering channel upstream of the bridge, and a 20m wide water filled meandering channel downstream which forms a chain of ponds. Existing road bridge 50m d/s of alignment.	Appears unchanged. Approximately 5 km up valley, a weir was constructed pre aerial imagery, and directly down stream from that a flood channel cut off has developed.	2	Sodosols/ Vertosols	No data
141.032	Condamine anabranh	n/a	Local - poorly developed channel	Non-Channelised Valley Floor with short section of low sinuosity channel	unconfined	No major elevation changes adjacent to basin floor.	1580m d/s converges with Grasstree Creek	Sinuuous to moderate meandering	1.30	0.001	Bend	Minimal processes occurring. Appears stable.	Existing ponding is beneath current road bridge (approx. approx. 90m long, 15-22m wide).	At and upstream of the alignment, the watercourse has been channelised in drains around a field, with at least 3 right angles.	4	Vertosol	Vertosol
142.6	Condamine South Branch	n/a	Local - poorly developed channel	Not a watercourse, flood channels located within flood basin, erosion channels developed downstream of the existing rail embankment	unconfined	Located in flood basin	2320m d/s converges with Grasstree Creek	n/a	n/a	n/a	n/a	Erosion downstream and upstream of existing culverts.	Existing rail embankment and culverts.	Erosion has continued upstream towards the rail embankments.	5	Vertosol	Vertosol

CH (km)	Watercourse ID	Associated field checking site	Watercourse type	Channel type ⁶	Valley Setting	Valley setting notes	Tributaries ¹	Planform	Sinuosity	Channel Gradient (rise/run)	Channel planform at alignment	Channel processes ⁶	Local humanmade hydraulic controls	Change since earliest aerial image	Existing case sensitivity to change ²	ASC - Regional	ASC - Site (Aurecon 2022)
144.215	Condamine River	1h/EP16a & 1d/ EP16	Main Stem	Meandering to sinuous channel	unconfined		60m u/s true right tributary converges	US- moderate meandering DS- sinuous	1.54	0.001	Bend	Well developed channel approx. 4m deep at alignment. Erosion occurring on bends both upstream and downstream of bridge, deposition on banks/adjacent floodplain.	Existing rail bridge at site.	Channel planform appears unchanged, more riparian vegetation, however historic maps show that 2 diversion were constructed in the late 1800's which later on resulted in an avulsion event occurring which developed a channel that is now the main Condamine River Channel in the Project area.	5	Vertosol	No data
149.99	Condamine North Branch	1a, 1b	Local - well developed channel	US - low sinuosity channel DS - Chain of ponds in meandering planform.	US- semi confined DS- 'unconfined' semi confined by ponds	US- Semi-confined by man made ponds on the true right. Lidar shows relatively flat terrain (unconfined) DS- 'unconfined' Local areas semi confined by ponds (4m embankment above the floodplain)	>7.5km u/s	US-Sinuosity to moderate meandering (channelised) DS- meandering	US - 1.395 DS - 3.283	0.000	Bend	Minor local erosion and deposition at channel bends. Minor-moderate bank erosion observed.	Existing rail embankment with bridge. Two large manmade ponds on the true right of alignment u/s (6m embankment, first is 500m x 350m, second is 600m x 330m). Artificially straightened upstream approx. 2.3km.	Construction of large ponds and channel straightening has occurred upstream of alignment. A pond has also develop upstream of the road bridge, approximately 40m by 60 m.	US - 4 DS - 2	Vertosol	No data
160.033	NC 16	n/a	Headwater	Washslope to Non-Channelised Valley Floor	unconfined		1082 m d/s converges with unnamed watercourse	Straight	1.01	0.023	Straight.	Minimal processes occurring, no evidence of bedload. Appears stable.	40m u/s humanmade pond Existing rail.	Appears unchanged. 40m u/s humanmade pond. Rilling has developed in bare soil exposed during cropping ~1km soundstream.	2	Vertosol	Vertosol
164.158	NC 15	19	Headwater	Non-Channelised Valley Floor / wash slope.	unconfined		420m d/s converges with NC14 115m d/s man made pond (approx. 45m wide)	Sinuosity	1.08	0.018	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	170 m u/s existing road 110 m d/s existing farmers pond off to the true left of watercourse.	Appears unchanged	2	Vertosol	No Data
164.418	NC 14	n/a	Headwater	Non-Channelised Valley Floor	unconfined		530m d/s converges with NC15	Straight/ sinuous	1.05	0.012	Straight.	Minimal processes occurring, no evidence of bedload. Appears stable.	240 m u/s existing road	Appears unchanged	2	Vertosol	Vertosol
165.072	NC 13	n/a	Headwater	Non-channelised Valley floor with some short sections of low sinuosity channels	semiconfined	Semi-confined to the northwest (585m from crossing) 30m elevation change	1516 m d/s true left NC 14	Sinuosity	1.16	0.013	Straight.	Channel has been straightened before earliest aerial imagery.	225 m d/s road, channel has been diverted along the side.	Surrounding Land Terraced. Channel straightened prior to earliest imagery, however largely appears unchanged since.	4	Vertosol	Vertosol
169.873	NC 12	n/a	Headwater	Non-channelised valley floor	unconfined		680m d/s	Sinuosity	1.07	0.029	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	Man made pond 180 m d/s of alignment in flow path (70m by 35m).	Channel unclear in imagery	2	Dermosols	Ferrosols
170.561	NC 11	n/a	Headwater	Non-channelised valley floor with sections of low sinuosity channels and bedrock constrained channel	semi confined	Confined to the east by 3 m elevation change (25 m away). Confined to the west by 2 m elevation change (50 m away)	1.4km d/s converges with NC12	Sinuosity	1.11	0.015	Bend	Bank erosion and scour holes downstream of proposed alignment. No in channel deposition observed, indicating a small bedload.	Multiple manmade ponds in flow path including a 25 m by 25 m pond 5 m u/s of alignment crossing. Existing culvert 150 m u/s.	Man made pond constructed to the right of the channel, slight changes to channel planform near this pond.	4	Dermosols	Ferrosols
171.9	NC 10	n/a	Headwater	Non-channelised Valley floor with some short sections of low sinuosity channels, man made pond upstream of alignment	unconfined		244 m d/s true right NC9	Straight	1.02	0.014	Straight.	Minimal processes occurring. Appears stable.	500m u/s humanmade pond enlarged 350m u/s humanmade pond 80m u/s main road culvert	Channel has been straightened and some upstream flow is diverted along road. Surrounding Land Terraced, road constructed 80m u/s with culvert. 500m u/s humanmade pond enlarged 350m u/s humanmade pond	4	Vertosol	Sodosols
172.232	NC 9	EP11	Headwater	Non-channelised Valley floor with some short sections of low sinuosity channels, wash slope downstream	unconfined		499 m d/s converges with NC 10	Straight	1.02	0.018	Straight.	Minimal processes occurring. Appears stable.	400m u/s culverted for new road 350m u/s humanmade pond 150m u/s culverted for new road 10m d/s culverted for new road	Surrounding Land Terraced Channel more defined and has been straightened. 400m u/s culverted for new road 350m u/s humanmade pond 150m u/s culverted for new road 10m d/s culverted for new road	4	Vertosol/ Rudosols	Vertosol
176.907	NC 8	n/a	Headwater	Washslope to Non-Channelised Valley Floor	unconfined		1.09km d/s converges with tributary	Straight	1.02	0.014	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	Man made pond (180m d/s, 60m long, 20m wide) in flow path.	Appears unchanged	2	Vertosol	Vertosol
178.689	NC 7	n/a	Headwater	Washslope, man made ponds in flow path both upstream and downstream of alignment	unconfined		1267 m d/s true right NCs 2	sinuous	1.11	0.007	Bend	Minimal processes occurring, no evidence of bedload. Appears stable.	130m d/s rail culvert 160m d/s road culvert	Channel unclear in imagery 130m d/s rail culvert 160m d/s road culvert	2	Vertosol	Sodosols
181.139	NC 6	n/a	Headwater	Non-Channelised Valley Floor with short section of low sinuosity channel	semi confined	Confined to the north by approx. 6m elevation change	410m u/s NCs1 converges with NC3 1.05km d/s NC5 converges with NC3	Straight/ sinuous	1.06	0.024	Bend	Minimal processes occurring. Appears stable.	Man made pond in flow path approx. 650m u/s.	Appears unchanged	2	Vertosol	Vertosol
181.795	NC 5	n/a	Headwater	Non-channelised Valley floor with some short sections of low sinuosity channels, and man made pond in flow path downstream	unconfined		697 m d/s true right NC 6	Straight	1.04	0.019	Straight.	Minimal processes occurring. Appears stable.	240m d/s farm track ford 320m d/s humanmade pond	Channel appears unchanged 240m d/s farm track ford 320m d/s humanmade pond enlarged	2	Vertosol	Sodosols
182.992	NC 4	n/a	Headwater	Washslope, Non-channelised Valley floor, man made pond in flow path directly downstream of alignment	unconfined	Manmade pond 35 m d/s of crossing	706 m d/s converges with NC 5	Straight	1.04	0.010	Straight.	Minimal processes occurring, no evidence of bedload. Appears stable.	50m d/s humanmade pond 450m d/s farm track ford	Surrounding Land Terraced 50m d/s humanmade pond enlarged, channel straightened d/s of pond.	4	Vertosol	Sodosols
184.866	NC 3	11/ EP7	Local - poorly developed channel	Non-Channelised Valley Floor with some sections of low sinuosity channels	confined	Confined to the east by 4m elevation change Confined to the west by 5m elevation change	190 US tributary joins 520m US tributary joins 1.73m DW tributary joins	US-Straight DS- Sinuous	US - 1.036 DS - 1.200	US - 0.0205 DS - 0.0155	Straight.	Minor deposition downstream.	Existing road bridge 75m d/s of alignment.	Appears unchanged	2	Dermosols	Vertosols/ Dermosols
186.179	NC 2	EP6	Headwater	Washslope, Non-channelised Valley floor, man made pond in flow path upstream of alignment	unconfined		2004 m d/s converges with NC 1	sinuous	1.15	0.025	Bend	Change in channel width after culvert, widens into pond area. Minor erosion on downstream banks.	700m u/s large humanmade pond 350m u/s humanmade pond 170m u/s humanmade pond 90m d/s road culvert	Channel appears unchanged. Surrounding Land Cleared and Terraced, and human made ponds constructed.	1	Dermosol/ Vertosols	Ferrosols/ Vertosols

CH (km)	Watercourse ID	Associated field checking site	Watercourse type	Channel type ⁶	Valley Setting	Valley setting notes	Tributaries ¹	Planform	Sinuosity	Channel Gradient (rise/run)	Channel planform at alignment	Channel processes ⁶	Local humanmade hydraulic controls	Change since earliest aerial image	Existing case sensitivity to change ²	ASC - Regional	ASC - Site (Aurecon 2022)
187.207	NC 1	EP5	Local - poorly developed channel	Non-Channelised Valley Floor with short section of low sinuosity channel	unconfined		760 m u/s true left 890 m d/s true left 1195 m d/s true left	straight to sinuous	1.05	0.024	Straight	Minimal processes occurring. Appears stable.	400m u/s humanmade pond 90m d/s road culvert 130m d/s humanmade pond 400m d/s humanmade pond	400m u/s humanmade pond 90m d/s road culvert, channel erosion d/s of culvert has resulted in development of a low sinuosity channel, increased sediment transported. 130m d/s humanmade pond 400m d/s humanmade pond	4	Vertosol/ Ferralsols	Ferralsols/ Vertosols
190.005	OC 5 (Half Mile Gully)	13	Local - poorly developed channel	Non-Channelised Valley Floor with short section of low sinuosity channel	unconfined		330m u/s Tributary 195m d/s 360m d/s	Straight/ sinuous	1.06	0.010	Straight	Minimal processes occurring. Appears stable.	Several man made ponds in flow path upstream and downstream of alignment. Pond 270m u/s from alignment approx. 5m deep, 200m wide , 600m long.	Appears unchanged	2	Vertosol	Ferralsols/ Vertosols
191.959	OC 4	9	Headwater	Non-Channelised Valley Floor / wash slope.	unconfined		460m u/s two tributaries converge 890m d/s one minor tributary	Straight	1.04	0.026	Bend	Minimal processes occurring, no evidence of bedload. Appears stable.	None nearby	Appears unchanged	2	Vertosol	no data
193.127	One Mile Creek	EP4	Local - developed channel sections	Low sinuosity channel	confined	Confined to the north by 7m elevation difference Confined to the south by 3m elevation difference	520m u/s 3 tributaries converge 315m d/s a tributary joins One Mile Creek	Straight/ sinuous	1.08	0.012	Straight	Low sinuosity channel approx. 1.5m to 3 m deep. Bed lowering and channel widening downstream of Berghafer road.	Multiple small ponds.	Channel appears to have becomes slightly straighter and wider, extensive along bank instabilities visable in some imagery..	4	Vertosol	no data
194.694	OC 3	n/a	Local - poorly developed channel	Non-channelised Valley floor with some sections of low sinuosity channels and wash slopes, man made pond upstream in flow path	confined	Confined by manmade dam/pond (approx. 172 m across by 110m)	160 u/s true right 1990 m d/s converges with Westbrook Creek	sinuous	1.09	0.029	Straight/bend	Man made pond upstream in flow path. Downstream minor erosion on banks due to channelisation from humanmade dam.	10m u/s humanmade dam 850m u/s humanmade dam	Upstream Land Terraced 10m u/s humanmade dam, channel straightened d/s of dam. 120 - 850m u/s channel has been straightened 850m u/s humanmade dam	4	Vertosol	Vertosol
197.376	Four Mile Gully	14/ EP3b	Local - poorly developed channel	Non-Channelised Valley Floor with short section of low sinuosity channel	semi confined	Semi confined to the north by approx. 5m elevation change	1100m d/s converges with Westbrook Creek	US- Straight/ sinuous DS- Sinuous	US - 1.048 DS - 1.087	0.011	Bend	Approx. 1.5m deep channel at alignment crossing. Shallow vegetated channel approx. 20m wide, with active channel approx. 5-10m wide. Minor slumping on right side of bank downstream of bridge. Deposition of gravelly silt immediately downstream of bridge where flow has scoured out vegetation.	Existing bridge	Appears unchanged	2	Vertosol	Vertosol
198.477	Westbrook Creek	EP3a	Local - well developed channel	Low sinuosity channel to chain of ponds.	semi confined	Semi confined to the west by 6m elevation change	218m u/s Westbrook Creek and Four Mile Gully converge	Sinuuous	1.07	0.003	Bend	In channel bench on upstream right bank. Slight erosion noted on downstream banks. Some fines deposition in grass on fairway immediately upstream of bridge.	None nearby	Channel appears to have becomes slightly more sinuous.	3	Vertosol	No data
199.289	Dry Creek	6/ EP2	Local - well developed channel	Low sinuosity channel to chain of ponds in places.	confined	Semi confined (approx. 30m wide) within current channel and floodplain (elevation difference of 2-3m either side of channel)	540m d/s Westbrook Creek 750m u/s Unnamed minor watercourse converges with Dry Creek	US- Sinuous DS- Straight	US 1.172 DS 1.015	0.005	Straight	Some minor erosion occurring downstream of existing causeway. Some ponding upstream of culvert.	600m u/s concrete culverted causeway.	Channel has been artificially straightened downstream of the alignment (approx. 330m of straightened channel).	4	Vertosol	No data
202.794	OC2	n/a	Headwater	Washslope to Non-Channelised Valley Floor	unconfined		300m d/s converges with Gowrie Creek 700m d/s converges with Dry Creek	US - Sinuous DS- Straight	US - 1.271 DS - 1.012	0.025	Straight	Minimal processes occurring, no evidence of bedload. Appears stable.	None nearby	Appears unchanged	2	Dermosol/ Vertosol	Vertosol
207.146	OC 1	n/a	Headwater	Washslope to Non-Channelised Valley Floor	unconfined		304 m d/s true left 318 m d/s converges with Gowrie Creek	straight	1.04	0.007	Straight/bend	Channel has been straightened small erosional channels up to 15m long have developed downstream of alignment.	None nearby	Surrounding Land Cropped	4	Vertosol	Sodosols
208.21	End Catchment	n/a	Local - poorly developed channel	Non-channelised Valley floor with some sections of low sinuosity channels	unconfined		195 m d/s converges with Gowrie Creek	Straight/ sinuous	1.06	0.0295	Straight	Minimal processes occurring. Appears stable.	Existing rail bridge 40 m d/s 20m d/s ford 750 m u/s ford 1100 m u/s ford	Channel has been artificially straightened upstream of the alignment (approx. 1500m of straightened channel)	4	Vertosol	Sodosols
126.17 (approx.)	Pine Creek	22	Local - poorly developed channel	Non-Channelised Valley Floor with some sections of low sinuosity channels	unconfined			sinuous	1.21	0.014	Straight	Ford changes channel form and behaviour, upstream ponding, downstream some erosion. Minor deposition of silt/sand on road and channel/floodplain.	None nearby	Channel planform appears unchanged. Pond created next to watercourse upstream, some vegetation cleared next to watercourse.	2	Sodosols	No data
30.6 (NS2B)	Macintyre River	EP44/ EP44a	Main Stem	Multi channel, main anabranch, meandering planform	unconfined	In broad floodplain Northern floodplain slightly higher elevation than southern	2200m u/s true right 2670 m u/s true right 4400m u/s true right 2092m d/s MR2 true right 3600m d/s MR1 true right	moderate meandering	1.46	0.001	Bend	Directly upstream of the alignment, there are two meander bends on the Macintyre River which show the typical geomorphic process of point bar accretion on the inside of the bends and erosion on the outside.	None nearby	The two meander bends directly upstream of the alignment have migrated approximately 20-30m downstream since 1949. Downstream of the alignment, the Macintyre River is less sinuous for approximately 4km, where it has historically cut off a large meander bend (some time prior to the earliest aerial imagery, 1949) which is now an ow-bow lake.	3	Sodosols	No Data
34.80 (NS2B)	MR 1	n/a	Headwater	Non-Channelised Valley Floor with short section of low sinuosity channel . Some side gully development	unconfined		5260m d/s converges with cut off of the Macintyre River 6800m d/s converges with Macintyre River	sinuous	1.10	0.001	Bend	Minimal processes occurring. Appears stable.	Pond u/s 320m (92m by 25m) 30m u/s existing road 215m u/s existing road	Appears unchanged apart from small man made pond upstream.	2	Sodosols	No Data
Table notes																	
1. US = upstream, DS = downstream																	
2. Existing case sensitivity to change classes																	
1. No change in channel planform observed since earliest aerial imagery																	
2. No change in channel planform since earliest aerial imagery at sites where geomorphic change might otherwise have been expected (e.g., highly erodible soils, poor catchment vegetation cover, poor channel vegetation cover).																	
3. Some natural historic channel change observed, such as meander cut off, or downstream meander migration.																	
4. Human interventions in watercourses to create unstable channel forms (e.g., straight sub-reaches, ponds/embankments resulting in or the potential for downstream scour																	
5. Rapid channel or planform change such as avulsion or gully development, human induced or natural.																	
6. Channel processes and channel types may differ from those in Appendix F due to the location of field checking sites compared to the proposed alignment watercourse crossings.																	

APPENDIX H

Geomorphology Report

Appendix H Hydraulic data

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

Appendix H

Hydraulic data

Hydraulic data extracted
H.1 Watercourse Culverts
H.2 Watercourse Bridge
H.3 Floodplain Culvert
H.4 Floodplain Bridge
H.5 0.05% AEP Bridge
H.6 Watercourses with very small catchments (<10 ha) and no defined channels

H.1 - Hydraulic Impact Assessment of Watercourses with Culverts

Watercourses with Culverts		1% AEP Existing Event				1% AEP Design Event				20% AEP Existing Event				20% AEP Design Event				Downstream scour protection in reference design	Culvert Aligned	Combined Geomorphic and Hydraulic Impacts					
		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)				Potential Impact Category	Impact Description	Initial Consequence		Residual Consequence	
		u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s					20% AEP	1% AEP	20% AEP	1% AEP
Culvert Site ID	Watercourse ID	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s								
C208.21	End catchment	1.215	1.1712	19.95	15.44	0.61	2.15	3.44	142.28	1.18	1.0	15.06	11.08	0.51	1.54	1.329	51.250999	Y 9.0m	N	Upstream decrease in flow, downstream increase	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely. Flow path dammed by existing road. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C207.15	OC 1	1.22	2.17	52.30	298.94	0.59	2.19	12.93	303.14	0.91	1.7	20.34	168.22	0.45	1.84	3.37	214.85	Y 8.1m	N	Upstream decrease, downstream within 10% of existing flow	Watercourse is a washslope to non channelised valley floor. with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C202.80	OC 2	1.39	1.18	82.5	55	0.57	1.78	8.2	162	1.04	0.87	41.7	29	0.24	1.33	0.58	84	Y 12.6m	N	Upstream decrease in flow, downstream increase	Watercourse is a washslope to non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C194.69	OC 3	0.14	1.21	0.12	24.09	0.27	1.97	0.92	54.73	0.05	0.92	0.22	22.5	0.32	1.24	2.09	8.17	Y 6.3m	N	Upstream and downstream increase	Design flows show an increase of greater than 10%, however the increased velocity occurs largely in the area of scour protection in the revised reference design and minor to moderate increased erosion may occur. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C193.10	One Mile Gully	2.85	2.7	180	160	3.03	3.07	33	12.9	1.71	1.65	43	82	1.75	0.52	40	1.22	Y 18.0m	N	Upstream within 10% of existing flow, downstream decrease	20% AEP, decrease in velocity downstream, channel is low sinuosity and may have some bedload, moderate increased deposition may occur. 1% AEP increased flow velocity downstream unlikely to cause potential impacts are occurs in area of scour protection in the revised reference design. Culvert is not aligned to flow, as design downstream flow velocites are less than a third of existing case for the 20% AEP, at ~0.5 m/s, there is minor to moderate impact of planform change. At the 1% AEP, there is major impact of planform change due to very high design flows of >3 m/s.	Minor to Moderate	Major	Not Significant to Minor	Minor
C189.99	OC 5	2.85	2.6	277	212	1.76	2.22	94.1	182.99	1.95	1.95	111	94	1.46	1.66	107	72	Y 12.0m	N	Upstream and downstream decrease	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Minor to Moderate	Not Significant to Minor	Minor
C186.16	NC1	1.96	1.82	199.35	195.12	0.84	1.29	9.64	53.87	1.38	1.04	84.22	33.72	0.41	1.13	3.12	42.23	Y 12.6m	N	Upstream decrease, downstream within 10% of existing flow	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C186.16	NC2	1.37	1.64	91.26	220.44	0.59	1.13	8.57	203.9	0.91	1.12	46.78	86.16	0.4	1.29	4.82	96.16	Y 12.6m	N, slightly offcenter	Upstream decrease in flow, downstream increase	Watercourse is a washslope to non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C182.99	NC 4	1.08	1.44	15.15	16.34	0.51	0.58	0.03	13.81	0.74	0.83	9.34	11.94	0.31	0.38	0.3	11.03	Y 19.2m	N	Upstream and downstream decrease	Watercourse is a washslope to non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Culvert is not aligned to flow and may result in minor impact of planform change.	Minor	Moderate	Not Significant to Minor	Minor
C181.78	NC 5	1.77	1.51	152	149.17	0.55	0.6	5.48	12.59	1.62	1.20	102.49	101.46	0.84	1.41	19.81	118.68	Y 14.4m	Y	Upstream decrease in flow, downstream increase	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely.	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor
C181.21	NC 6	1.85	1.4	147	81	1.05	2.28	11.7	281	1.48	1.67	81	37	0.95	1.71	26	146	Y 16.8m	Y	Upstream decrease, downstream within 10% of existing flow	20% AEP event, watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely. 1% AEP event, design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely.	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor
C178.63	NC 7	1.42	1.62	74.43	123.23	0.32	1.35	0.92	85.93	1.27	1.34	45.29	78.27	0.26	1.24	1.49	59.9	Y 10.8m	Y	Upstream decrease, downstream within 10% of existing flow	Watercourse is a wash slope with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor
C176.89	NC 8	0.97	0.89	113	88.2	0.38	1.02	12.4	124	0.86	0.75	86	56.2	0.37	0.78	12.8	82	Y 16.8m	Y	Upstream decrease, downstream within 10% of existing flow	20% AEP event, watercourse is a wash slope to non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely. 1% AEP event, design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely.	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor
C171.90	NC 10	1.59	1.00	86.46	179.79	0.51	0.79	3.59	232.91	1.49	0.73	63.91	113.03	0.56	0.43	9.49	40.09	Y 10.8m	Y	Upstream and downstream decrease	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity.	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor

Watercourses with Culverts		1% AEP Existing Event				1% AEP Design Event				20% AEP Existing Event				20% AEP Design Event				Downstream scour protection in reference design	Culvert Aligned	Combined Geomorphic and Hydraulic Impacts					
		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)				Potential Impact Category	Impact Description	Initial Consequence		Residual Consequence	
																						20% AEP	1% AEP	20% AEP	1% AEP
Culvert Site ID	Watercourse ID	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s								
C170.55	NC 11	2.26	2.31	461	435	2.26	3.2	52.5	699.4	1.78	1.75	216	197	2.04	2.5	54.5	339.8	Y 19.2m	Y	Upstream and downstream increase	Design flows show an increase of greater than 10%, the increased velocity extends beyond the scour protection in the revised reference design and up to major erosion may occur.	Major	Major	Minor	Moderate
C169.89	NC 12	2.68	3.12	505	837	2.32	2.74	201.77	201.77	2.32	2.61	375	460	1.86	1.56	211.84	144.6	Y 16.2m	N	Upstream and downstream decrease	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C165.06	NC 13	2.09	2.42	188.31	271.34	0.51	0.77	4.28	15.00	1.65	2.09	120.34	175.39	No Data	No Data	No Data	No Data	Y 14.4m	N, slightly offcenter	Upstream and downstream decrease. No data at 20% AEP	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C164.29	NC 14	2.19	1.47	363.88	95.52	2.33	1.98	364	166.33	1.78	1.21	196.22	60.34	1.74	1.3	169.18	85.27	Y 7.2m	Y	Within 10% of existing flow	20% AEP event, within 10% of existing case flow velocities, impacts unlikely. 1% AEP event, downstream velocities increase to 1.98 m/s, however as the increased velocities occur in the area of scour protection in the revised reference design, impacts are unlikely.	Not Significant	Not significant	Not Significant	Not significant
C164.16	NC 15	0.76	0.63	23.29	12.43	0.66	0.93	24.92	29.31	0.64	0.52	2.55	14.61	0.26	0.74	4.67	17.59	Y 5.4m	N/A	Upstream decrease in flow, downstream increase	Culvert aligned to pass flows travelling along/adjacent to roadway. Watercourse is a washslope to non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C125.48	SC 3	1.71	2.15	150.42	227.61	1.78	2.21	135.13	252.42	1.68	2.09	102.96	227.61	1.75	1.98	98.49	206.52	Y 10.8m	Y	Within 10% of existing flow	Within 10% of existing case upstream and downstream, potential impacts unlikely	Not Significant	Not Significant	Not Significant	Not Significant
C124.44	SC4	1.33	1.28	93.8	86.7	1.36	1.58	94	114	1.04	1.1	48	53.2	1.01	1.37	44.3	82.1	N	N	Upstream within 10% of existing flow, downstream increase	Existing conditions upstream, and minor to moderate potential erosion and channel type change downstream in the 20% AEP event. There is no scour in the revised reference design at this culvert. Culvert is not aligned to flow and may result in moderate impact of planform change.	Moderate	Moderate to Major	Minor	Minor
C120.31	SC 7	1.5	2.06	59	155	0.41	0.4	1.13	1.3	1.26	1.68	33.3	111	0.2	0.29	0.21	0.72	Y 10.8m	Y	Upstream and downstream decrease	Watercourse is a low sinuosity channel and may have bedload, design flow velocities are reduced to <0.3 m/s and may result in up to major deposition.	Moderate to Major	Moderate	Minor	Moderate
C119.38	SC 8	1.17	1.25	41.9	46	0.75	1.64	10.25	54.5	0.87	0.99	21.2	25.6	0.61	1.33	7.2	30.8	Y 9.0m	N	Upstream decrease in flow, downstream increase	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C118.43	SC 9	1.74	1.37	111	73	1.28	1.9	44	158.47	1.61	1.2	88	41	1.16	1.32	38.5	18	Y 9.0m	Y	Upstream decrease, downstream within 10% of existing flow	20% AEP event, watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely. 1% AEP event, design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely. Culvert located ~7m north of watercourse and ~45 degrees to flow. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C117.60	SC 10	1.9	1.97	174	178	0.64	2.2	7.1	250.69	1.61	1.65	112	116	0.86	1.81	8	152.22	N	Y	Upstream decrease, downstream within 10% of existing flow	20% AEP event, watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely. 1% AEP event, design flows show an increase of greater than 10%, there is no scour protection in the revised reference design and up to major erosion may occur.	Not Significant to Minor	Moderate to Major	Minor	Minor
C117.40	SC 11	1.75	1.49	103	75	2.1	1.54	118.5	118	1.36	1.24	59	45	1.54	1.57	83.8	114	Y 10.8m	N	Upstream and downstream increase	Design flows show an increase of greater than 10%, however the increased velocity occurs largely in the area of scour protection in the revised reference design and impacts are unlikely. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate to Major	Minor	Minor
C114.36	C Ck 3	1.75	1.6	190	100	1.54	1.36	1.37	61.5	1.19	1.16	68	47.5	1.39	1.15	130	39.1	N	Y	Upstream increase, downstream within 10% of existing flow	20% AEP event, upstream design flows show an increase of greater than 10%, there is no scour protection in the revised reference design in this area and up to moderate erosion may occur. Downstream flow velocities are within 10% of existing case and impacts are unlikely. 1% AEP, design flows have a reduction in flow velocity of greater than 10%, however watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport	Moderate	Minor	Minor	Minor
C113.28	C Ck 6	1.43	1.24	126	65.2	0.65	1.81	12.55	192.5	0.74	0.81	16	22.5	0.63	1.34	8.76	88.42	Y 5.4m	N	Upstream decrease in flow, downstream increase	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate to Major	Minor	Moderate
C113.07	C Ck 7	1.54	1.35	98.5	70	0.76	1.25	14	11.9	0.99	0.9	31	25.7	0.63	0.81	8.9	6.9	Y 14.4m	Y	Upstream decrease, downstream within 10% of existing flow	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely.	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor
C109.43	C Ck 8	1.11	1.12	38.29	29.63	0.55	0.27	7.3	0.47	0.84	0.83	12.09	9.87	0.14	0.36	0.08	1.78	N	Y	Upstream and downstream decrease	Watercourse is a washslope with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity.	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor

Watercourses with Culverts		1% AEP Existing Event				1% AEP Design Event				20% AEP Existing Event				20% AEP Design Event				Downstream scour protection in reference design	Culvert Aligned	Combined Geomorphic and Hydraulic Impacts					
		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)	Maximum Velocity (m/s)		Maximum Stream Power (W/m2)	Maximum Velocity (m/s)		Maximum Stream Power (W/m2)	Maximum Velocity (m/s)		Maximum Stream Power (W/m2)				Initial Consequence			Residual Consequence					
Culvert Site ID	Watercourse ID	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	Potential Impact Category	Impact Description	20% AEP	1% AEP	20% AEP	1% AEP		
C107.22	C Ck 9	0.8	0.78	72.43	65.45	0.48	0.3	1.38	2.01	0.63	0.58	23.07	17.67	0.43	0.36	3.68	12.81	Y 10.8m	N	Upstream and downstream decrease	Watercourse is a washslope with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Culvert is not aligned to flow and may result in minor impact of planform change.	Minor	Minor	Not Significant to Minor	Minor
C92.08	C Ck 10	0.85	1.2	53.24	126.77	1.40	1.40	135.54	120.87	0.60	0.95	23.44	66.95	1.03	0.99	61.98	68.85	Y 9.0m	N	Upstream increase, downstream within 10% of existing flow	Man-made pond has diverted flow around the original channel alignment. This creates greater apparent change within the model. 20% AEP event, upstream design flows show an increase of greater than 10%, there is no scour protection in the revised reference design in this area and up to moderate erosion may occur. Downstream flow velocities are within 10% of existing case and impacts are unlikely. 1% AEP event design flows show an increase of greater than 10% both upstream and downstream. While the downstream increase occurs in the area of scour protection in the revised reference design and impacts are unlikely, there is no scour protection upstream and up to moderate erosion may occur. Culvert is not aligned to flow and may result in moderate impact of planform change.	Moderate	Moderate	Minor	Minor
C90.96	C Ck 11	1.03	1	50.5	43.9	0.61	1.12	11.85	9.6	0.78	0.77	25	22.7	0.36	1.07	2.7	4.85	Y 14.4m	Y	Upstream decrease in flow, downstream increase	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely.	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor
C87.37	C Ck 12	1.82	1.69	225.89	188.18	1.34	1.42	122.18	176.41	1.00	1.13	57.03	65.08	1.02	0.95	52.66	45.65	Y 14.4m	Y	Upstream within 10% of existing flow, downstream decrease	Decrease in velocity downstream, channel is low sinuosity and may have some bedload however design flow velocities are sufficient to transport this and deposition is unlikely.	Not Significant	Not Significant	Not Significant	Not Significant
C84.38	C Ck 13	0.62	0.94	12.76	43.02	0.42	0.61	4.7	41.62	0.49	0.86	6.68	34.65	0.45	0.31	11.62	47.07	Y 16.2m	N, slightly offcenter	Upstream within 10% of existing flow, downstream decrease	Decrease in velocity downstream, channel is low sinuosity and may have some bedload, minor increased deposition may occur. Culvert is not aligned to flow, as design downstream flow velocities are close to a third of the existing case for the 20% AEP, at ~0.3 m/s, there is minor impact of planform change.	Minor	Moderate	Not Significant to Minor	Minor
C82.35	C Ck 14	1.25	1.26	46.3	50.1	0.31	1.82	1.1	200.33	0.99	0.96	25.3	24.2	0.3	1.31	0.9	67.22	Y 14.4m	Y	Upstream decrease in flow, downstream increase	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely.	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor
C79.01	C Ck 15	1.39	2.03	47.7	165	0.82	2.07	19.3	280	1.27	1.94	1.3	155	0.88	1.87	30.3	177	Y 10.8m	N	Upstream decrease, downstream within 10% of existing flow	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C74.97	CCs 19	1.52	1.56	101.8	105.74	1.03	1.05	33.02	72.1	1.1	1.25	48.74	61	0.97	1.06	26.34	40.65	N	Y	Upstream and downstream decrease	Watercourse is a gully and may have a large bedload, however while the design flow velocities are less than existing, they are still ~1 m/s and likley to be able to transport most if not all of the bedload, and minor increased deposition may occur.	Minor	Minor	Minor	Minor
C73.68	C Ck 16	1.8	1.73	114	103	1.0	1.9	8.9	106.4	1.6	1.4	107.7	61.1	0.7	1.5	4.2	67.3	N	Y	Upstream decrease, downstream within 10% of existing flow	Watercourse is a gully and may have a large bedload, reduction of flow velocity may cause up to major deposition. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely.	Moderate to Major	Moderate	Minor	Moderate
C73.61	C Ck 16a	1.04	0.91	44.62	36.99	0.35	0.77	2.42	35.63	0.82	0.59	12.77	14.79	0.42	0.47	2.87	6.62	Y 5.4m	N	Upstream and downstream decrease	Watercourse is a gully and will have bedload, reduction of flow velocity may cause up to major deposition. Culvert is not aligned to flow and may result in moderate impact of planform change	Moderate to Major	Moderate to Major	Minor	Moderate
C73.53	CCs 21	1.32	1.69	70.96	159.76	0.28	1.68	2.77	89.64	1.12	1.4	51.96	96.25	0.29	1.12	0.72	51.19	N	Y	Upstream and downstream decrease	Watercourse is a gully and may have a large bedload, reduction of flow velocity may cause up to major deposition.	Moderate to Major	Moderate to Major	Minor	Moderate
C73.44	CCs 21a	1.21	1.09	65.27	51.23	0.14	0.9	0.35	47.19	0.87	0.78	27.66	23.06	0.17	0.86	0.07	49.73	N	Y	Upstream decrease in flow, downstream increase	Watercourse is a gully and will have bedload, reduction of flow velocity may cause up to major deposition upstream. Culvert is not aligned to flow and may result in moderate impact of planform change. In the 20% AEP event, downstream design flows show an increase of greater than 10%, however the increased velocity of 0.86 m/s is less than the existing case upstream velocity of 0.87 m/s, and increased in erosion potential from the existing case is unlikely.	Moderate to Major	Moderate to Major	Minor	Moderate
C73.37	CCs 22	1.31	1.36	110.62	78.47	0.44	0.92	3.53	44.52	1.13	1.2	69.38	60.17	0.38	0.89	2.49	52.02	Y 7.2m	Y	Upstream and downstream decrease	Watercourse is a gully and will have bedload, reduction of flow velocity may cause up to major deposition upstream.	Moderate to Major	Moderate to Major	Minor	Moderate
C68.76	C Ck 17	0.46	0.5	2	2.58	0.41	0.87	1.44	6.8	0.08	0.12	0.02	0.18	0.03	0.19	0.004	0.2	N	N	Upstream decrease in flow, downstream increase	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Culvert is not aligned to flow and may result in moderate impact of planform change. 20% AEP event, erosion and channel channel type change unlikely as design velocities are <0.2 m/s. 1% AEP event, moderate channel type change and erosion possible.	Not Significant	Moderate	Not Significant	Minor
C66.81	C Ck 19	0.87	0.71	19.94	9.39	0.53	0.86	4.33	17.49	0.59	0.52	6.35	4.73	0.43	0.58	2.19	6.94	Y 7.2m	Y	Upstream decrease in flow, downstream increase	Watercourse is a washslope to non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely.	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor
C66.23	C Ck 20	2.14	2.32	156.4	635.67	1.08	3.1	121.32	741.04	1.81	2.04	98.86	309.13	0.91	2.35	41.91	289.86	Y 14.4m	Y	Upstream decrease in flow, downstream increase	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely.	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor	Not Significant to Minor

Watercourses with Culverts		1% AEP Existing Event				1% AEP Design Event				20% AEP Existing Event				20% AEP Design Event				Downstream scour protection in reference design	Culvert Aligned	Combined Geomorphic and Hydraulic Impacts																					
		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Potential Impact Category		Impact Description				Initial Consequence		Residual Consequence																			
																				20% AEP	1% AEP	20% AEP	1% AEP																		
Culvert Site ID	Watercourse ID	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s																								
C63.15	MB 1		1.64		1.25		215		101		0.4		1.8		5.1		325.72		1.32		1.01		125		60		0.41		1.41		5.9		159.77	Y 16.8m	N	Upstream decrease in flow, downstream increase	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely. Culvert is not aligned to flow and may result in moderate impact of planform change	Minor to Moderate	Moderate	Minor	Moderate
C62.94	MB 2		1.23		0.71		122		34		0.25		1.21		1.43		108.64		0.98		0.33		66		4.5		0.23		0.92		0.95		61.48	Y 16.8m	N	Upstream decrease in flow, downstream increase	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Minor	Moderate
C61.90	MB 3		2.33		2.22		492		445		0.61		2.61		28		576.22		1.86		1.73		286		246		0.87		1.89		67.6		367.48	Y 16.2m	Y	Upstream decrease, downstream within 10% of existing flow	20% AEP decrease in velocity downstream, channel is low sinuosity and may have some bedload, moderate increased deposition may occur. Downstream is within 10% of existing flow velocity and impacts re unlikely. 1% AEP event, up to major deposition may occur upstream. Design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and impacts are unlikely.	Moderate	Moderate to Major	Minor	Moderate to Major
C61.60	MB 4		1.82		1.76		215.76		243.99		1.07		1.79		85.29		282		1.47		1.43		148.59		146.17		1.07		1.49		86.41		191	Y 16.2m	N	Upstream decrease, downstream within 10% of existing flow	Watercourse is a wash slope with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Downstream velocities are within 10% of existing case and impacts are unlikely Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C60.44	MB 5		1.35		1.92		122.66		90.07		1.31		1.79		80.27		121.92		1.05		1.7		55.38		123.59		0.89		1.52		31.89		75.62	Y 16.2m	N	Upstream and downstream decrease	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor
C48.41	MB 8		1.95		1.98		89.27		454.87		0.52		1		1.03		110.3		1.64		2.10		89.27		454.87		0.82		1.00	No Data	No Data	Y 16.2m	N, slightly offcenter	Upstream and downstream decrease	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor		
C43.16	MB 9		0.435		0.447		2.83		2.68		0.28		0.39		0.44		1.59	No Flow	No Flow	No Flow	No Flow	No Flow	No Flow	No Flow	No Flow	No Flow	No Flow	No Flow	No Flow	No Flow	No Flow	N	N	Upstream and downstream decrease. No data at 20% AEP	Watercourse is a washslope with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Culvert is not aligned to flow and may result in moderate impact of planform change.	Minor to Moderate	Moderate	Not Significant to Minor	Minor		
C34.70 (NS2B MR 1			0.14		0.18		0.55		1.01		0.66		0.58		32.5		12.6	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N	Y	Upstream and downstream increase. No flow at 20% AEP	20% AEP event has not flow in the existing case or design case, and impacts are unlikely. 1% Aep event has an increase in design flows of >10%, there is no erosion protection at this watercourse in the revised reference design and up to minor erosion may occur.	Not Significant	Minor	Not Significant	Minor		
C30.60	MB 10		0.42		1.09		2.84		28.91		0.30		0.30		0.84		0.95		0.35		1.02		1.79		25.74		0.35		0.24		1.15		0.64	Y 7.2m	N	Upstream within 10% of existing flow, downstream decrease	Watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport. Upstream ponding might be increased due to decrease in flow velocity. Culvert is not aligned to flow and may result in minor impact of planform change.	Minor	Moderate	Not Significant to Minor	Minor
Key																																									
10% above or below of original velocity																																									
Reduction >10 %																																									
Increase >10%																																									

H.2 - Hydraulic Impact Assessment of Watercourses with Bridges

			1% AEP Existing Event				1% AEP Design Event				20% AEP Existing Event				20% AEP Design Event				Combined geomorphic and hydraulic impacts					
Watercourses with Bridges			Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)				Initial Consequence		Residual Consequence	
Site ID	Watercourse ID	Bridge Name	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	Change Potential Category	Description	20% AEP	1% AEP	20% AEP	1% AEP
310-BR31	Westbrook Creek	Westbrook Creek Rail Bridge	2.73	2.47	164.6	145					2.38	2.17	129	149	2.35	2.31	129	157	Floodplain encroachment by one/both abutments	Southern abutment does not intersect flow for any event. Northern embankment intersects floodplain flood channel for all events modelling, indicating that bankfull conditions occur more frequently than 20% AEP. <10% change in max velocities, impacts unlikely. A poorly aligned culvert (C198.68) at the flood channel restricts flow increasing flow velocities and SP around end of northern embankment.	Not Significant	Not Significant	Minor to Moderate	Minor to Moderate
310-BR04	MB 6	UT2 Macintyre Brook Rail Bridge	0.91	0.9	22.1	21.5					0.54	0.55	6.83	6.59	0.54	0.63	6.22	8.6	Watercourse encroachment by both abutments	Potential major impacts to channel planform and type due to channel encroachment. Increased flow velocity may increase erosion potential in 20% AEP event. 1% AEP flow event has a reduction in design flow velocity of more than 10% , however the watercourse has a Non-channelised Valley floor with no evidence for bedload, and therefor potential impacts of increased deposition are considered unlikely.	Moderate	Moderate to Major	Minor	Minor
310-BR03	MB 7	UT1 Macintyre Brook Rail Bridge	0.53	0.69	1.69	0.9					0.35	0.42	1.17	0.04	0.35	0.42	1.44	7.58	Floodplain encroachment by both abutments	Abutments do not intersect flow at the 20% AEP event, design max velocities are <10% of the existing case, impacts unlikely. Abutments intersect flow during the 1% AEP event, with up to a 12% reduction in flow, any potential impacts are unlikely.	Not Significant	Not Significant	Not Significant	Not Significant
*310-BR20	Four Mile Gully C Ck 18, Pariagara Creek	Toowoomba Cecil plains Road Rail Bridge	2.32	1.94	145	112					1.94	1.83	107	80	1.98	1.91	151	90	Floodplain encroachment by abutment up to channel edge (road embankment)	Southern embankment extends up to edge of watercourse, northern embankment is outside of the 1% AEP flood. <10% change in velocity at the 20% AEP event, and upstream 1% AEP event, and <20% increase in velocity for the downstream 1% AEP event, indicating Minor/Moderate erosion possible. As the Abutment extends to the channel edge, potential for major planform and channel type change.	Major	Major	Minor	Minor
310-BR05		Pariagara Creek Rail Bridge	2.27	2.22	146	154					2.02	1.99	85	102	2.02	1.99	86	103	Floodplain encroachment by both abutments	Abutments do not intersect flow during the 20% AEP event. Both abutments encroach the floodplain during the 1% AEP event, max design velocities are within 10% of the existing case for the 20% and 1% AEP events, impacts unlikely	Not Significant	Not Significant	Not Significant	Not Significant
310-BR30	NC 9	Oakey Pittsworth Road	1.35	1.00	1.50	5.00					0.67	0.59	2.19	2.85	0.67	0.50	1.33	3.11	Watercourse encroachment by both abutments	Modelling does not appear to include cross drainage under the existing road and shows the flow dammed by the road, which may not be correct. Potential major impacts to channel planform and type due to embankment encroachment.	Major	Major	Minor	Minor
310-BR11	Nicol Creek	Nicol Creek Rail Bridge	2.43	2.21	347	280					1.28	1.26	155	73	1.29	1.25	154	73	Floodplain encroachment by abutment up to channel edge	Flow does not intersect embankment at 20% AEP, as this is bankfull event. Southern embankment has a very Minor encroachment into the 1% AEP flood. The northern embankment extends to the channel edge and up to major planform and channel type change may occur. <10% change in velocity in 20% and 1% AEP events, however as the abutment extends up to the channel it may cause potential channel planform changes	Moderate to Major	Moderate to Major	Minor	Minor
310-BR07	Native Dog Creek	Native Dog Creek Rail Bridge	1.22	1.23	48.2	50					0.78	0.81	15.7	18.8	0.78	0.81	15.7	18.8	Floodplain encroachment by one embankment	Abutments do not intersect flow in the 20% AEP event, only the northern abutment intersects flow in the 1% AEP event. Design max velocities <10% change, impacts unlikely.	Not Significant	Not Significant	Not Significant	Not Significant
310-BR28	C Ck 2	Milmeran Inglewood Road Rail Bridge #2	1.33	1.64	55.3	115.7					1.03	1.23	28.4	51	1.01	1.22	26	50	Watercourse encroachment by one abutment	Southern embankment encroaches into channel, major planform and channel type change may occur. Northern embankment is located outside for the 1% AEP flood flow. <10% change in max design velocity, slight reduction at the 20% and 1% AEP events.	Moderate to Major	Moderate to Major	Minor	Minor
310-BR37	SC 2 Macintyre River	Milmeran Inglewood Road Rail Bridge	1.32	2.23	104	334					1.27	1.8	87.35	109.2	1.16	1.21	51.7	87.2	Floodplain encroachment by abutment up to channel edge by one embankment	Western embankment intersects channel edge at sharp bend, may result in major planform and channel change. Both embankments encroach on the 1% AEP floodplain. The western abutment contains culvert (C126.81) that drains flow from the south towards the channel in the north. Culvert dealing with backflow/ponding behind embankment, late flow as water declining.	Major	Major	Minor	Minor
270-BR11A		Macintyre River Viaduct Span A	2.04	2.05	221	235					1.48	1.52	71.5	60	1.47	1.51	70.6	59.1	Floodplain encroachment both embankments	Flow does not intersect embankments in 20% event. <10% change in max design velocities in the 1% AEP event, impacts unlikely	Not Significant	Not Significant	Not Significant	Not Significant
310-BR21/22	Grasstree Creek	Grasstree Creek Rail Bridge	1.09	1.11	13.7	19.4					0.67	0.73	5.35	6.85	0.68	0.76	5.45	7.87	Floodplain encroachment by both abutments	Floodplain flow occurs at the 20% event, indicating that the bankfull event is more frequent. <10% change in max velocities for 20% and 1% AEP, impacts unlikely. Enhancement opportunity as existing rail bridge shorter.	Not Significant	Not Significant	Not Significant	Not Significant
310-BR32	Dry Creek	Dry Creek Rail Bridge	3.24	3.03	295	241					2.28	2.5	189	156	2.23	2.52	160	186	Floodplain encroachment by one/both abutments	Embankments do not intersect flow at the 20% AEP flood. Southern embankment encroaches the 1% AEP Westbrook/Dry Creek floodplain. < 10% change in max velocity for all AEP events assessed, impacts unlikely. Floodplain flow occurs at the 20% event, indicating that the bankfull event is more frequent.	Not Significant	Not Significant	Not Significant	Not Significant
310-BR27	Condamine River North Branch	Condamine River North Branch Rail Bridge	0.48	0.63	5.82	16.7					0.38	0.38	0.3	2.08	0.38	0.38	1.99	2	Floodplain encroachment by both abutments	<10% change in max velocities for 20% AEP, impacts unlikely. In the 1% AEP event, design flow velocity upstream has an increase of more than 10%, potential erosion may occur.1 % AEP downstream has a decrease in flow velocity of more than 10%, but potential deposition is unlikely, as the velocities are above bankfull flow velocities, which are sufficient to transport the majority of the bedload.	Not Significant	Minor	Not Significant	Minor
310-BR25/26	Condamine River Cattle Creek	Condamine River Main Branch Combined Rail Bridge	1.31	1.3	15.6	15.3					1.12	1.11	14.3	13	1.14	1.13	14.8	13.4	Floodplain encroachment by both embankments	<10% change in max velocities for 20% and 1% AEP, impacts unlikely. Enhancement opportunity as existing rail bridge shorter	Not Significant	Not Significant	Not Significant	Not Significant
310-BR06		Cattle Creek Rail Bridge	2.04	1.96	279	264					1.41	1.55	224	295	1.41	1.55	223	297	No encroachment	Flow does not intersect embankments, impacts unlikely.	Not Significant	Not Significant	Not Significant	Not Significant
310-BR10	Bringalily	Bringalily Creek 3 Rail Bridge	1.78	1.69	300	334					1.36	1.31	112	112	1.44	1.31	83.64	113.8	Floodplain encroachment by one embankment	Floodplain flow occurs at the 20% event, indicating that the bankfull event is more frequent.	Not Significant	Not Significant	Not Significant	Not Significant
310-BR08	Back Creek 2	Bringalily Creek 1 Rail Bridge	1.55	1.67	102	92					1.17	1.29	56	101	1.16	1.3	55.5	85	Floodplain encroachment by abutment up to channel edge by one embankment	Southern embankment extends up to channel edge on outside of meander bend, up to major planform and channel type change may occur. Northern embankment encroaches floodplain and would also be located up to the edge of the original channel, however the channel location in this area has been forced through road culverts, resulting in a shift south away from the proposed rail embankment. <10% change in velocities in 20% and 1% AEP events.	Moderate to Major	Moderate to Major	Minor	Minor
*310-BR42	NC3	Biddeston Southbrook Road Rail Bridge	2.24	2.26	319	322					1.93	2.03	180	174	1.87	1.96	167	171	Watercourse encroachment by one embankment (road embankment)	Western abutment extends into channel, potential for major planform/channel type change. Eastern embankment currently outside of 1% AEP flood	Moderate	Major	Minor	Minor
310-BR38	Back Creek 1	Back Creek Rail Bridge	1.42	1.34	161	109					1.18	1.24	86.01	135.5	1.1	1.09	109	85	Floodplain encroachment by both embankments	Floodplain flow occurs at the 20% event, indicating that the bankfull event is more frequent. <12% change in max velocities for 20% AEP, slight reduction downstream, impacts unlikely as velocity sufficient to transport bedload.. 1% AEP shows increased in velocities up to 1.86 m/s, mainly around the eastern abutment, indication, major erosion may be possible.	Not Significant	Major	Not Significant to Minor	Minor
Key																								
10% above or below of original velocity																								
Reduction >10 %																								
Increase >10%																								

H.3 - Hydraulic Impact Assessment of Floodplains with Culverts

		1% AEP				20% AEP (1 in 5)																	
		Existing case				Design Case				Existing case				Design Case				Downstream scour protection in reference design		Combined geomorphic and hydraulic impacts			
		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)							
Floodplain culverts		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)				Initial Consequence			
Culvert Site ID	Floodplain	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	Potential Impact Category	Impact Description	20% AEP	1% AEP		
C198.98	Floodplain - Westbrook Creek	0.64	0.66	9.56	9.6	0.16	1.15	0.3	48.92	0.2	0.23	0.5	0.62	0.09	0.37	0.04	2.56	Y 6.3m	Floodplain constriction - some culverts oblique to flood channels	20% AEP minor to no flow occurs, reduction in flow velocity of more than 10%, very low design flows, <0.1 m/s, deposition possible. C198.98 has increased design flow velocity more than 10%, however impacts are unlikely as the design flow is only 0.37 m/s, and the culvert has scour protection in the revised reference design. 1% AEP reduction in flow velocity of more than 10%, however design flows assessed as sufficient to transport sediment. C198.98 has increased design flow velocity more than 10%, erosion may occur as the increased erosion extends beyond the scour protection in the revised reference design. Two culverts are located on flood channels, C198.98 and C198.68, both are not aligned to flow.	Not Significant to Minor	Minor-Moderate	
C198.80	Floodplain - Westbrook Creek	0.52	0.8	5.4	14.2	0.45	0.46	1.19	1.74	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	Y 7.2m					
C198.77	Floodplain - Westbrook Creek	0.79	1.02	12.75	26.77	0.43	0.52	1.13	1.82	0.12	0.2	0.06	0.49	0.07	0.16	0.01	0.08	Y 9.0m					
C198.68	Floodplain - Westbrook Creek, on a paleochannel	1.61	1.61	84.5	78.5	0.6	0.26	3	0.6	1.08	1.17	30.5	36	0.14	0.1	0.03	0.03	Y 19.2m					
Floodplain constriction																				Design case has flow up to 0.2 m/s, impacts unlikely. Design case 1% AEP shows slight reduction downstream from 0.31 to 0.21 m/s, impacts unlikely	Not significant	Not significant	
C197.31	Floodplain - Four Mile Gully	0.29	0.31	1.3	1.8	0.29	0.21	0.56	0.71	0.11	0.29	0.04	0.97	0.1	0.2	0.04	0.7	Y 6.3m	Floodplain constriction	In the 20% AEP event, a number of culverts do not flow, impacts are unlikely, the maximum design velocity is <0.4 m/s and erosion at these sites is unlikely. Design velocities for a majority of floodplain culverts are below 0.5 m/s for the 1% AEP event, except for two areas. One of these areas comprised four culvert sites, C149.02 to C147.82, has velocities greater than 0.5 m/s in the existing case and design velocities less than 10% higher than the existing case. The other area comprises three culvert sites, C141.46 to C141.38, and has downstream design flow velocities of up to 1.02 m/s for the 1% AEP, 0.38 m/s higher than the existing case. The sites have existing case upstream velocities of up to 0.87 m/s, within 17.5 % of the higher downstream velocities, and a reduction in stream power from 6.6 W/m2 in the existing case to 4.1 W/m2 in the design case. Stream power represents the ability to do geomorphic work, <10 W/m2 is considered very low and is consistent with the Condamine floodplain Classification and existing case maximum of 12.5 W/m2 across the floodplain. The higher velocities are local only and dissipate quickly downstream to existing case levels, note the highest velocities occur in the area of scour protection for culverts. Potential impacts from these three culvert sites have been assessed as minor to moderate for the 1% AEP event (rare likelihood), with a corresponding low risk. Therefore, impacts on the fluvial geomorphology of the Condamine River floodplain by the Project were assessed as low.	Not significant to minor	Not Significant to Moderate	
C153.44	Floodplain - Condamine (tributary)	0.55	0.58	0.57	0.68	0.22	0.34	1.35	4.05	0.43	0.42	0.33	0.35	0.19	0.21	0.89	0.88	N					
C151.30-C151.08 (7)	Floodplain - Condamine	0.06	0.08	0.08	0.13	0.4	0.16	3.15	0.11	0.05	0.06	0.06	0.08	0.07	0.1	0.12	0.07	N					
C150.74-C150.68 (3)	Floodplain - Condamine	0.13	0.23	0.28	0.42	0.16	0.3	0.45	0.42	0.05	0.05	0.02	0.02	0.06	0.06	0.04	0.09	N					
C149.02-C147.82 (4)	Floodplain - Condamine	0.69	0.91	0.74	5.15	0.47	0.96	8.6	5.3	0.16	0.29	0.46	0.4	0.10	0.3	2.06	0.75	N					
C147.91-C147.85 (2)	Floodplain - Condamine	0.24	0.22	0.7	1	0.07	0.08	0.06	0.1	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N					
C147.31-C147.01 (6)	Floodplain - Condamine	0.55	0.46	2.8	2.5	0.3	0.3	2.9	6.2	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N					
C146.69-C146.50 (5)	Floodplain - Condamine	0.46	0.38	4.7	6.4	0.43	0.17	4.6	1.24	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N C146.69 Y 5.4m C146.61-C146.50					
C146.45	Floodplain - Condamine	0.63	0.55	4.99	12.43	0.44	0.2	7.78	1.83	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	Y 5.4m Y 16.8m C143.57					
C143.87-C143.29 (15)	Floodplain - Condamine	0.42	0.35	5.12	6.1	0.31	0.18	3.1	0.95	0.43	0.35	4.45	5.22	0.33	0.13	3	0.45	N Remainder					
C142.61	Floodplain - Condamine, South Branch	0.51	0.51	6.5	3.3	0.35	0.19	5.3	0.74	0.5	0.5	6.4	3	0.32	0.15	3.6	0.54	Y 16.8m					
C142.58-C142.53 (2)	Floodplain - Condamine, area of existing erosion in flood basin	0.68	0.67	6.18	7.83	0.22	0.12	0.56	0.2	0.67	0.66	6.65	7.37	0.19	0.07	0.59	0.12	Y 16.8m					
C142.49	Floodplain - Condamine, area of existing erosion in flood basin	0.65	0.65	8.14	3.53	0.21	0.33	0.92	1.67	0.63	0.63	7.75	3.37	0.10	0.25	0.44	0.91	Y 16.8m					
C142.40-C142.32 (3)	Floodplain - Condamine, area of existing erosion in flood basin	0.52	0.52	5.03	3.8	0.28	0.1	2.69	0.05	0.51	0.5	4.83	3.47	0.16	0.09	1.1	0.11	Y16.8m					
C142.27-C141.12 (4)	Floodplain - Condamine, area of existing erosion in flood basin	0.66	0.54	4.73	3.29	0.25	0.27	1.66	1.44	0.64	0.53	3.67	2.7	0.18	0.20	0.5	0.78	Y16.8m					
C142.07	Floodplain - Condamine, area of existing erosion in flood basin, worst performing existing case culvert.	0.52	0.45	4.42	1.7	0.42	0.16	4.66	0.93	0.51	0.44	3.94	1.57	0.26	0.15	1.12	0.37	Y 16.8m Y 16.8m C141.96					
C141.96-C141.88 (3)	Floodplain - Condamine	0.35	0.37	0.76	1.35	0.19	0.33	0.62	2.45	0.31	0.37	1.26	0.98	0.17	0.26	0.45	1.47	N Remainder					
C141.84-C141.67 (7)	Floodplain - Condamine	0.28	0.29	0.75	1.35	0.31	0.31	0.39	2.12	0.26	0.24	0.31	0.58	0.27	0.19	0.34	0.67	N					
C141.61-C141.49 (5)	Floodplain - Condamine	0.32	0.31	0.48	0.47	0.19	0.33	0.38	0.57	0.24	0.19	0.4	0.24	0.17	0.13	0.28	0.07	N					
C141.46-C141.38 (3)	Floodplain - Condamine	0.87	0.64	6.62	1.15	0.57	1.02	2.15	4.05	0.32	0.24	0.68	0.39	0.18	0.39	0.3	0.31	Y 10.8m C141.40 and C141.38 N C141.46 Y16.8m C141.07					
C141.07/C141.00 (2)	Floodplain - Condamine	0.49	0.37	0.99	1.04	0.35	0.36	0.38	0.69	0.38	0.3	0.4	0.3	0.22	0.27	N/A	0.36	N C141.00					
C141.02	Floodplain - Condamine, anabranh	0.61	0.53	1.38	0.86	0.28	0.45	0.63	2.12	0.54	0.38	1.21	0.5	0.34	0.35	0.8	1.02	N					
C140.85	Floodplain - Condamine	0.16	0.16	0.22	0.27	0.23	0.19	1.06	0.72	0.1	0.07	0.37	0.05	0.11	0.07	0.63	0.12	N					
C140.79	Floodplain - Condamine	0.16	0.15	0.28	0.22	0.13	0.38	0.33	2.5	0.12	0.09	0.21	0.06	0.09	0.12	0.18	0.31	N					
C140.73	Floodplain - Condamine	0.17	0.18	0.41	0.43	0.11	0.09	0.31	0.15	0.11	0.1	0.1	0.33	0.13	0.09	0.22	0.22	N					
C140.66	Floodplain - Condamine	0.22	0.18	0.39	0.44	0.29	0.23	0.4	1.51	0.15	0.09	0.24	0.14	0.14	0.04	0.35	0.03	N					
C139.21-C139.13 (3)	Floodplain - Condamine	0.24	0.24	1.53	1.48	0.2	0.19	0.7	0.74	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	Y 10.8m C139.21 N Remainder					Floodplain constricted by embankment
C126.81-C126.77 (2)	Floodplain - SC 2	0.61	0.66	3	9.35	0.38	0.06	3.6	0.03	0.36	0.4	0.59	1.61	0.29	0.09	0.38	0.00035	Y 5.4m	Floodplain constricted by embankment - culvert slightly oblique to flood channel	Culvert located on flood channel, slightly oblique, results in reduction in design flow velocity of more than 10%, however as design flows are approximately 1m/s this reduction in flow will not impact floodplain sediment transport and impacts are unlikely. The natural channel for SC 7 has been impacted by the human made pond upstream and experiences reduced flows, most flow in the existing case now goes across the floodplain in the area of this floodplain culvert.	Not significant	Not significant	
C120.25	Floodplain - SC 7	1.53	1.53	67.89	74.88	1.03	1.34	21.2	53.23	1.25	1.28	41.4	49.65	0.99	0.97	24.82	23.14	Y 9.0m	Floodplain constriction and sidling	Majority of culverts have no flow in the 20% AEP event, for those culverts that flow max design velocity is 0.4 m/s and stream power is <2.5 w/m2, up to minor scour may occur upstream. 1% AEP design stream power max is 25 w/m2, a reduction on the existing case. 1% max velocity is 1.27 at C97.38, an increase form the existing case velocity of 1.08 at this site. Minor to Moderate erosion may occur as elevated velocites extend beyond scour protection in the revised reference design. In the 1% AEP, deposition may occur as some flows reduced to , 0.09 m/s.	Not significant to minor	Minor to Moderate	
C100.00	Floodplain - Bringalily	0.41	0.65	1.77	5.77	0.78	0.46	13.5	1.1	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	Y 9.0m Y 12.0m C99.77 Y 5.4m C99.84					
C99.84-C99.77 (2)	Floodplain - Bringalily	0.93	0.97	30	20.3	0.62	0.67	5.5	6.35	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow						
C98.87	Floodplain - Bringalily	0.07	0.08	0.11	0.01	0.08	0.15	0.01	0.48	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N					
C98.36	Floodplain - Bringalily	0.83	0.66	12.8	6.75	0.66	0.61	8.5	5.5	0.26	0.07	0.9	0.03	0.4	0.23	2.4	0.37	Y 5.4m					

		1% AEP				20% AEP (1 in 5)																
		Existing case				Design Case				Existing case				Design Case				Downstream scour protection in reference design	Combined geomorphic and hydraulic impacts			
Floodplain culverts		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)			Initial Consequence			
Culvert Site ID	Floodplain	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s		Potential Impact Category	Impact Description	20% AEP	1% AEP
C97.84	Floodplain - Back Creek 2	0.68	0.54	3.6	2.8	0.34	0.69	0.14	3.9	0.21	0.27	0.13	1.12	0.13	0.53	0.12	0.3	Y 9.0m	Floodplain constriction	20% AEP event, reduced velocities upstream, unlikely to effect floodplain sediment transport, and increased velocities downstream. The culvert has downstream scour protection in the area of increased flow velocities, reducing the impact potential, up to minor scour may occur. 1% AEP event shows upstream reduction in flow velocity and downstream increase. The max design velocity is 0.69 m/s, indicating up to moderate erosion may occur.	Minor	Minor to moderate
C97.38	Floodplain - Bringalily	1.11	1.08	17.6	25.9	0.55	1.27	1.75	25.5	No flow	0.43	No flow	2.95	No flow	0.17	No flow	0.23	Y 5.4m	Floodplain constriction and sidling	See description above for Bringalily Floodplain	Not significant	Minor to Moderate
C97.29	Floodplain - Bringalily	0.73	0.8	10.05	12.9	0.14	0.27	0.14	1.4	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N					
C97.01	Floodplain - Bringalily	0.17	0.2	0.18	0.25	0.09	0.2	0.06	0.16	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N					
C94.91	Floodplain - Bringalily	No flow	0.07	No flow	0.22	No flow	0.11	No flow	0.04	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N	Floodplain constriction and sidling	20% AEP event, no flow at some culverts, other culverts have flows less then 0.4 m/s, here is some scour protection in the revised reference design, but up to minor erosion may occur upstream. For the 1% AEP, other than culverts C69.80 to C68.89 consequences are not significant to minor. As sidling is mainly occurring, some culverts are oblique to floodplain flow, namely the culvert group C69.80 to C68.89, C69.14 which shows the largest change in the design flow, with an increased in flow velocity upstream from 0.54 m/s in the existing case to 1.36 m/s in the design case. Little change in downstream flow velocities. The culvert is located is a broad flood channel/basin, moderate to major impacts including downstream scour may occur.	No flow to Minor	Moderate to Major
C69.80-C68.89 (10)	Floodplain - Pariagara Creek	0.54	0.52	3.25	3.45	1.36	0.47	122	1.5	0.24	0.23	0.59	0.42	0.4	0.28	21.8	Y 10.8m C69.41, 10.8m C69.28, 10.8m C69.21 , 9m C69.14, 7.2m C69.10, N at others.					
C68.41	Floodplain - Pariagara Creek	0.65	0.59	10.3	5.67	0.68	0.62	7.1	4.2	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N					
C68.09	Floodplain - Pariagara Creek	0.61	0.71	5.2	7.7	1.03	0.76	15.17	6.14	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N					
C67.83-C67.64 (3)	Floodplain - Pariagara Creek	0.5	0.55	2.8	3.42	0.43	0.66	1.12	4.4	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N					
C55.40-C55.36 (2)	Floodplain - MB 6	0.36	0.59	3.55	6.97	0.44	0.56	0.27	4.97	No flow	0.43	No flow	4.48	0.5	0.33	2.07	1.91	Y 6.3m C55.06	Floodplain constriction and sidling	Existing case 20% AEP has no flow upstream, and up to 0.43 m/s downstream. Design case has flow both upstream and downstream, with max velocity of 0.5 m/s, there is some scour protection in the revised reference design, but up to minor erosion may occur upstream. 1% AEP design velocities show a increase upstream of greater than 10% and minor erosion may occur.	Minor	Minor
C45.64-C42.87 (23)	Floodplain - Macintyre Brook	0.43	0.52	4.7	7.7	0.54	0.49	0.8	3.4	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	Y 7.2m C43.56, C44.32, C44.67 N Remainder	Floodplain sidling	20% AEP, flows ranges from within 10% of existing, no flow to more than 10% decrease in design flow, as these flow velocities are considered sufficient to transport any sediment, potential impacts are unlikely. C31.44, C31.4 both have culverts in the existing case, which appear to have concentrated flows. C35.18 has a constructed straightened channel downstream of it leading to a human made pond, which results in concentrated flow and higher existing case flow velocities. 1% AEP C35.18 downstream flow velocities greater than 10% increase from existing extend beyond scour protection in revised reference design and up to major erosion may occur, minor erosion may also occur upstream on culverts in the group C45.64 to C42.87 where design flows are greater than 10% more than existing.	Not Significant	Minor to Major
C35.18	Floodplain - Macintyre Brook	0.77	1.14	8.76	11.91	0.71	1.49	Do data	Do data	0.75	0.93	Do data	Do data	0.68	0.91	Do data	Do data	Y 10.8m				
C32.03-31.44 (3)	Floodplain - Macintyre Brook	1.07	1.14	21.34	32.45	0.82	1.01	20.98	31.93	0.72	1.12	9.91	9.06	0.63	0.69	8.3	9.22	Y 5.4m C32.03, N remainder				
C31.97-C31.26(4)	Floodplain - Macintyre River	0.51	0.44	10.64	5.7	0.69	0.7	25.49	20.99	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	N	Floodplain constriction	No flow in the 20% AEP event. 1% AEP design results in increase in velocity for from 0.51 and 0.44 m/s to 0.69 and 0.7 m/s, some local erosion may occur.	No flow	Minor to Moderate
Table Notes																						
One Mile Gulley, Native Dog Creek, Back Creek 1 and Dry Creek do not have floodplain culverts.																						
Only culverts on the Macintyre River floodplain in Queensland are included																						
Key																						
10% above or below of original velocity																						
Reduction >10 %																						
Increase >10%																						

H.4 - Hydraulic Impact Assessment of Floodplains with Bridges

			1% AEP Existing Event				1% AEP Design Event				20% AEP Existing Event				20% AEP Design Event				Combined geomorphic and hydraulic impacts			
Floodplain Bridges			Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)				Initial Consequence	
Site ID	Floodplain	Bridge Name	u/s	d/s	u/s2	d/s2	u/s3	d/s3	u/s4	d/s4	u/s5	d/s5	u/s6	d/s6	u/s7	d/s7	u/s8	d/s8	Change Potential Category	Description	20% AEP	1% AEP
310-BR24	Condamine River	Condamine River South Branch Rail Bridge	0.55	0.53	7.65	9.55	0.56	0.56	12.4	13.3	0.54	0.53	7.46	8.96	0.55	0.54	12.1	12.7	Floodplain encroachment by both abutments (floodbasin bridge)	Floodplain flow occurs at the 20% event, indicating that the bankfull event is more frequent. <10% change in max velocities for 20% and 1% AEP, impacts unlikely. Enhancement opportunity as existing rail embankment in the location of the design bridge may be removed, reducing existing impacts of scour downstream of culverts	Not Significant	Not Significant
270-BR13	Macintyre River	Macintyre Floodplain #2 Rail Bridge	0.31	0.31	1.76	1.77	0.31	0.31	1.85	1.87	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	Floodplain encroachment by both embankments (flood channel)	No flow in 20% event. No change in max design veocities from existing case in 1% AEP.	Not Significant	Not Significant
270-BR12	Macintyre River	Macintyre Floodplain #1 Rail Bridge	0.53	0.52	8.6	8	0.66	0.52	17.2	7.8	No flow	No flow	No flow	No flow	No flow	No flow	No flow	No flow	Floodplain encroachment both embankments (floodplain bridge)	No flow in 20% event. Max velocities increase by ~25% to 0.66 m/s on the upstream abutments in 1% AEP event, indicating Minor erosion may occur if abutments unprotected.	Not Significant	Minor
Key																						
10% above or below of original velocity																						
Reduction >10 %																						
Increase >10%																						

Table H.5 - Hydraulic Impact Assessment for Bridges under an 0.05% AEP

			0.05% AEP Existing Event				0.05% AEP Design Event			
Bridges 0.05% AEP			Maximum Velocity (m/s)		Maximum Stream Power (W/m2)		Maximum Velocity (m/s)		Maximum Stream Power (W/m2)	
Site ID	Watercourse ID	Bridge Name	u/s	d/s	u/s	d/s	u/s	d/s	u/s	d/s
310-BR32	Dry Creek	Dry Creek Rail Bridge	3.55	3.2	361	342	3.39	3.46	305	334
310-BR31	Westbrook Creek	Westbrook Creek Rail Bridge	2.87	2.68	401	200	2.84	3.05	760	530
*310-BR20	Four Mile Gully	Toowoomba Cecil plains Road Rail Bridge	2.55	2.16	159	114	2.79	2.69	371	284
*310-BR42	NC3	Biddeston Southbrook Road Rail Bridge	2.29	2.3	334	346	2.39	2.4	325	335
310-BR27	Condamine River North Branch	Condamine River North Branch Rail Bridge	0.53	0.66	8.7	16.5	0.69	0.8	6.6	6.9
310-BR25/26	Condamine River	Condamine River Main Branch Combined Rail Bridge	1.45	1.45	17.9	19.1	1.44	1.44	18.5	19.6
310-BR24	Condamine River Floodplain	Condamine River South Branch Rail Bridge	0.54	0.54	7.61	12	0.73	0.73	20.2	18.1
310-BR21/22	Grasstree Creek	Grasstree Creek Rail Bridge	1.36	1.38	21.6	28.9	1.45	1.48	33.7	39.6
310-BR38	Back Creek 1	Back Creek Rail Bridge	1.63	1.58	174	148	2.44	2.62	440	810
*310-BR37	SC 2	Milmeran Inglewood Road Rail Bridge	2.08	1.39	386	129	2.52	1.85	107	267
310-BR28	C Ck 2	Milmeran Inglewood Road Rail Bridge #2	1.54	1.9	82	167	1.51	1.88	76	166
310-BR11	Nicol Creek	Nicol Creek Rail Bridge	2.69	2.44	414	315	3.01	2.8	637	750
310-BR10	Bringalily	Bringalily Creek 3 Rail Bridge	1.9	2.11	456	600	1.82	2.12	474	650
310-BR08	Back Creek 2	Bringalily Creek 1 Rail Bridge	1.96	2.06	144	162	1.45	1.53	64	65
310-BR07	Native Dog Creek	Native Dog Creek Rail Bridge	1.5	1.5	86	88	1.53	1.55	90	94
310-BR06	Cattle Creek	Cattle Creek Rail Bridge	2.47	2.35	453	382	2.49	2.35	454	382
310-BR05	C Ck 18, Pariagara Creek	Pariagara Creek Rail Bridge	2.33	2.28	159	164	2.43	2.39	169	175
310-BR04	MB 6	UT2 Macintyre Brook Rail Bridge	0.91	0.9	22.1	21.6	1.03	1.1	31	37.7
310-BR03	MB 7	UT1 Macintyre Brook Rail Bridge	0.59	0.7	4.1	7.9	0.58	0.71	16.2	45.9
270-BR13	Macintyre River Floodplain	Macintyre Floodplain #2 Rail Bridge	0.85	0.86	27.7	30.5	1.68	1.32	250	123
270-BR12	Macintyre River Floodplain	Macintyre Floodplain #1 Rail Bridge	0.7	0.68	15.9	14.4	1.25	1.07	90	55
270-BR11A	Macintyre River, Whalan Creek	Macintyre River Viaduct Span A	2.42	2.45	364	405	2.4	2.44	356	412

Table H.6 - Watercourses with very small catchments (<10 ha) and no defined channels

Chainage (m)	Proposed rail infrastructure	Catchment name	Hydraulic Model	Assessment of FIOs except for Flow distribution		FIO Flow Distribution		Additional Mitigation Section	Lot number of adjacent property/ies	Watercourse sensitivity to change
				Developed Case Model Results	Table summarising outcomes and mitigation	Developed case Model Results	Table summarising outcomes and mitigation			
32700 (NS2B)	Bridge - stream	MR 2	Macintyre River	Section 17.5	Table 17.27	Section 17.5.3.6		Section 17.6	1RP49163 / 14SP127017	2
58236	Embankment	MBs 6	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	62MA3456 / 61MH84	1
58613	Embankment	MBs 5	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	61MH84	1
58960	Cut	MBs 4	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	60MA3456 / 61MH84	1
59575	Cut	MBs 3	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	245CP902340	1
60915	Cut	MBs 2	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	143CP902340	1
61118	Cut	MBs 1	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	143CP902340	1
63666	Embankment	CCs 28	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	141MH193	1
63906	Cut	CCs 27	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	141MH193	1
64670	Embankment	CCs 26	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	93MH819 / 121MH94	2
67573	Culvert	CCs 25	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	97MH38	4
68017	Culvert	CCs 24	Macintyre Brook	Section 14.5	Table 14.18	Section 14.5.4.6		Section 14.6	97MH38	2
72941	Cut	CCs 23	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	171MH75	4
74197	Cut	CCs 20	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	4MH75	2
77466	Culvert	CCs 19b	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	102MH643 / 6MH643	4
77750	Culvert	CC s 19a	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	102MH643 / 5MH75	4
79500	Culvert	CCs 18a	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	2SP214649 / SP129536	4
79981	Culvert	CCs 18	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	2SP214649 / SP129536	2
80673	Culvert	CCs 17a	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	2SP214649 / SP129536	4
81187	Culvert	CCs 17	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	54SP129536 / 2SP214649	4
83480	Culvert	CCs 16a	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	2SP214649 / 54SP129536	2
85392	Culvert	CCs 16	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	54SP129536	2
87174	Culvert	CCs 15	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	AMH842 / 341FTY1881	2
92913	Culvert	CCs 14	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	10MH737	4
95064	Culvert	CCs 13	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	31SP118699	4
96200	Culvert	CCs 13a	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	2SP118699 / 2RP110474	4
99372	Culvert	CCs 12	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	107MH808 / 169MH786	2
107964	Culvert	CCs 11a	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	9MH365	4
108532	Culvert	CCs 11	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	9MH365	4
110934	Culvert	CCs 10	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	6MH364	4
111264	Culvert	CCs 9	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	6MH364	4
111901	Cut	CCs 8	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	6MH364	4
112329	Culvert	CCs 7	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	5SP194159	4
112997	Culvert	CCs 6	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	5SP194159	4
113997	Cut	CCs 5	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	1SP204014	4
114832	Embankment	CCs 4	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	1SP204014	4
114900	Culvert	CCs 3	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	1SP204014	4
115010	Culvert	CCs 2	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	1SP204014	4
115327	Culvert	CCs 1	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	1SP204014	4
116169	Cut	CCs 0	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	127DY303	4

123494	Embankment	SC 4c	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	3SP126840 / ZSP126840	2
123918	Bridge - Road	SC 4b	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	109DY241	2
124297	Embankment	SC 4a	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	109DY241	2
130987	Cut	SCs 1	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	3748DER34128	4
162208	Culvert	NCs 7	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	1RP7474 / 54SP112651 / 53SP112651	4
162849	Culvert	NCs 6	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	1RP7478 / 1RP7477 / 2RP7477 / 2RP7478	4
166108	Culvert	NCs 5	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	2RP7481 / 35SP104971	1
168636	Culvert	NCs 4	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	1RP7470 / 3385A341727 / 3546A341819	2
171000	Culvert	NCs 4a	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	2RP212352 / 1RP212352 / 7RP212353	1
173588	Culvert	NCs 3	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	6RP212368 / 12RP212366 / 15RP212368	2
177658	Culvert	NCs 2	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	20RP913044	2
180696	Embankment	NCs 1	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	4RP203202 / ARP152985 / 3RP203202	2
197903	Cut	OCs 3	WestBrook Creek	Section 7.5	Table 7.43	Section 7.5.3.6	Section 7.6		2AG3200	4
200527	Culvert	OCs 2	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	14RP24607	2
201235	Culvert	OCs 1	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	15RP24607	2
206876	Culvert	OC1a	Local	Section 18.6.3.5	Table 18.8	Section 18.6.3.6	Table 18.9	Section 18.7 and Section 22	44AG109	2



Geomorphology Report

Appendix I Laboratory and field testing data

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

Table I.1 - Field Testing Results

Location	Sample ID	Description	Pocket Penetrometer (kPa)			Shear Vane (kPa)							
			Samples	# of tests	PP mean	Initial	Residual	# of tests	Mean initial	Mean residual			
CCK 16	CH73.68-S3	Sandy silty CLAY, low plasticity, light greyish brown mottled orange, moist, stiff to very stiff	UTP	1	>440	UTP							
CCs 21	No sample (unable to collect)	SILT with fine sand, light grey, low plasticity	UTP	2	>440	104	14	2					
			UTP			UTP							
CCs 21	No sample - on true right bank in eroded area at culvert location	Silty CLAY with fine sand, low plasticity, light grey, very stiff, hard to indent with thumb	UTP	1	>440	UTP							
CCs 21	CH73.53-S1	Sandy, silty CLAY, low plasticity, brownish grey, mottled orange, very stiff	UTP	1	>440	UTP							
SC 7	CH120.31-S1	Sandy, silty organic CLAY, low plasticity, dark brown moist, rootlets.	75	7	82	54	19	3	50	18			
			75			33	11						
			50			63	25						
			50										
			75										
			125										
			125										
SC 7	No sample (similar material to CH120.31-1)	Sandy, silty organic CLAY, low plasticity, dark brown moist, rootlets.	150	7	128	37	13	3	33	11			
			75			31	8						
			75			31	12						
			200										
			220										
			75										
			100										
SC 2	BR37-S1	Organic SILT with fine sand, low plasticity, dark brown, moist, rootlets	220	4	273								
			400										
			200										
			UTP										
SC 2	BR37-S2	Sandy, clayey SILT, low plasticity, brownish grey, moist, rootlets	150	5	269	88	20	3	58	15			
			340			40	13						
			245			45	13						
			340										
			UTP										

NC 11	CH170.55-S1	Silty CLAY, high plasticity, reddish brown, dry to moist	50	8	88	39	10	5	39	12
			0.25			47	14			
			100			40	14			
			100			36	14			
			100			34	9			
			125							
			100							
			125							

Notes :

PP = Pocket Penetrometer

UTP = Unable to Penetrate

I.2 Laboratory Testing Results

1 Particle size distribution and hydrometer testing

Particle size distribution and hydrometer testing of the bank material at each high risk site was undertaken and the results are presented in Figure I.1.

Two distinct material types based on particle size were common across most of the sites, a fine to medium grained sand and a sandy silt/clay. The bank material for each site described in the sections below is based on the behaviour type as assessed by Atterberg limit testing, rather than the particle size.

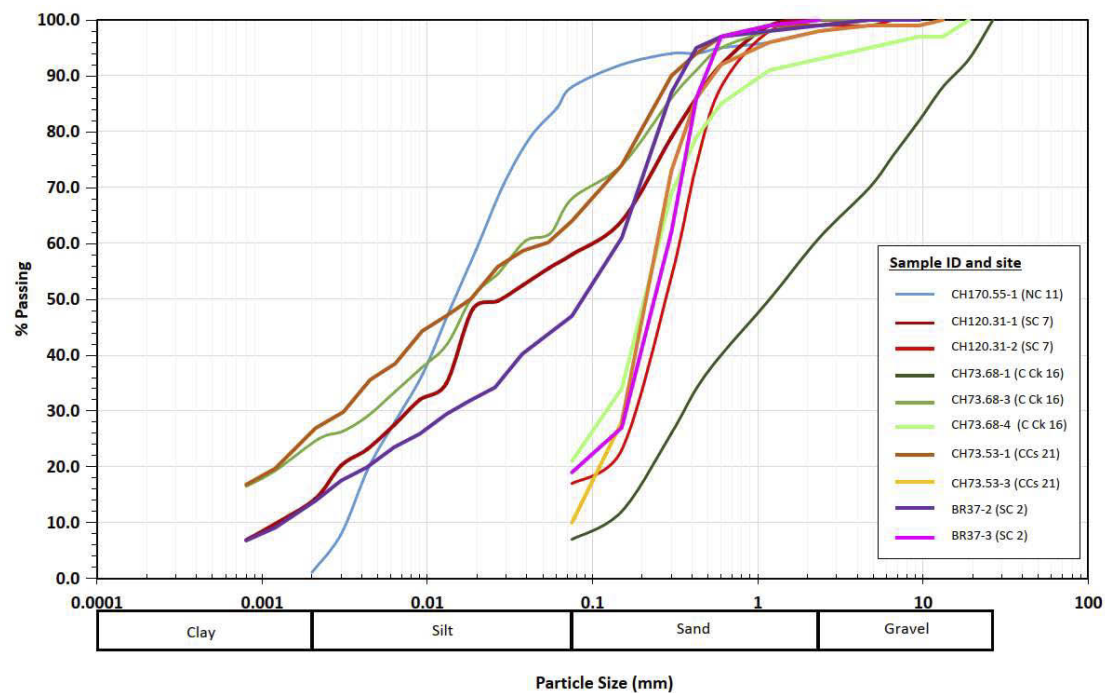


Figure I.1 Particle size distribution testing results for all high-risk sites

2 Atterberg testing

Results from the Atterberg limit testing are presented in Figure I.2. All samples tested plot above the A line on the graph therefore all behave as clay rather than silt. Four of the samples are low plasticity clays and one (site NC11) is a high plasticity clay.

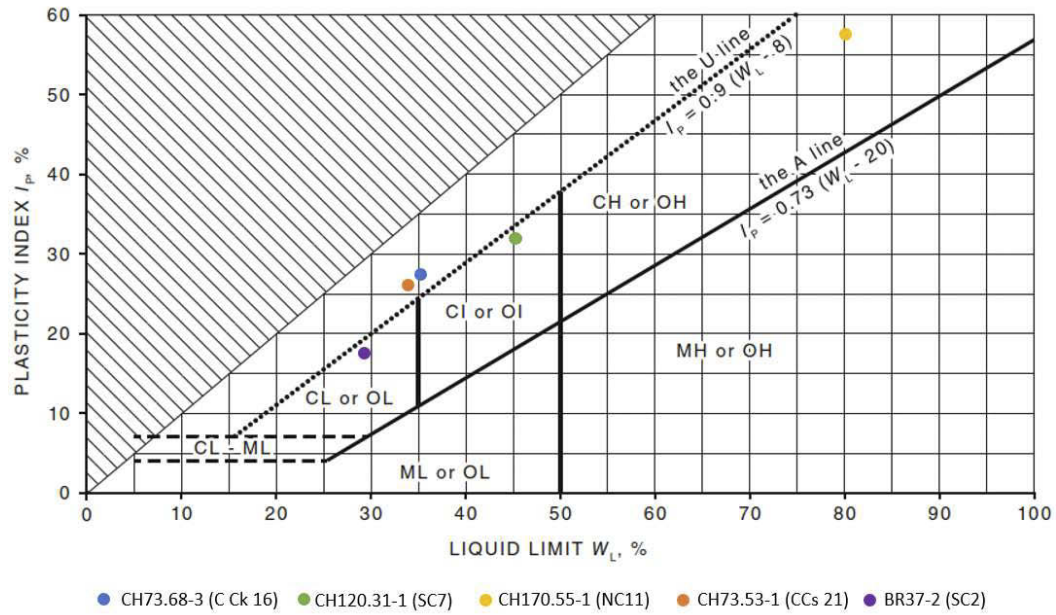


Figure I.2 Atterberg limit testing results

3 Emerson class testing

The results from the Emerson class testing are presented in Table I.1. The Emerson class number ranges from class 1, complete dispersion to class 5, no dispersion. The most dispersive soils were found at sites CCK 16 and CCs 21, class 1 and 2 respectively, representing complete dispersion and some dispersion. These are both active gully erosion sites adjacent to each other.

Table I.2 Emerson class laboratory test results

Site	Sample ID	Sample description	Emerson class
NC 11	CH170.55-1	Silty CLAY	Class 4
SC 7	CH120.31-1	Sandy silty CLAY (organic)	Class 5
CCK 16	CH73.68-3	Sandy silty CLAY	Class 1
CCs 21	CH73.53-1	Sandy silty CLAY	Class 2
SC 2	BR37-2	Sandy silty CLAY	Class 3

I.3 Field Results

Table I.3 Pocket Penetrometer and Shear Vane Testing Results

Location	Sample ID	Description	Pocket Penetrometer (kPa)			Shear Vane (kPa)				
			Samples	# of tests	PP mean	Initial	Residual	# of tests	Mean initial	Mean residual
CCK 16	CH73.68-S3	Sandy silty CLAY, low plasticity, light greyish brown mottled orange, moist, stiff to very stiff	UTP	1	>440	UTP				
CCs 21	No sample (unable to collect)	SILT with fine sand, light grey, low plasticity	UTP	2	>440	104	14	2		
			UTP			UTP				
CCs 21	No sample - on true right bank in eroded area at culvert location	Silty CLAY with fine sand, low plasticity, light grey, very stiff, hard to indent with thumb	UTP	1	>440	UTP				
CCs 21	CH73.53-S1	Sandy, silty CLAY, low plasticity, brownish grey, mottled orange, very stiff	UTP	1	>440	UTP				
SC 7	CH120.31-S1	Sandy, silty organic CLAY, low plasticity, dark brown moist, rootlets.	75	7	82	54	19	3	50	18
			75			33	11			
			50			63	25			
			50							
			75							
			125							
			125							
SC 7	No sample (similar material to CH120.31-1)	Sandy, silty organic CLAY, low plasticity, dark brown moist, rootlets.	150	7	128	37	13	3	33	11
			75			31	8			
			75			31	12			
			200							
			220							
			75							
			100							
SC 2	BR37-S1	Organic SILT with fine sand, low plasticity, dark brown, moist, rootlets	220	4	273					
			400							
			200							
			UTP							

Location	Sample ID	Description	Pocket Penetrometer (kPa)			Shear Vane (kPa)				
			Samples	# of tests	PP mean	Initial	Residual	# of tests	Mean initial	Mean residual
SC 2	BR37-S2	Sandy, clayey SILT, low plasticity, brownish grey, moist, rootlets	150	5	269	88	20	3	58	15
			340			40	13			
			245			45	13			
			340							
			UTP							
NC 11	CH170.55-S1	Silty CLAY, high plasticity, reddish brown, dry to moist	50	8	88	39	10	5	39	12
			0.25			47	14			
			100			40	14			
			100			36	14			
			100			34	9			
			125							
			100							
			125							

Note: PP = Pocket Penetrometer and UTP = Unable to Penetrate

APPENDIX H

Geomorphology Report

Appendix J Detailed assessments—Field observation sheets

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

Geomorphic Observations at Waterway NC 11 – CH 170.55 culvert - 4th August 2022

Contemporary Channel Morphology	Bed and Bank Material	Vegetation	Erosion Observations	Manning's roughness 'n'
Narrow, shallow channel with some sections well defined. Flow has been diverted into manmade pond. Flattened vegetation downstream of pond indicates recent overland flow outside of the main channel.	Bed and bank material differs along channel, it varies between rock (basalt), silt, gravel and grassed sections. See Figure 13 in Drawing set E for details.	Channel is partially grassed. Floodplain is grassed pasture with sparse established trees.	Generally stable. Two areas of bank erosion observed downstream see photo P10 and P11 below.	0.030 – 0.035 Some grass/weeds, little or no brush Theoretical 'n' = 0.0325*

*Refer Appendix K for theoretical 'n' calculation methodology

Geotechnical Observations and Soil Erodibility

Emerson Class	PSD (G = >2.36 mm, S = 0.075-2.36 mm, F = <0.075 mm)	Atterberg Limits	PP/shear vane (kPa)	
S1 – Class 4 (carbonate present)	S1 – G0%, S12%, F88% (silt 87% clay 1%) <i>silty CLAY</i>	S1 - LL 80% PL 23% PI 57%	PP average 88kPa – S1 Shear vane average 39/12 – S1	Modelled Existing 1% AEP Vmax = 2.0 m/s
				Modelled Design 1% AEP Vmax = 2.8 m/s

Photographic Record - references to the geomorphology map (Appendix A – Drawing set E, Figure 13) is included in brackets for selected photos

P1 – looking upstream from entrance into pond	P2 – looking downstream from upstream of culvert location, 1 m staff for scale	P3 – looking downstream from downstream near culvert location	P4 – main channel looking obliquely downstream
			

P5 – rock lined bank on true right downstream of culvert, 1 m staff for scale



P6 – silty CLAY bank on true left downstream of culvert. Sample 1 & 2.



P7 – weathered rock bank near culvert, 0.25 m white staff for scale



P8 – gravel bed material upstream of culvert, 0.25 m white staff for scale



P9 – rock lined channel bed near culvert, 0.25 m white staff for scale



P10 – eroded area in soil downstream from culvert (site E2)



P11 – bank erosion in soil above rock lined channel downstream from culvert (site E3)

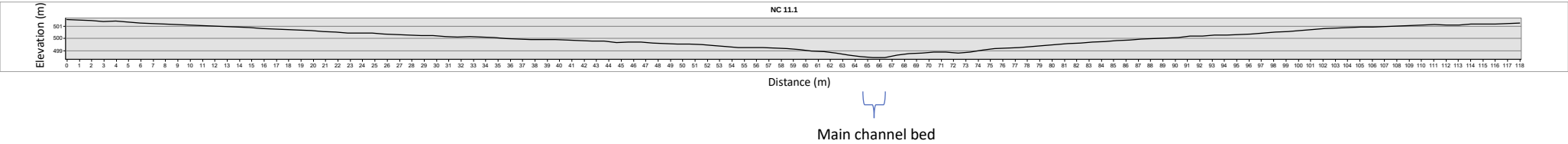


P12 – 2 m x 2 m hole within floodplain, may not be natural (site E4)

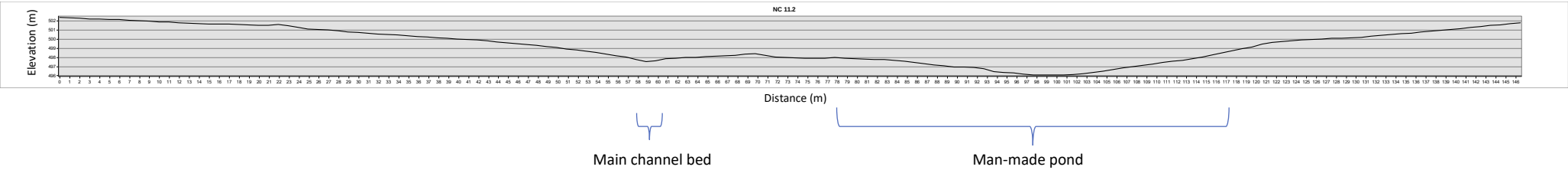


Site NC 11 cross sections – refer to Appendix A, Drawing set E, Figure 13 for location details

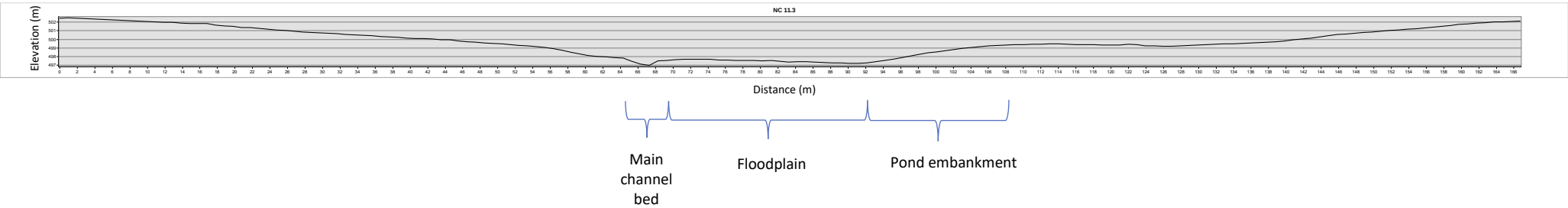
NC 11.1 - upstream of alignment



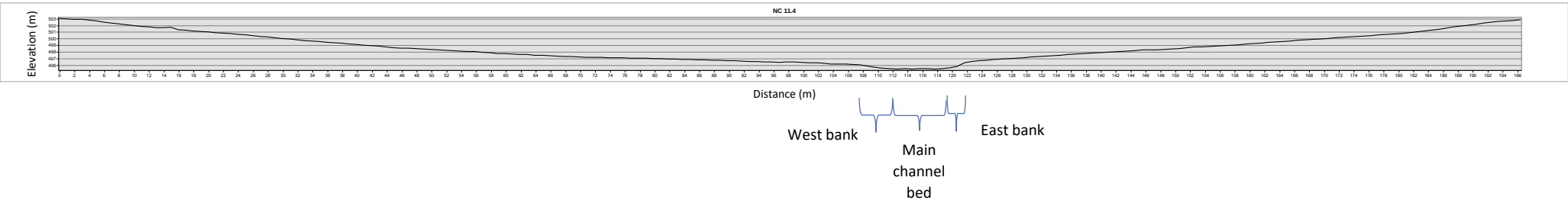
NC 11.2 – upstream of alignment



NC 11.3 – along alignment



NC 11.4 – downstream of alignment



Geomorphic Observations at Waterway SC 7 - CH 120.31 culvert – 2nd August 2022

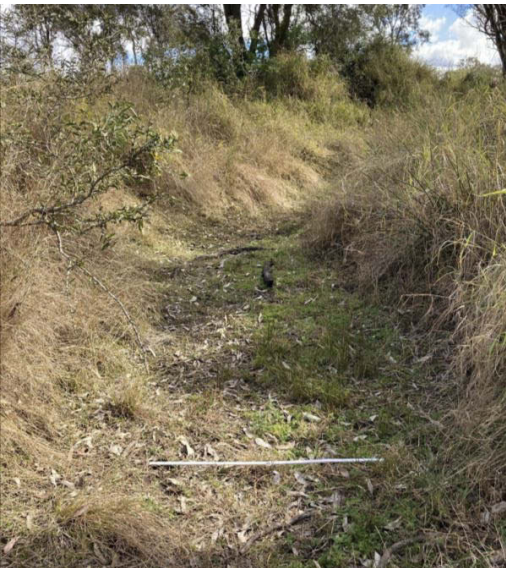
Contemporary Channel Morphology	Bed and Bank Material	Vegetation	Erosion Observations	Manning's roughness 'n'
Channel has been modified upstream of culvert, waterway flows into pond. Downstream of pond, the channel is well defined, sinuous and grassed with some areas of ponding water. Main water flow appears to be to the true left of the pond based on erosion observed in historic aerial imagery.	Bed and bank are dominantly grassed. Bank material when exposed is an organic silty clay underlain by a silty sand.	Weed/grassed channel with sparse shrubs and established trees. Floodplain is grassed pasture with sparse trees. Woody debris present within channel.	Grassed channel, no major erosion observed during site visit at main channel. Historical imagery indicates extensive scour along the true left of the pond approx. 180 m in length. Some bank erosion in black soils was observed at this location.	0.030 – 0.035 Some grass/weeds, little or no brush Theoretical 'n' = 0.0325*

*Refer Appendix K for theoretical 'n' calculation methodology

Geotechnical Observations and Soil Erodibility

Emerson Class	PSD (G = >2.36 mm, S = 0.075-2.36 mm, F = <0.075 mm)	Atterberg Limits	PP/shear vane (kPa)	Modelled Existing 1% AEP Vmax = 2.1 m/s
S1 – Class 5	S1 – G0% S42% F68% (silt 44% clay 14%) <i>sandy silty CLAY (organic)</i> S2 - G0% S73% F17% <i>silty SAND</i>	S1 - LL 45% PL 13% PI 32%	PP average 82kPa. Shear vane average 50/18 – S1 PP average 128kPa. Shear vane average 33/11 – silty CLAY	Modelled Design 1% AEP Vmax = 0.4 m/s

Photographic Record – references to the geomorphology map (Appendix A – Drawing set E, Figure 6) is included in brackets for selected photos

P1 – looking downstream from proposed culvert site	P2 – looking upstream from downstream extent of proposed culvert location	P3 – channel upstream of culvert, looking upstream	P4 – ponding water in channel downstream of culvert
			

P5 – vegetation covered bank material in channel, organic sandy silty clay, sample 1.



P6 – vegetation covered bank material in channel, silty sand, sample 2.



P7 – watercourse feeding into pond, looking upstream



P8 – looking downstream from true right of pond. Area of historic scour identified in aerial images.



P9 – erosion on true right bank downstream of pond (not in main channel). 0.5 m staff for scale.



P10 – close up of erosion on true right bank downstream of pond. 0.5 m staff for scale (site E1)



P11 – downstream from bank erosion, looking upstream towards pond

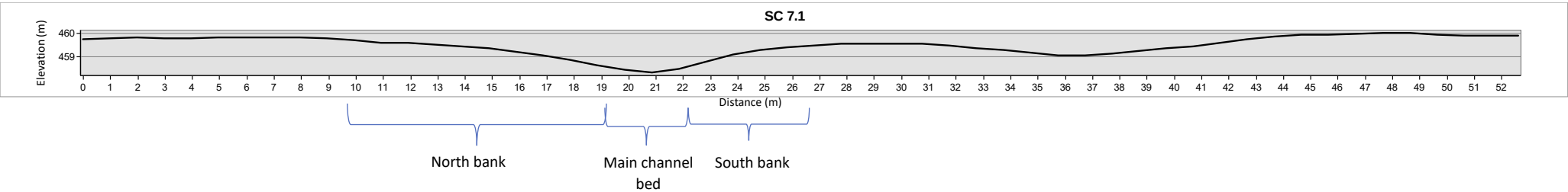


P12 – downstream from bank erosion, looking downstream

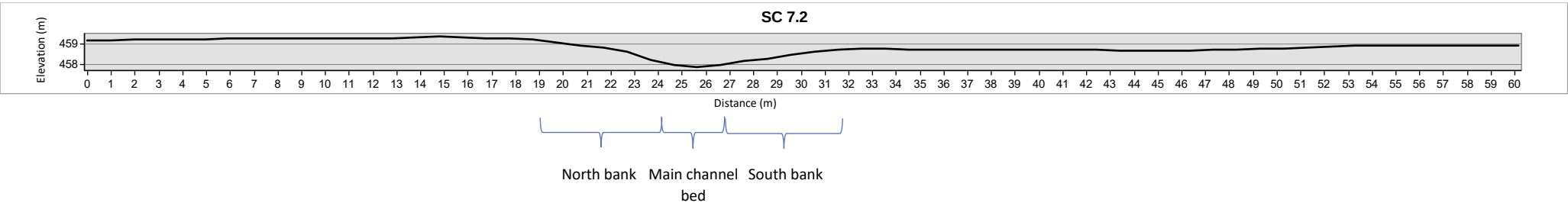


Site SC 7 cross sections – refer to Appendix A, Drawing set E, Figure 6 for location details

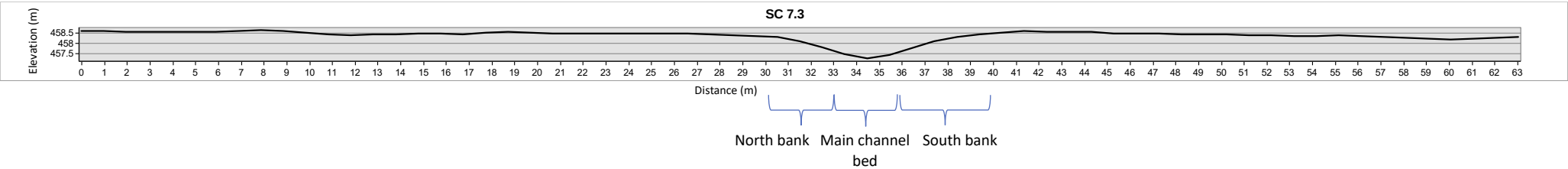
SC 7.1 – upstream of alignment



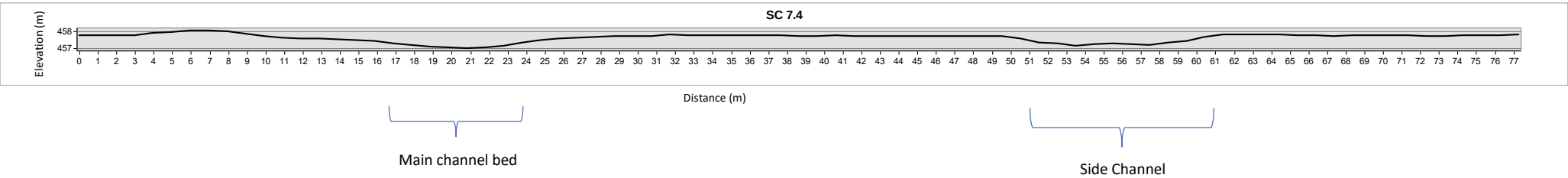
SC 7.2 – upstream of alignment



SC 7.3 – along alignment



SC 7.4 – downstream of alignment



Geomorphic Observations at Waterway C Ck 16 – CH 73.68 culvert – 1st August 2022

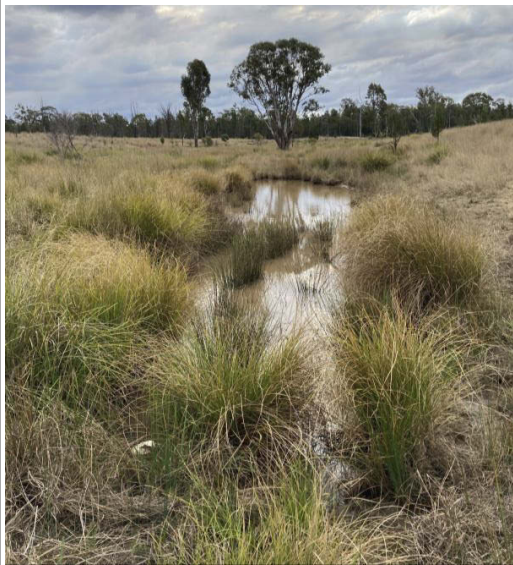
Contemporary Channel Morphology	Bed and Bank Material	Vegetation	Erosion/deposition Observations	Manning's 'n'
Relatively straight, broad vegetated valley with gently sloping banks in area of culvert. Two tight bends downstream, areas of ponding water within this section.	Majority of bed and bank is grass covered. The upper bank material is silty sand and gravelly sand (0.2 m to >0.5 m) overlying sandy silty clay. A minor incipient duricrust caps the banks, weathered to locally deposited fine to coarse gravel, which functions as an armouring layer. Bed material where exposed around pond edges is sand and silt.	Grassed channel with sparse shrubs and established trees. Woody debris present within channel and on banks.	Generally stable. ~10 patches of bare ground on the banks showing evidence for rainsplash and sheetwash erosion as illustrated on Figure 3 in Drawing set E and in photos P7 to P10 below.	0.030 – 0.035/0.04 - 0.55 Some grass/weeds, little or no brush + irregular section with pools/channel meander Theoretical 'n' = 0.0325*

*Refer Appendix K for theoretical 'n' calculation methodology

Geotechnical Observations and Soil Erodibility

Emerson Class	PSD (G = >2.36 mm, S = 0.075-2.36 mm, F = <0.075 mm)	Atterberg Limits	PP/shear vane (kPa)	Modelled Existing 1% AEP Vmax = 1.8 m/s (u/s)
S3 – Class 1	S1 - G39% S54% F7% <i>gravelly SAND</i> S3 - G0% S32% F68% (43% silt, 25% clay) <i>sandy silty CLAY</i> S4 - G7% S72% F21% <i>silty SAND</i>	S3 - LL 35% PL 8% PI 27%	Unable to penetrate (>440kPa) – S3	Modelled Design 1% AEP Vmax = 1.0 m/s (u/s)
				Modelled Existing 20% AEP Vmax = 1.59 m/s (u/s)

Photographic Record – references to the geomorphology map (Appendix A – Drawing set E, Figure 3) is included in brackets for selected photos

P1 – looking downstream from proposed culvert site	P2 – looking upstream from downstream extent of proposed culvert location	P3 – looking downstream from upstream extent of proposed culvert location	P4 – example of bank material exposed. Silty sand with eroded duricrust on top. Sample 4 location.
			

P5 – gravel armouring on bank, derived locally from erosion of duricrust



P6 - bed material exposed at edge of pond



P7 – bank erosion upstream of proposed culvert (site E6)



P8 – bank erosion downstream of proposed culvert (site E2)



P9 – gully erosion downstream of proposed culvert (site E3)



P10 – bank erosion upstream of proposed culvert (site E4)



P11 – bulk sample 1 & 2 material, gravelly sand

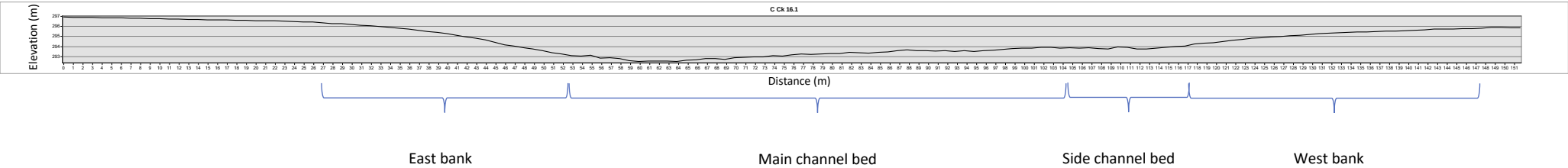


P12 – bulk sample 3 location. Sand overlying sandy silty clay

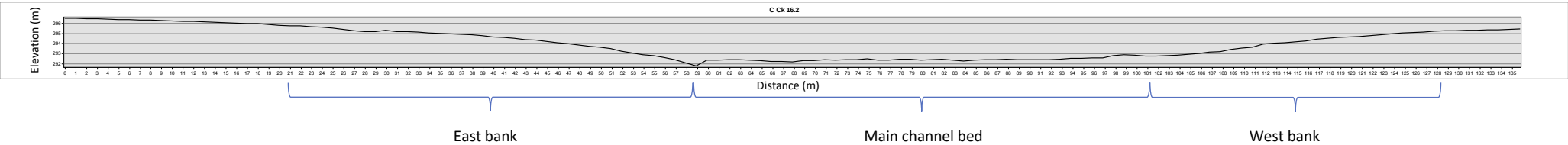


Site C Ck 16 cross sections – refer to Appendix A, Drawing set E, Figure 3 for location details

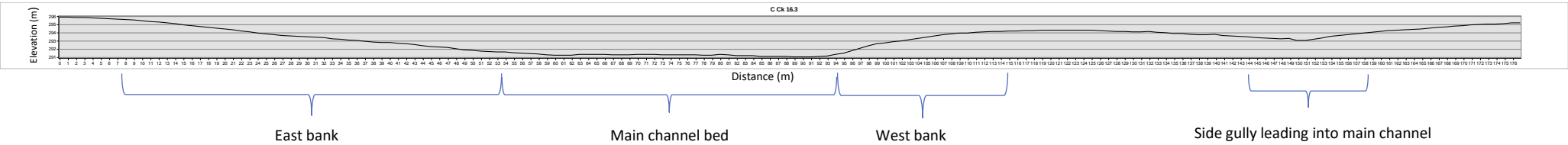
C Ck 16.1 – upstream of alignment



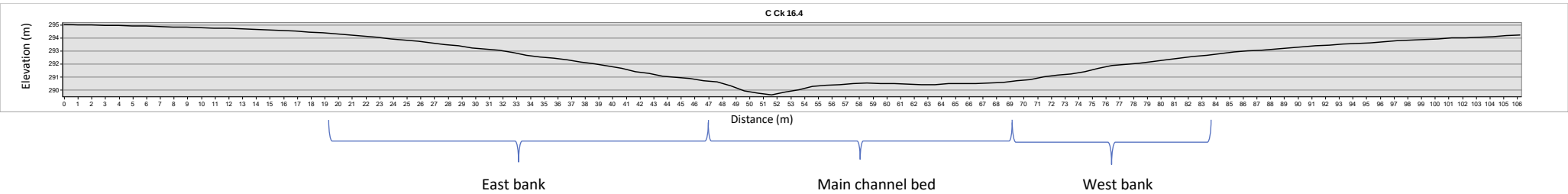
C Ck 16.2 – upstream of alignment



C Ck 16.3 – along alignment



C Ck 16.4 – downstream of alignment



Geomorphic Observations at Waterway CCs 21 – CH 73.53 culvert – 2nd August 2022

Contemporary Channel Morphology	Bed and Bank Material	Vegetation	Erosion Observations	Manning's roughness 'n'
Relatively straight, broad vegetated valley with gently sloping, shallow banks.	Bed and bank is dominantly grassed. Exposed bed material consists of fine sand. Bank material is sand overlying sandy silty clay.	Weed/grassed channel with sparse shrubs and established trees. Woody debris present within channel and on banks.	Bank erosion/slope wash of channel as illustrated on Figure 3 in Drawing set E and in photos P6 to P9 below. Deposition of sand deposits within channel are likely from bank erosion/slope wash.	0.030 – 0.035/0.04 - 0.55 Some grass/weeds, little or no brush + irregular section with pools/channel meander Theoretical 'n'= 0.0325*

*Refer Appendix K for theoretical 'n' calculation methodology

Geotechnical Observations and Soil Erodibility

Emerson Class	PSD (G = >2.36 mm, S = 0.075-2.36 mm, F = <0.075 mm)	Atterberg Limits	PP/shear vane (kPa)	Modelled Existing 1% AEP Vmax = 1.32 m/s
S1 – Class 2	S1 G0%, S36%, F64% (silt 37% clay 27%) <i>sandy silty CLAY</i> S3 G2%, S88%, F10% <i>SAND</i>	S1 - LL 34% PL 8% PI 26%	PP unable to penetrate (>440kPa) – S1 Shear vane 104/14 – S1	Modelled Design 1% AEP Vmax = 0.28 m/s

Photographic Record – references to the geomorphology map (Appendix A – Drawing set E, Figure 3) is included in brackets for selected photos

P1 – looking downstream from proposed culvert site	P2 – looking upstream from proposed culvert location	P3 – looking northeast along alignment, illustrating erosion at culvert location	P4 - bank material. Sand overlaying sandy silty clay
			

P5 – gravel armouring on bank, derived locally from erosion of duricrust



P6 – bank erosion on true right at culvert location, white staff for scale 0.25 m (site E12).



P7 – bank erosion on true left at culvert location, white staff for scale 0.5 m (site E12).



P8 – bank erosion on true left, downstream of culvert, white staff for scale 1.0 m (site E12)



P9 – bank erosion on true right downstream of culvert, white staff for scale 1.0 m (site E14).



P10 – sample 1 location, true left bank culvert

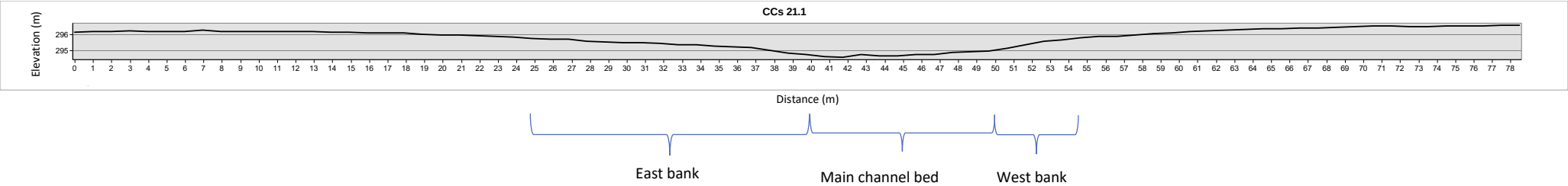


P11 – example of woody debris in channel, white staff for scale 1.0 m

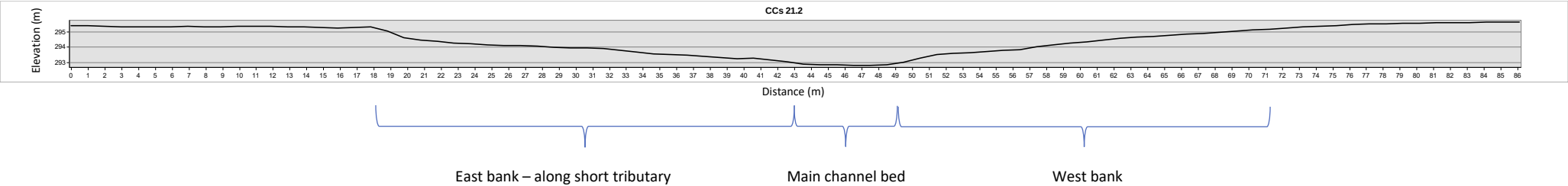


Site CCs 21 cross sections – refer to Appendix A, Drawing set E, Figure 3 for location details

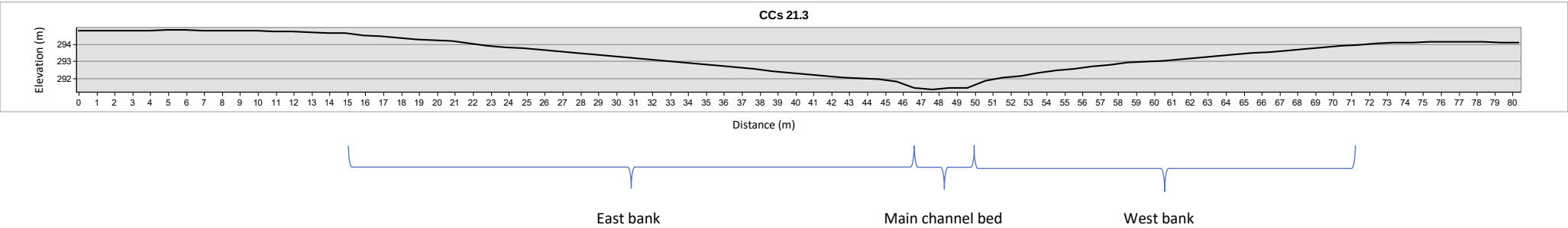
CCs 21.1 – upstream of alignment



CCs 21.2 – along alignment



CCs 21.3 – downstream of alignment



Geomorphic Observations at Waterway SC 2 – CH 126.96 Bridge (BR310-37) - 3rd August 2022

Contemporary Channel Morphology	Bed and Bank Material	Vegetation	Erosion Observations	Manning's roughness 'n'
Modified channel around bend, a grassed embankment/dammed area has been constructed to restrict flow to the east. Sinuous channel, incised, with banks up to 2 m in height.	Bank material is generally grass covered silty sand or sandy silty clay. Bed material where exposed is either fine to coarse sand or silt with gravel armouring.	Grassed banks with established trees lining channel. Sparse in channel vegetation (grass/weeds). Floodplain is grassed pasture with sparse trees.	Erosion observed consistent with meandering channels, erosion on outside of bends, deposition on inside of bends.	0.030 – 0.035/0.04 - 0.55 Some grass/weeds, little or no brush + irregular section with pools/channel meander Theoretical 'n' = 0.0325*

Geotechnical Observations and Soil Erodibility

Emerson Class	PSD (G = >2.36 mm, S = 0.075-2.36 mm, F = <0.075 mm)	Atterberg Limits	PP/shear vane (kPa)
S2 – Class 3	S2 – G0% S53% F47% (silt 33% clay 14%) <i>sandy silty CLAY</i> S3 – G0% S79% F19% <i>silty SAND</i>	S2 - LL 29% PL 12% PI 17%	PP average >270kPa. Shear vane average 58/15 – S2

Modelled Existing 1% AEP Vmax = 1.91 m/s (u/s)

Modelled Design 1% AEP Vmax = 1.84 m/s (u/s)

Modelled Existing 1% AEP depth of flow = 2.95 m

Modelled Design 1% AEP depth of flow = 3.08 m

Photographic Record – references to the geomorphology maps (Appendix A – Drawing set E, Figure 9 & 10) are included in brackets for selected photos

P1 – looking downstream at meander bend, with manmade embankment	P2 – looking upstream from the meander bend	P3 – looking downstream from meander bend corner	P4 – looking downstream from meander bend
			

P5 – 2 m high bank directly downstream of meander bend on true right



P6 – sand deposition on inside of meander bend (site D1)



P7 - bed material downstream of meander bend, silt with gravel and cobble armouring



P8 – bank material sample downstream of meander bend (sandy silty clay) – sample 2



P9 – bank material in area of meander bend (silty sand) – sample 3



P10 - second channel looking downstream. Downstream of dammed area



P11 – erosion at bend downstream of meander bend (site E2)



P12 – sand bar & woody debris deposition within channel downstream of meander bend (site D2)



P13 – erosion at bend downstream of meander bend (site E3)



P14 – in channel vegetated sand bar upstream of meander bend (ICB2)



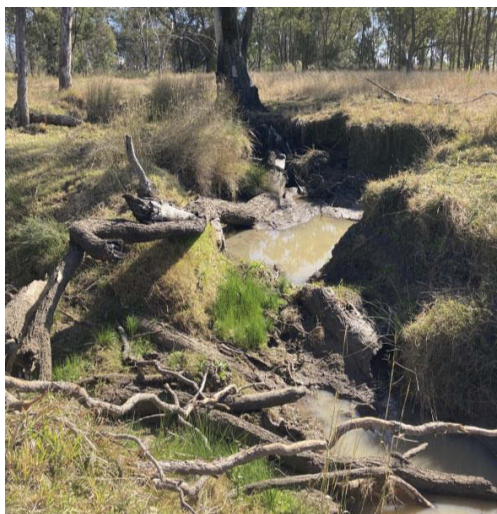
P15 – upstream of road culvert, looking downstream



P16 – bank erosion downstream of road culvert (site E4)



P17 – downstream of road culvert area of channel that has been naturally dammed (site E4)

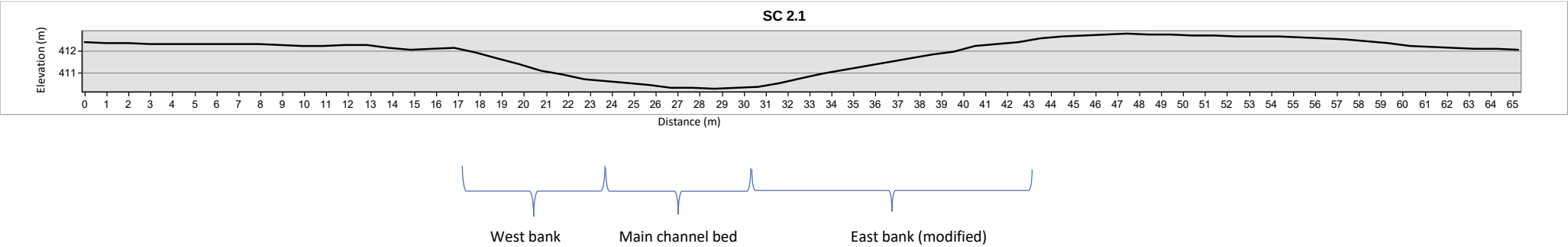


P18 – bank erosion and slumping downstream of road culvert, 1 m white staff for scale (site E4)

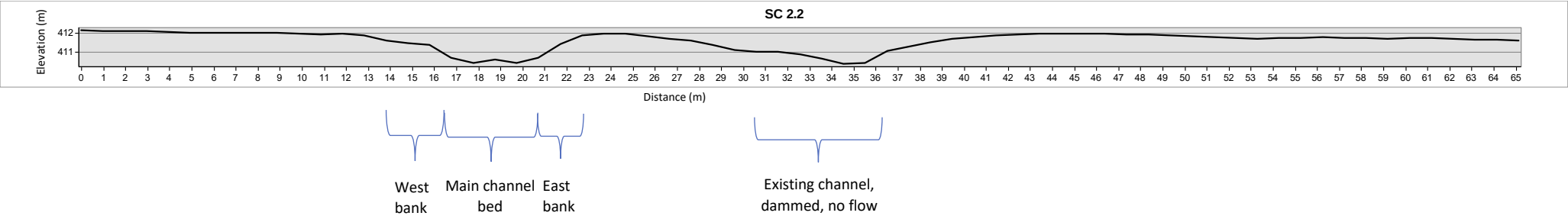


Site SC 2 cross sections – refer to Appendix A, Drawing set E, Figure 9 and 10 for location details

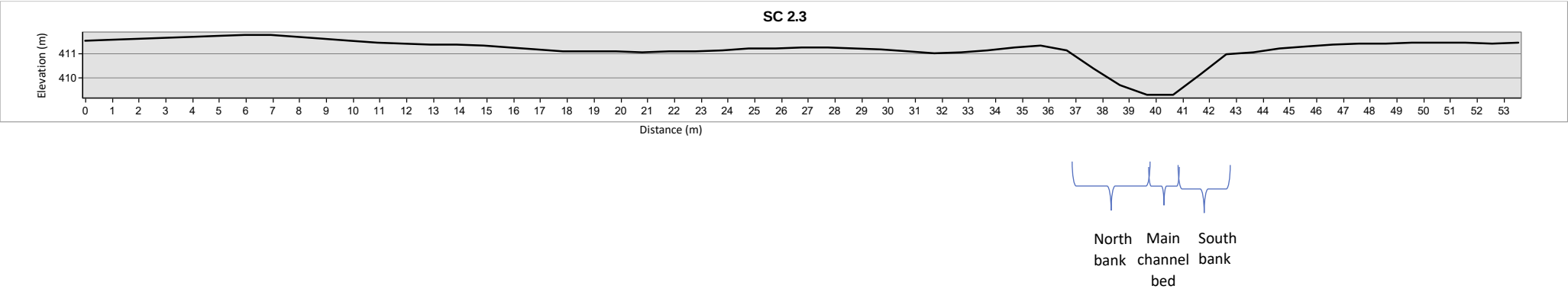
SC 2.1 – at meander bend



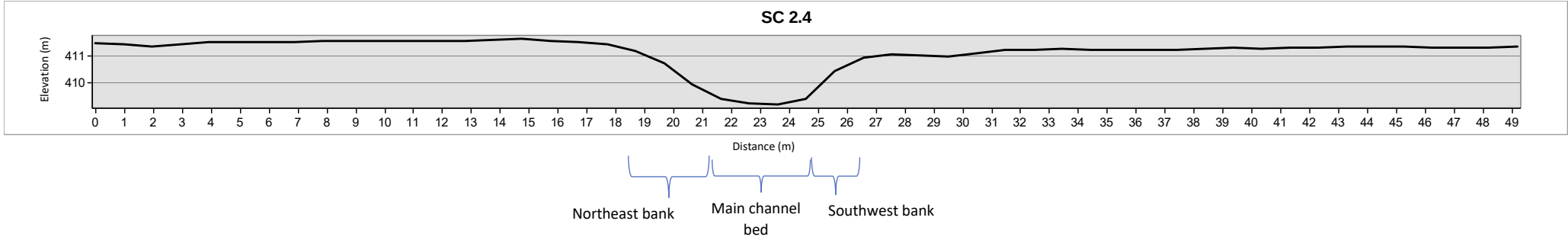
SC 2.2 – downstream of meander bend



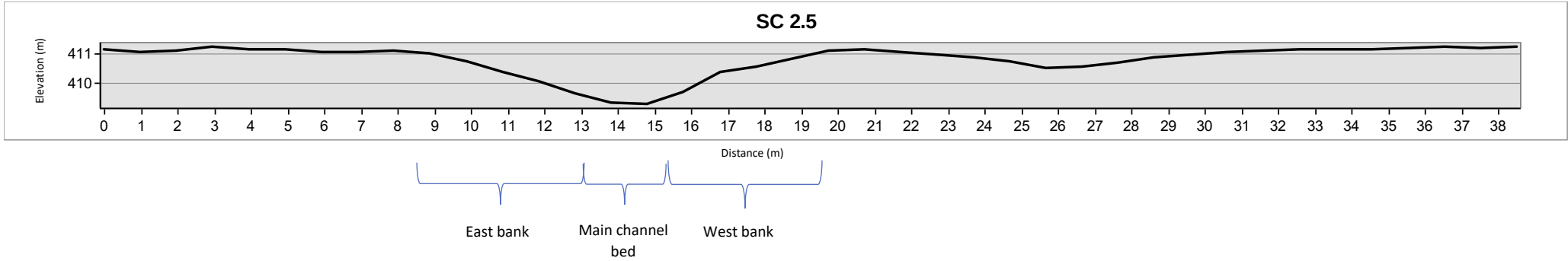
SC 2.3 – downstream of meander bend



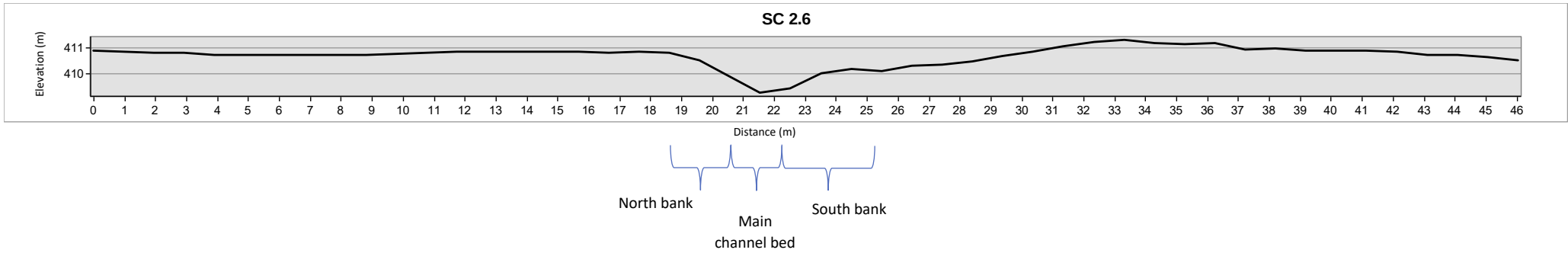
SC 2.4 – downstream of meander bend



SC 2.5 – along alignment near road



SC 2.6 – downstream of road



APPENDIX

H

Geomorphology Report

Appendix K Detailed assessments— Theoretical erosion threshold velocity methodology and results

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

Appendix K ETV methodology for cohesive and cohesionless soils

K.1 EVT assessment considerations for cohesive soils

Many parameters influence the erosion of cohesive soils. These parameters include the physical and chemical properties of soil, as well as the physical, chemical, and mechanical characteristics of the eroding fluid. Please note that this assessment assumes bare soils.

The physical and chemical properties of soil include the following:

- Soil temperature
- Dominant ions of the clay
- Sodium adsorption ratio
- Cation exchange capacity
- Clay content
- Organic matter content
- Swelling
- Plasticity index (PI)
- Particle size distribution of the non-cohesive fraction
- Water content
- Void ratio
- Consolidation
- Stratification

K.2 Cohesive Erosion - Scour in Cohesive Soils (USDT, 2015)

Our approach to assessing the ETV of the cohesive soils within proximity of the alignment is adapted from a publication produced by the U.S. Department of Transportation (USDT) named *Scour in Cohesive Soils* (2015) and Hydraulic Engineering Circular 18 (HEC-18) (2012).

This method is based on a Power relationship (refer *Equation 1*) developed from testing cohesive soils from across the United States that can be used to estimate critical shear stress and erosion rates for a range of cohesive soils. It was noted that the method is less representative of ETVs in soils with Plasticity Indices greater than 25 percent, a fines fraction greater than or equal to 90 percent, and/or shear stress of greater than 100 Pa.

The critical shear stress found in *Equation 1* (USDT, 2015) is then input into *Equation 2* (HEC-18, 2012) along with Manning's roughness and water depth to find the erosion threshold velocity of the material.

Equation K1.

$$\tau_c = \alpha \left(\frac{W}{F} \right)^{-2.0} PI^{1.3} q_u^{0.4}$$

Where:

τ_c = Critical shear stress, Pa

α = Unit conversion constant, 0.1 for S.I.

W = water content, dimensionless ratio

F = Fraction of fines by mass (<75 μm), dimensionless ratio

PI = Plasticity index, dimensionless ratio

q_u = Unconfined compressive strength, Pa

Equation K2.

$$V_c = \frac{K_u}{n} \left(\sqrt{\frac{\tau}{\rho g}} \right) y_1^{\frac{1}{6}}$$

Where:

V_c = Critical velocity, m/s

K_u = Unit conversion, 1.0 for S.I.

n = Manning's roughness coefficient

T_c = Critical shear stress

ρ = density of water, kg/m³

g = acceleration due to gravity, m/s²

y_1 = depth of water, m

K.2.1 Inputs

Manning's roughness assessment

Manning's roughness was assessed based on observations made on-site during field investigations across the alignment and n values taken from Austroads Guide to Bridge Technology Part 8 (2019) table A.2 (Figure 1 of this appendix). Where a terrain does not fit the exact description provided in Austroads, or the terrain is varied around the sample, the range of Manning's roughness will be noted.

Austroads Table A.2 provides a range of values for Manning's roughness based on the terrain of main channels and adjacent flood channels. For the purpose of determining Manning's roughness as a calculation input, the mid-point between the ranges given in Table A.2 has been adopted as 'n'.

Type of channel	n
1. Main channel	
1. Fairly regular section	
(a) Some grass and weeds, little or no brush	0.030–0.035
(b) Dense growth of weeds, depth of flow materially greater than weed height	0.035–0.05
(c) Some weeds, light brush on banks	0.035–0.05
(d) Some weeds, heavy brush on banks	0.05–0.07
(e) Some weeds, dense willows on banks	0.06–0.08
(f) Trees within channel with branches submerged at high stage	Add 0.01–0.02
2. Irregular Section, with pools, slight channel meander To (a) to (f) above as applicable	Add 0.01–0.02
3. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stage	
(a) Bottom, gravel, shingle and few boulders	0.04–0.05
(b) Bottom, shingle with large boulders	0.05–0.07
2. Adjacent flood channels	
1. Pasture, no brush	
(a) Short grass	0.030–0.035
(b) High grass	0.035–0.05
2. Cultivated areas	
(a) No crop	0.03–0.04
(b) Mature row crops	0.035–0.045
(c) Mature field crops	0.04–0.05
3. Heavy weeds, scattered brush	0.05–0.07
4. Light brush and trees	0.06–0.08
5. Medium to dense brush	0.10–0.16
6. Dense willows, summer, not bent over by current	0.15–0.20
7. Cleared land with tree stumps (250 to 450 per ha)	
(a) No sprouts	0.04–0.05
(b) With heavy growth of sprouts	0.06–0.08
8. Heavy stand of timber, a few fallen trees, little undergrowth	
(a) Flood depth below branches	0.10–0.12
(b) Flood depth reaches branches	0.12–0.16
Major Streams (surface width at flood stage > 30 m) Roughness coefficient is usually less than for minor streams of similar description on account of less effect offered by irregular banks or vegetation on banks. Values of n may be somewhat reduced. The value of n for large streams of mostly regular section may be in the range.	0.12–0.16

Source: Based on DTMR (2010).

Figure 1: Manning's 'n' values for natural channels (Austroads, 2019).

UCS Strength

Pocket penetrometer field tests have been used as input for UCS. Mousavi et al., (2021)¹ established that pocket penetrometer field tests can be used to predict UCS of fine-grained soils with good accuracy. The advantage of a pocket penetrometer is that many tests can be undertaken in-situ to get an average strength of the soil across the location. Some soils were unable to be penetrated with the pocket penetrometer, indicating a strength above what was able to be measured by the instrument. In these instances, the maximum value of the pocket penetrometer was recorded.

Laboratory testing

The remaining required calculation inputs come from laboratory testing. A particle size distribution test (PSD) is required to determine the percentage of particles within a sample that pass through a < 0.075 mm sieve. This is defined as the fines fraction, and it is measured by percentage of mass.

Plasticity Index (PI) is a measure of the plasticity of the soil, the PI is defined as the difference between the Liquid Limit (LL – where the soil starts to behave as a liquid), and the Plastic Limit (PL – where the water content is low enough so the soil can no longer be remoulded without cracking). These values are found through Atterberg Limit tests.

K.3 Cohesionless erosion - shields incipient motion calculations

The Shields formula calculates stability of granular material within running water. Incipient motion analysis based on Shields diagram is presented in Bridge Scour (Melville and Coleman, 2000) (refer Figure 2 of the Appendix) and is used to evaluate threshold flow conditions for the motion of a given sediment. Shields diagram indicates that for flows less than the threshold conditions for the boundary material, a channel is stable with no motion of sediment. For flows exceeding these conditions, the boundary sediment will be entrained into the flow. It is worth noting that incipient motion is when the very first few grains of soil begin to move, can occur at very low velocities, and will be limited to a grain size range, perceptible erosion would occur at higher velocities. Therefore using the Shields incipient motion equation for ETV is considered conservative.

The ETV for the D50 grain size and D84 grain size has been assessed for the non-cohesive samples. The D84 grain size is where 84% of material is smaller than 84 mm, and D84 represents the grain size when the majority of the sample will experience incipient motion.

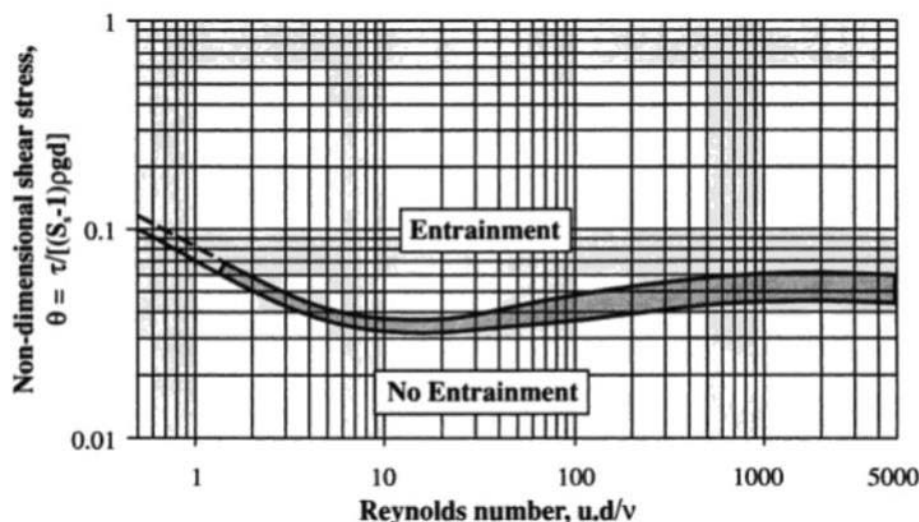


Figure 2: Diagram defining the threshold of sediment entrainment. The shaded band indicates the spread of the data used by Shields.

Shields diagram can be used to describe incipient flow conditions in terms of critical shear stress:

¹ Mousavi, F., Abdi, E., Ghalandarayeshi, S., Page-Dumroese, D. 2021 Modelling unconfined compressive strength of fine-grained soils: Application of pocket penetrometer for predicting soil strength. *Cantena* 196 (2021)

Equation K3.

$$\tau_c = \rho u_{*c}^2$$

Where:

τ_c = Critical shear stress

ρ = Density of water

u_{*c} = Shear velocity (m/s)

A useful approximation for shear velocity for quartz sediments (of sediment specific gravity, $S_s=2.65 \text{ kg/m}^3$) in water at 20°C is shown in Bridge Scour and presented below:

Equation K4.

$$u_{*c} = 0.0115 + 0.0125d_{50}^{1.4} \quad 0.1 \text{ mm} < d_{50} < 1 \text{ mm}$$

Equation K5.

$$u_{*c} = 0.0305d_{50}^{0.5} - 0.0065d_{50}^{-1} \quad 1 \text{ mm} < d_{50} < 100 \text{ mm}$$

Hydraulic Engineering Circular 18 (HEC-18) provides a conceptual framework relating shear stress, soil types, and erosion rates to a variety of materials. The critical shear stress found through methods presented in Bridge Scour can then be used to solve the equation presented in HEC18 for erosion threshold velocity. The equation for erosion threshold velocity presented in HEC18 is presented below.

Equation K6.

$$V_c = \frac{K_u}{n} \left(\sqrt{\frac{\tau}{\rho g}} \right) y_1^{\frac{1}{6}}$$

Where:

V_c = Critical velocity, m/s

K_u = Unit conversion, 1.0 for S.I.

n = Manning's roughness coefficient

τ_c = Critical shear stress ρ = density of water, kg/m^3

g = acceleration due to gravity, m/s^2

y_1 = depth of water, m

Sheilds is comparable to existing calculations of incipient motion such as Ackers and White and Hanco. This is shown in Figure 3, where you can see that Sheild is a conservative approach to describe incipient flow conditions for medium sand and finer material, the most erodible materials.

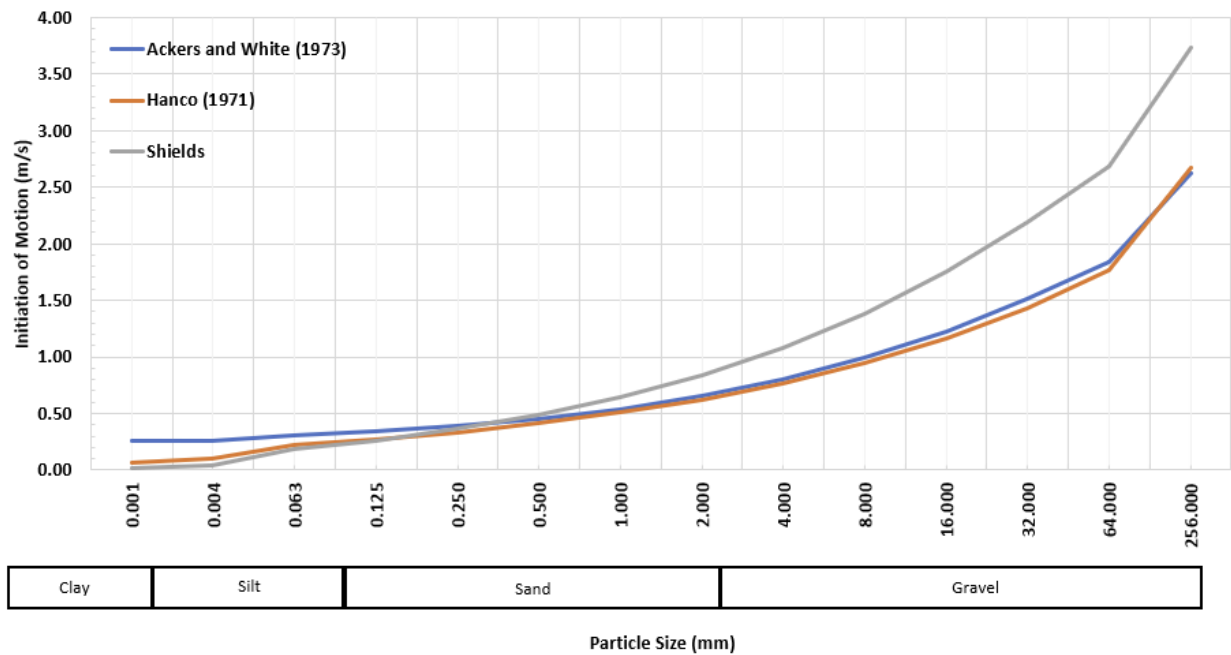


Figure 3: Diagram comparing initiation of motion and particle size, showing three approaches, for a mean flow depth of 1m.

K.3 Existing ETV Guidance

This section is provided to summarise the key documents that outline maximum allowable velocities across a range of soils and water depths. These documents have been used as comparison tools against the ETV results presented within this report. They ensure the results are in line with the guidance provided by the relevant governing bodies in Queensland.

K.3.1 Guide to Bridge Technology, Austroads (2019)

Guide to Bridge Technology Part 8 – Hydraulic Design of Waterway Structures

This document produced by Austroads provides guidance on the selection of the design floods required for the various aspects of the design of waterway structures the hydraulic design of bridges, and the design of works required to protect these structures from scour. Included is a graph showing erodibility categories of soil and rock, refer to Figure 4 of this appendix. While not ETVs, this figure provides an understanding of relative erodibility between different soil and rock types. The most highly erodible category (very high erodibility) comprises fine sand and non-plastic silt, noncohesive materials. Coarser non-cohesive soils, such as gravels and cobbles have medium to low erodibility.

Cohesive materials have plasticity, as the amount of soil plasticity increases, the erodibility decreases from high erodibility for low plasticity silts through to low erodibility for high plasticity clays.

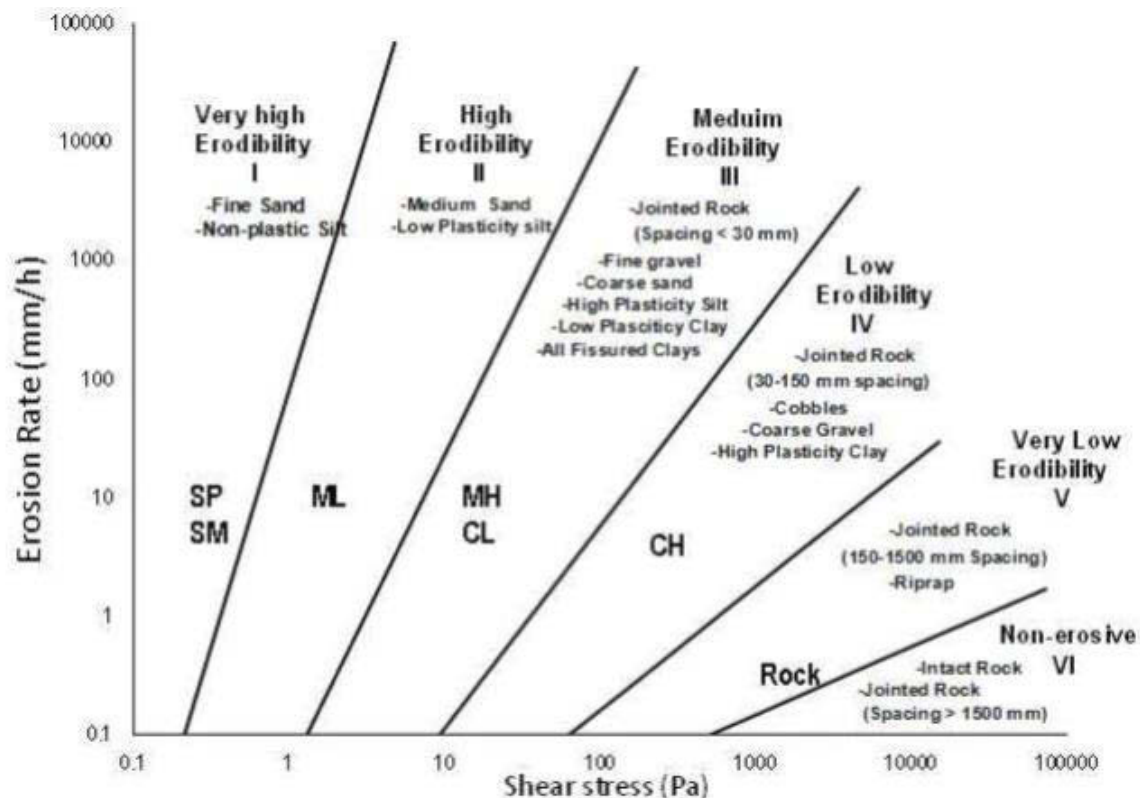


Figure 4: Generalised relationship for erosion in a range of soil and rock types.

Guide to Road Design Part 5, Drainage – General Hydrology Considerations

This document provides road designers and other practitioners with guidance on the design of drainage systems. The guide provides advisable maximum culvert velocities and typical maximum stream velocities before scour will occur in unprotected soils of various types, and can be considered similar to ETVs, refer to Figure 5 of this Appendix.

Stream bed soil type	Maximum advisable culvert velocity (m/s)	Maximum allowable stream velocity (m/s)
Silt	1.0–1.5	< 0.3
Clay, soft	1.0–1.5	0.3–0.6
Clay, stiff	1.2–2.0	1.0–1.2
Clay, hard	1.2–2.0	1.5–2.0
Sand, fine	1.0–1.5	< 0.3
Sand, coarse	1.0–1.5	0.4–0.6
Gravel, 6 mm	1.0–1.5	0.6–0.9
Gravel, 25 mm	1.2–2.0	1.3–1.5
Gravel, 100 mm	2.5	2.0–3.0
Rocks, 150 mm	3.5	2.5–3.0
Rocks, 300 mm	3.5	4.0–5.0

Source: Derived from DTMR (2010b) and VicRoads (2003).

Figure 5: Desirable flow velocities in culverts or unprotected stream beds (Austroads, 2021).

Melville and Coleman (2000) Bridge Scour

Melville and Coleman (2000) provide a comprehensive review of scour processes at bridges and has been relied upon for the production of for the Austroads documents. They present equations and graphs for assessing scour. Also illustrated is the relationship between water flow depth and competent velocity (the maximum velocity at which no erosion occurs, comparable to ETV) for both non-cohesive (Figure 6 of this appendix) and cohesive sediment (Figure 7 of this appendix). For deeper water depths, higher competent velocity occurs for both soil groups.

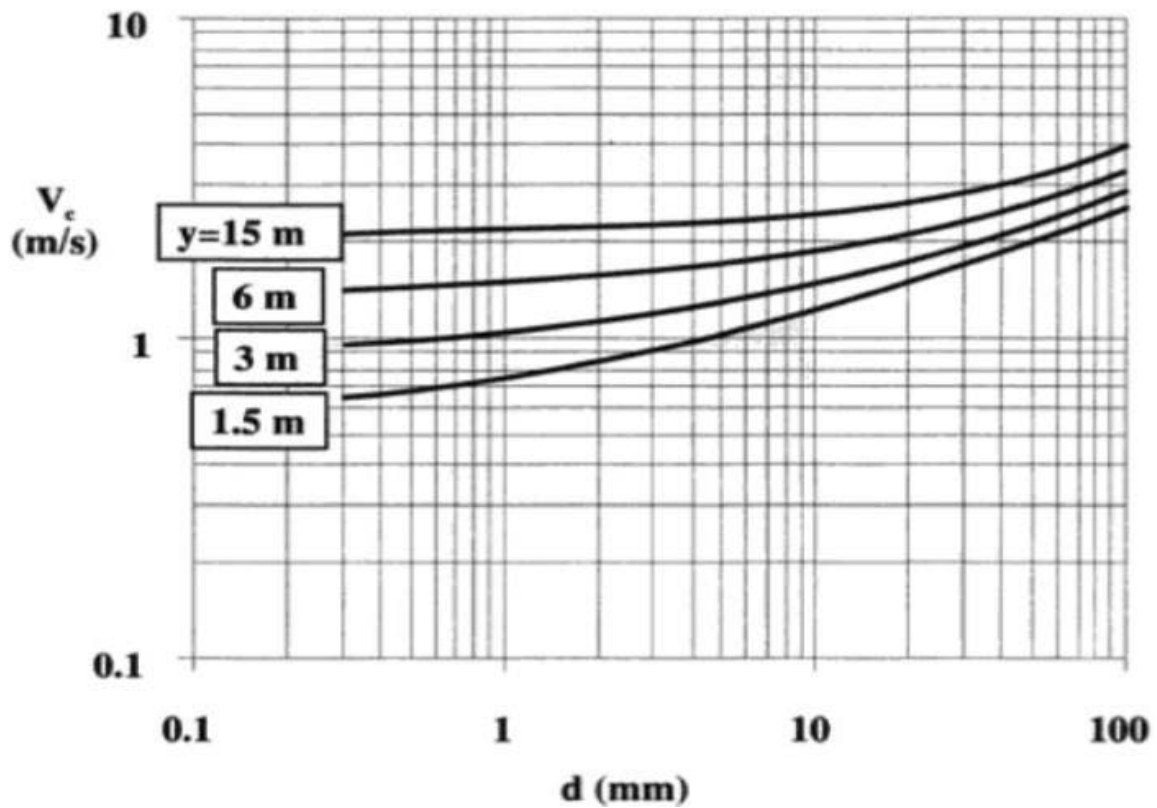


Figure 6: Competent velocity chart for non-cohesive sediment, from Melville and Coleman (2000) figure 3.4 after Neill (1987).

Flow depth (m)	V_c (m/s)		
	High soil scourability	Medium soil scourability	Low soil scourability
	(very soft to soft clays)	(firm to stiff clays)	(stiff to hard clays)
1.0	0.5	0.9	1.6
1.5	0.6	1.0	1.8
3.0	0.6	1.2	2.0
6.0	0.7	1.3	2.3
15.0	0.8	1.5	2.6

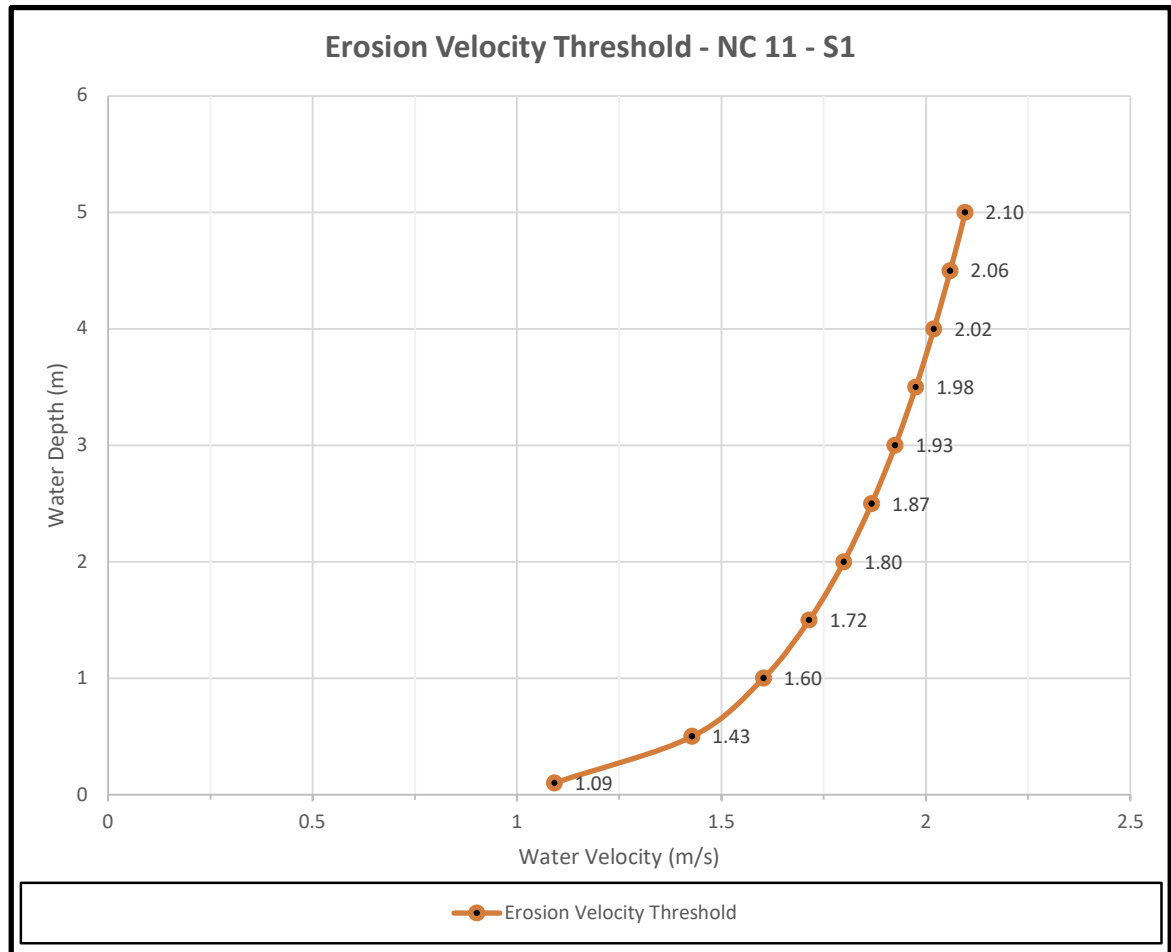
Figure 7: Competent mean velocities for cohesive soils, from Melville and Coleman (2000 Table 3.3, after Harris, 1988).

Border to Gowrie - EVT calculation from bulk samples

SITE AND SAMPLE INFORMATION	
Site ID	NC 11
Chainage (km)	170.55
Sample ID	S1

CALCULATION INPUTS	
Mannings roughness	0.0325
Moisture Content (%)	36.5
Fines Fraction (%)	88
Plasticity Index (%)	57
UCS (Pa)	88260
Emerson Class	4

NOTES	
UCS from pocket penetrometer	
Slaking with no dispersion after remould (carbonate or gypsum present)	

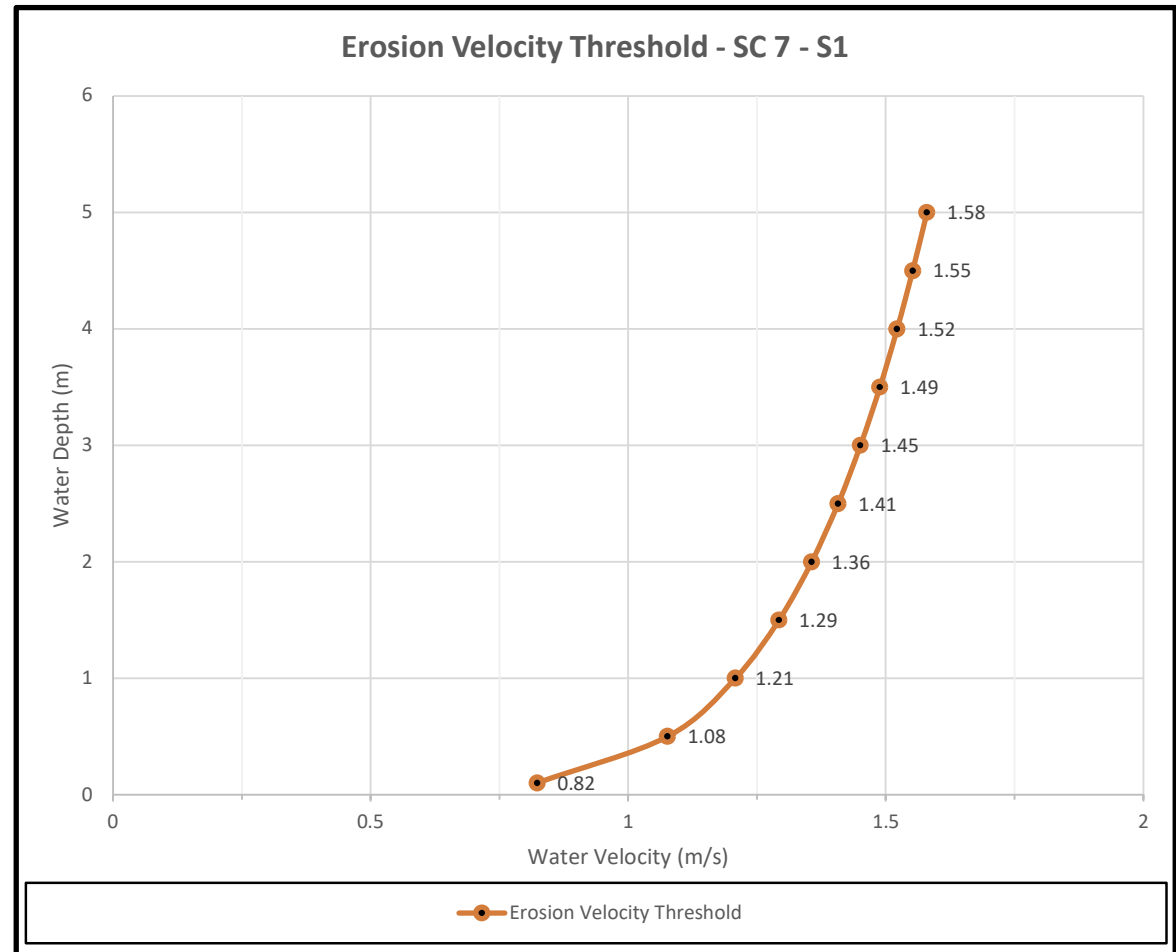


Border to Gowrie - EVT calculation from bulk samples

SITE AND SAMPLE INFORMATION	
Site ID	SC 7
Chainage (km)	120.31
Sample ID	S1

CALCULATION INPUTS	
Mannings roughness	0.0325
Moisture Content (%)	21.4
Fines Fraction (%)	58
Plasticity Index (%)	32
UCS (Pa)	78000
Emerson Class	5

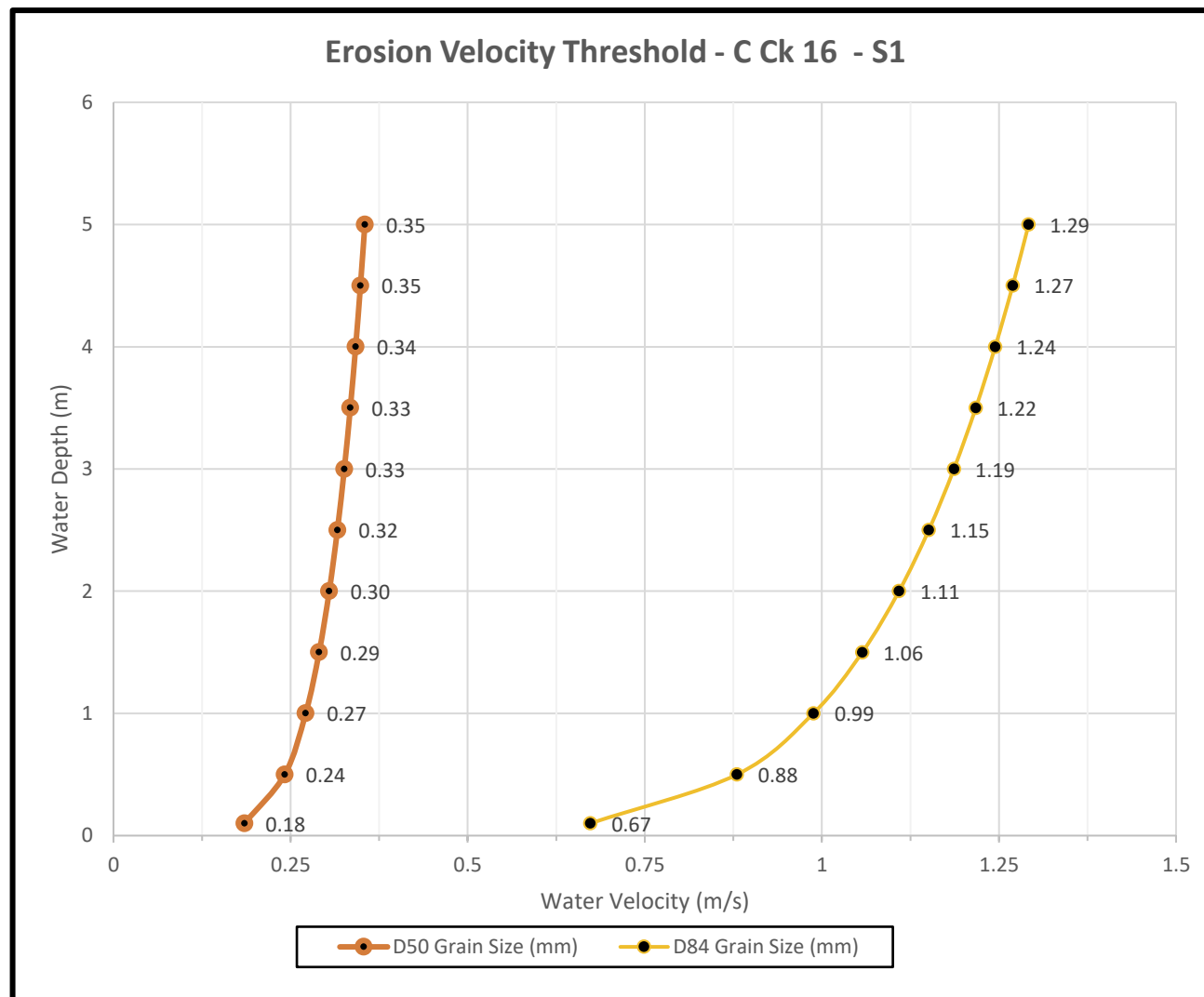
NOTES	
UCS from pocket penetrometer	
Slaking followed by dispersion after 1:5 soil:water suspension	



Border to Gowrie - EVT calculation from bulk samples

SITE AND SAMPLE INFORMATION	
Site ID	C Ck 16
Chainage (km)	73.68
Sample ID	S1

CALCULATION INPUTS	
Mannings roughness	0.0325
D50	1.18
Critical shear stress	0.76
D84 (mm)	11.00
Critical shear stress, D84	10.11

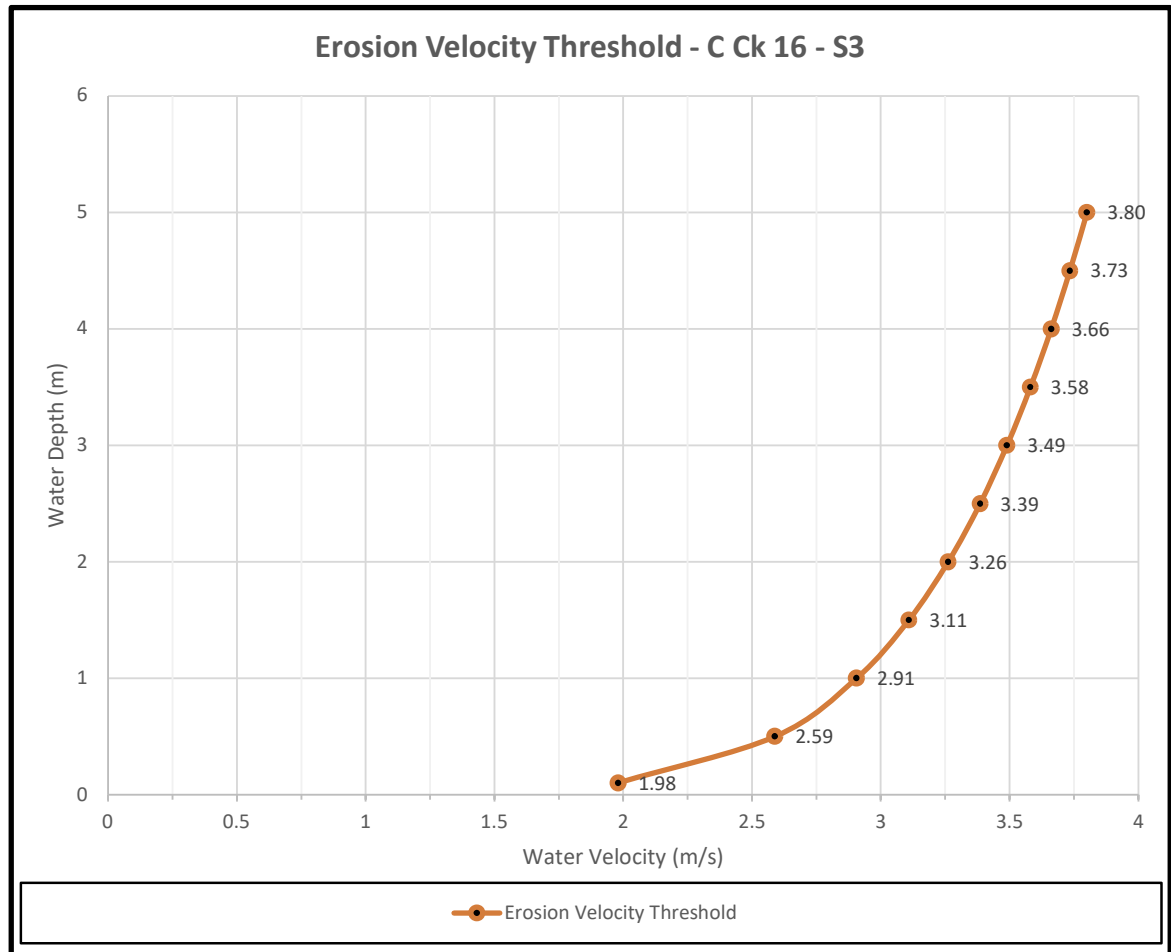


Border to Gowrie - EVT calculation from bulk samples

SITE AND SAMPLE INFORMATION	
Site ID	C Ck 16
Chainage (km)	73.68
Sample ID	S3

CALCULATION INPUTS	
Mannings roughness	0.0325
Moisture Content (%)	13.2
Fines Fraction (%)	68
Plasticity Index (%)	27
UCS (Pa)	440000
Emerson Class	1

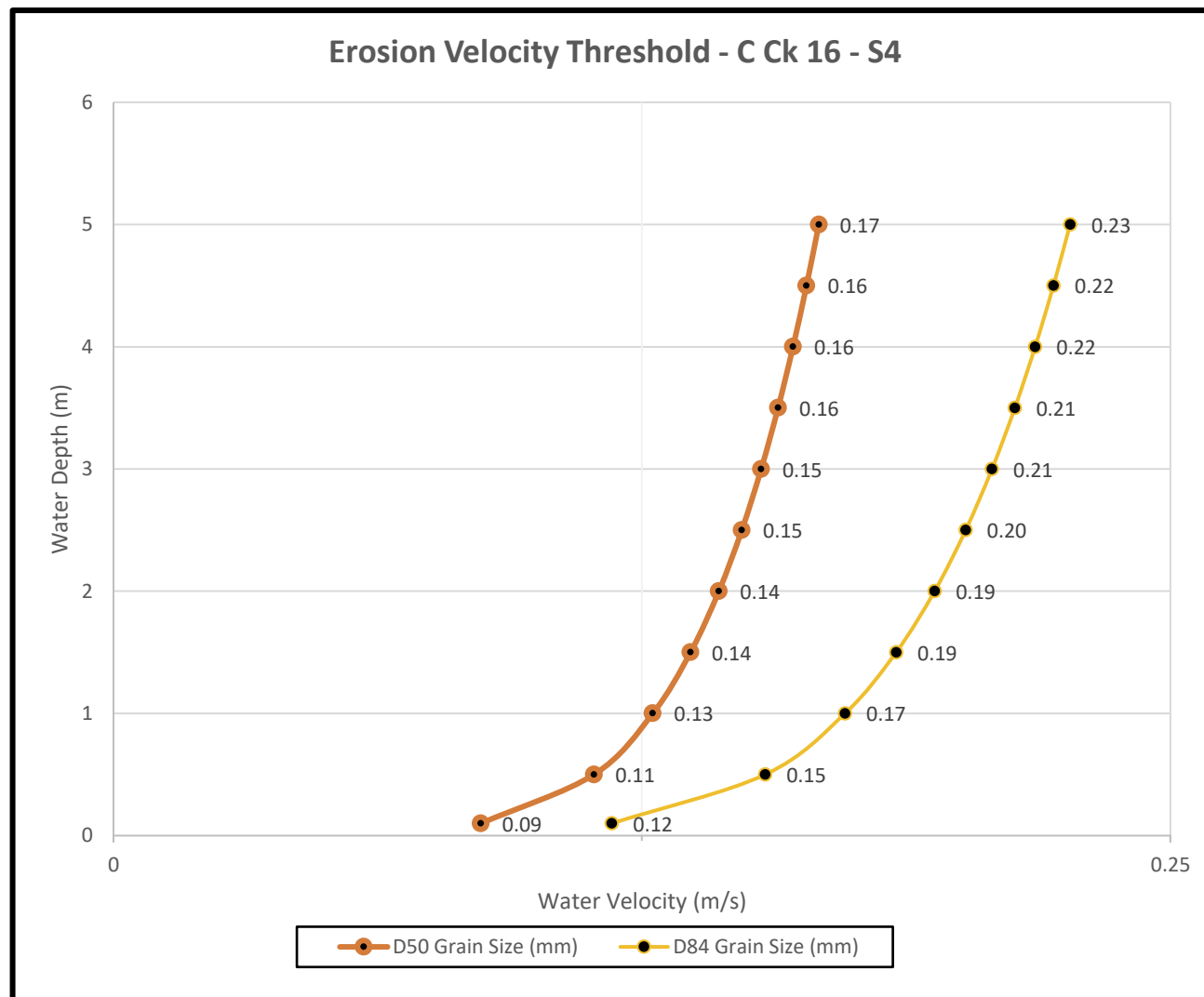
NOTES	
UCS from pocket penetrometer	
Slaking followed by complete dispersion	



Border to Gowrie - EVT calculation from bulk samples

SITE AND SAMPLE INFORMATION	
Site ID	C Ck 16
Chainage (km)	73.68
Sample ID	S4

CALCULATION INPUTS	
Mannings roughness	0.0325
D50 (mm)	0.22
Critical shear stress, D50	0.17
D84 (mm)	0.60
Critical shear stress, D84	0.31

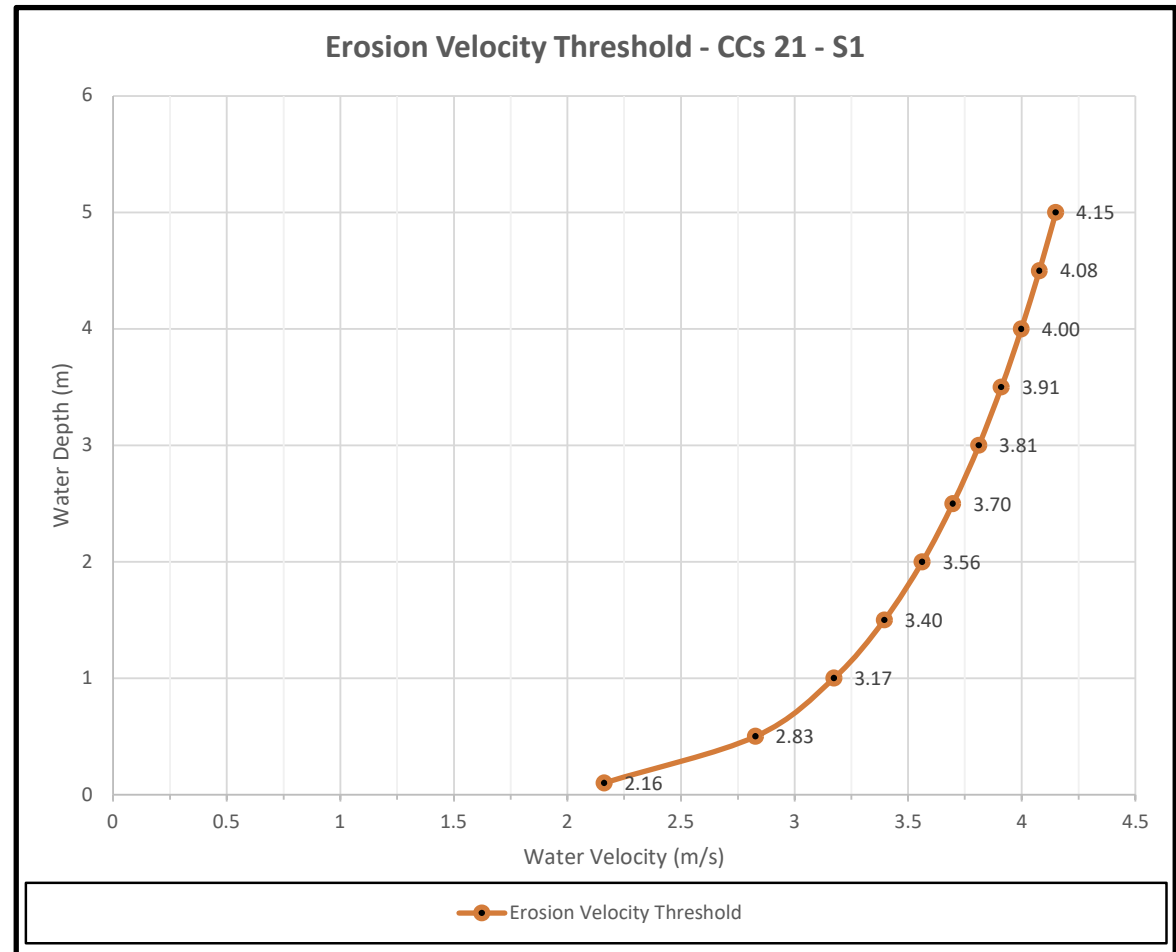


Border to Gowrie - EVT calculation from bulk samples

SITE AND SAMPLE INFORMATION	
Site ID	CCs 21
Chainage (km)	73.53
Sample ID	S1

CALCULATION INPUTS	
Mannings roughness	0.0325
Moisture Content (%)	11.1
Fines Fraction (%)	64
Plasticity Index (%)	26
UCS (Pa)	440000
Emerson Class	2

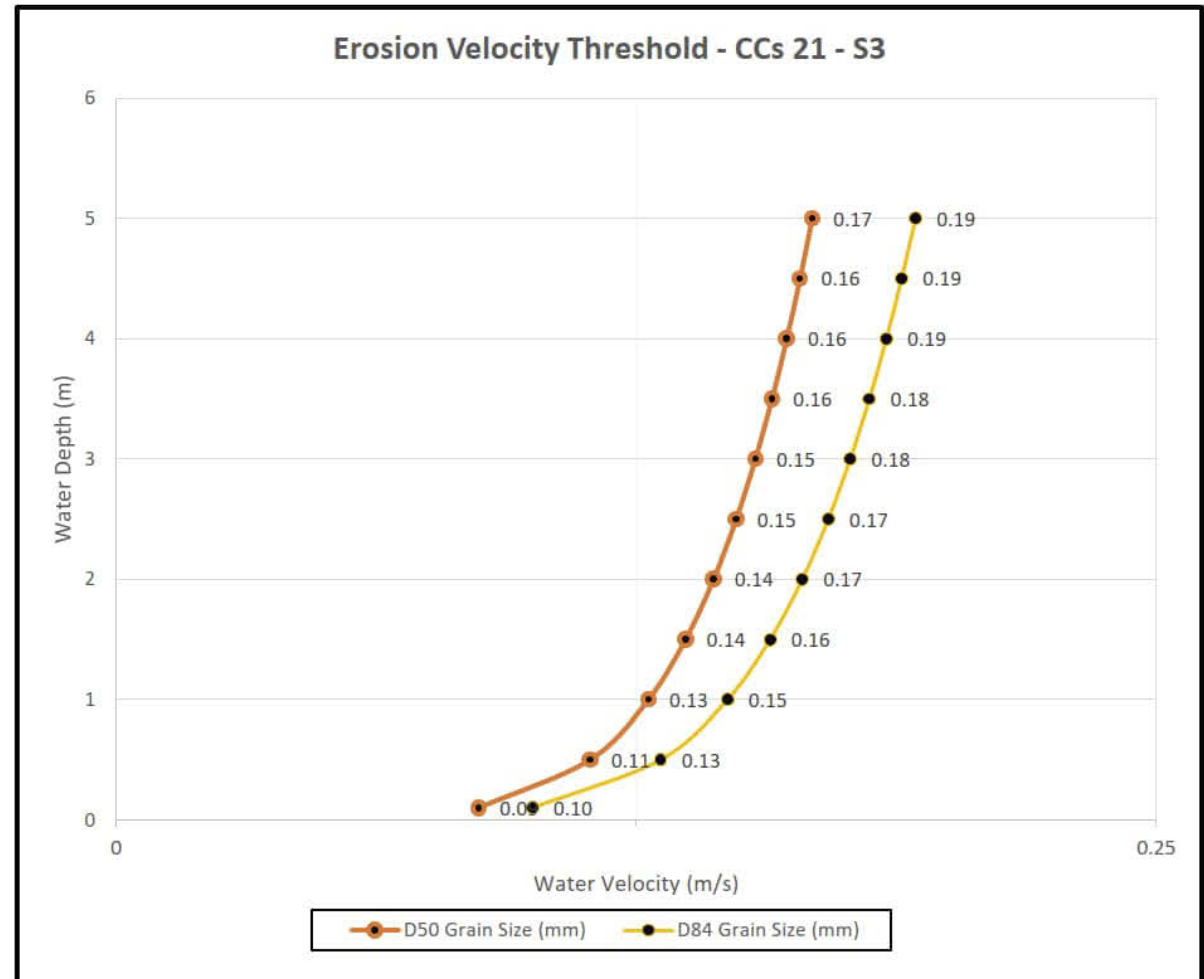
NOTES	
UCS from pocket penetrometer	
Slaking followed by some dispersion	



Border to Gowrie - EVT calculation from bulk samples

SITE AND SAMPLE INFORMATION	
Site ID	CCs 21
Chainage (km)	73.53
Sample ID	S3

CALCULATION INPUTS	
Mannings roughness	0.0325
D50 (mm)	0.22
Critical shear stress	0.17
D84 (mm)	0.40
Critical shear stress, D84	0.22

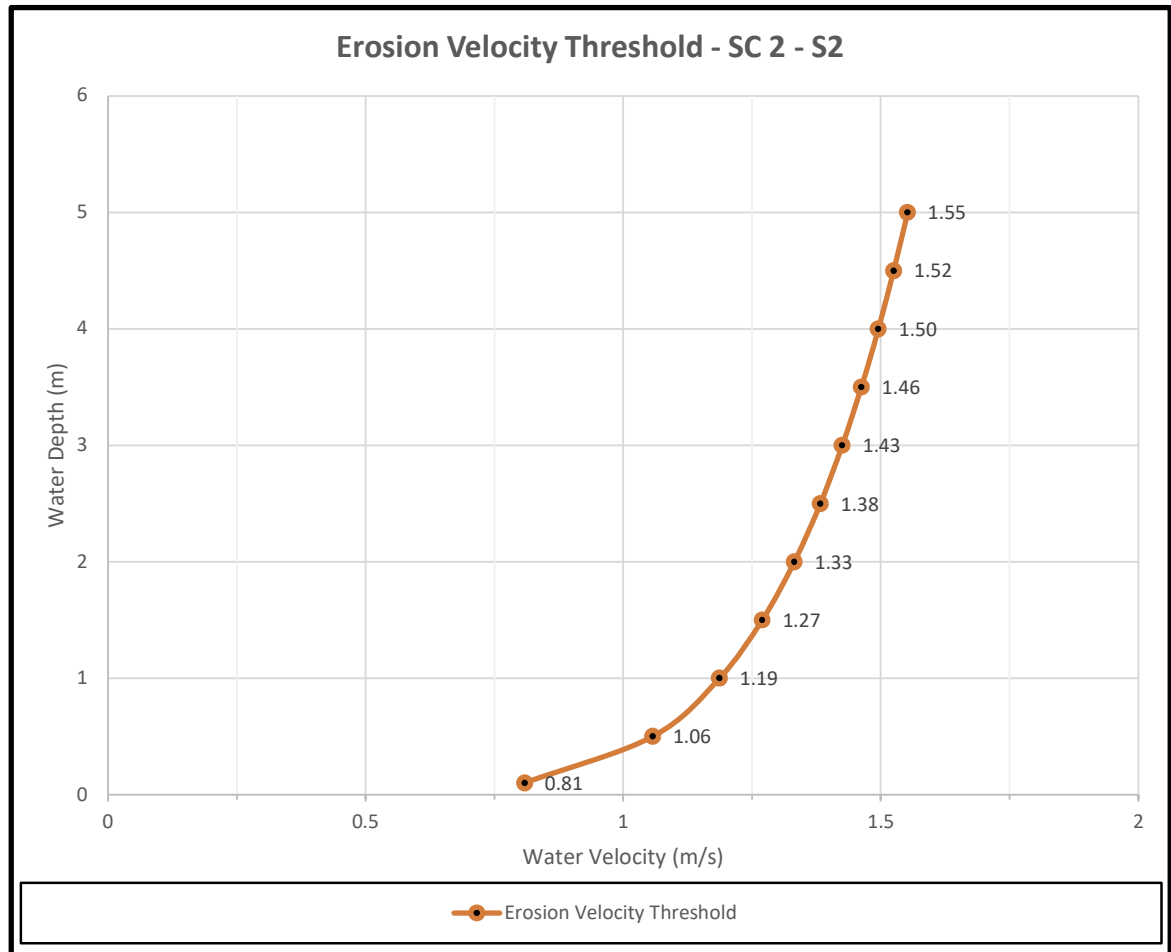


Border to Gowrie - EVT calculation from bulk samples

SITE AND SAMPLE INFORMATION	
Site ID	SC 2
Chainage (km)	126.96
Sample ID	S2

CALCULATION INPUTS	
Mannings roughness	0.0325
Moisture Content (%)	15
Fines Fraction (%)	47
Plasticity Index (%)	17
UCS (Pa)	270000
Emerson Class	3

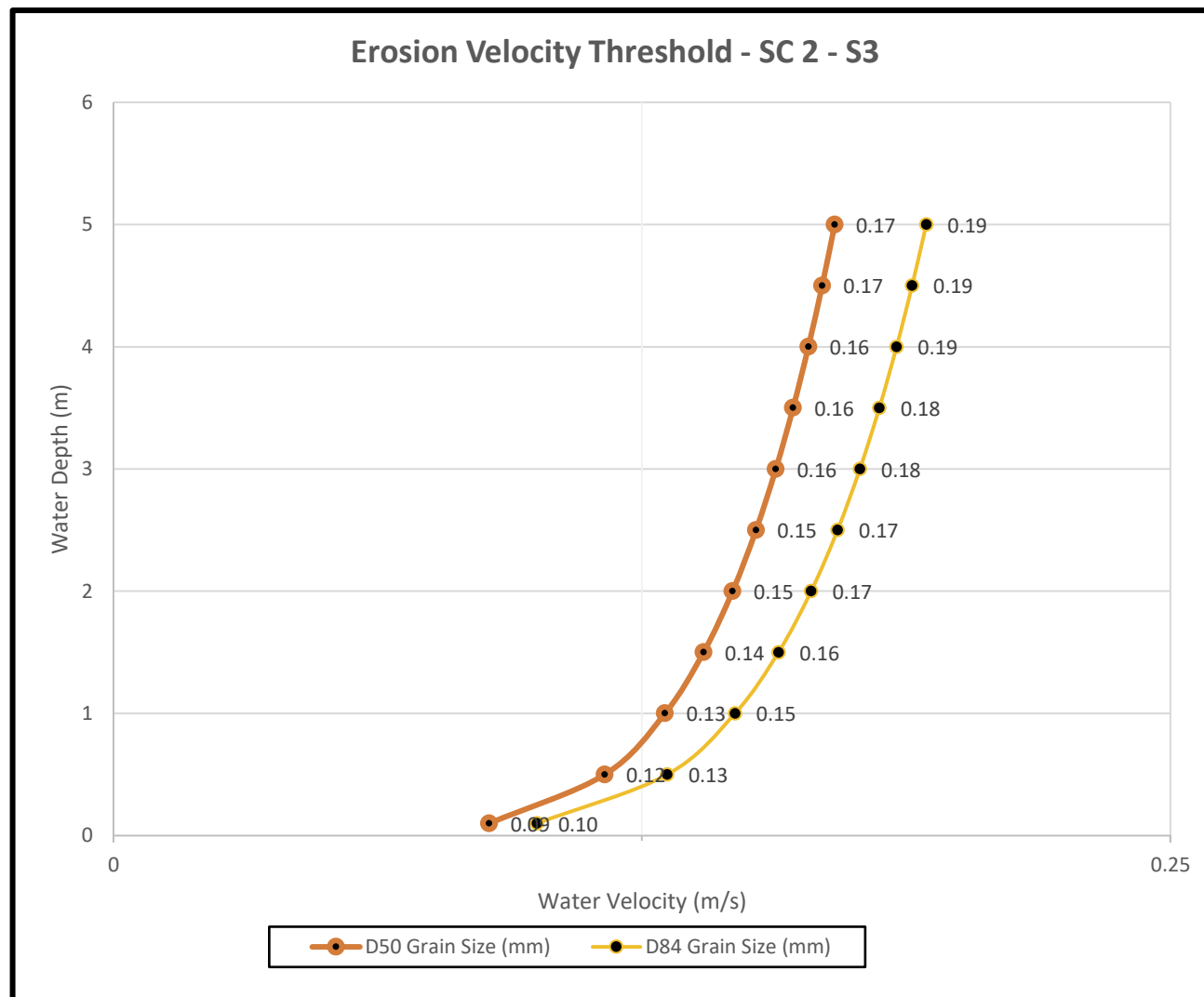
NOTES	
UCS from pocket penetrometer	
Slaking followed by dispersion after remould at field moisture content	



Border to Gowrie - EVT calculation from bulk samples

SITE AND SAMPLE INFORMATION	
Site ID	SC 2
Chainage (km)	126.96
Sample ID	S3

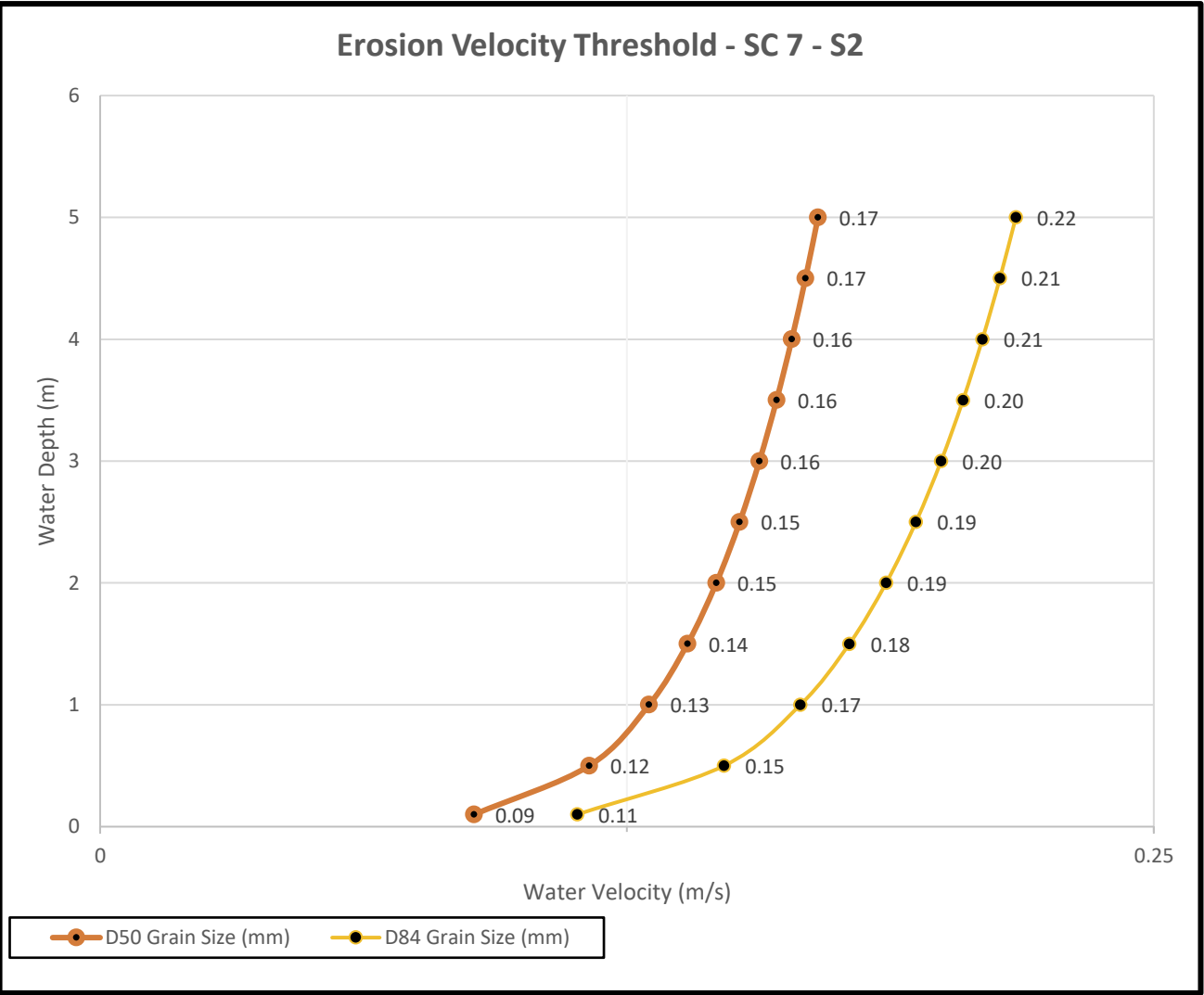
CALCULATION INPUTS	
Mannings roughness	0.0325
D50 (mm)	0.25
Critical shear stress	0.18
D84 (mm)	0.40
Critical shear stress, D84	0.22



Border to Gowrie - EVT calculation from bulk samples

SITE AND SAMPLE INFORMATION	
Site ID	SC 7
Chainage (km)	120.31
Sample ID	S2

CALCULATION INPUTS	
Mannings roughness	0.0325
D50 (mm)	0.25
Critical shear stress	0.18
D84 (mm)	0.55
Critical shear stress, D84	0.29



APPENDIX H

Geomorphology Report

Appendix L Detailed assessments

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

Appendix L Detailed Assessments

Detailed assessments undertaken at initial case potential high-risk sites demonstrate the effectiveness of the methodology in improving the understanding of baseline conditions and providing input into site-specific future Project stage mitigation measures to reduce risk (included in Section 5.2). The initial case risk assessment for Project watercourses and floodplains is included in Sections 6.1 and 6.2.

No floodplains were assessed as having initial case high risk. Of the 13 watercourses identified as having initial case high risk, detailed assessments were undertaken at five sites between 1 August and 4 August 2022. These assessments are documented in the Sections below, with maps in Appendix A (Drawing set E), summary field sheets are in Appendix J, field and laboratory testing data Appendix I, and ETV assessment documented in Appendix K (of the Revised draft EIS Geomorphology technical report). The five sites include:

- NC11, initial case high risk due to erosion and channel type change potential impacts
- SC7, initial case high risk due to the potential impact of deposition.
- C Ck 16, initial case high risk due to the potential impact of deposition.
- C Cs 21, initial case high risk due to the potential impact of deposition.
- SC 2, initial case high risk due to planform and channel type change potential impacts at a modified and complex site.

The other eight initial case high risk sites include:

- Five sites had little change in flow characteristics between Existing Case and Design Case, but the location of the design infrastructure resulted in initial case high risk of planform and channel type change. The five watercourses have either non channelised valley floor or chain of ponds channel types. These channel types do not migrate across the landscape as meandering channels do and none of these sites have shown any change in planform type, location or channel change since earliest image. Other than increased flow velocity at one of the abutments of the proposed Nicol Creek Bridge during the 1% AEP, channel and floodplain flows have very little change in flow characteristics between existing and design, and floodplain impacts are minimal. Due to the very low lateral migration rates and low floodplain impacts, the proposed mitigation is to move bridge abutments > 5 m from the channel edge or align culverts to the channel and flow path. Drawing set F in Appendix A (of Revised draft EIS Geomorphology technical report) delineates the location of the channel at each site, with the 5 m recommended minimum set back. These mitigation measures will be incorporated during the detailed design process. Additional assessment of geomorphic processes at these sites at this stage were considered to add little value to the understanding of the impacts on the geomorphic processes or add value in developing mitigation measures. These sites were not further assessed and include:
 - o Four Mile Gully - Toowoomba Cecil Plains Road Rail Bridge (310-BR20)
 - o Back Creek 2 - Bringalily Creek 1 Rail Bridge (310-BR08)
 - o NC 3 - Biddeston Southbrook Road Rail Bridge (310-BR42)
 - o C Ck 2 - Millmerran Inglewood Road Rail Bridge #2 (310-BR28)
 - o Nicol Creek Nicol Creek Rail Bridge (310-BR11)
- Three smaller gully sites all assessed as high risk due to deposition potential. These sites are located in the same area of gullying as C Ck 16 and C Cs 21, which were assessed, and include:
 - o C Ck 16a
 - o CCs 21a
 - o CCs 22

In addition to the sites listed above, the Coordinator-General has requested detailed assessments be undertaken at four sites within floodplains and overland flow pathways. These assessments will take place prior to the commencement of detailed design.

1 Site NC 11

This site was identified as a high-risk site in the initial risk assessment due to the hydraulic Design Case indicating potential large increase in velocity downstream from the Existing Case potentially resulting in erosion and channel type change.

Watercourse NC 11 is a Strahler Order 1 headwater approximately 2 km west of Pittsworth that eventually flows into Fourteen Mile Creek. It has a non-channelised valley floor channel type with some sections of low sinuosity channels in dermosols soils as well as bedrock constrained channel sections. The flow path at the site location has been modified by the construction of a pond. Design infrastructure for the site is four side-by-side 3 m wide by 2.7 m high reinforced concrete box culverts (culvert site C170.55). Existing assessment data is summarised in Table 1-1.

Table 1-1 Site summary NC 11

Site	NC 11
Chainage (m)	170548
Proposed rail infrastructure	Culvert
Strahler Order	1
Erskine (2017) Channel Classification	Non-channelised valley floor with sections of low sinuosity channel and bedrock constrained channel
Watercourse type	Headwater
Catchment area (ha)	107.8
Catchment slope (rise/run)	0.0609
Catchment vegetation	Grassland/crops
Catchment soil type – ASC Order	Dermosols
Catchment soil erodibility	Very low (1) to moderate (3)
Valley setting	Semi-confined to the east by 3 m elevation change (25 m away). Confined to the west by 2 m elevation change (50 m away).
Tributaries	1.4 km downstream (d/s) converges with NC12
Planform	Sinuuous
Sinuosity	1.111
Channel slope (rise/run)	0.0152
Channel planform at alignment	Bend
Geomorphology notes	Multiple manmade ponds in flow path including a 25 m by 25 m pond 5 m upstream (u/s) of the Project alignment crossing. Existing culvert approximately 150 m u/s
Aerial imagery change	Pond constructed to the right of the channel between 2004 and 2009, slight changes to channel planform near this pond.

1.1 Landforms

The site is located within a valley floor surrounded by gentle hill slopes. The visible channel starts about 1.5 km upstream of the Project alignment and joins with another stream approximately 1.5 km downstream. The Project alignment crosses near the location of a 25 m x 25 m pond adjacent to the main channel. An annotated site plan is shown in the Revised draft EIS Geomorphology technical report on drawing E.3 in Appendix A and site inspection photos are presented in the site summary sheets in Appendix J.

The main channel is a narrow, shallow channel on the valley floor with some sections that are well defined. Cross sections presented in Appendix J illustrate the geometry of the channel.

Upstream of the Project alignment crossing the main channel is relatively straight and not well defined, the base of the channel is approximately 1 m to 2.5 m wide, widening locally at the pond inlet to about 4 m, with indistinct banks, at most 0.2 m to 0.3 m high. At the alignment crossing and directly downstream the channel bends and becomes more distinct and from here downstream is approximately 1.5 m to 2 m wide with shallow banks about 0.3 to 0.5 m high. Thirty-five metres downstream of the Project alignment the channel bed drops steeply by 1 m (site E2 on Drawing 3 Drawing Set E in Appendix A of the Revised draft EIS Geomorphology Technical Report).

The floodplain is a relatively flat pastured area that is contained by gentle hill slopes. Flattened vegetation downstream of the pond indicates recent out of channel flow across the floodplain on the true right of the main channel. The pond to the east of the main channel is within the floodplain.

1.2 Bed/bank material and vegetation

The channel bed and bank material are variable. The bed and bank material includes weathered rock, gravel/cobbles, silty clay or grass. Where there is a distinct channel, the channel has been defined by the bed material (rock, soil/grassed and gravel) and is illustrated on Figure 3 in Drawing set E, Appendix A of Revised draft EIS Geomorphology technical report. The section of channel upstream of the Project alignment crossing is in rock with grassed banks, downstream it comprises grass or silt clay with some gravel.

Descriptions of the sampled bank material and the rock are as follows:

- Sample 1 (CH170.55-S1): silty CLAY, high plasticity, reddish brown, dry to moist, firm
- BASALT, dark grey, weathered on surface (orange brown), massive to jointed, vesicular, very low to low strength, highly weathered with onion skin weathering. Subvertical joints downstream, typically spaced 50 to 80 mm, generally open 2 mm to 5 mm, clay infill, undulating, rough. Joints oriented perpendicular/oblique to flow direction.

The floodplain is grassed pasture with sparse established trees.

1.3 Geomorphic processes

Four areas of erosion were observed (E1 to E4), including along bank erosion and scour holes of minor to moderate consequence category (Appendix A of Revised draft EIS Geomorphology technical report, Drawing Set E 3 for site locations). They all occurred downstream of the Project alignment in soil. One site (E4) may have been human-made or altered. Along bank erosion areas were located as expected on the outside of channel bends, with along bank eroding length of about 2 m. Flattened vegetation adjacent to the main channel indicates recent out of channel flow. No erosion of the rock-lined channel banks or bed was observed. Figure 1 provides site photo examples.

No significant areas of deposition within the channel were observed, indicating a small existing bedload. No areas of slumping and cracking of the banks were observed.

Following the terminology of the Queensland Bridge Scour Manual (*Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour 2018*) the type of scour at this site is classed as *long-term aggradation/degradation and short-term bend scour*.



Figure 1 NC 11 site photos. Left, Photos P9 – rock channel near design culvert. Right, Photo P10 – minor erosion (erosion site E2) in the silty clay channel bed, 1 m drop in bed level directly upstream of this erosion. See Appendix A drawing E3 for photos locations and descriptions.

Figure note: See Appendix A drawing E3 for photos locations and descriptions.

1.4 Existing human induced change at the site

The Gore Highway crosses the watercourse approximately 150 m upstream of the Project alignment crossing, with four side by side > 1 m diameter concrete culverts installed beneath the road.

A pond has been constructed between 2004 and 2009 adjacent to the flow path of this waterway, slightly to the right of the main channel and within the Project footprint.

1.5 Hydraulic characteristics

The existing and Design Case hydraulic characteristics at the site are presented in Table 1-2. In the Design Case during a 1% AEP and 20% AEP event there is a large reduction in velocity and stream power upstream of the proposed design culvert location and a large increase downstream.

Table 1-2 Site NC11 hydraulic characteristics

	1% AEP		20% AEP	
	Existing Case	Design Case	Existing Case	Design Case
Maximum velocity (m/s)	u/s 2.3 d/s 2.3	u/s 2.3 d/s 3.2	u/s 1.8 d/s 1.8	u/s 2.0 d/s 2.6
Maximum SP (W/m ²)	u/s 461 d/s 435	u/s 52.5 d/s 699	u/s 216 d/s 197	u/s 55 d/s 340
Depth of flow (m)	u/s 1.6 d/s 0.8	u/s 1.5 d/s 1.1	u/s 1.0 d/s 0.6	u/s 1.0 d/s 0.7

1.6 Erosion threshold velocities and site erosive potential

The theoretical ETVs and combined geomorphic ETV are included in Table 1-3.

A theoretical ETV was calculated for one sample, CH170.55-S1, a silty clay material. Note that the theoretical ETVs have been calculated for the water depth where the maximum flow velocity occurs (either upstream or downstream of the culvert). Where there is a change between existing and Design Case in the calculated ETV, this comes from a change in water depth.

Applicable geomorphic site observations and considerations:

- The sample was taken from an area of bare soil with visible Existing Case minor to moderate erosion and represents the most erodible soil observed at the site
- It is considered reasonable that the erosion observed at the site was from a relatively frequent event such as the 20% AEP with maximum flow velocities on the order of those modelled for Existing Case conditions of 1.8 m/s
- Erosion is localised
- No correlation between Field work erosion and modelled flow velocity was observed, (e.g. there is no clear difference in velocity between areas of erosion and areas of stable channel)
- Vegetation cover in the channel provides protection against the erosion
- As the erosion is localised and not extensive within the channel, the ETV of the soil is likely to be similar to but slightly lower than the Existing Case 20% AEP maximum velocity of approximately 1.8 m/s.

Based on the considerations above, a combined geomorphic ETV for the silty clay, without vegetation cover, of 1.6 m/s has been assessed. Maximum Design Case velocities are 2.6 m/s in the 20% AEP event, 1 m/s above the combined geomorphic ETV, indicating that major erosion may occur without additional mitigation measures.

Table 1-3 Site NC11 erosion threshold velocity (m/s)

Sample ID	Theoretical ETVs based on bulk sample laboratory testing				Combined geomorphic ETV
	1% AEP		20% AEP		
	Existing Case	Design Case	Existing Case	Design Case	
CH170.55-S1 Silty CLAY	1.7	1.6	1.6	1.5	1.6 (bare soil)

1.7 Potential impacts of the Project

This section summaries the potential alterations to geomorphic processes from the Project assuming the design considerations in the revised reference design have been implemented, as well as the proposed mitigation measures for future stages.

The design results in an increase in velocity from 1.8 m/s to 2.6 m/s for the 20% AEP event and 2.3 m/s to 3.2 m/s for the 1% AEP event directly downstream. These increased velocities extend for ~40 m downstream of the culvert. This could result in up to major erosion in this area where the channel is in silty clay, particularly where bare soil is exposed. Erosion is unlikely in rock lined sections of channel.

The size of the design culvert is four side by side 3 m wide by 2.7 m high reinforced box culverts with the main channel approximately 1.5 m to 2 m wide at this location. The flow capacity of the design infrastructure is comparable to the culvert approximately 150 m upstream of the site beneath Gore Highway. However, the channel bed material is different directly downstream of the culverts under the Gore Highway, where the bed has natural gravel/cobble armouring.

2 Site SC 7

This site was identified as a high-risk site in the initial risk assessment due to the hydraulic Design Case indicating potential large reduction in flow velocity upstream and downstream from the Existing Case potentially causing deposition.

Site SC 7 is a tributary of Back Creek, approximately 10 km northwest of Millmerran. The existing watercourse has been heavily modified by an in-channel pond constructed ~200 m upstream of the Project alignment crossing that has essentially dammed the watercourse. The watercourse is Strahler Order 3, within a non-channelised valley floor in vertosol soils. Design infrastructure for the site comprises three side by side 2.4 m wide by 1.8 m high reinforced concrete box culverts (culvert site C120.33). Existing assessment data is summarised in Table 2-1.

Table 2-1 Site summary SC 7

Site	SC 7
Chainage (m)	120310
Proposed rail infrastructure	Culvert
Strahler Order	3
Erskine (2017) Channel Classification	Low sinuosity channel
Watercourse type	Local – poorly developed channel
Catchment area (ha)	719.8
Catchment slope (rise/run)	0.0356
Catchment vegetation	Grassland with bush
Catchment soil type – ASC Order	Vertosol
Catchment soil erodibility	Low (2) to moderate (3)
Valley setting	Unconfined – semi confined approximately 1500 m downstream due to existing road
Tributaries	1249 m u/s
Planform	sinuous
Sinuosity	1.198
Channel slope (rise/run)	0.0120
Channel planform at the Project alignment	straight
Geomorphology notes	Manmade ponds 150 m u/s (70 m by 70 m), 1120 m u/s (50 m by 25 m), 1373 m u/s (100 m by 50 m)
Aerial imagery change	The human made pond directly upstream of the site has cut off the natural watercourse. Scour downstream of the pond has occurred over at least the last 10 years, most notably during the 2011 floods. The pond was enlarged between 2013-2015

2.1 Landforms

The site is located on a pastured plain. The watercourse extends approximately 2.8 km downstream into Back Creek. Figure E6 in Appendix A of the Revised draft EIS Geomorphology report is an annotated site map and ground photos are presented in the site summary sheets in Appendix J of Revised draft EIS Geomorphology technical report. Flows overtopping the in-channel pond upstream exit to the south of the natural watercourse, and a new overland flow pathway has developed in this area.

The main channel is generally well-defined, sinuous, and grassed with small in channel ponds. Cross sections presented in Appendix J illustrate the geometry of the channel.

Upstream from the Project alignment crossing the watercourse has a 1.5 m to 2.5 m wide channel with subvertical grassed banks between 0.5 m to 1.5 m high, with no base flow. Downstream from the alignment the watercourse broadens up to 8 m wide in area of ponding water 30 m downstream of the alignment, with the banks becoming less defined at a shallow angle ranging from 0.5 m to 0.8 m high. The channel becomes indistinct 150 m downstream of the alignment crossing.

The floodplain is a relatively flat pastured area that has contoured levees to control overland flows.

2.2 Bed/bank material and vegetation

Almost all of the channel bed and bank is vegetated. The bed is vegetated with grass/weeds and sparse shrubs. Bed material, where exposed is silty clay with organics. This material, Sample 1, extended from the ground surface to depths greater than 0.7 m in the base of the channel. Excavations into the vegetated bank exposed the same silty clay material to below bed level at both sites investigated. At one site sand (Sample 2) was intersected at 0.6 m below the top of the bank, approximately 0.2 m below bed level. As it was not intersected or exposed elsewhere, the sand is inferred as not laterally continuous. The banks are vegetated with long grass, sparse shrubs, and established trees. Woody debris is sparsely scattered throughout the channel.

Descriptions of sampled bank material are as follows:

- Sample 1 (CH120.31-S1): sandy silty CLAY, low plasticity, dark brown, moist, firm, rootlets (organic)
- Sample 2 (CH120.31-S2): silty SAND, non-plastic, light brown, moist, uniformly graded.

The floodplain is grassed pasture with established trees.

2.3 Geomorphic processes

No major erosion or deposition or was observed within the main channel or along its banks, including slumping and cracking of the banks. The channel generally appears stable with no current base flow and minimal existing bedload as it is effectively cut off from the upstream watercourse due to the pond capturing the main flow and any sediment transported from upstream. Any potential mobile sediment comprises small areas of a veneer of clay/silt on in-channel pools. This surficial material is unlikely to be bedload, but the settling of suspended sediment load in ponds after a flow or rainfall event.

Aerial imagery dating from 2011 shows ~180 m of scour downstream of the pond 120 m to the southwest of the main natural channel SC 7. The scour has since been recontoured and was not observed during the site visit. This area is within the flow path that is directed into a separate cross drainage feature south of the site. Minor bank erosion in black soils, up to 0.4 m height was observed in this area as detailed in Figure 2.

Following the terminology of the Queensland Bridge Scour Manual (*Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour 2018*) the type of scour at this site is classed as *long-term degradation*.



Figure 2 SC 7 site photos. Left, Photos P2 – looking upstream towards proposed culvert location. Right, Photo P9 – minor erosion on true right bank downstream of pond.

Figure note: See Appendix A drawing E6 for photos locations and descriptions.

2.4 Existing human induced change at the site

A pond 150 m upstream of the Project alignment crossing has cut off the watercourse, with the pond now capturing the main flow.

Flood levees along Blackwell Road adjacent to the site and within the surrounding paddocks direct and channelise flow across the floodplain.

2.5 Hydraulic characteristics

The Existing and Design Case hydraulic characteristics at the site are presented in Table 2-2.

In the Design Case during a 1% AEP and 20% AEP event there is a large reduction in velocity and stream power upstream and downstream of the proposed culvert location.

Development of the pond upstream of the watercourse has effectively cut it off. The hydraulic characteristics shown are likely to be imprecise due to the presence of the pond upstream, however, the modelled hydraulics are not inconsistent with the observed site geomorphology and are considered a useful assessment guide.

Table 2-2 Site SC7 hydraulic characteristics

	1% AEP		20% AEP	
	Existing Case	Design Case	Existing Case	Design Case
Maximum velocity (m/s)	u/s 1.5 d/s 2.1	u/s 0.4 d/s 0.4	u/s 1.3 d/s 1.7	u/s 0.2 d/s 0.4
Maximum SP* (W/m ²)	u/s 59 d/s 155	u/s 1.1 d/s 1.3	u/s 33 d/s 111	u/s 0.2 d/s 0.7
Depth of flow (m)	u/s 1.3 d/s 1.1	u/s 1.6 d/s 0.9	u/s 1.0 d/s 0.8	u/s 0.8 d/s 0.7

Table note:

* Design stream power values appear unrealistically low and may be a function of the model.

2.6 Erosion threshold velocities and site erosive potential

The design flow velocities result in a reduction in flow velocity for this site and erosion due to the Project is not considered a risk during operation.

The theoretical ETVs and combined geomorphic ETV are included in (Table 2-3).

A theoretical ETV was calculated for sample CH120.31-S1 (sandy silty CLAY), which was well vegetated. Note that the theoretical ETVs have been calculated for the water depth where the maximum flow velocity occurs (either upstream or downstream of the culvert). Where there is a change between existing and Design Case in the calculated ETV, this comes from a change in water depth.

Applicable geomorphic site observations and considerations:

- It is considered reasonable that the observed condition of the channel during the site visit reflect the geomorphic processes from a relatively frequent event such as the 20% AEP, with maximum flow velocities on the order of those modelled for Existing Case conditions of 1.7 m/s
- Almost all the channel is well vegetated
- No scour/erosion or deposition was observed at the site, indicating that it can accommodate Existing Case velocities in its current vegetated state
- At least one near surface (between 0.6 m and 0.2 m below ground surface) pocket of sand exist at this site. Such pockets, if exposed, may be an erosion risk during construction until they are vegetated.

Based on the considerations above, a combined geomorphic ETV for the sandy silty clay with grass vegetation cover of >1.7 m/s has been assessed. This is well above the maximum design flow velocities.

Table 2-3 Site SC7 erosion threshold velocity (m/s)

Sample ID	Theoretical ETVs based on bulk sample laboratory testing				Combined geomorphic ETV
	1% AEP		20% AEP		
	Existing Case	Design Case	Existing Case	Design Case	
CH120.31-S1 sandy silty CLAY	1.2	1.3	1.2	1.1	>1.7 (vegetated)

2.7 Potential impacts of the Project

This section summaries the potential alterations to geomorphic processes from the Project assuming the design considerations in the revised reference design have been implemented, as well as the proposed mitigation measures for future stages.

The site was identified as initial case high-risk as the reduction in Design Case velocity could result in reduced transport of bedload leading to aggregation. Detailed site investigations were undertaken to determine if the design flow velocities would be sufficient to transport any bedload material. The detailed site investigations identified the following:

- The mobile sediment at SC7 is minimal, at most a veneer of silt/clay on in-channel ponds
- A human made pond has been constructed across the channel approximately 150 m upstream, which would trap sediment transported from upstream, reducing the amount of sediment transported through SC7.

Minimum flow velocities required to transport silt and clay already entrained within a flow are very low, <0.1 m/s, lower than the design flow velocities for the 20% AEP event of 0.2 to 0.4 m/s.

From this more detailed assessment it can be confirmed that this site is in fact an initial case low-risk site for aggregation due to the following reasons:

- There is minimal evidence for sediment transport at the site
- Design flow velocities are sufficient to transport any potential bedload material observed at the site.

3 Site C Ck 16

This site was identified as a high-risk site in the initial risk assessment due to the hydraulic Design Case indicating a large reduction in flow velocity upstream potentially causing deposition. Design flow velocities downstream are within 10 per cent of the Existing Case and are considered within model error with a not significant consequence classification.

Site C Ck 16 is a tributary of Canning Creek, approximately 9 km northeast of Inglewood. It is a site of active gully erosion and occurs in highly erodible sodosol soils. C Ck 16 is a Strahler Order 2 local – poorly developed channel with a non-channelised valley floor channel type. Design infrastructure for the site is three side by side 3 m wide by 1.8 m high reinforced concrete box culverts (culvert site C73.68). Existing assessment data is summarised in Table 3-1.

Table 3-1 Site summary C Ck 16

Site	C Ck 16
Chainage (m)	73682
Proposed rail infrastructure	Culvert
Strahler Order	2
Erskine (2017) Channel Classification	Gully
Watercourse Type	Local – poorly developed channel, with multi-channel threads within the valley floor downstream of the site
Catchment area (ha)	166.1

Site	C Ck 16
Catchment slope (rise/run)	0.0095
Catchment vegetation	Grassland/ crops
Catchment Soil Type – ASC Order	Sodosols
Catchment Soil Erodibility	High (4) to very high (5)
Valley setting	Unconfined
Tributaries	270 m u/s true left CCs 20, 260 m u/s true right, 154 m u/s true left, 45 m d/s true right, 225 m d/s CCs 21, 530 m d/s joins Canning creek
Planform	Sinuuous
Sinuosity	1.233
Channel slope (rise/run)	0.0091
Channel planform at the Project alignment	Bend
Geomorphology notes	Active gully erosion
Aerial imagery change	Channel narrower and shorter in 1959 aerial imagery; vegetation has been cleared.

3.1 Landforms

The site is in a gully landform complex which extends 2 km upstream and approximately 500 m downstream. The part of the gully landform complex associated with site C Ck 16 covers approximately 3.5 ha. It is incised 1 m to 2 m below the valley side slopes and has a base width of 25 m to 40 m. There are several tributary gullies that branch off the main gully. Within the Revised draft EIS Geomorphology technical report, an annotated site maps is in Appendix A (Figure E3) and ground photos are presented in the site summary sheets in Appendix J.

The main channel is a relatively straight, broad vegetated valley directly upstream and downstream of the Project alignment crossing, with two tight bends approximately 150 m downstream. Cross sections presented in Appendix J illustrate the geometry of the channel. The base of the main channel is approximately 25 m wide at the location of the alignment crossing with gently sloping grassed banks but widens up to 40 m further upstream. Several side gullies, up to 10 m wide, feed into the main channel as illustrated on Figure 9 in Drawing set E, Appendix A.

The upper extent of the gully was dry during the site inspection. However, several ponds were observed downstream of the Project alignment crossing and are illustrated in Drawing E9, Appendix A.

No floodplain landform is present at the site.

3.2 Bed/bank material and vegetation

Most of the channel bed and bank is vegetated with some areas of bare gully erosion. The bed is vegetated with grass/weeds and some sparse shrubs and established trees. Bed material where exposed around pond edges is sand and silt. The banks are grassed with sparse trees. Woody debris, typically large individual tree trunks up to 10 m in length, and 0.5 m diameter, are sparsely scattered within the channel. There is dense scrub cover in the catchment upstream.

The bank material where exposed was dry and very difficult to hand dig, interpreted as an incipient duricrust that has been weathered and then locally deposited as fine to coarse gravel on the gully slopes and base. Where the bank material could be excavated the material is variable, a combination of silty sand and gravelly sand (0.2 m to > 0.5 m deep) overlying sandy silty clay.

Descriptions of sampled bank material are as follows:

- Sample 1 and 2 (CH73.68-1 and CH73.68-2) – gravelly fine to coarse SAND with clay/silt, orangish brown, moist, poorly graded, gravel, fine to medium, subangular to subrounded

- Sample 3 (CH73.68-3) – sandy silty CLAY, low plasticity, light greyish brown mottled orange, moist, hard, shear vane and pocket penetrometer unable to penetrate
- Sample 4 (CH73.68-4) – silty SAND, orangish brown, moist, uniformly graded.

3.3 Geomorphic processes

The main geomorphic process at this site is gully erosion. Most of the gully is grassed however there are approximately 10 areas of bare ground on the banks and side gullies. These are typically < 150 m² in area and showed evidence for rainsplash and sheetwash erosion. These areas are illustrated and described within Revised draft EIS Geomorphology technical report, on Figure 9 in Drawing set E, Appendix A with photos in Appendix J. Two photos from Appendix J are included in Figure 3.

The largest side gully erosion site on the true left near the downstream bend has deposited sand within the vegetated channel. At the time of the site inspection this sand had not been transported into the ponding water within the channel. Other than slopewash from the surficial erosion, no further sediment deposition was observed within the channel. No major slumping or cracking of the banks was observed.

Aerial imagery dating from 1959 shows the gully was shorter and narrower than the contemporary gully. The extent of post-1959 gully development is annotated in Appendix A of the Revised draft EIS Geomorphology technical report.

Following the terminology of the Queensland Bridge Scour Manual (*Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour 2018*) the type of scour at this site is classed as *long-term degradation*.



Figure 3 C Ck 16 site photos. Left, Photos P3 – looking downstream towards proposed culvert location. Right, Photo P9 – gulley erosion on side gully downstream of Project alignment, just outside the earthworks area.

Figure note: See Appendix A drawing E9 for photos locations and descriptions.

3.4 Existing human induced change at the site

Millmerran Inglewood Road crosses near the head of the gully, with a culvert installed beneath the road. This site was inspected during the site inspection with observations summarised in Appendix F of the Revised draft EIS Geomorphology technical report.

Based on aerial imagery vegetation change is evident in the upper section of the gully. Most of the larger established vegetation has been removed since 1959 resulting in the slope being more susceptible to erosion. Other areas with bare soils (not from natural geomorphic processes) that are susceptible to erosion

include vehicle tracks along the fence line to the north of the site and stock tracks within the surrounding area.

3.5 Hydraulic characteristics

The existing and Design Case hydraulic characteristics at the site are presented in Table 3-2. In the Design Case 1% AEP and 20% AEP event there is a large reduction in velocity and stream power upstream of the proposed culvert location.

Table 3-2 Site C Ck 16 hydraulic characteristics

	1% AEP		20% AEP	
	Existing Case	Design Case	Existing Case	Design Case
Maximum velocity (m/s)	u/s 1.8 d/s 1.7	u/s 1.0 d/s 1.9	u/s 1.6 d/s 1.4	u/s 0.7 d/s 1.5
Maximum SP (W/m ²)	u/s 114 d/s 103	u/s 8.9 d/s 106	u/s 108 d/s 61	u/s 4.2 d/s 67
Depth of flow (m)	u/s 0.8 d/s 0.7	u/s 1.0 d/s 0.8	u/s 0.5 d/s 0.6	u/s 0.5 d/s 0.6

3.6 Erosion threshold velocities and site erosive potential

The site was assessed as high-risk due to the reduction in flow velocity upstream. While a small increase in design flow velocities occur downstream, this is considered low risk low as the increases is within 10 per cent and therefore within the natural variability and model error. However, this site is a gully erosion site and erodible sands exist in the gully side slopes, these represent an erosion risk when the ground surface is not vegetated.

The theoretical ETVs and combined geomorphic ETV are included in Table 3-3.

Theoretical ETVs were calculated for three samples, CH73.68-1 and 2 (gravelly SAND), 3 (sandy silty CLAY) and 4 (silty SAND). The strength estimates for this unit are conservative, as the soil was too hard to be measured in the field (instrument refused), meaning that the theoretical ETVs are also conservative.

Note that the theoretical ETVs have been calculated for the water depth where the maximum flow velocity occurs (either upstream or downstream of the culvert). Where there is a change between existing and Design Case in the calculated ETV, this comes from a change in water depth.

The theoretical ETVs for the sand sample 4 are very low and unlikely to be accurate to the extent shown, however the ETVs are very low for this material. While sand particles may be transported if already in suspension at velocities < 0.1 m/s, initiation of erosion is considered unlikely until flow velocities of >0.3 m/s.

Applicable geomorphic site observations and considerations:

- It is considered reasonable that the observed condition of the channel during the site visit reflects the geomorphic processes from a relatively frequent event such as the 20% AEP, with maximum flow velocities on the order of those modelled for Existing Case conditions of 1.6 m/s
- Major erosion and gully development was observed in bare sand at the site, including where sample CH73.68-1/2 and 4 were taken from, indicating that the ETVs of this soil are well below the 20% AEP Existing Case max velocities
- Sandy silty CLAY, sample CH73.68-3, was taken from below the sand. This material was intermittently exposed in active gullies
- When vegetated, these soils may accommodate design flow velocities for the 20% AEP event without erosion
- Woody debris was present in the gully floor
- There are several different materials at this site, including sand, clay and an intermittent duricrust (an erosion resistant layer)

- The intermittent presence of the duricrust at the site protects the underlying material from erosion and it is inferred that erosion in the sand banks may preferentially occur where this layer is not present
- No erosion was occurring in the silty CLAY, which was noted as difficult to dig.

Based on the considerations above, a combined geomorphic ETV for the silty clay of greater than 2.7 m/s was assessed. This is well above the design flow velocities, although it is noted that this soil is dispersive which may reduce the ETV. A combined geomorphic ETV for the bare silty sand of ~ 0.3 m/s and bare gravelly fine sand of 0.3 to 0.4 m/s were assessed. The combined geomorphic ETVs for the sand samples are well below both the Existing Case and design flow velocities for the 20% AEP event, indicating that major erosion is likely to continue to occur if this soil is not vegetated or other mitigation undertaken.

Table 3-3 Site C Ck 16 erosion threshold velocity (m/s)

Sample ID	Theoretical ETVs based on bulk sample laboratory testing				Combined geomorphic ETV
	1% AEP		20% AEP		
	Existing Case	Design Case	Existing Case	Design Case	
CH73.68-1/2 (2 bags) gravelly fine to coarse SAND with clay/silt	0.26	0.26	0.24	0.25	0.3 to 0.4 (bare soil)
CH73.68-3 sandy silty CLAY	2.8	2.8	2.6	2.7	>2.7 (vegetated)
CH73.68-4 silty SAND	0.12	0.12	0.11	0.12	0.3 (bare soil)

3.7 Potential impacts of the Project

This section summarises the potential alterations to geomorphic processes from the Project assuming the design considerations in the revised reference design have been implemented, as well as the proposed mitigation measures for future stages.

The reduction in velocity from 1.6 m/s to 0.7 m/s and 1.8 m/s to 1.0 m/s for the 20% AEP and 1% design AEP events case would likely result in medium to coarse grained gravel not being transported. However, as particles of this grain size only make up a small proportion of the sediment load the impacts of the Project on the fluvial system are considered low and readily mitigated in routine maintenance.

Channel constriction may also lead to accumulation/blockage of the culvert from woody debris upstream that is too large to pass through the culvert. Routine maintenance would prevent this from having potential alterations to the geomorphic processes. The installation of screens/racks at the culvert inlet would aid collection and removal of woody debris, as the woody debris would be less likely to get jammed within the culvert.

Gully erosion will continue to develop at this site, and the Project presents an opportunity to undertake mitigations works in this area to reduce this erosion. Additional proposed mitigation measures to minimise gully development are included in Section 5 of the Revised draft EIS Geomorphology report.

4 Site CCs 21

Site CCs 21 was identified as a high-risk site in the initial risk assessment due to the hydraulic Design Case indicating a large reduction in flow velocity upstream potentially resulting in deposition. Design flow velocities downstream are either the same or slightly less than Existing Case conditions. Therefore, potential Project impacts downstream of the culvert are considered low risk.

Site CCs 21 is adjacent to site C Ck 16 on a small tributary of Canning Creek, approximately 9 km northeast of Inglewood. It is a site of active gully erosion and occurs in highly erodible sodosol soils. CCs 21 is a Strahler Order 1 headwater within a gully. Design infrastructure for the site is one 1.35 m diameter reinforced concrete pipe (culvert site C73.53). Existing assessment data is summarised in Table 4-1.

Table 4-1 Site summary CCs 21

Site	CCs 21
Chainage (m)	73529
Proposed rail infrastructure	Culvert
Strahler Order	1
Erskine (2017) Channel Classification	Gully
Watercourse type	Headwater
Catchment area (ha)	<10
Catchment slope (rise/run)	-
Catchment vegetation	Grassland/ crops
Catchment soil type – ASC Order	Sodosols
Catchment soil erodibility	High (4) to very high (5)
Valley setting	Unconfined - multi channel threads occur also within the valley floor downstream
Tributaries	115 m d/s converges with C Ck 16
Planform	Straight
Sinuosity	1.021
Channel slope (rise/run)	0.0264
Channel planform at the Project alignment	Straight
Geomorphology notes	Active gully erosion
Aerial imagery change	Channel narrower and shorter in 1959 aerial imagery; vegetation has been cleared. Difficult to quantify due to low resolution of the imagery.

4.1 Landforms

The site is in the same gully landform complex as site C Ck 16. The gully CCs 21 is in extends 380 m upstream and 140 m downstream and covers < 1 ha. It is incised 1 m to 2 m below the valley side slopes and has a base width of 3 m to 5 m. The Revised draft EIS Geomorphology technical report includes an annotated site maps in Appendix A (Figure E9) and ground photos are presented in the site summary sheets in Appendix J. Cross sections presented in Appendix J illustrate the geometry of the channel.

No floodplain landform is present at the site.

4.2 Bed/bank material and vegetation

The channel bed and bank are dominantly well vegetated, with some areas of bare gully erosion. The bed is vegetated with grass/weeds with sparse shrubs and established trees. The bed material where exposed is fine sand. Woody debris is scattered throughout the channel, including individual tree trunks up to 6 m in length, 0.3 m in diameter and some areas with a build-up of smaller sticks. There is dense scrub cover in the catchment just upstream.

The upper bank material where exposed was dry and difficult to hand dig, interpreted as a minor incipient duricrust that has been weathered and then locally deposited as gravel. Where the bank material could be excavated the material is sand (0.05 m to 0.3 m deep) overlying sandy silty clay.

Descriptions of sampled bank material are as follows:

- Sample 1 (CH73.53-1) – sandy silty CLAY, low plasticity, light brownish grey, moist, hard, shear vane and pocket penetrometer unable to penetrate
- Sample 3 (CH73.53-3) – SAND, orangish brown, moist, uniformly graded.

4.3 Geomorphic processes

The main geomorphic process at this site is gully erosion. The gully is partially vegetated with extensive areas of bare sand along the banks and showed evidence for sheetwash erosion, particularly near the Project alignment crossing. These areas are illustrated and described on Figure 9 in Drawing set E, Appendix A of the Revised draft EIS Geomorphology technical report, two example photos are included in Figure 4.

Some minor slumping of the banks and development of small side gullies within the eroded areas was observed downstream of the Project alignment crossing.

Fine sand deposits are present within the channel that have been deposited locally from bank erosion and have not yet been moved through the system.

Aerial imagery dating from 1959 shows the gully was shorter and narrower than the contemporary gully. The extent of post-1959 gully development is annotated in Figure 3.3, Appendix A of the EIS Geomorphology technical report.

Following the terminology of the *Queensland Bridge Scour Manual (Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour 2018)* the type of scour at this site is classed as *long-term degradation*.



Figure 4 CCs 21 site photos. Left, Photos P1 – looking downstream from proposed culvert location. Right, Photo P6 – gully erosion on side gully at true right of design culvert location.

Figure note: See Appendix A drawing E9 for photos locations and descriptions.

4.4 Existing human induced change at the site

Millmerran Inglewood Road crosses near the head of the gully, with a culvert installed beneath the road.

Based on aerial imagery vegetation change is evident in the upper section of the gully. Most of the larger established vegetation has been removed since 1959 resulting in the slope being more susceptible to erosion. Other areas with bare soils (not from natural geomorphic processes) that are susceptible to erosion include vehicle tracks along the fence line to the northwest of the site and stock tracks within the surrounding area.

4.5 Hydraulic characteristics

The existing and Design Case hydraulic characteristics at the site are presented in Table 4-2. In the Design Case during a 1% AEP and 20% AEP event there is a large reduction in velocity and stream power upstream of the proposed culvert location.

Table 4-2 Site CCs 21 hydraulic characteristics

	1% AEP	Design Case	20% AEP	Design Case
	Existing Case		Existing Case	
Maximum velocity (m/s)	u/s 1.3 d/s 1.7	u/s 0.3 d/s 1.7	u/s 1.2 d/s 1.4	u/s 0.3 d/s 1.1
Maximum SP (W/m ²)	u/s 71 d/s 160	u/s 3 d/s 90	u/s 52 d/s 96	u/s 1 d/s 51
Depth of flow (m)	u/s 0.34 d/s 0.35	u/s 1.23 d/s 0.45	u/s 0.20 d/s 0.28	u/s 0.38 d/s 0.27

4.6 Erosion threshold velocities and site erosive potential

This site was assessed as high-risk due to the potential impacts of the *reduction* in flow velocity upstream, erosion due to the Project during operation is considered a low risk only. However, this site is a gully erosion site and highly erodible sands exist in the gully side slopes. These represent an erosion risk during construction until they are vegetated.

The theoretical ETVs and combined geomorphic ETV are included in (Table 4-3).

Theoretical ETVs were calculated for two samples, CH73.53-1 (sandy silty CLAY) and 2 (SAND). The strength estimates for the clay unit are conservative, as they were too hard to be measured in the field meaning that the calculated ETVs are also conservative.

Note that the theoretical ETVs have been calculated for the water depth where the maximum flow velocity occurs (either upstream or downstream of the culvert). Where there is a change between existing and Design Case in the calculated ETV, this comes from a change in water depth. The calculated ETVs for the sand sample 3 are very low and unlikely to be accurate to the extent shown, however the ETVs are very low for this material. While sand particles may be transported if already in suspension at velocities <0.1 m/s, initiation of erosion is considered unlikely until flow velocities of >0.3 m/s. Applicable geomorphic site observations and considerations:

- It is considered reasonable that the observed condition of the channel during the site visit reflects the geomorphic processes from a relatively frequent event such as the 20% AEP, with maximum flow velocities on the order of those modelled for Existing Case conditions of 1.4 m/s
- Major erosion and gully development was observed in bare sand at the site, including where sample CH73.51-2 was taken from, indicating that the ETVs of this soil are well below the 20% AEP Existing Case max velocities
- Sandy silty CLAY, sample CH73.53-1, was taken from below the sand. This material was intermittently exposed in active gullies
- There are a number of different materials at this site, including sand, clay and an intermittent duricrust (an erosion resistant layer)
- When vegetated, these soils may accommodate design flow velocities for the 20% AEP event without erosion
- Woody debris was present in the gully floor
- The intermittent presence of the duricrust at the site protects the underlying material from erosion and it is inferred that erosion in the sand banks may preferentially occurs where this layer is not present
- No erosion was occurring in the silty CLAY, which was noted as difficult to dig.

Based on the considerations above, a combined geomorphic ETV for the silty clay of greater than 2.6 m/s was assessed. This is well above the design flow velocities, although it is noted that this soil is dispersive which may reduce the ETV. A combined geomorphic ETV for the bare sand of ~0.3 m/s was assessed. This is well below the Existing Case and design flow velocities for the 20% AEP event, indicating that major erosion is likely to continue to occur if this soil is not vegetated or other mitigation undertaken.

Table 4-3 Site CCs 21 erosion threshold velocity (m/s)

Sample ID	Theoretical ETVs based on bulk sample laboratory testing				Combined geomorphic ETV
	1% AEP		20% AEP		
	Existing Case	Design Case	Existing Case	Design Case	
CH73.53-1 sandy silty CLAY	2.7	2.8	2.6	2.6	>2.6 (vegetated)
CH73.53-3 SAND	0.1	0.1	0.1	0.1	0.3 (bare soil)

4.7 Potential impacts of the Project

This section summaries the potential alterations to geomorphic processes from the Project assuming the design considerations in the revised reference design have been implemented, as well as the proposed mitigation measures for future stages.

The reduction in velocity from 1.2 m/s to 0.3 m/s for the 20% AEP Design Case could result in reduced transport of fine to coarse grained gravel at these velocities. However, as particles of this grain size only make up a small proportion of the sediment load the impacts of the Project on the fluvial system are considered low and readily mitigated in routine maintenance.

Channel constriction may also lead to accumulation/blockage of the culvert from woody debris upstream that is too large to pass through the culvert. Routine maintenance would prevent this from having potential alterations to the geomorphic processes.

Gully erosion will continue to develop at this site, and the Project presents an opportunity to undertake mitigations works in this area to reduce this erosion. Additional proposed mitigation measures to minimise gully development are included in Section 5.2 of the Revised draft EIS Geomorphology report.

5 Site SC 2

This site was identified as a high-risk site in the initial desktop risk assessment due to the location of the design west bridge embankment at the apex of the meander bend approximately 100 m west of the crossing potentially impacting the watercourse planform and channel type. Design flow velocities both at the meander bend and where SC 2 crosses the Project alignment are within or very close to the not significant consequence limit of less than 10 per cent change.

Site SC 2 is a Strahler Order 4 tributary of Back Creek, approximately 3 km south of Millmerran. It is a developed channel with human modifications, including partially damming of the channel, where the design bridge BR310-37 intersects the meander bend. Existing assessment data is summarised in Table 5-1.

Table 5-1 Site summary SC 2

Site	SC 2
Chainage (m)	126960
Proposed rail infrastructure	Bridge – road
Strahler Order	4
Erskine (2017) Channel Classification	Chain of ponds within a developed channel
Watercourse type	Local – developed channel sections
Catchment area (ha)	2127.1
Catchment slope (rise/run)	0.0271
Catchment vegetation	Grassland with bush

Site	SC 2
Catchment soil type – ASC Order	Sodosols
Catchment soil erodibility	High (4) to very high (5)
Valley setting	Unconfined
Tributaries	390 m d/s converges with Back Creek 1
Planform	Moderate meandering
Sinuosity	1.400
Channel slope (rise/run)	0.0065
Channel planform at the Project alignment	Bend
Geomorphology notes	Bridge encroachment at meander bend, not actively eroding, modified channel at bend.
Aerial imagery change	Channel planform appears unchanged, increased vegetation

5.1 Landforms

The site is located on a pastured plain. The watercourse extends > 5 km upstream and 1.2 km downstream into Back Creek. The Revised draft EIS Geomorphology technical report includes an annotated site maps in Appendix A(Figure E12) and ground photos are presented in the site summary sheets in Appendix J.

The main channel is a sinuous, incised channel with a meander bend where the design infrastructure goes up to the edge of the watercourse. Cross sections presented in Appendix J, of the Revised draft EIS Geomorphology technical report, illustrate the geometry of the channel.

The base of the channel is up to 6 m wide at the meander bend with gently to moderately sloping banks that have previously been modified to restrict flow to the east.

Upstream of the bend the channel is relatively straight for at least 70 m, the channel width varies from 1 m to 3 m wide with bank heights are 1 m to 1.5 m. Downstream of the bend the main channel is also relatively straight for at least 50 m, the channel width varies from 2.5 m to 5 m wide with bank heights of 1 m to 2 m. In channel bars are present and are illustrated and described in Drawing E12 and E13, Appendix A (in the Revised draft EIS Geomorphology technical report).

On the true right bank directly downstream of the bend an approximately 0.5 m bund has been constructed on the bank edge and extends for approximately 10 m. To the east of this, parallel to the main channel downstream of the meander bend is a second channel that is approximately 5 m wide. This channel is dammed at the head which is part of the modifications at the meander bend and is likely an existing flow path.

The floodplain is a relatively flat pastured area that has contoured levees to control surface flow.

5.2 Bed/bank material and vegetation

The bank material is generally grass covered sandy silty clay (Sample 2), with established trees lining the channel edge. The bed material where exposed is either fine to coarse sand or silt with coarse gravel and cobble armouring. Sparse in channel vegetation consisted of grass and weeds, woody debris was also present.

Descriptions of the sampled material are as follows:

- Sample 2 (BR37-2) – sandy silty CLAY, low plasticity, brownish grey, moist, firm to stiff, rootlets.
- Sample 3 (BR37-3) – silty SAND, light brown, moist, uniformly graded.

Sample 2 comes from the outside of the sharp meander bend and is inferred to represent in situ soils. Sample 3 comes from the inside of a meander bend, where deposition of sand was observed. Sample 3 is likely the result of long-term accretion on the inside of a meander bend and is therefore not considered representative of bed and bank material elsewhere.

The floodplain is grassed pasture with sparse established trees.

5.3 Geomorphic processes

Three erosion sites were mapped on the outside of bends downstream of the meander bend and upstream of the road crossing. The outside of the sharp meander bend is vegetated and not currently eroding; however, deposition is occurring on the inside bend. Twenty metres downstream of the apex of the bend, the single channel splits into two anabranches with an established island between, the right anabranch has been dammed by a human made embankment resulting in an artificially sharper meander bend at this site (Figure 5). Of the Revised draft EIS Geomorphology technical report, Drawing E12 and E13 in Appendix A illustrate and describe the geomorphic features at the site.

Major channel erosion was observed from 75 m downstream of Millmerran Inglewood Road (Figure 5). A build-up of woody debris within the channel has dammed the channel creating a 1 m base level change of the channel bed with extensive erosion and slumping of the channel banks observed directly downstream of this.

Following the terminology of the *Queensland Bridge Scour Manual (Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour 2018)* the type of scour at this site is classed as *long-term aggradation/degradation and short-term bend scour*.



Figure 5 SC 2 site photos. Left, Photos P3 – looking downstream from apex of meander bend towards human made embankment in channel (indicated by the dashed white line). Right, Photo P16 – Major channel erosion that starts ~75 m downstream of the existing road culvert.

Figure note: See Appendix A drawing E12 for photos locations and descriptions.

5.4 Existing human induced change at the site

As noted above, 20 m downstream of the apex of the sharp meander bend, the single channel splits into two anabranches with the true right one having been dammed by a human-made embankment resulting in an artificially sharper meander bend at this site. The embankment is a gently to moderately sloping grassed earth embankment. Downstream of the embankment, the cut-off channel has formed a pond area, and would act as a back flow channel during flood events.

A vehicle access track crosses the watercourse downstream of the meander bend denoted by the bare soils which are more susceptible to erosion.

5.5 Hydraulic characteristics

The Existing and Design Case hydraulic characteristics at the site are presented in Table 5-2. During a 1% AEP and 20% AEP event there is no large increase or reduction in stream velocity or stream power between the design and Existing Case (typically less than 10 per cent difference).

Table 5-2 Site SC2 hydraulic characteristics – at meander bend

	1% AEP	Design Case	20% AEP	Design Case
	Existing Case		Existing Case	
Maximum velocity (m/s)	u/s 1.9 d/s 1.4	u/s 1.8 d/s 1.3	u/s 1.7 d/s 1.2	u/s 1.7 d/s 1.2
Maximum SP (W/m ²)	u/s 286 d/s 316	u/s 239 d/s 325	u/s 297 d/s 301	u/s 309 d/s 325
Depth of flow (m)	u/s 3.0 d/s 2.5	u/s 3.1 d/s 2.7	u/s 2.4 d/s 2.3	u/s 2.7 d/s 2.5

5.6 Erosion threshold velocities and site erosive potential

As there is little change in design flow velocities for this site, and what change occurs is a slight reduction, ETVs are not relevant for the risk assessment of the Operations stage of the Project. However, an ETV assessment of the bank material on the outside of the bend has been undertaken, as this was identified as a potential avulsion site.

The theoretical ETVs and combined geomorphic ETV are included in (Table 5-3).

A theoretical ETV was calculated for sample BR37-2 (sandy silty CLAY). Note that the theoretical ETVs have been calculated for the water depth where the maximum flow velocity occurs (either upstream or downstream of the culvert). Where there is a change between existing and Design Case in the calculated ETV, this comes from a change in water depth.

Applicable geomorphic site observations and considerations:

- It is considered reasonable that the observed condition of the channel during the site visit reflects the geomorphic processes from a relatively frequent event such as the 20% AEP, with maximum flow velocities on the order of those modelled for Existing Case conditions of 1.7 m/s.
- No erosion was occurring on the outside of the meander bend. This indicates that the outside of the meander bend, which comprises vegetated silty CLAY, can accommodate Existing Case velocities on the order of 1.7 m/s without erosion. If not vegetated, the silty clay would have a lower ETV.
- Sand had been deposited on the inside of the bend, indicating regular transport of sand.

Based on the considerations above, a combined geomorphic ETV of the vegetated sandy silty clay of greater than 1.7 m/s has been assessed.

Table 5-3 Site SC 2 16 erosion threshold velocity results (m/s)

Sample ID	Theoretical ETVs based on bulk sample laboratory testing				Combined geomorphic ETV
	1% AEP		20% AEP		
	Existing Case	Design Case	Existing Case	Design Case	
BR37-2 sandy silty CLAY	1.4	1.4	1.4	1.4	>1.7 m/s (vegetated)

5.7 Potential impacts of the Project

This section summaries the potential alterations to geomorphic processes from the Project assuming the design considerations in the revised reference design have been implemented, as well as the proposed mitigation measures for future stages.

Encroachment of the west bridge embankment at the apex of the meander bend approximately 100 m west of the crossing will stop southwards migration of the bend and may result in impacts to the long-term watercourse planform behaviour. The watercourse could avulse, and if so, the water would flow for 50 m along the side of the embankment. As such the embankment would need some form of erosion protection. This would not be difficult to implement and would not result in adverse geomorphic effects. We note this section of the channel has already been modified previously with an earth embankment to contain the flow, and no active erosion on the outside of the bend was observed. Therefore, the avulsion risk is considered to be very low in the short to medium term.