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**KENDERDINE STORMWATER CATCHMENT**  
**MANUKAU CITY**  
**Stormwater Modelling and Upgrade Option**  
**Assessment**

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Prepared for  
**Fraser Thomas Ltd**  
February 2006

# KENDERDINE STORMWATER CATCHMENT MANUKAU CITY

## Stormwater Modelling and Upgrade Option Assessment

February 2006

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## **GLOSSARY**

AEP Annual Exceedence Probability

CMP Catchment Management Plan

FTL Fraser Thomas Limited

HMSL Hydraulic Modelling Services Ltd

LIR Land Information Records

MCC Manukau City Council

MOUSE DHI pipe network modelling software

MPD Maximum Probable Development

NIMT North Island Main Trunk

## **REFERENCES**

1/ Guidelines for Stormwater Runoff Modelling in the Auckland Region,  
TP108, Auckland Regional Council, 1999.

## **DISTRIBUTION**

Fraser Thomas Ltd	4 copies
Hydraulic Modelling Services Ltd	1 copy

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# 1 INTRODUCTION

## 1.1 General

This report investigates the capacity of the stormwater drainage systems within the Kenderdine catchment. It considers runoff for the current and the Maximum Probable Development (MPD) land-use according to the District Plan. Pipe upgrades required to convey the 20%AEP 24-hour event within the pipe system are identified. Options to mitigate flooding within the catchment during the 1%AEP event with the MPD land-use were investigated.

Mitigation options considered include:

- Better utilisation of available storage within the Kohuora Crater.
- Increasing the size of the culvert at 36 Hillside Road.
- Increasing the pipe capacity upstream of the railway line and upgrading the Hillside Road culvert.

## 1.2 Catchment Description

The Kenderdine Stormwater catchment is situated in Manukau City approximately 1km north of the Manukau Shopping Centre. The boundaries of the catchment can be seen in Map A1 (Appendix 1).

The area of the catchment is 321ha and consists of a wide valley that runs east to west. It is drained via a stream which runs along the valley floor.

The Kohoura crater is situated on the northern side of the valley and drains to the main stream via an 1.8m diameter culvert situated in a low point in the crater wall. The floor of the crater contains open drains and an area of peat swamp which acts as stormwater retention. The floor of the crater also contains a closed landfill.

The North Island Main Trunk (NIMT) railway line runs north to south through the catchment. The railway line is situated on an elevated embankment

where it crosses the valley floor. This prevents overland flow across the track. A 1.8m diameter culvert runs under the track. The upper reach of the stream to the east of the railway has been piped.

There are a number of culverts along the main stream which are required for road crossings (South Western Motorway, Ferndown Ave, Hillside Road, Wyllie Road, and North Island Main Trunk Railway to Kenderdine Road). There are two privately owned culverts required for vehicle access to properties off Hillside Road. Table 1 lists key culvert sizes.

Table 1 Key Culverts

<b>Location</b>	<b>Culvert Size</b>	<b>Culvert length</b>
South Western Motorway	2.5m diameter	63.8m
Ferndown Ave	Twin 1.8m diameter	43.4m
Hillside Road	1.8m diameter	19.2m
Driveway culvert, 40, 42, 46, 48, 50 Hillside Road	2.0 to 3.2m wide x 1.9m high box section. Modelled as 2.2 x 1.9m box section.	13.9m
Driveway and carport culvert, 36 Hillside Road	1.5 x 1.5m box section.	13.9m
Wyllie Road	1.6 x 1.6m box section	22.9m
Crater Outlet	1.8m diameter	205.1m
North Island Main Trunk Railway to Kenderdine Road	1.6m diameter	126.2m

The catchment contains an extensive network of relatively small diameter pipes that drain to the crater, main stream, and the piped section of stream upstream of the railway line.

Flooding problems within the catchment can be categorised into three types:

- Flooding due to insufficient capacity in the pipe reticulations resulting in overland flows and localised ponding.
- Flooding due to the main stream having insufficient capacity resulting in the stream overtopping its banks.
- Flooding in the crater entering private property.

The land-use is predominantly residential with a commercial area centred on George Street.

### **1.3 Model Accuracy**

The catchment boundaries used for the hydrological model were delineated onsite by Hydraulic Modelling Services Limited (HMSL) staff and should be sufficiently accurate for the intended purpose. The percentage impervious area for each catchment was supplied by Manukau City Council (MCC) and is considered to be accurate.

The location of cross-sections surveyed along the main stream can be seen in Map A3 (Appendix 1). The greatest distance between cross-sections is approximately 420m between x sect 32 Hillside Road and XSECT09 which is located adjacent to 118 Hillcrest Road. This reach contains three culverts which will have a greater effect on hydraulics along this reach than variation in the cross-section. All of these culverts have been surveyed. The rest of the cross-sections on the main channel are less than 210m apart.

The lid and invert levels of 40% of the manholes were obtained from the various sources described in Section 2.3. The remaining 60% of the manholes were estimated from 2m contour plans.

Survey information was provided for a culvert under the Southwestern Motorway near the loop in the southern end of Hillside Road and for another culvert further downstream on the western side of the motorway. No information was supplied regarding the open drains that connect the piped reticulation to these culverts, or the drain between these culverts. The network layout and open drain cross-sections in this area are assumed.

The storage volume in the crater, which is a critical aspect of the stormwater network, is assumed based on previous analysis of the network by Manukau Consultant. The drainage network in much of the crater is assumed.

## 2 METHODOLOGY

### 2.1 Modelling Software

The modelling software used is required to incorporate the following hydrological and hydraulic capabilities:

Hydrology: The model converts rainfall into runoff taking into account losses that include evaporation, infiltration and different land-uses.

Hydraulics: The model uses the surface flow at the point of entry to the drainage system and conveys flows within the system. Further, the model determines the peak transient flood levels along the piped and open channel sections, accounts for energy losses at culverts, and permits storage on floodplains.

The MOUSE software package, which is widely used within New Zealand by a number of territorial local authorities and consultants, was used for this project. MOUSE uses the rain depth distribution, the catchment area and land-use run-off factors to calculate flows to a point in a subcatchment and also produces flow hydrographs and performs the hydraulic analyses.

The benefits of using MOUSE include:

1. The resulting flows are temporal (not steady) during the duration of the storm event. This is better than the Rational Method as the flows are allowed to change through the flood event.
2. MOUSE also accounts for the dynamic effects of subcatchment inflows and channel storage. It produces flows, velocities and water levels throughout the drainage, system based upon the cross-sections and a longitudinal grid system.
3. MOUSE can calculate backwater effects for a constantly changing flow and downstream control conditions.

## 2.2 Hydrological Model

The whole study area was divided into 380 subcatchments by HMSL staff. Subcatchment delineation was done onsite with reference to the 2m contour plans and stormwater network reticulation plans. The subcatchments were named according to the manhole that each drains to. Subcatchment boundaries were supplied to MCC GIS staff, who provided pervious and impervious areas for each catchment and a plan showing subcatchment boundaries. Map A2 (Appendix 1) shows the subcatchment boundaries. This plan does not show subcatchments names as this would make the plan overly cluttered. The subcatchments names are stored in MCC's GIS system. Separate pervious and impervious catchments were entered into the model for each subcatchment. This allows the curve numbers for pervious and impervious areas to be changed independently.

Curve Numbers were determined from 'Table 3.3 – Curve Numbers for Typical Auckland Conditions' in TP108. Impervious areas were given a Curve Number of 98. Pervious areas were given a Curve Number of 39 (urban lawns, Group A Soils).

Initial abstraction depth was set to 0mm for impervious catchments and 5mm for pervious catchments as per 'Table 3.1 – Initial Abstraction Depths' in TP108.

Table B1 (Appendix B) contains the catchment names, areas, and Curve Numbers used for both the current and MPD situations.

The percentage impervious area of each subcatchments was increased by 5% to a maximum of 54% for the MPD case. Some subcatchments, such as the commercial areas around George Street, already have impervious areas exceeding 54%. The impervious areas in these catchments were not increased for the MPD model. Impervious catchments were given a Lag Time of 0.17 hours, while pervious catchments were given a Lag Times of 0.5 hours. The areal reduction factor was set to 1.0 for all catchments.

Synthetic design rainfall events were derived from TP108. Rainfall was modelled in 10 minute increments. The 1%, 2%, 20%, and 50%AEP events were analysed.

### **2.3 Hydraulic Model**

The manhole locations, names, and pipe diameters were provided by MCC.

Manhole lid and invert levels used in the model were taken from a variety of sources including:

- Data provided by MCC.
- Papatoetoe City Council Underground Services Plans which were drawn in the 1960s.
- Survey undertaken by GHD Ltd for MCC in 1995.
- Survey undertaken by Fraser Thomas Limited (FTL) during May 2005 for this project.

Where no lid or invert information was available the levels were interpolated using 2m contour plans provided by MCC and the levels of upstream or downstream manholes where available. Of the 737 manholes in the model, 437 have interpolated lid and invert levels.

Fraser Thomas Limited (FLT) provided surveyed cross-sections of the main stream and the largest channel in the crater. FTL also provided survey data for the driveway culverts off Hillside Road. It is recommended that the surveyed manhole lid and invert levels be captured in the MCC asset data system for future use. The location of surveyed cross-sections can be seen in Map A3 (Appendix 1). Results of the cross-section survey are shown in Table B5 (Appendix B).

There are a number of pipe outlets around the periphery of the crater floor. Levels for some of these pipe outlets were surveyed by FTL. Assumed open channels were added to the model to connect these pipe outlets to the portion of the open channel in the crater that FTL had surveyed. Map A3 (Appendix

1) shows the surveyed and assumed open drains. No information was available as to the size, shape or location of the assumed open drains. While the storage capacity of the crater is a critical feature of the stormwater system, surveying of the crater was not commissioned due to the practical difficulties (extensive vegetation and high groundwater levels in the crater), and prohibitive cost of such an exercise.

According to the Manukau Consultants Comprehensive Flood Management Study (1992) the peak water level in the crater during the 1%AEP event is RL8.0m. Subsequently, the size of the assumed open drains was adjusted to give a modelled peak water level of 8.0m for the 1%AEP event, resulting in a cross-section 2m wide at the base, 5m wide at the top and 3m deep for the assumed open drains.

Simulation of the 1%AEP storm indicates that over 50% of the manholes in the catchment will overflow. Without any survey data relating to overland flow paths nor any information as to the actual level at which the overland flow would operate, the overland flows were accounted for by adding weirs to the overflowing manholes, with the weir crest height set to the manhole lid level. The contour plans were used to determine the point of discharge downstream of the weirs. It is generally assumed that secondary flows travel along roads unless the topography or manhole locations indicate otherwise.

The hydraulic parameters for the main stream and open channels were set to Manning's  $M = 30$  and all pipes were set to Manning's  $M = 85$ .

An assumed water level of RL1.0m was used as the downstream boundary condition. To check the sensitivity of the model to the downstream boundary condition, a model of the existing system based on current land-use was also run for the 1%AEP storm with the downstream water level increased to RL2.0m. This resulted in higher water levels as far upstream as cross-section 2. The location of cross-section 2 can be seen in Map A3 (Appendix 1)

### 3 RESULTS

Tables A2 and A3 (Appendix B) show the water depths and flows calculated throughout the system for all model runs. Table 2 below gives water levels, flows and velocities at the outlet of the motorway culvert for all scenarios modelled. Table 3 gives water levels at key locations for the various model runs as detailed on Table 3.

Table 2 Motorway Culvert Water Levels, Flows and Velocities for All Events Modelled.

Event	Catchments	Network	W.L RL (m)	Flow (m <sup>3</sup> /s)	Velocity (m/s)
Water Quality	Current	Existing	1.9	1.9	0.8
50%AEP	Current	Existing	2.4	6.4	1.1
20%AEP	Current	Existing	2.6	10.0	1.2
2%AEP	Current	Existing	2.9	16.4	1.4
1%AEP	Current	Existing	3.0	18.5	1.5
Water Quality	MPD	Existing	1.9	2.0	0.8
50%AEP	MPD	Existing	2.4	6.6	1.1
20%AEP	MPD	Existing	2.6	10.2	1.3
2%AEP	MPD	Existing	2.9	16.8	1.4
1%AEP	MPD	Existing	3.0	18.9	1.5
20%AEP	Current	Option 1a	2.7	12.3	1.3
20%AEP	MPD	Option 1	2.8	12.7	1.3
1%AEP	MPD	Option 1	3.2	22.4	1.6
1%AEP	MPD	Option 2a + Option 1	3.3	26.2	1.7
1%AEP	MPD	Option 2b + Option 1	3.2	22.5	1.6
1%AEP	MPD	Option 2c + Option 1	3.2	22.2	1.6
1%AEP	MPD	Option 3 + Option 1	3.2	24.7	1.6

Table 3 Water Levels at Key Locations for Various Models.

Event	1%AEP	1%AEP	1%AEP	1%AEP	1%AEP	1%AEP	1%AEP
Land-use	Current	MPD	MPD	MPD	MPD	MPD	MPD
Network	Existing	Existing	Option 1	Option 2a + Option 1	Option 2b + Option 1	Option 2c + Option 1	Option 3 + Option 1
<b>NODEID and Location*</b>							
550313, Crater, near Malaspine Place, 1	8.22	8.26	8.32	8.42	8.54	8.51	8.31
295529, In crater near outlet, 2	8.22	8.26	8.32	8.42	8.54	8.20	8.31
296662, Upstream Hillside Road culvert, 3	8.85	8.86	9.08	9.14	9.08	9.08	9.08
345823, Upstream of Wallace Road, 4	18.07	18.08	17.57	17.57	17.57	17.57	16.08
Outlet1, Upstream of 36 Hillside Rd culvert, 5	11.58	11.59	10.89	10.89	10.89	10.89	11.05
XSECTRAIL, Upstream of railway, 6	14.62	14.62	15.41	15.42	15.41	15.42	14.93
CULV5-INLET, Upstream Wyllie Rd culvert, 7	12.96	12.97	13.12	13.12	13.12	13.12	13.45
STREAM JUNCTION 2, Crater outlet/main stream junction, 8	8.14	8.17	8.25	8.37	8.22	8.21	8.33
STREAM JUNCTION 4, Upstream motorway culvert, 9	3.83	3.86	4.08	4.23	4.09	4.07	4.17
345809, Miles Ave, upstream of railway, 10	18.30	18.31	17.68	17.68	17.68	17.68	16.39
345745, Upstream of Landscape Road, 11	20.75	20.75	20.54	20.54	20.54	20.54	19.35
XSECT07A, Main stream adjacent to Daphne Street, 12	6.61	6.62	6.71	6.82	6.71	6.70	6.78
296194, Claude Street, 13	20.63	20.65	20.34	20.34	20.34	20.34	20.34

Notes:

\* The numbers 1 to 13 in the node location column refer to the key points marked on the Map A3.

Option 1 = Pipe reticulation capacity upgraded to cater for 20%AEP event.

Option 2a = Restrict crater outlet to 600mm diameter.

Option 2b = 1800mm diameter one way flow into crater and 600mm diameter one way flow out of crater.

Option 2c = Split crater into two storage areas.

Option 3 = Upgrade pipe upstream of railway line + Hillside and Wyllie Road culverts.

### 3.1 Existing System

The model of the existing system, with the current and MPD land-use, was run for the 1%, 2%, 20%, and 50%AEP events and the water quality storm.

Map A4 (Appendix 1) shows the extent of flooding in the crater and along the main stream for the 1%AEP event based on 2m contour plans and model accuracy described in Section 1.3 of this document. The difference in water levels between the current and MPD land-use situations is only about 100mm. Thus only one plan is illustrated for both the current and MPD land-use situations as the difference is indistinguishable for the scale of plan used.

Map A5 and A6 (Appendix 1) show the location and peak flows of the overland flows that occur during the 1%AEP event for the current and MPD land-use situation based on the information used as described in Section 1.3.

Although flood levels and overland flow paths may be used for Land Information Record (LIR) purposes it is recommended that the levels be confirmed by detailed surveying and modelling given the model accuracy described in Section 1.3.

Figure 1 shows the flows in the main stream upstream and downstream of the crater outlet, and also through the crater outlet culvert. Figure 2 shows the water level in the main stream at the crater outlet and in the crater at the culvert inlet. Prior to the peak of the storm the water level in the stream is slightly higher than the water level in the crater. This results in a backflow, of up to  $3\text{m}^3/\text{s}$ , into the crater as illustrated by the green line in Figure 1. This helps to attenuate the flow in the main stream, downstream of the crater outlet.

Figure 1 Flows 1%AEP 24-hour storm current land-use and network.

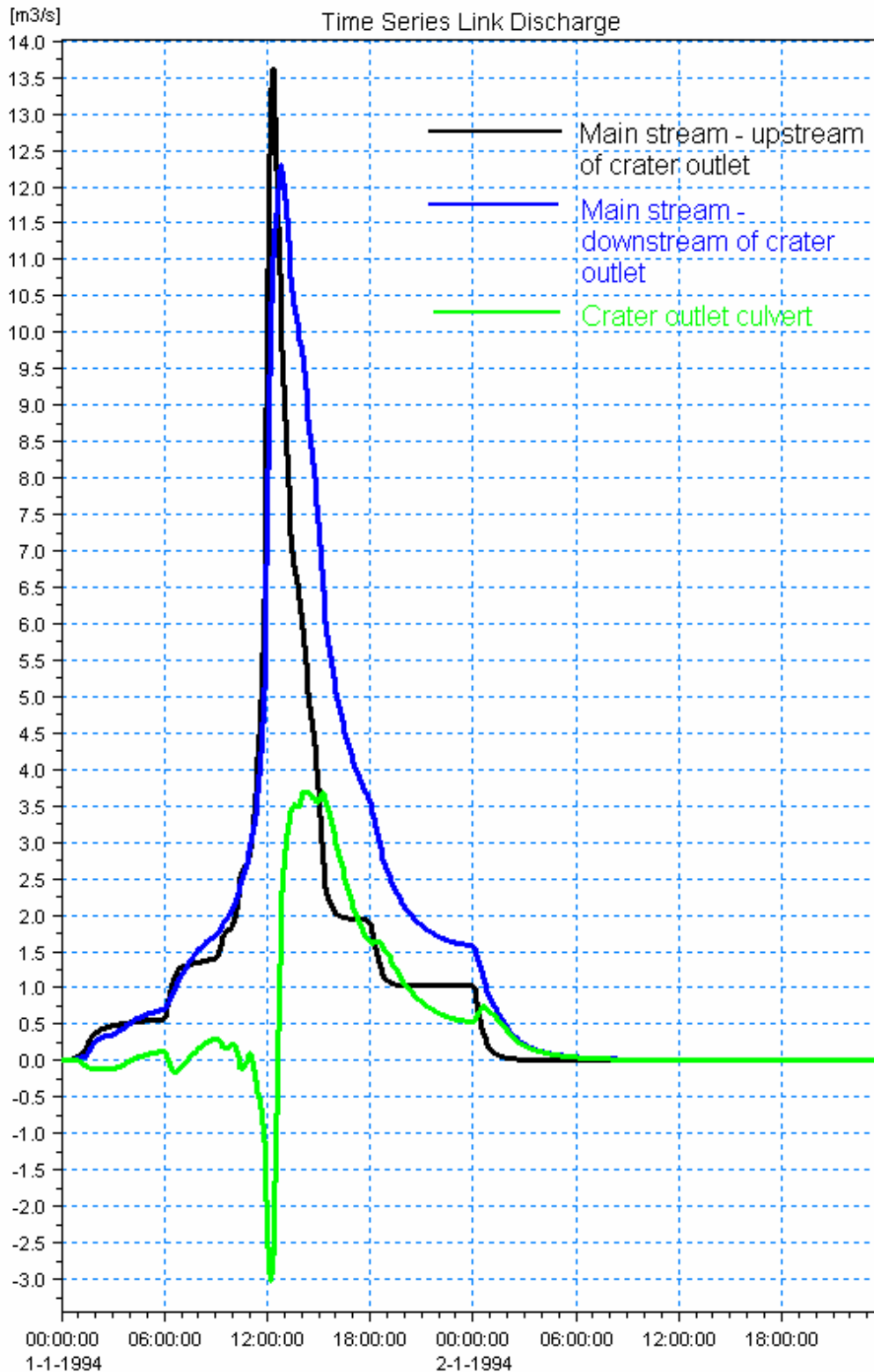
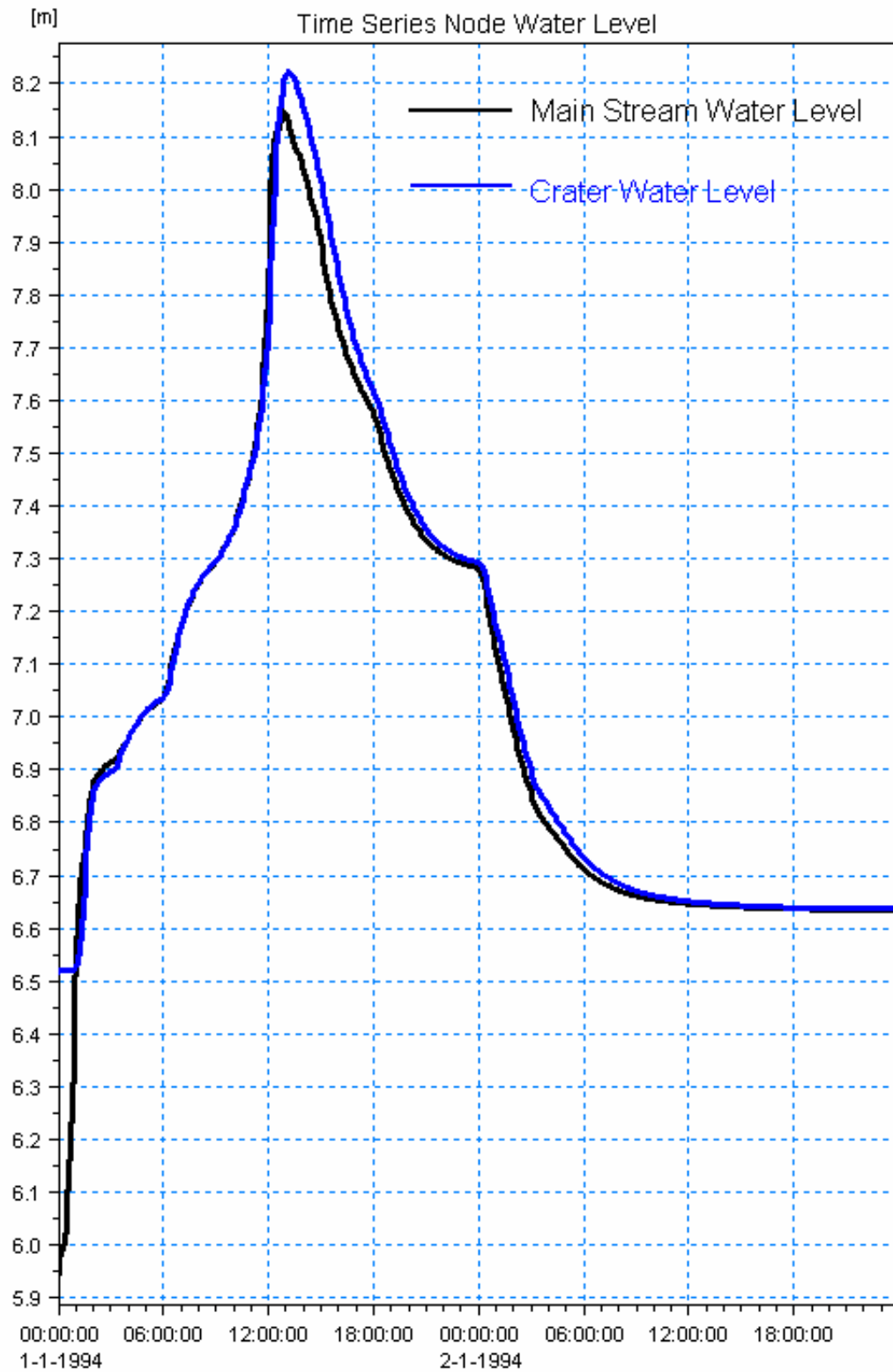




Figure 2 Water levels 1%AEP 24-hour storm current land-use and network



### 3.1.1 Comparison with LIR Information and Previous Studies.

The modelled flood locations are consistent with the information shown in Map A9 (Appendix 1) MCC LIR Information which was provided by MCC. The flood locations and overland flow paths identified in Figures A4 and A5 are also consistent to the locations shown in the LIR information.

Manukau Consultants prepared a report titled 'Comprehensive Flood Management Study Kenderdine Catchment Papatoetoe'. This report included a questionnaire which was sent out to residents and identified the following stormwater issues:

1. The land upstream of the NIMT flooded prior to the installation of new pipes under the NIMT railway. Since the installation of 900mm diameter pipes no reported floodings have occurred.
2. The stormwater pipe upstream of Evelyn Street surcharges.
3. Flooding in the main stream between Kenderdine and Hillside Roads.
4. Flooding and overland flows upstream of Hill Road.
5. Flooding on Narada Place on Ferndown Avenue.

Modelling undertaken for this report confirms that flooding will occur in the locations identified by the resident's questionnaire, and that flooding upstream of the railway line could still occur despite the upgrade.

Manukau Consultants also identified the following issues that are likely to occur during events in excess of the 20%AEP rainfall event:

1. More widespread flooding along 60m north of Evelyn Street.
2. Flooding in the main stream upstream of 36 Hillside Road.
3. Possible ponding upstream of Landscape and Wallace Roads.
4. Overland flow risk in floodplains.

Modelling undertaken for this report confirms that flooding will occur in the locations detailed above. It is also likely that flooding will occur on Fairview Road between Carruth Road and Landscape Road for the 20%AEP event.

## **3.2 Upgrade Options**

### **3.2.1 Option 1: Upgrade Pipes to Convey 20%AEP Event and 36 Hillside Rd Culvert to Convey 1%AEP Event.**

Pipe upgrades required to convey the 20%AEP event within the pipe network were determined for the current and MPD land-use scenarios. The location of pipes requiring upgrades is shown in Maps 7 and 8 (Appendix 1) respectively. Table B4 (Appendix B) shows the existing and required pipe diameters.

A single 1.5m by 1.5 box culvert that passes under a driveway and carport at 36 Hillside Road causes significant localised backwater effect during large storms. The backwater effect extends as far upstream as Wyllie Road during the 1% AEP event and will result in flooding of low lying properties in the area. The effect of upgrading this culvert was tested and the model indicates that a 2.0m diameter culvert would have sufficient capacity for the 1%AEP event. A culvert of this size was included in the model for upgrading the pipes to cater for the 20%AEP event.

The other culverts on the main stream do not significantly restrict flow.

Upgrading the pipe reticulation will increase flows and water levels in the main stream. Figure 3 shows the flows in the main stream upstream and downstream of the crater outlet and also through the crater outlet. Comparing Figure 1 with Figure 3 gives an indication of the increase in flows in the main stream during the 1%AEP event, which results from upgrading the pipe reticulation capacity to convey the 20%AEP event.

It is recommended that the suggested pipe upgrades be confirmed by detailed survey and design given the model accuracy described in Section 1.3.

### 3.2.2 Option 2: Utilising Storage within the Crater

If suitable parts of the Kohoura Crater floor are utilised for stormwater retention ponds, it may be possible to reduce the peak flood levels and flows along the main stream.

The model of the existing network shows backflow of water into the crater that occurs for a short period of time during large events until the water level in the crater exceeds the water level in the main stream, at which point the flow direction changes and water flows out of the crater. The backflow into the crater helps to attenuate the peak water level and flow in the main stream. Figure 3 shows the flows in the main stream upstream and downstream of the crater outlet culvert, and the flow through the crater outlet culvert for the 1%AEP event, with the MPD catchments and the pipe network upgraded as per Option 1.

Three approaches were tested for better utilisation of the storage available within the crater, with the intention of significantly reducing peak flood levels in the main stream. The options analysis considered the MPD land-use scenario and assumed all pipes have been upgraded in accordance with Option 1.

#### 3.2.2.1 Option 2a: Restrict Crater Outlet

The first approach considered the restriction of the crater outlet to 600mm diameter to reduce peak flows out of the crater. It was found that restricting the outlet increased the peak water level within the crater and also reduces backflow from the main stream into the crater. This results in higher peak water levels and flows downstream in the main stream. This option results in the water level at the junction of the crater outlet and the main stream increasing from RL8.25m to RL8.38m. Figure 4 shows the flows in the main stream upstream and downstream of the crater outlet culvert, and the flow through the crater outlet culvert for this approach.

This option results in higher peak water levels in the crater and in the main stream downstream of the crater outlet, as such it is worse than the existing situation.

Figure 3 Flows 1%AEP 24-hour storm MPD land-use and Option 1 network.

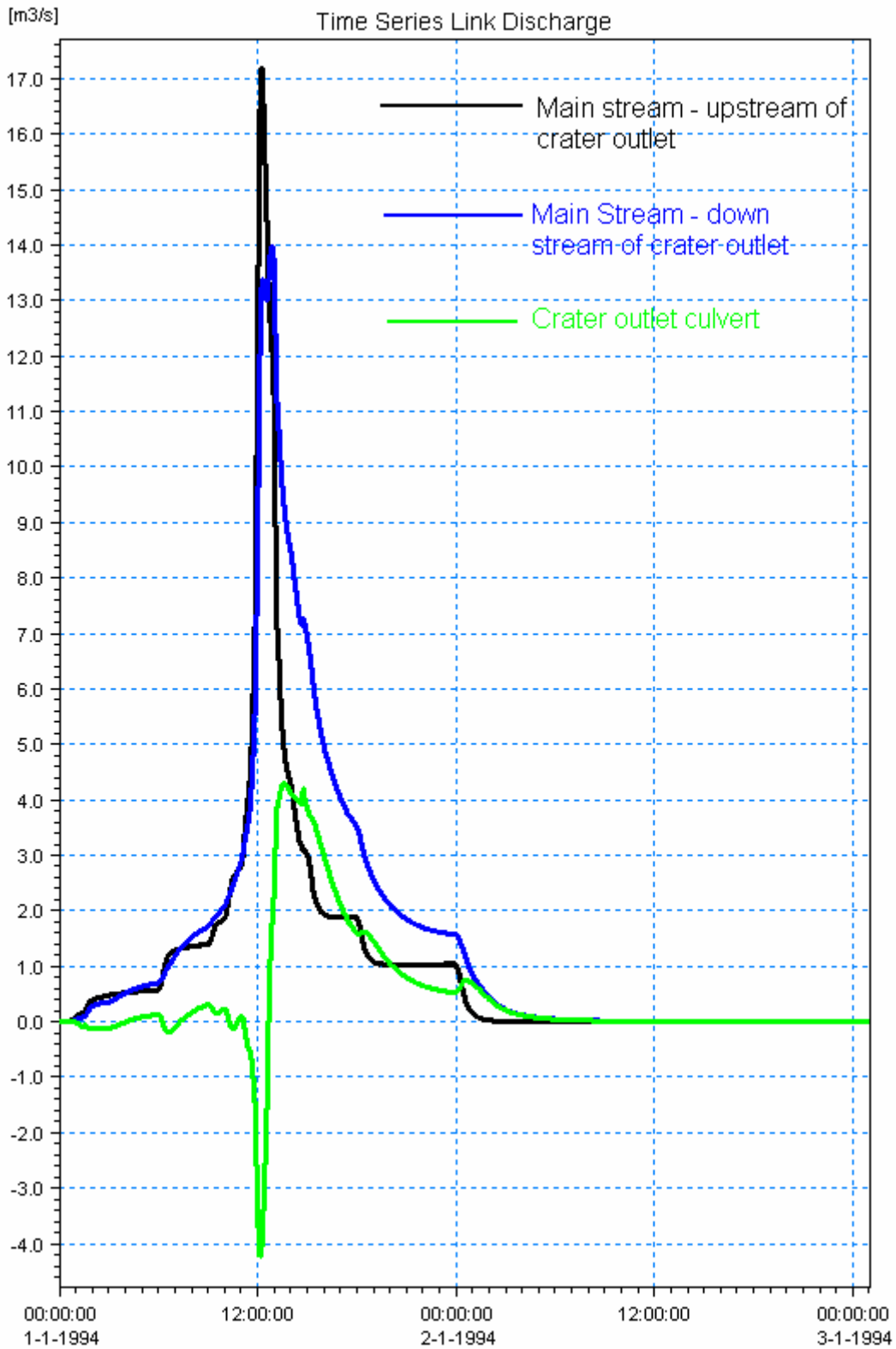
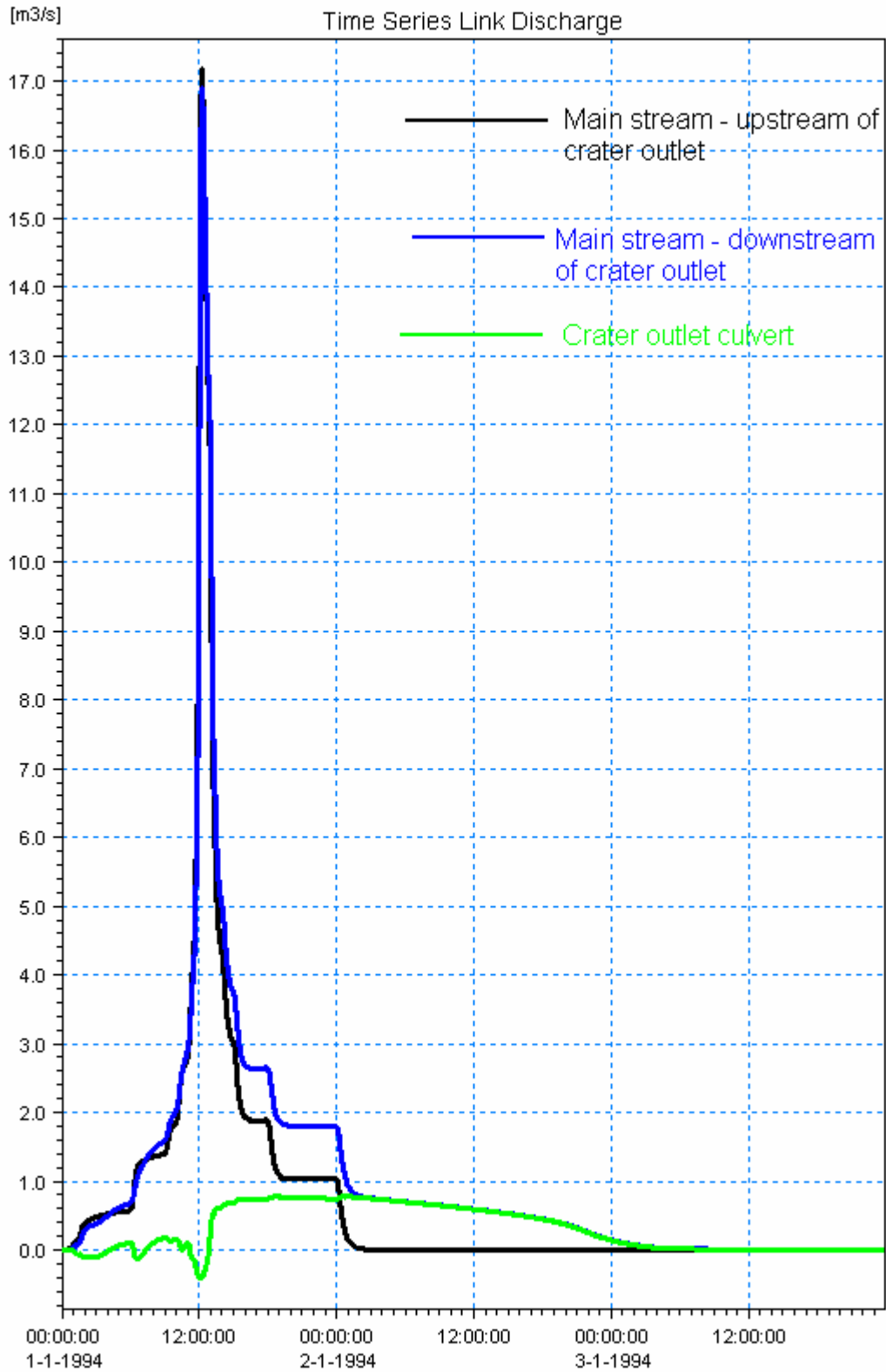


Figure 4 Flows 1%AEP 24-hour storm MPD land-use and Option 1 + Option  
2a network.



### 3.2.2.2 Option 2b: 1800mm Diameter Inflow and 600mm Diameter Outflow from Crater

The second approach tested was to allow higher flows into the crater than out of the crater. This was done by placing a 600mm diameter culvert in parallel with the 1800mm crater outlet culvert. Back flow gates were allowed for on both pipes so that water can only flow into the crater through the 1800mm culvert and out of the crater through the 600mm culvert. The main stream peaks slightly before the crater, allowing more water to enter the crater and reducing the peak flood level in the main stream. However, the effect on water levels in the main stream is negligible. This option results in the water level at the junction of the crater outlet and the main stream decreasing from RL8.25m to RL8.22m. Figure 5 shows the flows in the main stream upstream and downstream of the crater outlet culvert, and the flow through the crater outlet culvert for this approach.

This option provides a very small improvement over the existing situation.

### 3.2.2.3 Option 2c: Separate Crater into Two Storage Ponds

The third approach tested was to separate the crater into two storage areas, one to store and slowly release water from the crater catchments and the second to store backflow from the main stream. The crater is already divided by an embankment shown in Figure 7. The culvert through this embankment can be restricted to reduce the discharge from upstream to downstream. The model was run with the culvert under the embankment reduced to 600mm diameter and the pipe outlet from Beaufort Place extended to the upstream side of the culvert and embankment. This results in water from the crater catchments ponding upstream of the culvert to RL8.4m, an increase in water level of 0.2m above the existing peak water level. This option may require the purchase of some low lying properties on Malaspina Place. A storage pond was added to the model in the location of the baseball field. The baseball field pond fills with backflow from the main stream to RL8.0m. The peak water level at the junction of the crater outlet and the main stream decreases from RL8.25m to RL8.21m. The peak flow in the main stream downstream of the crater outlet is reduced from 14.0m<sup>3</sup>/s to 13.1m<sup>3</sup>/s. This

**Figure 5 Flows 1%AEP 24-hour storm MPD land-use and Option 1 + Option 2b network.**

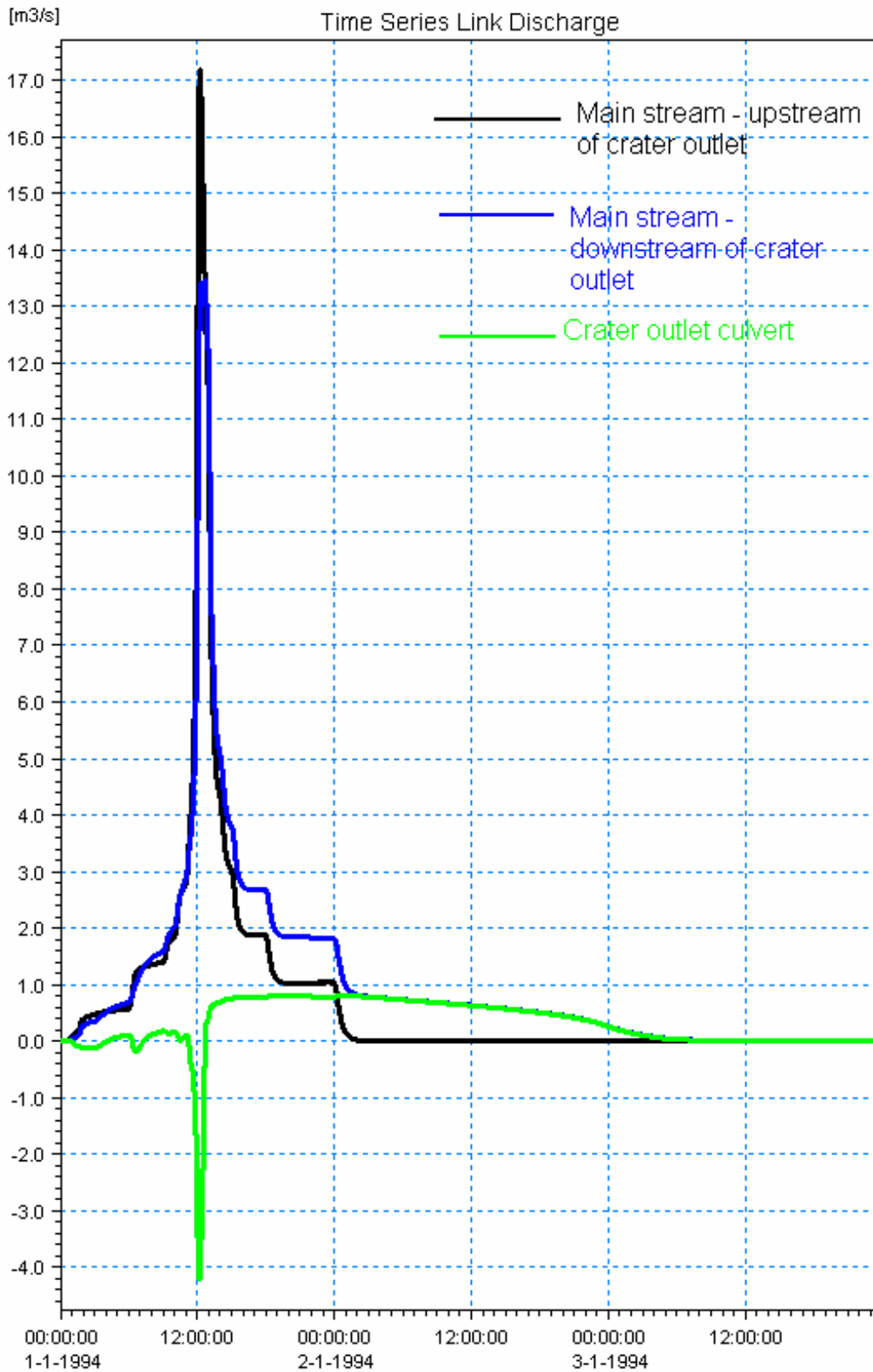


Figure 6 Flows 1%AEP 24-hour storm MPD land-use and Option 1 + Option 2c network.

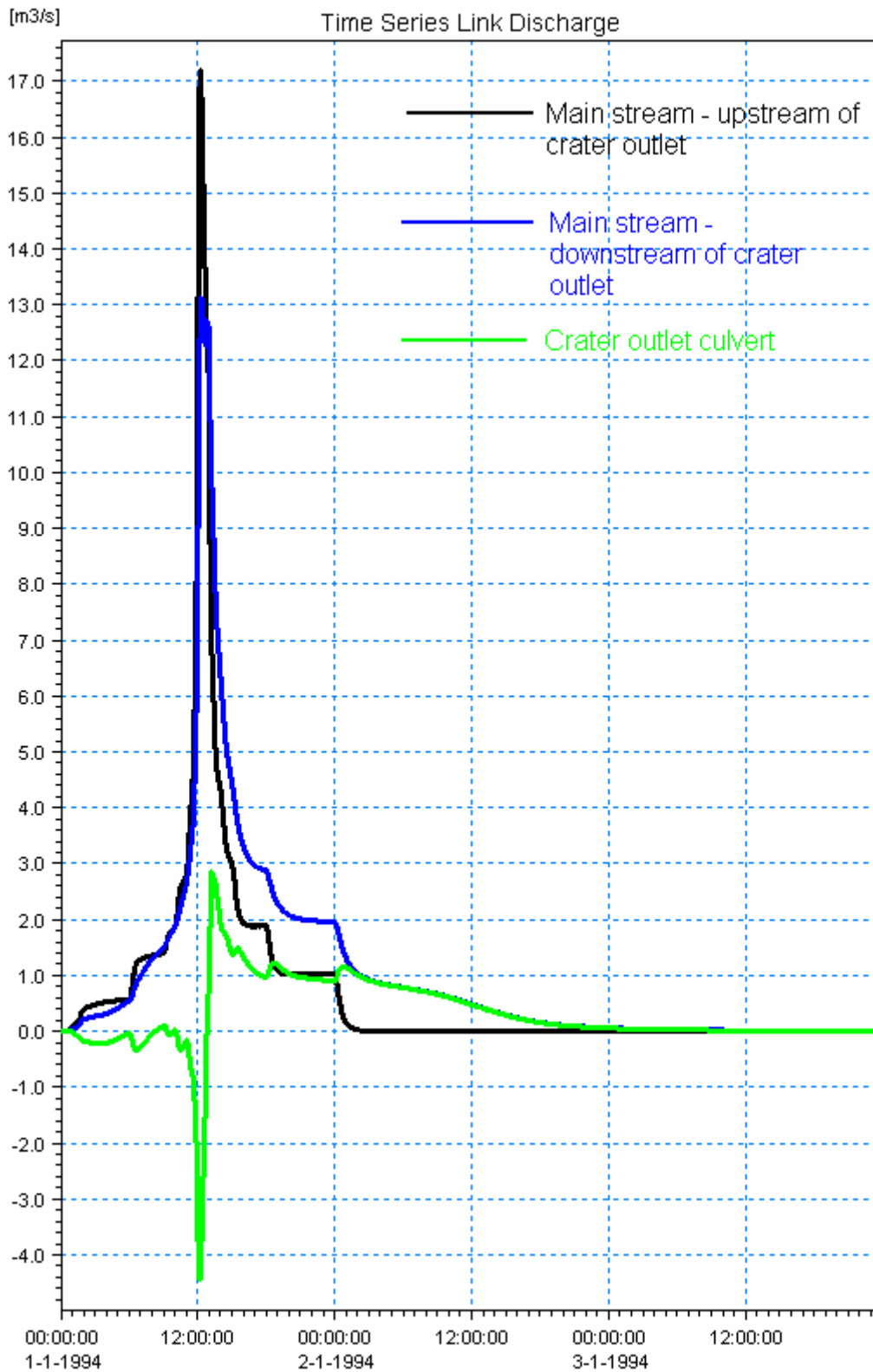


Figure 7 Possible storage pond and embankment location.



results in a minimal reduction in water levels in the main stream below the crater outlet. This reduction is insufficient to mitigate the increase resulting from the upgrade to the pipe network to 20%AEP capacity. Figure 6 shows the flows in the main stream upstream and downstream of the crater outlet culvert, and the flow through the crater outlet culvert for this approach.

The total backflow volume into the crater for this option is 17,200m<sup>3</sup>. The total volume of flow in the main stream past the crater outlet is 188,600m<sup>3</sup>. Approximately 9% of the total flow from the main stream enters the crater. The total volume of flow out of the crater is 93,299m<sup>3</sup>.

This option provides greater flow attenuation in the main stream than the options 2a and 2b. However, the flow attenuation is too small to significantly reduce water levels in the main stream.

None of the options 2a, 2b, or 2c have a significant effect in the main stream upstream of the crater outlet.

### 3.2.3 Option 3: Pipe Upgrades Upstream of the Railway Line and Hillside and Wyllie Road Culverts

The upper reach of the main stream upstream of the railway has been piped. However, the pipes are under capacity for the 20%AEP event and it is expected that there will be some overland flow along the valley floor during larger events. The roadways run across the floor of the valley rather than along the valley floor, and as such overland flow paths are through private property. It is likely that a number of properties in this area would be flooded during the 1%AEP event. Maps 4 and 5 (Appendix 1) show the location of flooding and secondary flow paths.

Options to consider include:

1. Purchasing a number of houses in the valley floor to create an overland flow path or to reinstate the stream with a sufficiently large cross-section to contain the flow. This option would involve considerable expenditure to implement.

2. Purchasing a number of properties in the valley floor and construct a retention dam here. This may reduce the increase in peak water levels and flows downstream.
3. Increasing the capacity of the pipes along the valley floor to cater for the overland flow.

The third option has been modelled with a duplicate main running from Fairview Road to the main stream east of Kenderdine Road to cater for all overland flow during the 1%AEP event. When analysing these options the MPD land-use scenario was considered and it was assumed that all pipes had been upgraded to convey the 20%AEP event for the MPD catchments. It was also assumed that the culvert at 36 Hillside Road had been upgraded to a 2.0m diameter.

The duplicate main would need to extend from the end of Mahon Place to the outlet of the Kenderdine Road culvert, with pipe diameters ranging from 900mm at the upstream end, to 1600mm at the downstream end of the line.

Construction of this pipeline is likely to be difficult as the pipeline would have to pass several properties and would have to cross the railway line.

Increasing the capacity of this pipe would also increase the downstream peak flows and water levels. The culverts at Wyllie Road and Hillside Road would need to be upgraded to 2.0m and 2.2m diameter respectively to adequately pass flood flows without creating a restriction.

## 4 SUMMARY AND DISCUSSION

Given the level of accuracy discussed in Section 1.3 of this document, it is strongly recommended that sufficient field surveys be undertaken prior to undertaking any capital works in the catchment. In particular it is important to accurately describe the available storage in the crater.

During larger events it is likely that flooding of private property will occur in the following locations:

- The valley floor upstream of the railway line.
- Adjacent to the main stream between Wyllie Road and Hillside Road.
- Low lying properties on Malaspina Place adjacent to the crater floor.
- Daphne Road adjacent to the main stream.
- Claude Avenue, Narada Place.

Upgrading the pipe network to provide capacity for the 20%AEP event will reduce but not eliminate flooding in the valley floor upstream of the railway and in the Claude Avenue and Narada Place during larger events. Upgrading these pipes will increase peak water levels in the crater and main stream. The effect of this is particularly pronounced at the 36 Hillside Road culvert. Upgrading this culvert to 2.0m diameter, which is sufficient to pass the 1%AEP event without creating a significant head loss, was included in the pipe network upgrade model.

The water level in the main stream peaks before the water level in the crater and backflow into the crater occurs. This helps to attenuate peak flows and water levels in the main stream downstream of the crater outlet. The various options tested to better utilise storage in the crater have a minimal effect on the water levels in the main stream. The effect is insufficient to offset the increase in water levels in the main stream during the 1%AEP event, which result from upgrading the pipe reticulation to the 20%AEP event capacity.

The only exception to this is upstream of the 36 Hillside Road culvert where all modelled mitigation options result in a drop in water level, as these options include upgrading this culvert.

Undertaking works to better utilise the storage available in the crater does not appear worthwhile..

Upgrading the pipe network in the valley floor upstream of the railway line to cater for the 1%AEP event will result in an increase in water level downstream in the main stream, necessitating the upgrade of the culverts at 36 Hillside Road and Wyllie Road. Even with the upgrade to the Wyllie Road culvert the water level upstream of the culvert will increase.

It is recommended that survey manhole invert and lid levels and cross-section information be captured into MCC's GIS for future use.

# **APPENDIX A**

## **MAPS**

# **APPENDIX B**

## **TABLES**