

Appendix DD

Hydraulics / Hydrology

**Pekapeka to Otaki Expressway
Specialist Report
Flood Hazards**



Pekapeka to Otaki Expressway Specialist Report Flood Hazards

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1. Executive Summary

The route for the proposed Peka Peka to Otaki (PP2O) Expressway crosses a series of floodplains for different watercourses including the Waitohu Stream, the Mangapouri Stream, the Otaki River and the Mangaone Stream. It is intended to construct the Expressway as a raised embankment across these floodplain areas so that it can act as a lifeline in extreme flood situations. However blockage of the floodplain by a raised barrier runs counter to the philosophy of allowing extreme floods to break out of the primary watercourse and follow natural overflow paths to the sea. This report presents an assessment of effects on the existing flood hazards for each of these floodplain and waterway crossings. In each case appropriate mitigation measures are identified which are targeted towards achieving hydraulic neutrality with respect to the existing situation.

In the case of the Waitohu Stream crossing, dry culverts are required to be incorporated within the Expressway embankment to provide continuity for existing natural drainage paths. These include culverts through both the southern and northern approach embankments to the 75m span bridge crossing of the stream and for the Greenwood sub-catchment to the north of the stream. In addition to conveying surface runoff from the Greenwood sub-catchment, the latter culvert also captures flood breakout flows caused by the throttling of flood flows by the existing State Highway 1 (SH1) Bridge upstream of the proposed Expressway crossing. The degree of effect of the Expressway crossing of the Waitohu Stream and floodplain is assessed to be LOW because the extent of flood inundation for the proposed situation is only very marginally different to that for the existing situation.

By design the North Island Main Trunk (NIMT) railway culvert and the County Road culvert (both upstream of the existing SH1 culvert) act in concert to throttle flood flows in the Mangapouri Stream above the 5% AEP flood in order to reduce the downstream flood hazard through Otaki Township. This results in the occurrence of extensive flood inundation upstream of the railway embankment. As the NIMT railway line is to be relocated westwards to make way for the proposed Expressway, the new Expressway and NIMT railway culverts will be required to take over the flood flow throttling function of the existing railway culvert. The degree of effect of the Expressway crossing of the Mangapouri Stream is assessed to be LOW because the new culverts have been sized so that the extent of upstream flood inundation in the proposed situation is no worse than in the existing situation.

The proposed Expressway crossing of the Otaki River will be comprised of two parallel bridges with a very similar span to that of the downstream NIMT rail bridge although the piers on the Expressway bridges will be much more widely spaced. Due to the long span length and the small pier width to span ratio, the Expressway bridges will not act as a constriction to flood flows and pier head losses will be much lower than on the rail bridge.

The proposed Expressway embankment across the Otaki River floodplain will cause ponding of floodwaters upstream if an extreme flood overtopped the Chystall's Bend extended stopbank protecting Otaki Township. The upstream ponding will be moderated by incorporating a dry culvert through the embankment adjacent to the stopbank which will allow leakage of ponded floodwaters into a natural overland flow path downstream of the Expressway and the existing SH1. The degree of effect of the Expressway crossing is assessed to be MEDIUM due to the increased extent of flood inundation in the Mangapouri Stream flood ponding area relative to the existing situation (although this same area would be inundated by a significant localised flood in the Mangapouri Stream itself). The action of the Expressway embankment as a flood detention barrier means that the Expressway would provide a positive benefit for property owners to the west of SH1 up to the level of the 0.2% AEP design flood.

The existing NIMT railway crossing of the Mangaone Stream and floodplain is a raised embankment which already functions as a flood detention barrier and incorporates culverts on the main stream channel and an overflow path as flood outlets. This provides some degree of flood protection to downstream floodplain residents. The proposed Expressway will be located upstream of the existing railway and will therefore need to take over the present flood detention function of the railway embankment. New culverts will be required under the proposed Expressway and the local link road on both the main stream channel and overland flow paths to provide continuity of existing floodplain drainage paths. The degree of effect of the proposed Expressway is assessed to be LOW as the extent of upstream flood inundation is only marginally increased and the area of inundation covers only pastoral land.

2. Project Description

The planned upgrading of State Highway 1 between Peka Peka and Otaki North is “part of the Wellington Northern Corridor Road of National Significance (RoNS) – a planned four-lane expressway from Wellington Airport to Levin.”

SH1 is the major route in and out of Wellington, linking the centres of Palmerston North, Wanganui and Levin with Wellington. By improving transport networks through the Kapiti Coast, this project will contribute to economic growth and productivity.

Currently the Peka Peka to North Otaki section of SH1 has a relatively poor and worsening safety record. It also experiences high levels of congestion during peak periods, weekends and holiday periods. This congestion is compounded by a high proportion of local traffic, and an increasing level of shopping-generated parking and pedestrian movements in the Otaki urban area. A bypass of Otaki, and the provision of a high-standard highway through the area will increase the efficiency of movements between Wellington and the North, will ease local congestion, improve safety, and will facilitate local, regional and national economic development.

The scope of this project is therefore to construct a high quality four-lane expressway bypassing the township of Otaki and the settlement of Te Horo. Together with the MacKays to Peka Peka section to the south, it forms the Kapiti Expressway and when both sections are completed will provide a superior transport corridor providing much improved, reliable and safer journeys through the Kapiti Coast.

The project seeks to safeguard for double tracking of the main trunk rail line and also involves the relocation of the track through Otaki in order to accommodate the proposed expressway.

3. Site Description / Existing Environment

The route for the proposed four-lane expressway between Peka Peka and North Otaki essentially runs parallel to the existing State Highway 1 (SH1) along a narrow coastal plain. This coastal plain is made up of a series of floodplains for one major river (the Otaki River), one medium sized river (the Waitohu Stream), and several smaller streams (including the Mangaone Stream at Te Horo and the Mangapouri Stream through Otaki Township).

The existing SH1 has a history of being inundated by floodwaters every few years at a number of locations including the bridge over the Waitohu Stream immediately to the north of Otaki Township and the culvert system crossing the Mangaone Stream at Te Horo. The natural overflow path for the Otaki River, if a super-design flood was to overtop the current Chystall's Bend stopbank providing protection to Otaki Township, would be directly across the route of the proposed expressway. The

present combination of the North Island Main Trunk Railway (NIMT) culvert and the County Road culvert on the Mangapouri Stream upstream of the SH1 crossing (along the northern edge of the Otaki River floodplain) is designed to throttle flood flows for events in excess of a 5% AEP flood in order to protect downstream properties through Otaki Township.

It is proposed to construct the Expressway as a raised embankment across these floodplain areas and elevate it sufficiently so that it can act as a lifeline and to remain open in extreme flood conditions. However the concept of a "lifeline" formed by a raised embankment which cuts across and blocks a natural floodplain runs completely counter to the philosophy of allowing a super-design flood to break out of its primary watercourse and follow a natural overflow path to the sea. Blockage of the floodplain in such an event could also exacerbate the flood risk to properties lying upstream and outside any natural overflow path.

This report presents an assessment of effects of the proposed Expressway on the existing flood hazard for each of the floodplain crossings. This assessment of effects is a summary of a more detailed description contained in the companion report "*Peka Peka to Otaki Expressway Scheme Assessment Report Addendum: Design Flood Levels for Waterway Crossings*". In order to make this assessment, it was first necessary to establish the magnitude of the existing flood hazard for each floodplain crossing. The extent of flood inundation resulting from the proposed Expressway was then quantified and the effects relative to the existing flood hazard determined. As part of the conceptual design phase, mitigation measures have been evaluated with the objective of achieving hydraulic neutrality with respect to the existing situation. This means that the flood hazard downstream of each crossing should be no worse than it is at present.

4. Waitohu Stream Crossing

4.1 Existing Situation and Flood Hazard

The existing State Highway 1 crosses the alluvial fan and floodplain of the Waitohu Stream on the northern boundary of Otaki Township. The bridge crossing is a relatively low structure and lies on a moderate bend in the stream. Aggradation of gravel bed material occurs under the bridge and floodwaters occasionally break out of the stream channel and inundate the road.

The design flood for the stream crossing was selected as the flood resulting from the 2 hour duration 1% annual exceedance probability (AEP) rainfall event (adjusted for the effects of possible future climate change) on the Waitohu Catchment. The 2 hour critical rainstorm duration is based on recent floodplain management investigations undertaken by GWRC (2003, 2004b).

Figure 1 shows the extent of flood inundation resulting from a 1% AEP flood adjusted for climate change for the current floodplain situation in the vicinity of the existing SH1 and proposed Expressway bridge crossings of the Waitohu Stream (but without the Expressway in place). The extent of inundation is indicated by the shaded area superimposed on the background of an aerial photograph. The inundation map incorporates red directional arrows to indicate the general direction of flow paths at the flood peak (note that these arrows are indicative only rather than being calculated). The blue lines indicate the primary flow paths incorporated in the one-dimensional computational hydraulic model used to predict flood levels and discharges along the stream and floodplain.

It is immediately apparent from this flood inundation map that the existing SH1 bridge acts as a throttle on flood flows and causes floodwaters to break out along the right (north) bank upstream of the bend which the bridge crosses. These floodwaters combine with surface runoff from the Greenwood sub-catchment to the north of the Waitohu Stream to then flow across SH1 which is currently at grade on natural ground. Floodwaters also break out on both the left and right banks immediately upstream of the existing SH1 bridge and outflank it.

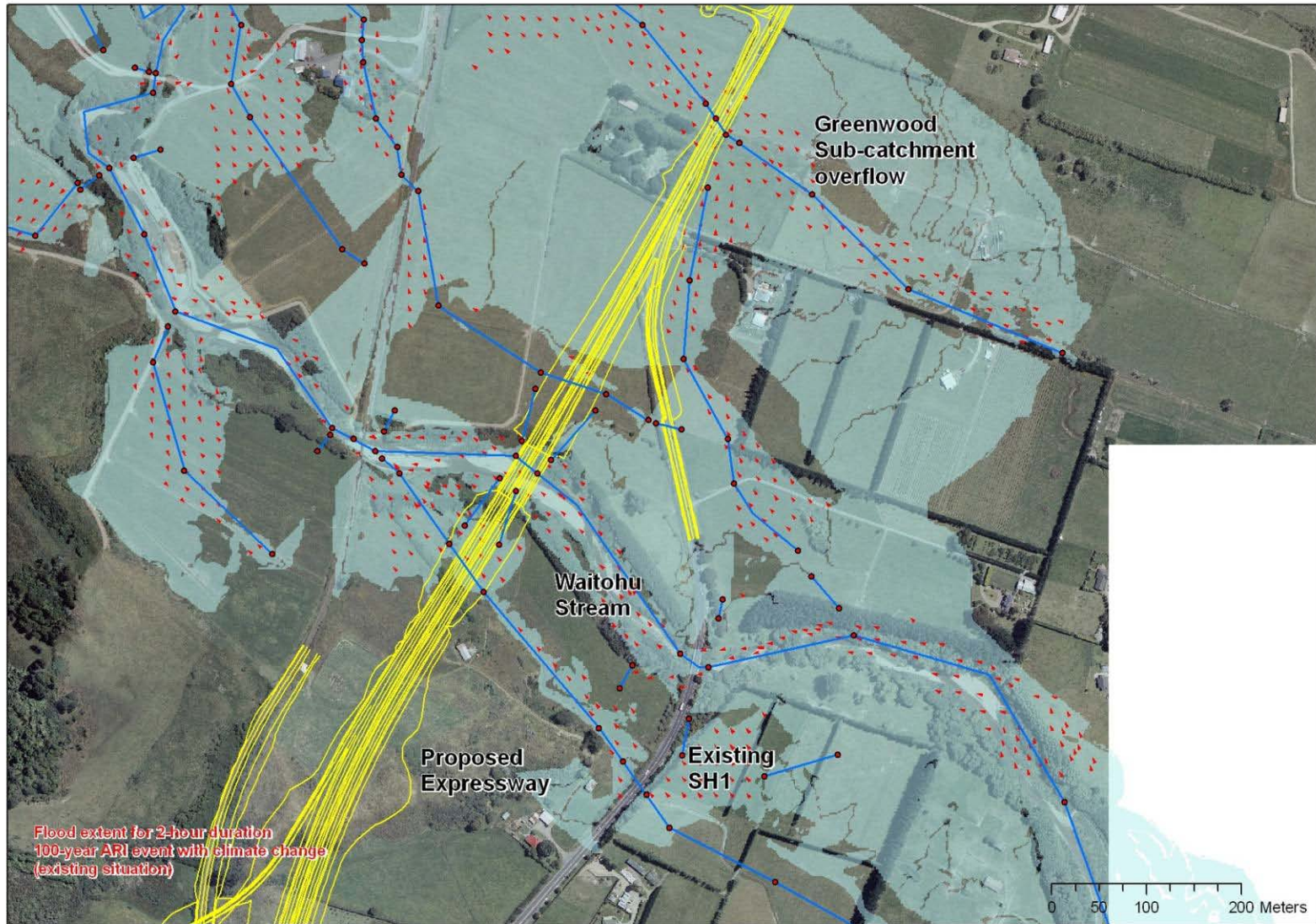


Figure 1 Extent of flood inundation for flood induced by 2 hour duration 1% AEP rainstorm in vicinity of existing SH1 bridge crossing of Waitohu Stream (current situation)

Although this flood inundation pattern highlights the fact that the existing SH1 bridge acts as a restriction for flood flows, it is the intention of the PP2O Project to retain this bridge in its present form without modification or replacement.

4.2 Proposed Situation

The proposed Expressway bridge will cross the Waitohu Stream approximately 260m downstream and to the west of the existing SH1 bridge crossing. The proposed Expressway crossing is located within a geomorphologic zone of instability characterised by lateral channel instability and sediment deposition (GWRC, 2004a). GWRC have defined a fairly wide design alignment for the stream downstream of the existing SH1 bridge to reflect this instability zone. The Scoping Report for the PP2O Expressway recommended a minimum 75m bridge span length to accommodate this instability zone and GWRC's design alignment for the stream. The stream crossing will be comprised of two parallel bridges, one bridge for each traffic direction.

The Scheme Assessment has assumed that this minimum span length could be provided by a bridge with three spans of 25m each. This would allow the two cylindrical-shaped piers on each parallel bridge to be located on either side of the existing main flow channel of the stream.

The alignment of the proposed Expressway passes directly through the extensive flood inundation area to the north of the Waitohu Stream Crossing caused by the combination of surface runoff sourced from the Greenwood sub-catchment and right bank breakout flows from upstream of the bend which the existing SH1 bridge crosses (see Figure 1). This area lies right at the northern end of the Peka Peka to North Otaki section of proposed Wellington Levin Expressway.

As the Expressway will be constructed in stages with construction of the Pekapeka to North Otaki section likely to precede the North Otaki to Levin section, two situations with the proposed Expressway need to be considered:

- the first with the approach embankment on the northern side of the Waitohu Stream Bridge Crossing sloping down to the grade of the natural ground across the northern floodplain (the situation prior to completion of the North Otaki to Levin section of the Expressway); and
- the second with the approach embankment on the northern side of the Waitohu Stream Bridge elevated above natural ground level and clear of the predicted peak flood level for the design 1% AEP flood (the situation post completion of the North Otaki to Levin section of the Expressway).

In the former situation, the northern end of the proposed Expressway will be exposed for a limited period of time to being inundated by floodwaters in significant flood events as occurs at present.

In the latter situation the embankment conveying the Expressway will act as a floodplain barrier preventing the natural drainage from east to west of surface runoff from the Greenwood sub-catchment and breakout flows from the Waitohu Stream upstream of the existing SH1 Bridge. The embankment will require a dry culvert to convey these flows under the expressway in significant flood events.

4.3 Effects of Proposed Situation

Blocking the floodplain with a raised embankment will generally have the effect of elevating upstream flood levels. Providing dry culverts through the southern and northern approach embankments to the bridge Expressway bridge crossing to preserve natural drainage paths helps to reduce flood levels down towards those of the existing situation, as long as those culverts are sufficiently large (the dry culverts are located where the blue primary flow path lines in Figures 1 and 2 cross the Expressway embankment) . Flood levels downstream of the proposed Expressway embankment are unaffected compared to those for the existing floodplain situation.

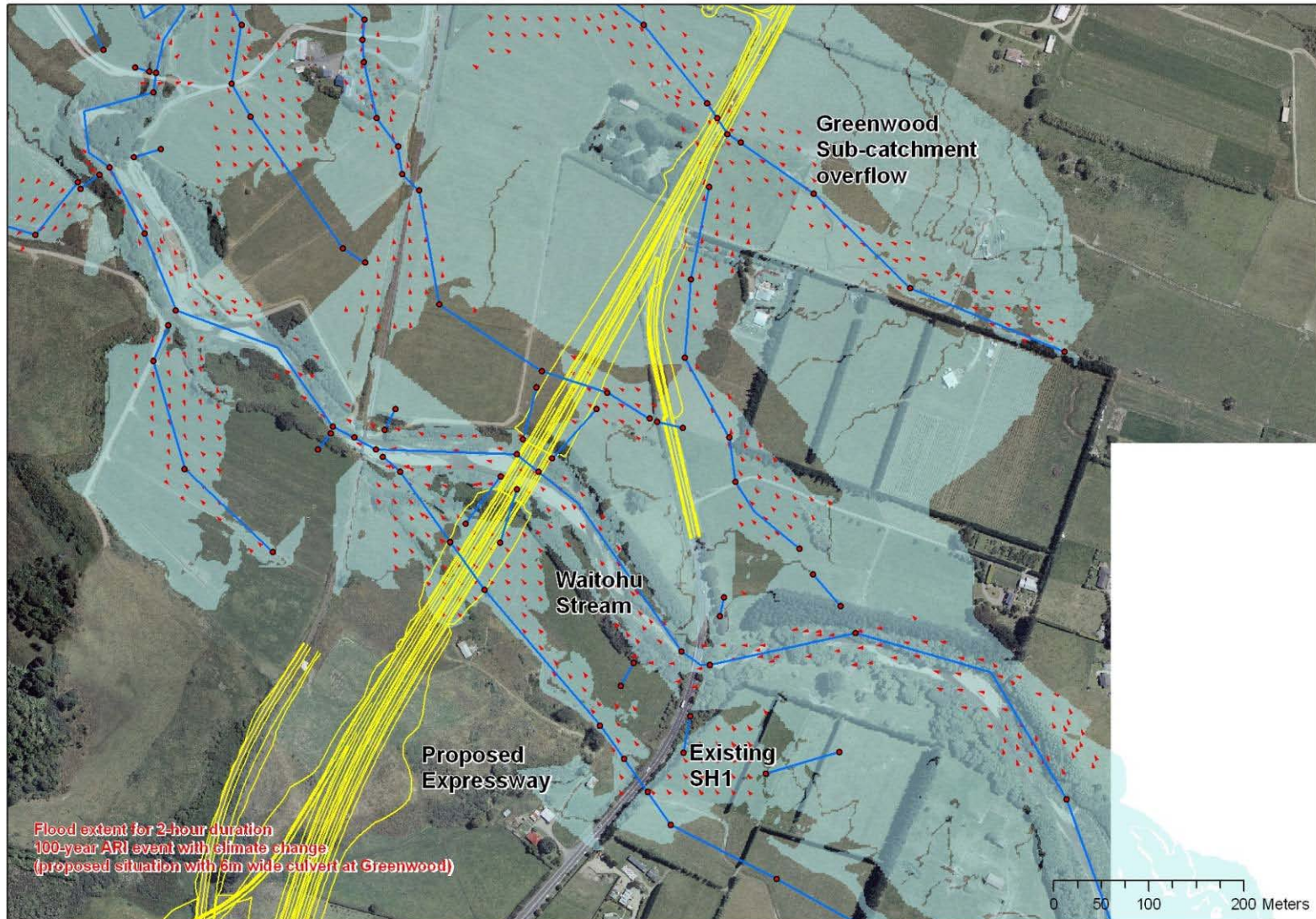


Figure 2 Extent of flood inundation for flood induced by 2 hour duration 1% AEP rainstorm in vicinity of existing SH1 and proposed Expressway bridge crossings of Waitohu Stream (future situation with proposed Expressway in place)

Figure 2 shows a map similar to Figure 1 which illustrates the extent of flood inundation resulting from the design 1% AEP rainstorm (adjusted for the effects of possible future climate change) in the vicinity of the Waitohu Stream crossing for the final configuration of the proposed Expressway (with the North Otaki to Levin section completed).

The extent of flood inundation in Figure 2 is very similar to that shown in Figure 1. The only differences in the extent of inundation between the two figures lie in a narrow strip immediately upstream of the proposed Expressway. This indicates that the increased flood levels for the proposed Expressway situation have only a fairly local effect due to the steepness of the floodplain.

Because of the similarity in flood inundation patterns between the existing situation and the proposed situation for the final configuration of the Expressway, the inundation pattern for the proposed situation prior to the completion of the North Otaki to Levin section of the Expressway will also be very similar. In this case the primary overland flow path for storm runoff from the Greenwood sub-catchment will remain unblocked by the proposed Expressway so that flood levels for that part of the floodplain will be unchanged from the existing situation.

4.4 Mitigation Measures

Table 1 summarises the types and dimensions of the dry culverts required to mitigate the blocking effect of the proposed Expressway embankment at critical locations across the floodplain.

Table 1 Culvert types and dimensions for proposed Expressway crossing of Waitohu Stream and floodplain

Location	Type	Size (m)	Length (m)	Slope (%)
southern approach embankment	box	5m x 1m	40	0.125
northern approach embankment	circular	3 x 0.45m diameter	40	2.25
Greenwood sub-catchment drainage – post Otaki to Levin construction	box	10m x 2.5m	25	0.8

These culverts have been incorporated in the conceptual design for the Expressway.

4.5 Relative Effects of Proposed Stream and Floodplain Crossing

Figures 1 and 2 show that there are at least a couple of residential properties within the flood inundation area upstream of the route of the proposed Expressway: one property directly along the Greenwood sub-catchment overland flow path and another property just to the south between the same overland flow path and the main stream breakout flow path. Inspection of the predicted backwater profiles along both these branches upstream of the Expressway route for the design flood indicates that, due to the steepness of the floodplain, these properties are located sufficiently far upstream for the change in the backwater effect induced by the dry culvert under the Expressway to be negligible compared to the existing situation with peak flood levels, at worst, only marginally increased.

The head losses induced by the tapered rectangular-shaped piers on each parallel bridge will be fairly small (< 0.035m) because of the low pier width to single span length ratio. This means that flood levels in the main stream channel will only be elevated a very small amount whenever the stream is passing a flood large enough for the piers to become wet. In any case, the extent of these elevated flood levels will rapidly diminish with distance upstream of the bridges due to the steepness of the stream slope.

4.6 Degree of Effect

The degree of effect for the Expressway crossing of the Waitohu Stream and its associated floodplain is assessed to be LOW.

4.7 Costs

Costs of the dry culverts identified in Table 1 as required mitigation measures have been included in the overall scheme construction cost.

5 Mangapouri Stream

5.1 Existing Situation and Flood Hazard

The area upstream of the existing County Road culvert acts as a flood detention area. In a significant flood event, water will start to pond in the area upstream before starting to spill over the road to the north of the culvert, filling the area between the North Island Main Trunk (NIMT) railway line and County Road (Figure 3). The railway embankment acts as a second and higher "dam" to pond upstream floodwaters. The County Road culvert and the railway culvert in combination throttle flood flows to limit downstream flood inundation through Otaki. The area between the railway embankment and the existing State Highway 1 (SH1) acts as a third detention pond for floodwaters with the outflow controlled by the discharge characteristics of the SH1 culvert and road overflow.

In significant flood events then, the culvert and stream system in the existing situation in the SH1 / County Road / Rahui Road triangle behaves hydraulically as a system of three detention ponds in series.

Figure 4 shows the extent of flood inundation for the 1% AEP design flood adjusted for the effects of possible future climate change to 2090 upstream of the existing NIMT railway line.

5.2 Proposed Situation

The route of the proposed Expressway through this area requires the NIMT railway line to be relocated parallel with and to the west of the Expressway.

The culvert through the proposed Expressway must emulate the current throttling function of the existing County Road and railway line culverts with the Expressway embankment acting as a "barrier to hold the ponded floodwaters so as to ensure that downstream flood levels are minimised.

The relocated NIMT railway line will also require a culvert to convey the Mangapouri Stream. It is envisaged that there will be some form of drain between the Expressway and the railway line embankments to collect storm runoff from the surfaces of both facilities.

The culvert and stream system in the SH1 / County Road / Rahui Road triangle will thus be modified in the proposed situation to behave as a series of four interconnected detention ponds under flood conditions, similar to the current situation.

The route of the proposed Expressway also requires an existing flood detention pond to which storm runoff from the 37 hectare urban Te Manuao Catchment (immediately to the north of Mangapouri Catchment on the Waitohu Stream alluvial fan) is directed. Presently the attenuated outflow from this detention pond is conveyed by a pipe down the hill into the Mangapouri Stream. With the construction of the Expressway this outflow will need to be rerouted to the "detention pond" upstream of the Expressway embankment.



Figure 3 Existing culvert system along Mangapouri Stream in SH1 / County Rd / Rahui Rd triangle with footprint of proposed PP20 Expressway and relocated NIMT railway overlaid

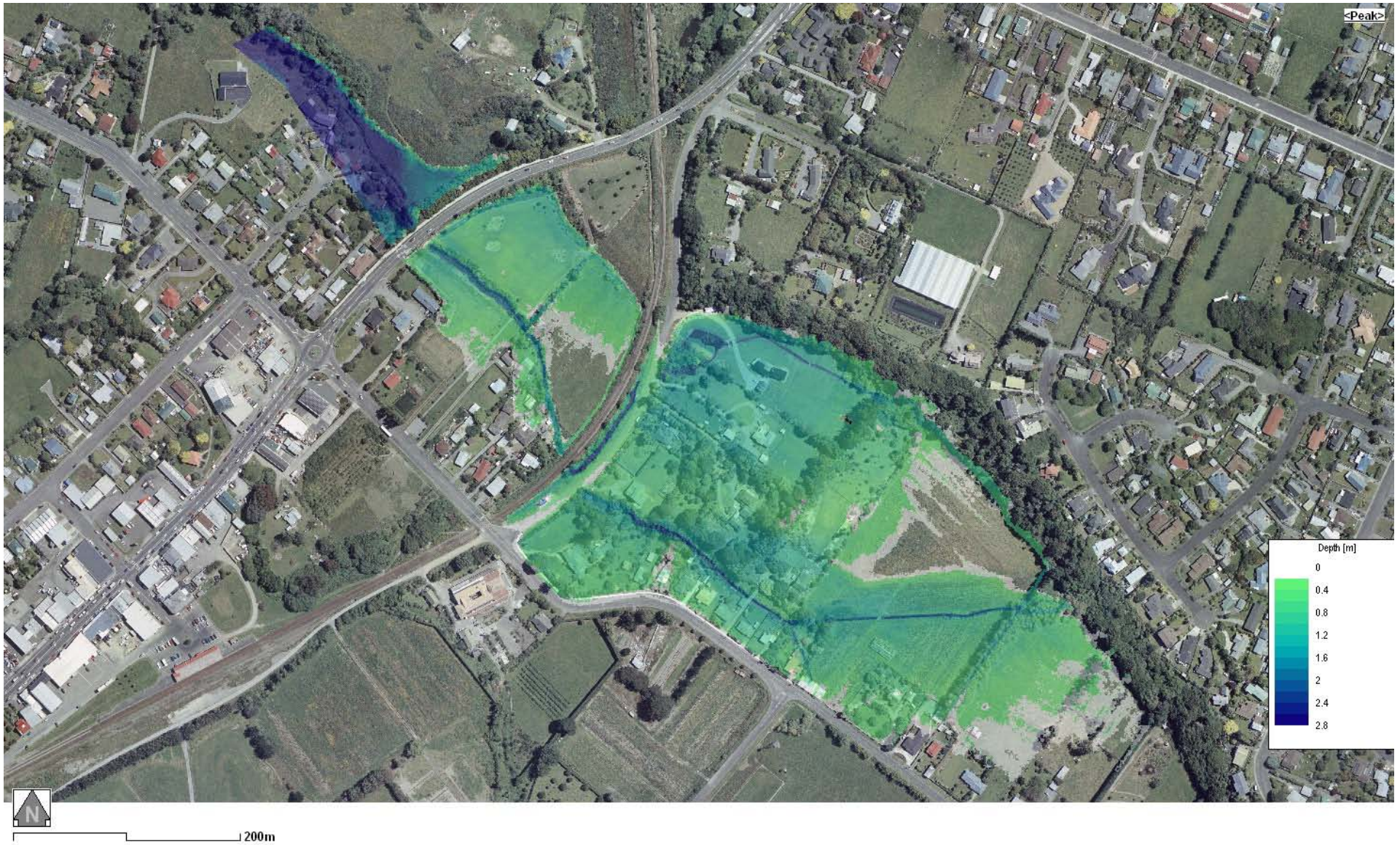


Figure 4 Inundation map for existing situatoin 1% AEP flood adjusted for possible future climate change effects

Although an existing culvert under State Highway 1 theoretically provides drainage for stormwater from 44.5 hectare catchment to the south of the Mangapouri Catchment, this culvert is reported to be effectively blocked by vegetation growth. Surface runoff from the catchment is presently thought to pond on the racecourse and adjacent open ground and infiltrate into the alluvial gravels of the floodplain.

The proposed Expressway embankment will cut off the natural drainage path for this small catchment. Provision has therefore been made for potentially diverting surface runoff into the Mangapouri Stream upstream of the Expressway. Alternatively it could be diverted southwards to pass through a dry culvert under the expressway and under the existing State Highway 1 near the Chrystal's Bend extended stopbank (along the north bank of the Otaki River).

5.3 Relative Effects of Proposed Drainage System Configuration

Preliminary flood level predictions for the proposed situation indicate that flood levels will be:

- lower than those upstream of the NIMT railway line / County Road culvert in the existing situation for smaller flood magnitudes (10% and 5% AEP floods for current climate conditions);
- approximately the same at the same locations for large flood magnitudes (0.5% and 0.2% AEP floods adjusted for effects of possible climate change to 2090);
- marginally lower at the same locations for the 1% AEP flood for both current climate and possible future climate change to 2090 conditions.

Peak flood discharges downstream of the existing SH1 culvert are lower for the proposed Expressway situation. This means that the proposed Expressway will have a slight positive benefit in that peak flood levels and discharges downstream of the existing SH1 culvert would be lower compared to those for the existing situation.

The effect of the proposed stormwater diversion from the small Te Manuao urban catchment in the north to the flood ponding area upstream of the proposed Expressway embankment will be to increase peak flood levels upstream such that they are only marginally worse (< 0.1m) than in the existing situation.

Figure 5 shows the extent of flood inundation for the design 1% AEP flood adjusted for possible future climate change effects to 2090.

5.4 Mitigation Requirements

Table 2 summarises the required culvert types and dimensions for the modified culvert and stream system in the SH1 / County Road / Rahui Road triangle. The existing County Road and SH1 culverts will remain unchanged. The Expressway and relocated NIMT railway culverts will be new ones.

Table 2 Culvert types, dimensions and levels for proposed Expressway situation

Location	Type	Diameter (m)	Length (m)	Slope (%)
existing County Rd	circular	1.2	19.3	negative
proposed Expressway	circular	1.372	40	0.125
relocated NIMT railway	circular	1.372	20	0.125
existing SH1	twin circular	0.9	20	0.5

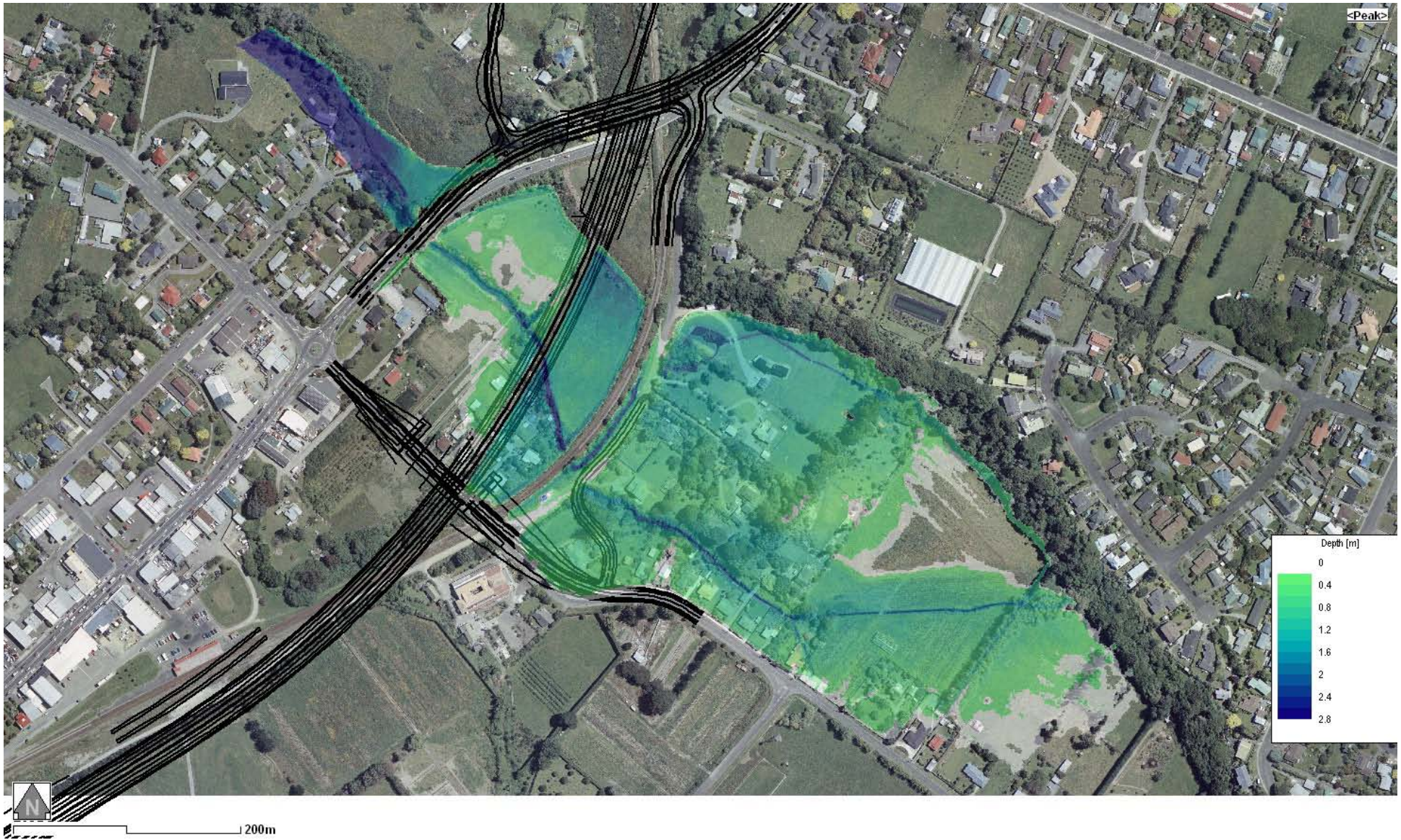


Figure 5 Inundation map for proposed Expressway situation 1% AEP flood adjusted for possible future climate change effects

These Expressway and relocated NIMT railway culverts have been incorporated in the conceptual design for the proposed Expressway.

5.5 Degree of Effect

The degree of effect for the Expressway crossing of the Mangapouri Stream is assessed to be LOW.

5.6 Costs

Costs of the Expressway and relocated NIMT railway culverts which are required as part of the modified drainage system for the Mangapouri Stream have been included in the overall PP2O scheme construction cost.

6 Otaki River and Floodplain

6.1 Existing Situation and Flood Hazard

The existing SH1 crossing of the Otaki River lies to the south of Otaki Township which is located on the floodplain for the river (Figure 6). The bridge crossing is located approximately 60m downstream of the NIMT railway bridge across the river.

The Otaki River incorporates a stopbank system along the true right (northern) bank which provides a 1% AEP standard of flood protection (based on current climate conditions) to the township of Otaki. This stopbank (known as Chystall's extended stopbank) starts from some high ground about 2.5km upstream of the existing SH1 bridge and then ends downstream at the NIMT railway line. It partially encloses the basin occupied by Stresscrete's precast concrete factory immediately upstream of the railway line so that the factory site lies between the stopbank and the river. The railway embankment between the end of the stopbank and the river has been strengthened to form part of the primary flood defence system for Otaki Township.

The Mangapouri Stream flows along the northern edge of the Otaki River floodplain adjacent to high ground.

In view of the very significant nature of the Otaki River, the design flood magnitude for the Expressway crossing of the Otaki River was selected as the 0.2% annual exceedance probability (AEP) flood based on current climate conditions. This closely approximates the 1% AEP flood adjusted for possible future climate change effects to 2090.

The 2,130m³/s magnitude of the 0.2% AEP flood is based on an estimate used in recent computational hydraulic modelling investigations undertaken by GWRC (2007) for the design of the Chystall's extended stopbank along the right (north) bank of the Otaki River. The stopbank was actually designed for the 1% AEP flood of 1,810m³/s based on current climate conditions (the freeboard on the stopbank for this flood is about 0.5m). However GWRC (2007) also investigated the effect of residual flood breakout across the floodplain from upstream of the extended stopbank (but excluding the effect of stopbank overtopping) for the 0.2% AEP flood.



Figure 6 Aerial view of Otaki River and floodplain in vicinity of existing and proposed river crossings

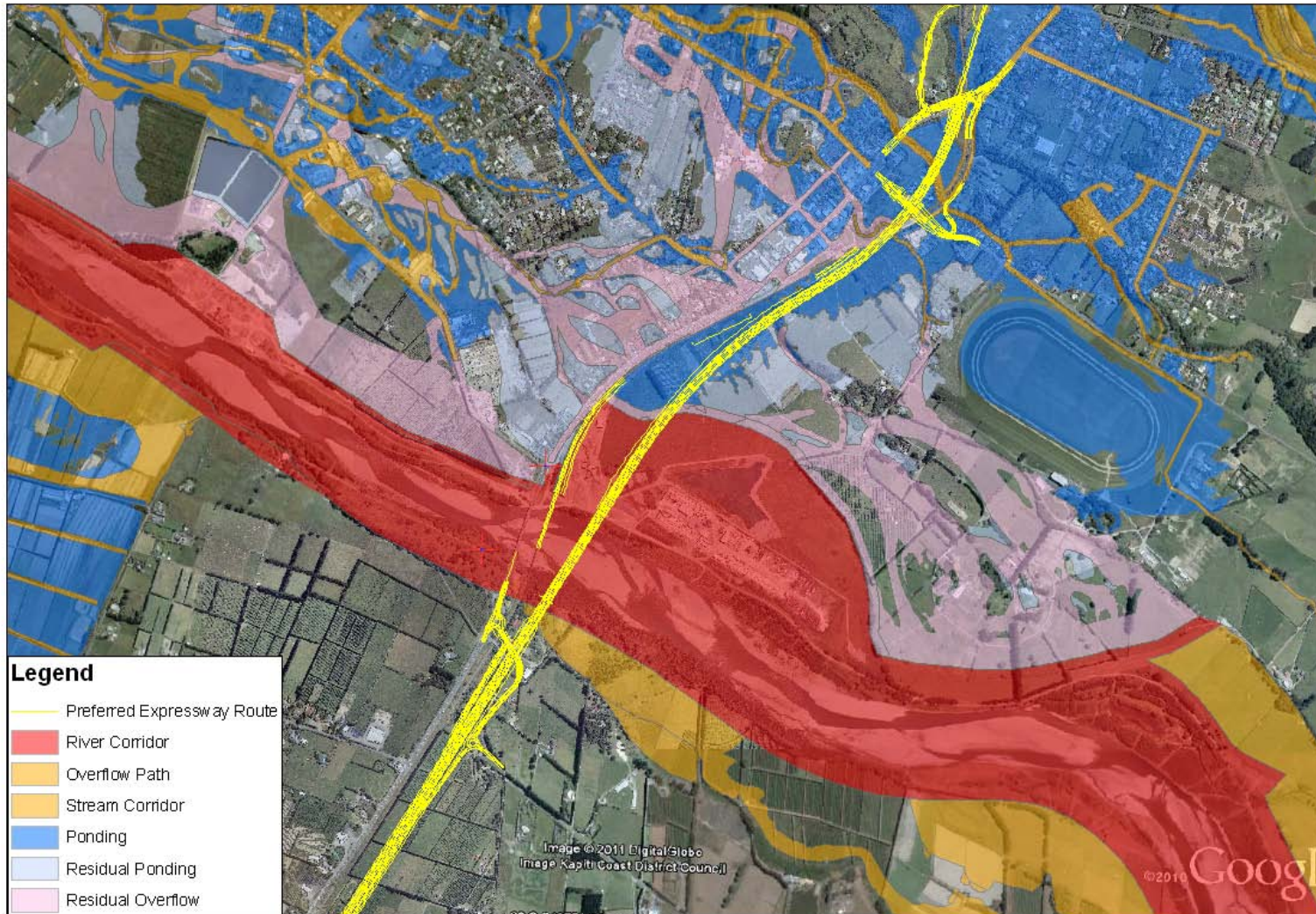


Figure 7 Composite GWRC / KDCDC flood hazard map for existing situation on Otaki River and floodplain

Figure 7 shows the extent of flood inundation of the Otaki River floodplain from a combined GWRC / KCDC flood hazard map (this is a composite hazard map covering flood hazards from all potential sources including stopbank overflow from the river and urban stormwater overflow). The floodplain areas shaded in pink represent residual overflow from the section of stopbank upstream of the extended Chrystall's Bend stopbank around the perimeter of the concrete factory yard. Ponding of stopbank-overtopping sourced floodwaters occurs upstream of the existing NIMT railway line (shown by the light blue areas upstream of the railway line in Figure 7) before the overflow from this ponding disperses via various overland flow paths through and around Otaki Township (shown by the pink areas downstream of SH1 and the railway line). Note that the dark blue shaded areas in Figure 7 indicate areas of surface water ponding from rainfall.

6.2 Proposed Situation

The proposed Expressway bridge crossing will be located approximately 120m upstream of the NIMT Railway Bridge (Figure 6). The crossing will be comprised of two parallel bridges, one for each traffic direction. Each bridge will have a very similar overall span to the railway bridge so that it does not act as a constriction to flood flows in the main river. However the piers will be much more widely spaced (up to 30m apart) than the piers on the railway bridge so that pier head losses will be much lower. Each pier will be of a tapered rectangular shape supported by a pile cap and twin cylindrical piles.

The northern approach embankment to the Expressway Bridge will bisect the basin occupied by Stresscrete's precast concrete factory. The embankment will be higher than the Chrystall's extended stopbank so as not to compromise the existing standard of flood protection provided to Otaki Township. The embankment will therefore act as a partial dam under flood conditions for any floodwaters entering the basin enclosed by the stopbank. This is described further below.

As noted before, the existing Chrystall's Bend extended stopbank has been designed for a 1% AEP flood with 0.5m freeboard based on current climate conditions. Although GWRC have designed the stopbank to be raised in the future to maintain the original design standard in the face of increasing flood magnitudes due to climate change effects, there is no guarantee that such upgrading will be undertaken in the future. The effects of the design 0.2% AEP flood based on current climate conditions (approximately equivalent to a 1% AEP flood adjusted for possible future climate change effects) were therefore assessed based on the current stopbank configuration. This represents a worst case scenario.

The Expressway crossing of the Otaki River floodplain to the north of the river will be constructed as a raised embankment. This will act as a flood detention barrier in the event of the Chrystall's Bend extended stopbank being overtopped.

6.3 Relative Effects of Proposed River and Floodplain Crossing

With the current stopbank configuration, the design 0.2% AEP flood based on current climate conditions and other super-design floods would overtop the existing stopbank along much of its length and flow overland across the floodplain. This is illustrated by Figure 8 which shows the extent of flood inundation across the floodplain resulting from stopbank overtopping by the 0.2% AEP super-design flood adjusted for possible future climate change effects to 2090. Depending on the level of stopbank overtopping, such overtopping could potentially also cause a stopbank breach to develop.

Construction of the proposed Expressway provides an opportunity to provide a secondary line of flood defence for Otaki Township in the event of the occurrence of stopbank overtopping. The embankment on which the Expressway is conveyed can be constructed so that it is elevated sufficiently to act as a flood detention dam and at least partially store the volume of water overtopping the stopbank, thereby reducing the effects of flood inundation downstream through Otaki Township. The embankment for the proposed Expressway has been configured in this way with the vertical alignment generally set to

have a minimum 0.3m freeboard above predicted flood levels in the ponding area upstream of the embankment for the design 0.2% AEP flood based on current climate conditions overtopping the Chystall's Bend extended stopbank.

Figure 9 shows the extent of flood inundation for the proposed Expressway situation for the 0.2% AEP super-design flood adjusted for possible future climate change effects to 2090. In this case the Expressway has been assumed to incorporate a 20m wide by 1m high dry culvert through the embankment to allow leakage of of upstream ponded floodwaters to the downstream side. Upstream of the Expressway embankment, the extent of flood inundation is mostly confined to a narrow strip 100-200m wide. However it does spread northwards into the detention pond area for localised flood events in the Mangapouri Stream. This in fact appears to be the only area where residential properties are inundated by the ponding of stopbank overtopping floodwaters as the narrow strip pf inundation to the east of the Expressway and south of Rahui Road appears to be devoid of any houses.

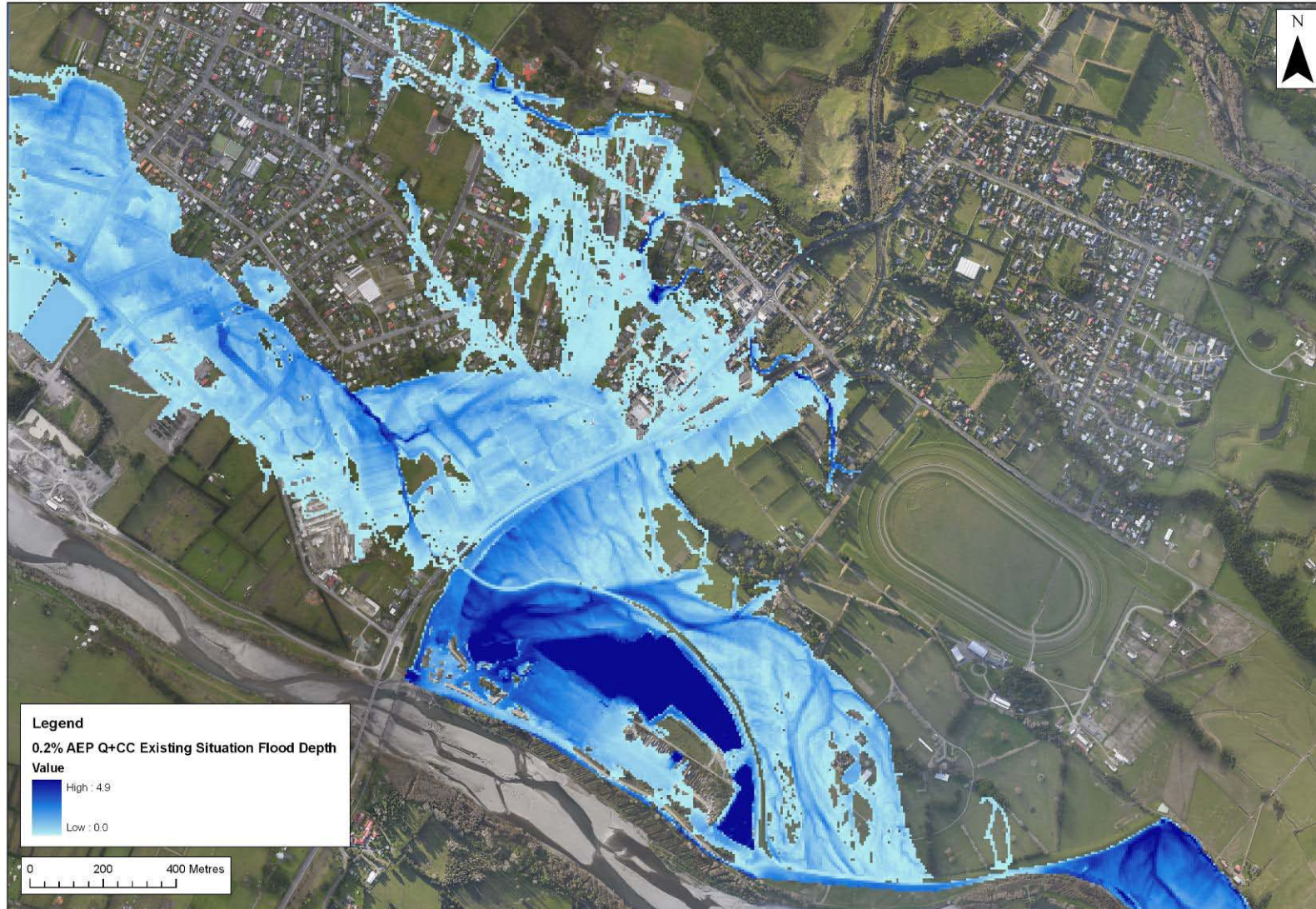


Figure 8 Extent of flood inundation upstream for existing situation on Otaki River floodplain for 0.2% AEP flood adjusted for possible effects of future climate change with stopbank overtopping

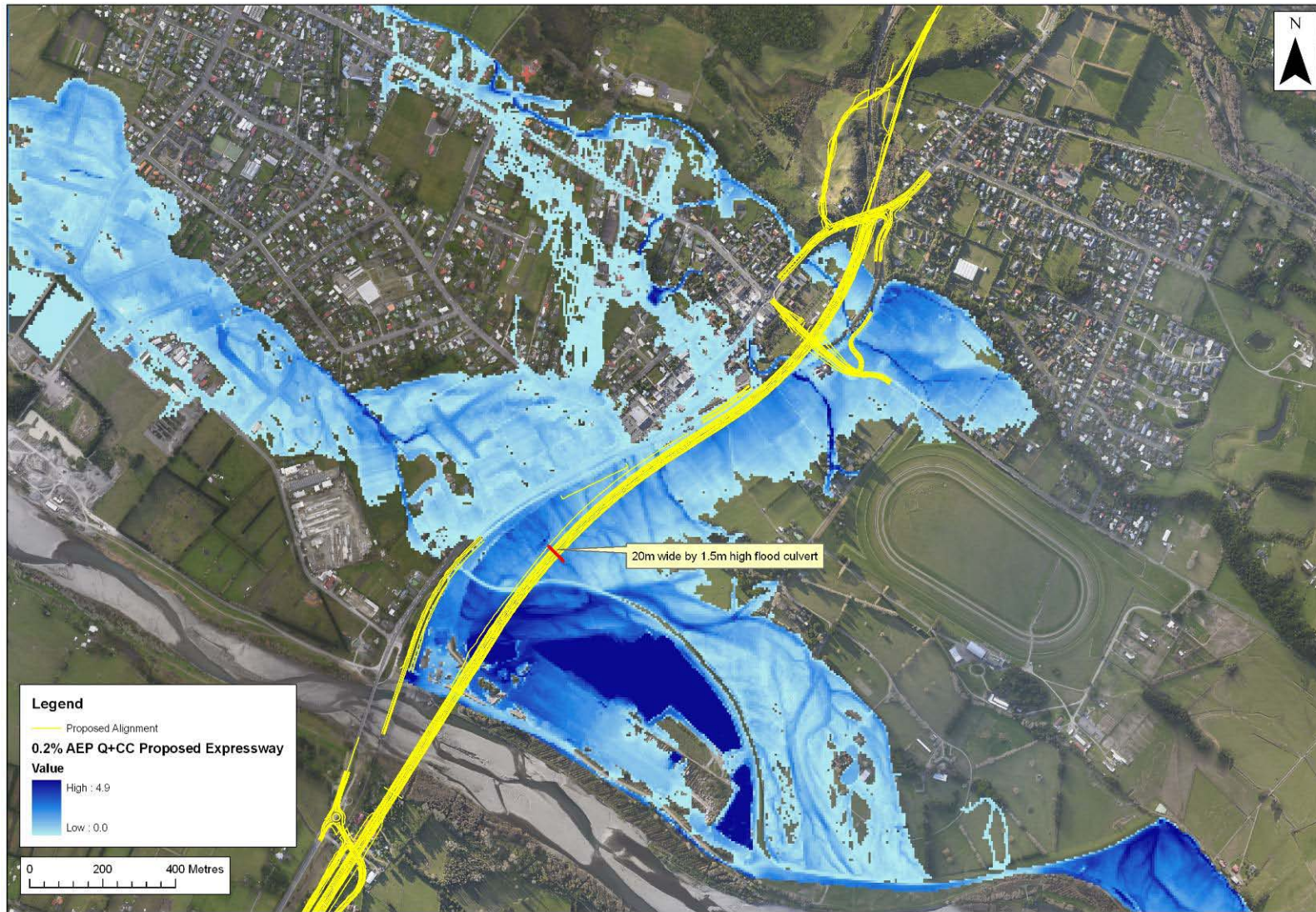


Figure 9 Extent of flood inundation for proposed Expressway situation for 0.2% AEP adjusted possible effects of future climate change with stopbank overtopping

Downstream of the Expressway embankment, the flood inundation pattern for the proposed situation (Figure 9) is fairly similar to that for the existing situation (Figure 8) with the bulk of the overland flow following a natural secondary overflow path parallel to the line of the river but confined along its northern boundary by a low terrace (this covers an area of light industrial development within Otaki Township). There is also a small amount of overland flow to the north through some of the residential and commercial parts of Otaki Township although the magnitude of this is reduced compared to that for the existing situation (Figure 8). The reduction is a consequence of the incorporation of the normally dry culvert through the Expressway embankment adjacent to the Chystall's Bend extended stopbank.

6.4 Mitigation Measures

In order to reduce the extent of flood inundation for the design flood case and for any super-design flood case as seen in Figure 9, a dry culvert through the road embankment immediately to the north of the Chystall's Bend extended stopbank needs to be provided. This culvert would enable outflow from the detention pond area upstream of the Expressway embankment to be directed more towards existing secondary overland flow paths across the existing SH1 and downstream as seen in Figure 8.

The vertical alignment of the Expressway embankment across the Otaki River floodplain has been configured to gradually slope down from the river crossing in the south to get under the Rahiui Road overbridge adjacent to the Mangapouri Stream. The level of the Expressway at the overbridge has been set below the required level determined from the flood inundation investigations. As a consequence a low bund along the eastern side of the Expressway will need to be provided over a short distance south of the Rahiui Road overbridge in order to contain floodwaters and prevent breakout from occurring through Otaki Township for the design flood and other larger sup-design floods.

6.5 Degree of Effect

The degree of effect for the Expressway crossing of the Otaki River and floodplain is assessed to be MEDIUM upstream of the proposed Expressway relative to the existing situation. This is due to the increased extent of inundation in the Mangapouri Stream flood ponding area upstream of the Expressway embankment in the proposed situation (Figure 9) compared to the existing situation (Figure 8). However the additional extent of inundation is no worse than that resulting from the design flood in the Mangapouri Stream (Figure 4) which would typically arise from a short duration high intensity rainstorm (i.e. thunderstorm) compared to longer duration frontal weather systems which generate large floods in the Otaki River Catchment.

The proposed Expressway will provide a positive benefit for property owners to the west of the Expressway up to the level of the 0.2% AEP design flood case as the embankment conveying the road will act as a partial flood detention barrier for floodwaters overtopping the Chystall's Bend extended stopbank.

6.6 Costs

The cost of the dry culvert which is required as a flood mitigation measure for limiting the depth and extent of ponding upstream of the Expressway embankment has been included in the overall engineering cost for the PP20 Project.

7 Mangaone Stream Crossing

7.1 Existing Situation and Flood Hazard

The Mangaone Stream exits from the foothills of the Tararua Ranges and flows westwards across the coastal plain over a distance of about 7km to the sea. State Highway 1 and the NIMT railway line, which run parallel to each other along the coastal plain, follow a roughly north-east / south-west alignment and cross the Mangaone Stream at Te Horo, about halfway between the foothills and the sea.

Under significant flood conditions, the Mangaone Stream breaks out of its relatively low banks across an alluvial fan (which forms part of the coastal plain) and follows a number of separate flow paths down to the railway line. The railway line acts as a partial barrier for these flood flows with intercepted overland flows from the alluvial fan being directed back towards the Mangaone Stream by the natural topography of the plain. Figure 10 shows an aerial photograph looking east across SH1 and the NIMT railway line after the peak of the 28 October 1998 flood (the second largest flood on record) in the Mangaone Stream. This shows overland flow paths across the alluvial fan surface upstream of main stream crossing with floodwaters ponded upstream of the railway line and flood breakout along the Lucinsky overflow path on the right bank downstream of the SH1 culvert. SH1 would have been inundated by overtopping flow during this flood event.

A complex culvert system has been constructed to convey intercepted flood flows past the railway line and SH1 (Figure 11). The Mangaone Stream has railway and road culvert crossings but there are additional inter-connected overflow culverts (that are normally dry) under both transport facilities that direct flow through a gap in the houses and other buildings on the west side of SH1. This overflow floodway is located close to the low point on the coastal plain to the south of main stream crossing and in fact conveys the bulk of the flood volume past SH1 in a significant flood event, Road overflow (and probably also railway embankment seepage) is a known problem in significant flood events and occurs every few years as illustrated by Figure 10..



Figure 10 28 October flood in Mangaone Stream - view looking east across SH1 and NIMT railway line crossings of stream



Figure 11 Existing SH1 and NIMT railway crossings of Mangaone Stream with layout of stream channel and secondary overland flow paths

The School Road drain to the south of the Mangaone Stream also collects surface runoff from part of the coastal plain upstream of the railway line and SH1. It directs runoff to the overflow culvert system from the Gear Road / School Road intersection. It also has known flood inundation problems which are related to the configuration and size of the drain itself rather than the railway line and SH1. Historic modification of natural drainage paths in this area may also be factor in the School Road flooding issue.

The main stream channel downstream of the SH1 crossing has limited flood capacity and extensive overland flow from flood breakouts occurs as a consequence (MWH 2002a; MWH, 2002b).

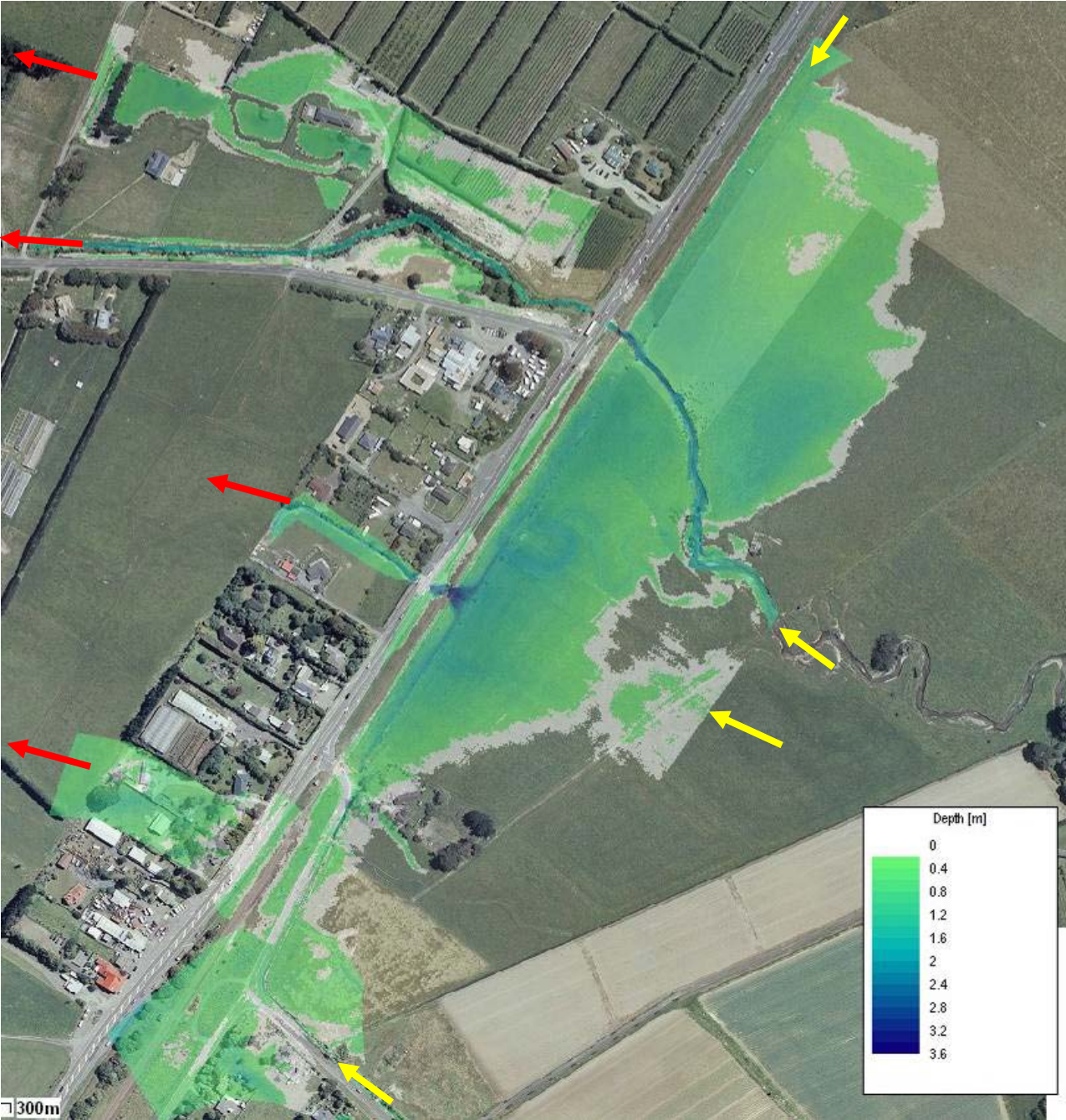


Figure 12 Flood inundation map for existing situation for 1 % AEP flood adjusted for possible climate change effects to 2090

The design flood for this crossing was selected as the 1% AEP flood adjusted for the effects of possible future climate change. This flood has an estimated peak discharge of 80.2m³/s at the existing NIMT railway line and State Highway 1 (SH1) road crossings of the Mangaone Stream.

The hydraulic performance of the existing Mangaone Stream / School Road Drain System was analysed using a one-dimensional computational hydraulic model. Figure 12 shows the estimated upstream extent of flood inundation for the existing situation for the 1% AEP flood adjusted for the effects of possible future climate change,

7.2 Proposed Situation

The proposed Expressway will run parallel with the NIMT railway line and SH1 but on the upstream side of the railway line. This will require new culverts under the Expressway to provide continuity with existing drainage paths. (Figure 13)

The situation is further complicated by the need to provide an east / west local road link connecting Gear Road / School Road with Te Horo Beach Road. The Scoping Report recommendation was for an overbridge connection off School Road which then turned ninety degrees behind Te Horo Village on the west side of SH1 To connect to Te Horo Beach Road at a tee intersection. Consultation with local residents indicated a preference for an alternative option which involves a northerly extension to a relocated Gear Road on the east side which loops round to cross over the Expressway via an overbridge and then loops southwards to connect up with Te Horo Beach Road at a tee intersection. This option has since been endorsed by NZTA as the preferred solution on the basis of a recommendation from the PP2O Project Team.

The preferred option involves two additional crossings of the Mangaone Stream, with both the eastern and western approach embankments to the overbridge located through known overland flow path areas. In the case of the eastern approach embankment, the overland flow paths run parallel to the general direction of the stream upstream of the NIMT railway and SH1 road crossings (see Figure 13). With the western approach embankment, the overflow path runs through the old Lucinsky property having broken out of the main channel along the right bank downstream of the existing SH1 culvert. (Figure 10).

Road geometric design considerations indicate that the eastern approach embankment does not need to rise above natural ground level in order to achieve the required clearance over the expressway till north of the additional Mangaone Stream Crossing upstream of the Expressway. However the governing criterion for setting road levels in this area will be achieving the required freeboard above design flood level at the Mangaone Stream crossing and at the overland flow path just to the south of the main stream crossing. This will require the roadway to be elevated but not to same level as the Expressway.

7.3 Relative Effects of Proposed Stream and Floodplain Crossing

With the proposed Expressway and local link road in place, peak flood levels upstream of the existing railway and SH1 road culverts remain much the same as for the existing situation and peak discharges downstream of SH1 are also very close. This means that the extent of flood inundation downstream of Te Horo along the Mangaone Stream will be unchanged from the present situation for a flood of the same magnitude. However there will be a moderate increase in flood levels upstream of the Expressway.

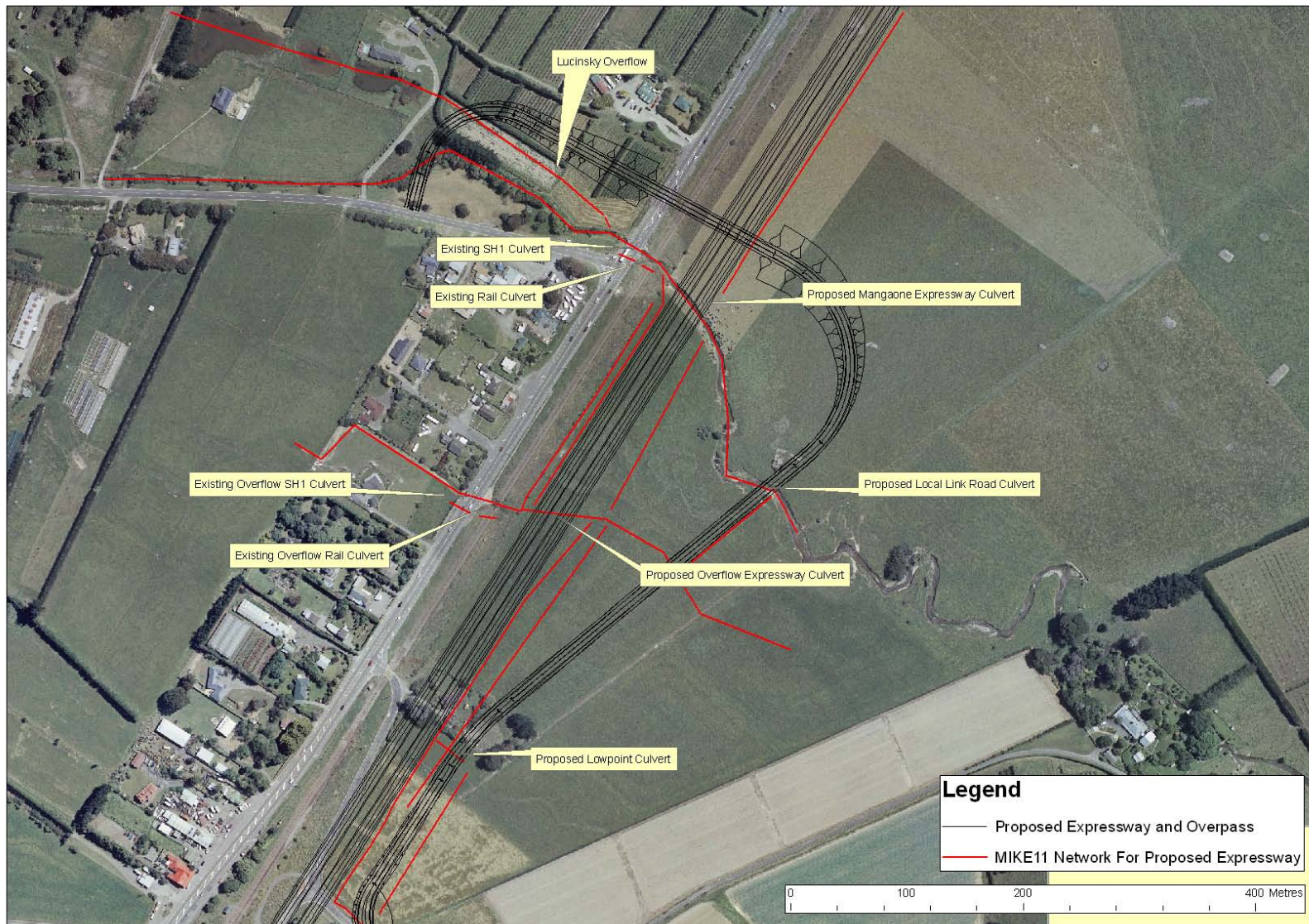


Figure 13 Proposed Expressway crossing of Mangaone Stream with local link road Option B

The Expressway embankment through this area takes over the function of the railway embankment in the existing situation as a flood detention bund. In order to make a valid comparison between the existing and proposed situations (by excluding the effect of the sloping alluvial fan surface), it is necessary to consider the relative maximum flood depth of the upstream pond in each case (rather than the peak flood level), even though the railway line and the expressway embankment are spatially separated by a distance of more than 50m.

Table 4 below compares the relative peak flood depths for the design flood at three locations along the length of the flood pond areas in the existing and proposed situations.

Table 4 Relative peak flood depths for design 1% AEP flood adjusted for climate change effects in flood ponding areas for existing and proposed situations

Location	Existing Situation (u/s of railway embankment)			Proposed Situation (u/s of expressway embankment)			Relative Increase in Peak Depth (m)
	Ground Level (m MSL)	Peak Flood Level (m MSL)	Peak Depth (m)	Ground Level (m MSL)	Peak Flood Level (m MSL)	Peak Depth (m)	
Mangaone Stream	18.25	19.34	1.09	18.65	20.41	1.76	0.67
Mangaone Overflow	17.85	19.33	1.48	18.45	20.44	1.99	0.51
School Rd Drain	18.85	19.28	0.43	19.45	20.36	0.91	0.48

Table 4 indicates that the relative increase in peak flood depths between the proposed and existing situations at these ponding area locations is in the range of about 0.5-0.7m. The increased peak flood depths in the proposed situation are due to a number of factors:

- the prevention of road overtopping on the Expressway in the design flood case;
- the elimination of leakage over the railway line and SH1 from the Gear Road / School Road intersection which occurs in the existing situation; and
- the slope (> 1%) of the alluvial fan surface that the Mangaone Stream flows across towards the sea.

The increased peak flood depths will be reflected in a slightly greater areal extent of flood inundation in the proposed situation relative to the existing situation.

For flood levels upstream of the Expressway to remain similar to those in the present situation, overtopping of the Expressway embankment would have to be allowed to occur which runs counter to the design requirement for the Expressway to be a lifeline link.

The local link road embankment and culvert across the Mangaone Stream causes peak flood levels in the design flood case to be further elevated. The predicted flood level is likely to be a conservative estimate as, in practice, leakage of ponded floodwaters from the storage area upstream of the local link road to the storage areas either side of the Expressway culvert crossing of the Mangaone Stream would occur. This leakage has only been partially allowed for in the computational hydraulic modelling.

Peak flood levels and discharges upstream of the local link road crossing of the Lucinsky overflow (west of SH1) in the design flood case are generally very similar to the corresponding values for the existing situation. This means that the incorporation of a wide box culvert (10m x 1m) in the western approach embankment to the local link road overbridge is sufficient to not impede flood breakout flows along the Lucinsky overflow path (the flow depths along this overflow path are shallow and wide).

Although the peak flood levels upstream of the Expressway are higher in the design flood case, the extent of flood ponding is constrained by the eastern approach embankment to the local link road overbridge and, more importantly, the steep slope (> 1%) of the alluvial fan surface upstream of the Expressway.

Figure 14 shows the estimated upstream extent of flood inundation for the proposed situation for the 1% AEP design flood adjusted for the effects of possible future climate change. This inundation map indicates that the extent of flood ponding upstream of the Expressway and local link road is well short of any residential properties and covers only land used for pastoral purposes. Fortunately this area is devoid of such properties that would remain after construction of the Expressway.

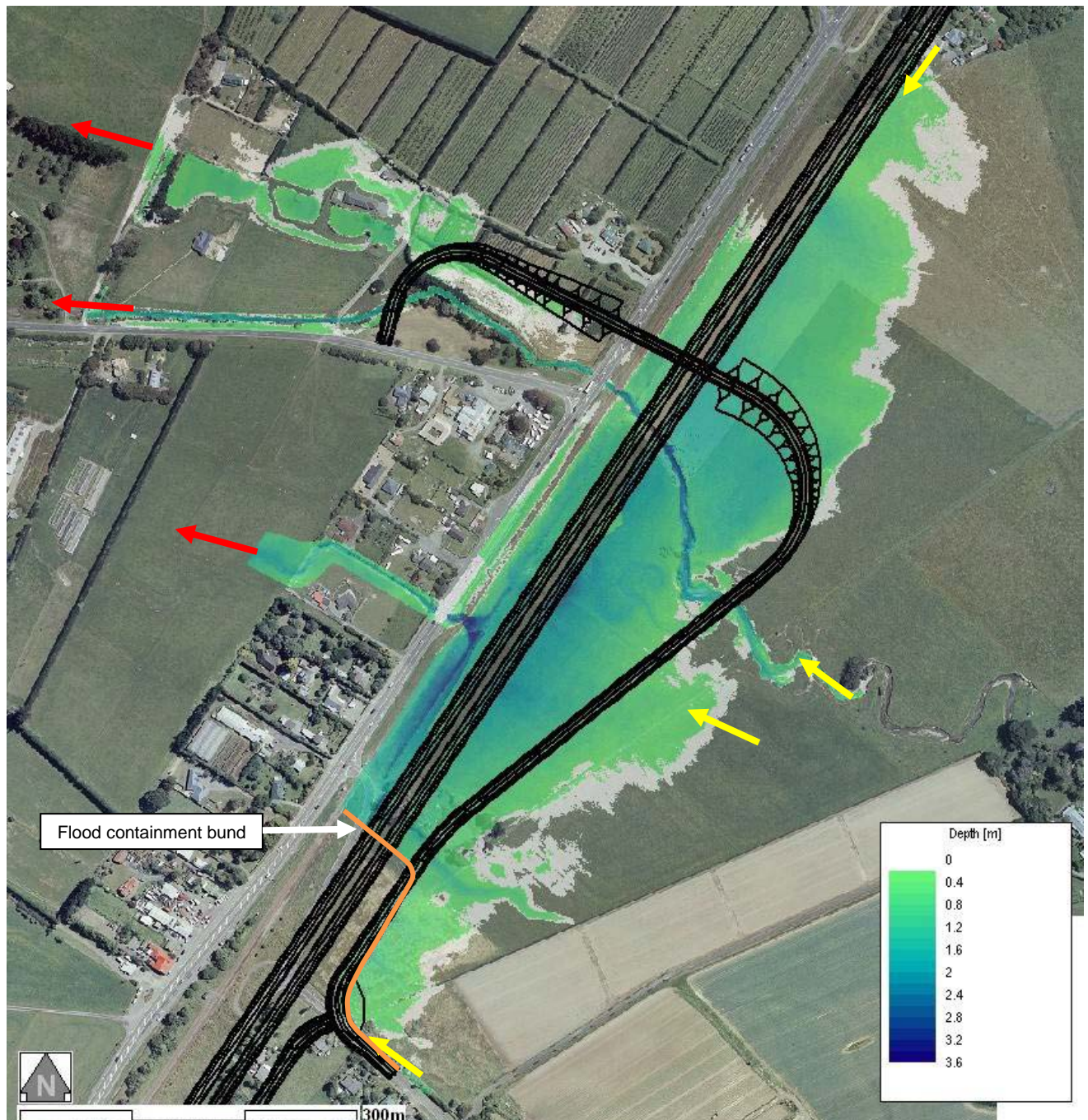


Figure 14 Flood inundation map for proposed situation for 1 % AEP flood adjusted for possible climate change effects to 2090 (inflow paths indicated by yellow arrows, outflow paths by red arrows)

7.4 Mitigation Measures

Table 5 summarises the required culvert types and dimensions for the modified culvert and stream system for the Mangaone Stream Crossing. The existing NIMT railway and SH1 culverts will remain unchanged.

Table 5 Culvert types and dimensions for Mangaone Stream Crossing (local link road Option B)

Location	Type	Size (m)	Length (m)	Slope (%)
Mangaone Stream				
Local link road – proposed (eastern side)	box	10.0 x 2.0	16	1.19
Expressway	box	5.0 x 2.0	50	2.14
NIMT railway - existing	box	3.0 x 2.8	2	2.5
SH1 - existing	box	4.8 x 1.75	8	2.5
Local link road – proposed (western side)	single span bridge	as per waterway		
Mangaone Overflow				
Local link road - proposed	see note 1 below			
Expressway - proposed	box	8.0 x 1.5	50	0.76
NIMT railway - existing	box	6.0 x 1.5	4.5	11.1
SH1 - existing	box	3.7 x 2.1	8	2.5
School Rd Drain				
Local link road – proposed	circular ³	0.35	16	0
Lucinsky Overflow				
Local link road – proposed	box	10.0 x 1.0	16	0.63

Notes

1. No culvert provided at this location as local link road assumed to be constructed at grade through the overland flow path.
2. Road level at this location to be determined as a result of the investigations summarised in this memo
3. School Road Drain assumed to be diverted to run parallel with new local link road from Gear Road / School Road intersection to a low point in the ground topography opposite existing Gear Road / SH1 intersection. A 0.35m diameter culvert under local link road provided to connect to flood storage area between local link road and proposed Expressway. In extreme flood situations, flood storage area would expand to inundate local link road and culvert.

7.5 Degree of Effect

The degree of effect for the Expressway crossing of the Mangaone Stream and floodplain is assessed to be LOW.

The proposed Expressway will provide a positive benefit for property owners to the west of the existing SH1 where currently overland flow breaks out of the main stream channel under significant flood conditions.

7.6 Costs

Costs of any culverts which are required as part of the complex drainage system for the Mangaone Stream Crossing will be included in the overall engineering cost for the PP2O Project.