Client: Catholic Education Office - Sydney

FLOOD STUDY OF BUNNERONG TO BOTANY BAY SWC11 AT WALSH AVENUE, MAROUBRA

SUPPORTING DOCUMENTATION FOR DEVELOPMENT APPLICATION

FOR PROPOSED MULTI PURPOSE HALL AT MARIST COLLEGE PAGEWOOD

REPORT

Clapham Design Services Pty Ltd

MAY 2005

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EXECUTIVE SUMMARY

This Flood Study of Bunnerong to Botany Bay SWC11 stormwater channel at Walsh Avenue, Maroubra, has been prepared as a supporting documentation for a Development Application at Marist College Pagewood. This report recommends a floor level for the proposed building based on the predicted 100 year Average Recurrence Interval (ARI) flood elevation plus 0.3m freeboard.

The catchment of Bunnerong to Botany Bay SWC11 has three interesting features.

i. Bunnerong to Tasman Sea SWC11AMP stormwater diversion tunnel was built in 1965 to divert the upper catchment area to Lurline Bay.

ii. A streamgauge operated during the 1970s and 1980s, by UNSW was located on SWC11, and pluviographs operate in the catchment.

iii. very porous deep sands within the catchment that exhibit extremely high infiltration rates

Bunnerong to Tasman Sea SWC11AMP has the capacity to divert the 100 year ARI flood discharge from its 237 hectares catchment to Lurline Bay. Bunnerong to Botany Bay SWC11 has a catchment area of 139 hectares at Walsh Avenue adjacent to Marist College. In rare/extreme events, greater than the 100 year ARI flood, bypass from SWC11AMP would bypass into SWC11.

The hydrology in the Maroubra area reflects extremely high infiltration rates in the catchment due to very porous deep sands. A PhD thesis in hydrology carried out by Dr Monica Bufill at the University of Wollongong found no runoff to occur from pervious areas. While impervious areas cover some 50% of land area, runoff coefficients were found to be in the order of 0.14 to 0.24, suggesting that a significant proportion of impervious areas discharge into the porous deep sands and underlying aquifer, either by design or accident.

The hydrologic computer model RAFTS was utilised to simulate the rainfall-runoff process for the catchment, and therein compute design flood discharges from design storm events, based on local rainfall intensities and temporal patterns from Australian Rainfall and Runoff (AR&R 1987). The RAFTS model was calibrated using the streamgauge and rainfall data for the 5 largest flood events recorded, occurring during March1978 (2 events), June 1979, March 1983 and November 1984.

The hydraulic computer model HEC-RAS was set-up to evaluate the flood behaviour within Bunnerong to Botany Bay SWC11, and via three potential overland flowpaths downstream of Walsh Avenue. The HEC-RAS model determines design flood elevations, velocities and inundation extents, and simulates steady flow conditions using peak flood discharges from the RAFTS model.

The 100 year ARI flood discharge at the site is predicted to be 17.1 m^3/s and the 100 year ARI flood elevation at the site is predicted to be 20.24 mAHD. Floodplain planning adopts a minimum freeboard of 0.3m above the predicted 100 year ARI flood elevation. The floor level of the proposed building at Marist College is to be set at 20.57 mAHD, which matches the floor level of an existing adjacent building at the College, provides adequate freeboard for the design flood event.

In rare/extreme flood events, say larger than 1 in 500 year ARI, the proposed building may be exposed to inundation above the floor level. Floodplain planning accepts a residual flood risk above the flood planning level, rather than unnecessarily sterilising vast tracks of land up to the Probable Maximum

Flood. The College may wish to in time develop a flood excavation plan for such a rare/extreme flood event.

In summary, the main recommendation from this report is that:

- 1% AEP design flood levels at Marist College is to be based on the flood elevation estimates of the hydraulic models developed from flood discharge estimates of the hydrologic model.
- floor level of the proposed building should be no lower than 20.57 mAHD to provide a 0.3m freeboard above the 1% AEP flood level.

GLOSSARY

Afflux	The rise in flood elevation compared to baseline conditions resulting from the effects of a culvert or encroachment within the floodplain
Annual Exceedance Probability	The chance of a flood of a given or larger size occurring in one year
Australia Height Datum (*AHD*)	Survey datum corresponding approximately to mean sea level.
Average Recurrence Interval (*ARI*)	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event.
Baseline	Taken as the pre-development case
Catchment	Catchment represents the area contributing runoff to a point
design flood	A hypothetical flood representing a specific likelihood of occurrence
Discharge	The rate of flow of floodwater measured in volume per time.
flood behaviour	The characteristics of a flood such as elevation, depth and velocity.
flood fringe	Land irregularly affected by flooding but not designated as floodway.
flood hazard	The potential threat to persons or property due to flooding.
flood level	The elevation of flood waters.
flood planning levels	The combination of flood levels and freeboards selected for planning purposes based on flood risk, social, economic and ecological effects.
flood prone land	Land inundated as a result of the PMF.
Floodplain	Land adjacent to a creek that is inundated by floods up to the PMF.
flood standard	The flood selected for planning and floodplain management activities. Wyong Council has adopted the 1% AEP event as the flood standard.
floodway areas	Areas of a floodplain where high discharge occurs during floods and at which location a blockage would cause a significant flood level rise.
Freeboard	A factor of safety expressed as a height above the flood standard, to compensate for factors such as wave action and model uncertainties.
high hazard	Danger to life and limb, evacuation difficulty, structural damage.
Hydraulic	The term given to the study of water flow in rivers and watercourses
Hydrograph	A graph showing how a river's discharge changes with time.
Hydrology	The study of the rainfall-runoff process in catchments.
low hazard	Depths and velocities allowing evacuation of people and property.
peak flood level, flow or velocity	The maximum flood level, flow or velocity during a flood event.
post development	After works such as land filling, buildings, road construction, etc.
probable maximum flood (*PMF*)	An extreme flood deemed to be the maximum flood likely to occur.
Runoff	Rainfall from a catchment that ends up as flowing water.
Velocity	The speed at which flood waters are moving.

1.0 INTRODUCTION

1.1 NEED FOR THE STUDY

Marist College Pagewood is located within Randwick Council LGA immediately to the north of Heffron Park, 10 kilometres to the south of Sydney's CBD (*refer* **Figure 1**). Bunnerong to Botany SWC11 stormwater channel runs adjacent to the eastern boundary of the college at Walsh Avenue. Ground level contours on the CMA orthophotomap indicates that the college is within a ground depression (refer **Figure 2**).

Marist College is seeking development consent to construct a new building. This flood study is required to determine the minimum floor level for the building based on the adjacent design flood elevation within SWC11.

1.2 OBJECTIVES AND SCOPE

The objectives of the flood study are to

- perform hydrologic modelling for SWC11 and SWCAMP
- justify adopted model calibration parameters
- define design flood discharges at the site
- establish a hydraulic model of SWC11 at the site
- establish a hydraulic model of the flood relief flowpath 1 via Fitzgerald Ave to Bunnerong Road
- establish a hydraulic model of the flood relief flowpath 2 via Heffron Park to Bunnerong Road
- establish a hydraulic model of the flood relief flowpath 3 to low-lying playing fields at Heffron Park
- determine the design flood elevation for the 100 year ARI flood event
- recommend a minimum floor level for the proposed building at the site

2.0 CATCHMENT AND CHANNEL DESCRIPTION

2.1 BUNNERONG TO TASMAN SEA SWC11AMP

Bunnerong to Tasman Sea SWC11AMP[1] (*refer* **Figure 3**), a stormwater diversion tunnel built in 1965, has a catchment of 237 hectares to the tunnel leading to Lurline Bay. The catchment is highly urbanised with residential development the predominant land-use. The old Randwick Barricks site at Kingsford is a significant feature within the catchment, with Bundock Street running on its northern side and Holmes Street to its south.

Redevelopment of the Department of Defence site (Bundock Street Development) into a low density exclusive residential development, community facility and park, has been the subject of a parliamentary inquiry, with presentation to the Parliamentary Standing Committee on Public Works. Development is now proceeding. The environmental significant Bundock Wetland forms a significant feature within the site, which doubles as a major flood detention basin. An army oval area is also to be designed to embellish its flood detention performance on a second drainage branch through Randwick Barricks. Post development flood discharges from the site are designed to be within the capacity of SWC11AMP.

Sydney Water owns the SWC11AMP trunk drainage system. Details on the channel, pipe and culvert system within SWC11AMP was obtained from Bunnerong to Tasman Sea (SWC11AMP) Capacity Assessment (Sydney Water, 2002). In rare/extreme events, greater than the 100 year ARI flood, bypass from SWC11AMP would bypass into SWC11.

2.2 BUNNERONG TO BOTANY BAY SWC11

Bunnerong to Botany Bay SWC11[2] (*refer* **Figure 4**) has a catchment area of 139 hectares at Walsh Avenue adjacent to Marist College. The catchment is highly urbanised with residential development the predominant land-use, while commercial areas are centred on Anzac Parade at Maroubra Junction. A small detention basin on the Snape Park branch of SWC11 is located at playing field at Snape Park.

SWC11 was constructed by the Public Works Department during the great depression, and then transferred to Sydney Water. Details on the channel, pipe and culvert system within SWC11 was obtained from Bunnerong to Botany Bay (SWC11) Capacity Assessment (Sydney Water, 2002).

At the intersection of Walsh Avenue and Fitzgerald Avenue, adjacent to the south-eastern boundary of the college, SWC11 enters a closed culvert system for about 800m before re-emerging into an open channel downstream of Bunnerong Road near Matraville Primary School.

2.3 FLOOD RELIEF FLOWPATHS

A site investigation was undertaken to assess the potential flood relief flowpaths downstream of Walsh Avenue. These are indicated on **Figure 5**.

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[1] *SWC11AMP is the designation used by Sydney Water*

[2] *SWC11 is the designation used by Sydney Water*

3.0 DATA REVIEW

3.1 PAST HYDROLOGIC STUDIES

A number of academic thesis and papers have been prepared using streamgauging from SWC11, and associated rainfall data.

The most comprehensive investigation using streamgauging and rainfall data from the Bunnerong to Botany Bay streamgauge formed part of a PhD thesis by Dr Monica Bufill prepared under supervision of Dr Michael Boyd at the University of Wollongong. The thesis determined there to be no runoff from pervious areas. While impervious areas may cover 50% of land area, runoff coefficients were found to be in the order of 0.14 to 0.24, suggesting that a significant proportion of impervious areas discharge into the porous deep sands and underlying aquifer, either by design or accident.

Randwick Council treats private flood studies as commercial in confidence.

A private flood study has been conducted for part of SWC11 for:

- Pacific Square Development at Maroubra / Maroubra Mall

A private flood study has conducted for part of SWC11AMP for:

- Design of elements of the redevelopment of Randwick Barricks, Kingsford

Publicly available information is found via documentation for a Parliamentary Inquiry of the proposed redevelopment of Randwick Barricks, Kingsford.

3.2 STREAM GAUGING DATA

UNSW operated a streamgauge on SWC11 at Nagle Park Maroubra during the 1970s and 1980s, prior to decommissioning the streamgauge in the 1990s. Monica Bufill's PhD thesis list the peak streamgauge results, and flow hydrograph at 3 minute time intervals, for 39 events between March 1977 and June 1988 (*refer* **Appendix A**). The 3 peak flood discharges at the streamgauge were found to be the following events:

17 March 1983:	2.115 m^3/s
8 November 1984:	1.703 m^3/s
3 March1978:	1.647 m^3/s

A further two large events was also selected for calibration runs.

18 March1978:	1.553 m^3/s (ranked 5th)
19 June 1979:	1.407 m^3/s (ranked 8th)

3.3 RAINFALL PLUVIOGRAPH DATA

Pluviograph raingauge data for within the catchment is available from UNSW at the following locations:

Nagle Park:	station 566001
Avoca Street:	station 566002

- Storey Street / Snape Park: station 566006

Monica Bufill's PhD thesis list the rainfall intensities at 3 minute time intervals for the 39 listed events, including for the five calibration events selected for this study.

Peak 30 minute intensities and indicative ARIs are given below:

17 March 1983:	70.4 mm/hr	2 to 5 year ARI
8 November 1984:	69.7 mm/hr	2 to 5 year ARI
3 March1978:	55.3 mm/hr	1 to 2 year ARI
18 March1978:	37.0 mm/hr	< 1 year ARI
19 June 1979:	43.5 mm/hr	1 year ARI

The peak 120 minute intensity was maximum for the 8 November 1984 event, as given below:

- 8 November 1984: 43.6 mm/hr 10 to 20 year ARI

3.4 CHANNEL CROSS-SECTIONS

Channel cross-sections, dimensions, reach lengths and grades of the Sydney Water Channel were obtained from Bunnerong to Botany Bay (SWC11) Capacity Assessment Report. The invert level at the entrance to the culvert system at Fitzgerald Avenue was taken from the detailed survey.

3.5 SURVEY FOR FLOOD RELIEF FLOWPATHS

A survey brief for the flood study was provided to G. J. Atkins & Associates Consulting Land Surveyors, who then surveyed 19 cross-sections and a series of spot levels to detail the geometry of potential flood relief flowpaths (*refer* **Appendix B**).

4.0 HYDROLOGY

4.1 RAFTS MODEL INTRODUCTION

The RAFTS hydrologic model has been adopted in this study to estimate flood discharges for design (*synthetic*) and historic storm. Parameters of catchment area, land cover, catchment slope and rainfall loss are used to simulate the catchment response to a specific storm to generate flood hydrographs. The catchment is sub-divided into a series of subcatchments which are differentiated by drainage sub-division and topography. Flood discharges are computed at subcatchment outlets, including at culvert locations.

Direct model calibration uses stream gauging data to adjust model calibration parameters (*Pern, Bx and rainfall losses*) until a good match is achieved with the simulated historic flood. Stream gauging was available for SWC11 for events during the 1970s and 1980s. Consideration was made of calibration parameters established for the Hydrologic and Hydraulic Study of Botany Wetlands (SMEC, 1992).

Calibration runs for this study involve use of streamgauging and rainfall pluviograph station records for five of the largest recorded runoff events: 3 March1978, 18 March1978, 19 June 1979, 17 March 1983 and 8 November 1984.

4.2 RAFTS DATA

Subcatchment Details

The RAFTS model of the SWC11 comprises 12 subcatchments upstream of Bunnerong Road. The RAFTS model of SWC11AMP catchment comprises an additional 4 subcatchments upstream of the stormwater tunnel. The subcatchment layout plan is given in **Figures 4 & 6**. The following nodes are of particular interest:

- Node 1_00 represents the flow at the Bundock Wetland Detention Basin.
- Node 2_00 represents the flow at the Army Oval Detention Basin.
- Node 1_02 represents the flow at SWC11AMP tunnel.
- Node 1_04 represents the flow near to the streamgauging station.
- Node 1_06 represents the flow adjacent to Marist College.

The PhD thesis found no runoff to occur from pervious areas. While impervious areas may cover 50% of land area, runoff coefficients were found to be in the order of 0.14 to 0.24, suggesting that a significant proportion of impervious areas discharge by design or accident into the porous deep sands and underlying aquifer. This information means that to replicate gauged flows, it will be necessary to establish an effective impervious area directly connected to SWC11 during calibration, with an upper limit being the physical impervious proportion.

Catchment Slope

Catchment weighted slopes adopted for the subcatchments SWC11 and SWC11AMP range between 0.2 and 3.0 per cent.

Pern and Bx

Bx is the Storage Coefficient Multiplication Factor that globally modifies the calculated storage time delay coefficient (*B*) for all subcatchment. Pern 'n' is the subcatchment roughness factor. Bx and Pern 'n' are modified to represent the different response of impervious and pervious surfaces, and can slow down the catchment response time or speed it up. **Table 1** shows adopted 'n' values.

TABLE 1 PERN VALUES

Surface Type	Pern value
Impervious area	• 0.015
Urban pervious area	• 0.025

Source - RAFTS User Manual

A Bx value of 1.5 was adopted during calibration for the Hydrologic and Hydraulic Study of Botany Wetlands (SMEC, 1992). Due to the similarities of Bunnerong catchment to the Botany Wetlands catchment, a Bx value of 1.5 was adopted for this study during calibration and design storm simulations.

Rainfall

Rainfall intensity-frequency-duration (IFD) tables were used for design storms (**Appendix A**). Rainfall temporal patterns for design storms are taken from AR&R.

Soil Characteristics and Rainfall Losses

Rainfall infiltration is influenced by the soil landscapes within the catchment. The catchment has very porous deep sands.

RAFTS has two options to account for soil infiltration. The simple option uses an initial loss followed by a continuing loss (*see* **Table 2**), which generates surface runoff but not base flow or interflow. The more complex representation uses the Australian Representative Basin Module (*ARBM*) with complex data requirements and generates surface, interflow and base flow. Initial and continuing losses are intuitive, suitable for sandy catchments and is it often used for urbanised catchments.

Based on a review of the Hydrologic and Hydraulic Study of Botany Wetlands (SMEC, 1992), initial and continuing losses adopted are 100 mm & 100 mm/hr respectively for pervious areas, and 5 & 2 mm/hr respectively for impervious areas.

TABLE 2 INITIAL & CONTINUING LOSS RATES

	Initial Loss (mm)	Continuing Loss Rate (mm/hr)
Impervious areas	5.0	2.0
Pervious areas - sandy	100	100

Source – Hydrologic and Hydraulic Study of Botany Wetlands (SMEC, 1992)

Channel Routing / Lag Times

Channel routing effects can be specifically modelled by use of the simply lag time approach or based on a more complex Muskingum-Cunge channel routing module. The use of lag times for routing was adopted as acceptable for SWC11.

Detention Basin

Appendix C includes a stage storage description of the Bundock Wetland detention basin. An army oval area is also to be designed to embellish its flood detention performance. Post development flood discharges from the site are designed to be within the capacity of SWC11AMP. In lieu of specific data for the Army oval detention basin, it is assumed to be a scaled version of the stage-storage characteristics available for the Bundock Wetland Basin, with the control being the downstream culvert system capacity.

A small detention basin is located at playing field at Snape Park is located on the Snape Park branch of SWC11, and does not effects flows at the streamgauge. The detention basin is thought to reduce the peak flood discharge in the 100 year ARI event by about 2 m3/s. The small detention basin at Snape Park has not been modelled in this study.

4.3 HISTORIC EVENTS FOR CALIBRATION / VERIFICATION

The calibration events used are 17 March 1983 (rank 1), 8 November 1984 (rank 2), 3 March1978 (rank 3), 18 March1978 (rank 5) and 19 June 1979 (rank 8).

Table 3 shows that the assumption of a 25% effective impervious percentage directly connected to SWC11 results in a general overestimate of peak flows by 28% on average for the 5 calibration events. Overestimation would be by 205% for a 60% effective impervious percentage. While it may be possible to further reduce the effective impervious percentage, we have adopted the 25% effective impervious percentage as a reasonable and slightly conservative estimate.

TABLE 3 RAFTS MODEL CALIBRATION RESULTS AT STREAMGAUGE STATION

Event	Gauge flow peak m^3/s	Effective Impervious Percentage Directly Connected to SWC11					
		60%		30%		25%	
		Peak flow m^3/s	Ratio % Model/Historic	Peak flow m^3/s	Ratio % Model/Historic	Peak flow m^3/s	Ratio % Model/Historic
17-3-1983	2.115	8.26	390	4.04	191	3.422	161
8-11-1984	1.703	5.33	314	2.66	156	2.238	132
3-3-1978	1.647	5.58	338	2.86	173	2.405	146
18-3-1978	1.553	4.25	274	2.10	135	1.775	115
19-6-1979	1.407	2.97	211	1.51	107	1.254	89
Average			305%		153%		128%

Streamgauge at RAFTS node 1-04

4.4 HYDROLOGIC MODEL SIMULATION RESULTS

Model simulation results are based on the adopted RAFTS input data and calibration parameters. The design flood discharges at subcatchments along SWC11 and SWC11AMP for fully urbanised conditions are shown in **Table 4**. The critical storm duration at the site is the 90 minutes duration event.

TABLE 4 DESIGN FLOOD DISCHARGES

Catch-ment	Location Description	PEAK DESIGN FLOOD DISCHARGES (m^3/s)				
		1 YR ARI	5 YR ARI	20 YR ARI	100 YR ARI	500 YR ARI
1_00	Bundock Wetland	6.49	11.32	15.01	18.45	23.28
3_00	Army Basin	4.28	7.67	10.23	12.72	16.02
1_01		3.03	3.22	3.54	4.28	4.97
4_00		3.00	5.23	6.96	8.64	10.89
1_02	SWC11AMP Tunnel	8.54	12.58	16.07	19.38	23.32
1_03		1.10	1.93	2.55	3.16	3.95
1_04	Streamgauge	1.70	2.95	3.85	4.83	6.07
2_00	Snape Park	1.37	2.40	3.17	3.93	4.93
2_01		2.37	4.18	5.59	7.04	8.89
2_02		3.07	5.42	7.22	9.06	11.43
1_05		4.80	8.58	11.44	14.43	18.34
5_00		1.17	2.05	2.74	3.38	4.25
1_06	**Marist College**	**5.68**	**10.20**	**13.49**	**17.07**	**21.64**
6_00		0.97	1.69	2.24	2.77	3.49
7_00		0.40	0.69	0.92	1.13	1.43
8_00		1.49	2.60	3.44	4.25	5.34
6_01		2.85	4.98	6.59	8.13	10.22
1_07		8.30	14.73	19.42	24.40	30.55
node1		15.05	24.91	33.25	42.40	52.68

90 minute duration events

The 100 year ARI flood discharge at the site is predicted to be 17.1 m^3/s. The absolute accuracy of flood estimates may be within 20% (+ *or* -). This is commonly considered acceptable as hydrology is a discipline with inherent uncertainties, particularly where direct calibration data is not available.

5.0 HYDRAULICS

5.1 CAPACITY ASSESSMENT

Bunnerong to Botany Bay (SWC11) Capacity Assessment (Sydney Water, 2002) provides an indicative capacity estimate of the channel alongside the college to be 25.5 m^3/s. The first reach under Heffron Park, 3 culvert cells each 1.829m wide x 1.524 m high, has been estimated in the Capacity Assessment to have a capacity of 26.0 m^3/s. These capacities exceed the predicted 100 year ARI flood discharge of 17.1 m^3/s. However, it is noted that the Capacity Assessment uses simplified hydraulic methods and thus a HEC-RAS analysis is now undertaken.

Bunnerong to Tasman Sea (SWC11AMP) Capacity Assessment provides an estimate of the capacity entering the stormwater tunnel. The main tunnel is indicated to have a capacity of 27.7 m^3/s. The Garden Street branch has an indicated capacity of 8.7 m^3/s (comparable to 100 year ARI flood discharge at node 4_00). On this basis, no bypass would be expected from SWC11AMP to SWC11.

A culvert inlet control analysis of the entrance to the culverts under Heffron Park has been conducted, with the rating table given in **Table 5**.

TABLE 5 INLET CONTROL ANALYSIS OF CULVERT ENTRY AT HEFFRON PARK

Elevation mAHD	Discharge (m^3/s)	Comment
16.85	0.0	Invert at 16.85mAHD
17.25	2.48	
17.65	6.5	
18.05	11.5	
18.45	17.2	Obvert at 18.39 mAHD
18.85	21.2	
19.25	25.2	Headwall at 19.40mAHD
19.65	29.1	
20.05	32.9	
20.45	35.6	Proposed floor level at 20.57mAHD

Inlet control alone is inadequate to confirm system capacity, as outlet control may also occur. A HEC-RAS analysis is now undertaken to assess outlet control performance.

5.2 DESCRIPTION OF HEC-RAS

The HEC-RAS hydraulic model is a flood profile program developed by US Army Corp of Engineers Hydrologic Engineering Centre, with both steady state and unsteady state computational modules. HEC-RAS can be used to estimate peak flood elevations in channels, taking into account the effects of hydraulic controls such as culverts. HEC-RAS utilises channel cross-sections, roughness, road crossing dimensions, and upstream or downstream flood elevations to simulate the floodplain response to flood discharges and predict design flood elevations and other parameters such as velocity.

5.3 HYDRAULIC MODEL LAYOUT - SWC11 CHANNEL

The HEC-RAS hydraulic models developed in this study is shown as follows:

- The model layout for SWC11, extending between Donovan Avenue and 900m downstream of Fitzgerald Avenue, is shown in **Figure 8** (*refer* **Photo Exhibit 1**).

- The model layout for the flood relief flowpath downstream of the site via Fitzgerald Avenue and Bunnerong Road is shown in **Figure 9** (*refer* **Photo Exhibit 2**).

- The model layout for the flood relief flowpath downstream of the site via Heffron Park to Bunnerong Road is shown in **Figure 10** (*refer* **Photo Exhibit 3**).

- The model layout for the flood relief flowpath to low-lying playing fields at Heffron Park is shown in **Figure 11** (*refer* **Photo Exhibit 4**).

Selected input data is detailed in **Appendix D**.

Extensive experience of the author in modelling numerous Sydney Water channels using HEC-RAS has found that the concrete lined channel and overbank areas need to be considered carefully and often need to be modelled separately. Combined modelling of concrete lined channels and grassed overbank areas can lead to an unrealistically reduced capacity, as the higher overbank roughness causes an overall cross-section roughness to reduce channel velocities, based on the HEC-RAS computational method.

5.4 HYDRAULIC MODEL PARAMETERS

Topography of Flood Relief Flowpaths

Flood relief flowpath cross-sections for the model were selected at sufficiently close intervals to represent the potential for variations in flowpath cross-sections. Additional cross-sections were positioned in the vicinity of the crests or flow constrictions. Refer **Section 2.2** for details on the survey data utilised.

Roughnesses

A field inspection of flowpath land-cover was conducted to assess suitable Mannings 'n' roughnesses for the model. Roughness 'n's within the model cross-sections are shown in Appendix D on cross-section plots, and are based on the following:

- Concrete channel SWC11 is modelled with a roughness 'n' of 0.014

- Park and grassed areas are modelled with a roughness 'n' of 0.035

- Flow along roads are modelled with a roughness 'n' of 0.016

- A composite roughness 'n' of 0.020 is the order of are used were the road and verge are combined

Upstream and Downstream Boundary Condition

Upstream and downstream flood level boundary conditions were set based on indicative channel slopes. The model extent was set sufficiently away from the site to avoid undue influence of this assumption.

Design Flood Discharges

Peak flood discharges for the HEC-RAS model were taken from the RAFTS model described previously.

5.5 CALIBRATION PARAMETERS

The parameter normally adjusted to achieve model calibration of HEC-RAS is the roughness value 'n'. Due to the absence of detailed historical flood records within the study area, experience in calibrating models for other catchments was used to select suitable calibration parameters for the model.

5.6 DESIGN FLOOD SIMULATIONS

The design flood profile for SWC11 is shown in **Appendix D**. The design flood elevation simulation results for SWC11 are tabulated in **Appendix D**. A range of flows were considered to develop a rating curve of discharge versus flood elevation for the flood relief flowpaths (*refer* **Tables 6, 7 & 8**).

Based on a HEC-RAS model, the SWC11 culvert under Heffron Park is estimated to carry 15 m^3/s without undue pressurisation. Based on inlet control alone, about 27.0 m^3/s could enter the culvert for ponding to the top of headwall 19.40 mAHD.

TABLE 6 FLOOD LEVELS VS DISCHARGE FOR FITZGERALD AVENUE FLOWPATH

Flood Level at Walsh Ave (mAHD)	Discharge (m^3/s)	Comment
20.35	0.5	Proposed floor level less freeboard is RL 20.27mAHD
20.39	1	
20.44	2	
20.48	3	
20.51	4	
20.54	5	Proposed floor level at 20.57mAHD

TABLE 7 FLOOD LEVELS VS DISCHARGE FOR FLOWPATH THROUGH HEFFRON PARK TO BUNNERONG ROAD

Flood Level at Walsh Ave (mAHD)	Discharge (m^3/s)	Comment
20.30	0.5	Proposed floor level less freeboard is RL 20.27mAHD
20.33	1	
20.37	2	
20.43	3	
20.49	4	
20.54	5	Proposed floor level at 20.57mAHD
20.73	10	
20.87	15	

TABLE 8 FLOOD LEVELS VS DISCHARGE FOR FLOWPATH TO LOW PLAYING FIELDS AT HEFFRON PARK

Flood Level at Walsh Ave (mAHD)	Discharge (m^3/s)	Comment
20.10	0.5	
20.16	1	
20.24	2	Proposed floor level less freeboard is RL 20.27mAHD
20.31	3	
20.37	4	
20.43	5	Proposed floor level at 20.57mAHD
20.65	10	
20.83	15	
20.98	20	
21.11	25	

5.7 FINDINGS

The 100 year ARI flood discharge at the site is predicted to be 17.1 m^3/s. Based on a HEC-RAS model, the SWC11 culvert under Heffron Park is estimated to carry 15 m^3/s without undue pressurisation. Based on inlet control alone, about 27.0 m^3/s could enter the culvert for ponding to the top of headwall 19.40 mAHD. A conservative assumption, considering outlet control, is that the culvert under Heffron Park will only carry 15 m^3/s.

Flood relief overland flowpaths will come into action to convey the flow difference of 2.1 m^3/s between the 100 year ARI flow (17.1 m^3/s) and the conservative culvert capacity 15 m^3/s. Based on developed rating curves for the 100 year ARI flood is anticipated to rise to 20.24 mAHD at Walsh Avenue. On this based the proposed floor level of 20.57 mAHD will meet the 100 year ARI flood standard including freeboard.

The total capacity of culvert plus flood relief overland flow paths is taken as 35 m^3/s at the proposed floor level (20.57mAHD with no freeboard).

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

This Report documents the flood study of Bunnerong to Botany Bay SWC11 stormwater channel at Walsh Avenue, Maroubra, for a Development Application at Marist College Pagewood.

A PhD thesis Dr Monica Bufill investigated the hydrology at SWC11 by analysis of streamgauging and rainfall pluviograph data from 39 flood events between 1977 and 1988. The thesis found no runoff to occur from pervious areas. While impervious areas may cover 50% of land area, runoff coefficients were found to be in the order of 0.14 to 0.24, suggesting that a significant proportion of impervious areas discharge by design or accident into the porous deep sands and underlying aquifer.

A RAFTS model was developed and calibrated using streamgauging data on SWC11 at Nagle Park. The Bx and infiltration loss parameters were adopted based on the RAFTS calibration for the adjacent botany Wetlands catchment. To reflex the effective runoff coefficients, the impervious fraction within the catchment draining to SWC11 was modified. The assumption of connection of 25% of impervious areas over-estimates the peak flows from the five selected calibration events by an average of 28%. This level was adopted to keep conservatism in the modelling.

The 100 year ARI flood discharge adjacent to Marist College is estimated as 17.1 m3/s.

The culvert system under Heffron Park is estimated to have capacity for 15 m3/s from SWC11 upstream of Fitzgerald Avenue. The flood elevation must rise in SWC11 to 20.24 mAHD to achieve this capacity. Floodplain planning adopts a minimum freeboard of 0.3m above the predicted 100 year ARI flood elevation.

6.2 RECOMMENDATIONS

The floor level of the proposed building at Marist College is to be set at 20.57 mAHD, which matches the floor level of an existing adjacent building at the College, and provides adeqaute freeboard for the design flood event.

REFERENCES

REPORTS

Institution of Engineers, Australia (*1987 and later editions*) Australian Rainfall and Runoff - A Guide to Flood Estimation, editor-in-chief D Pilgram.

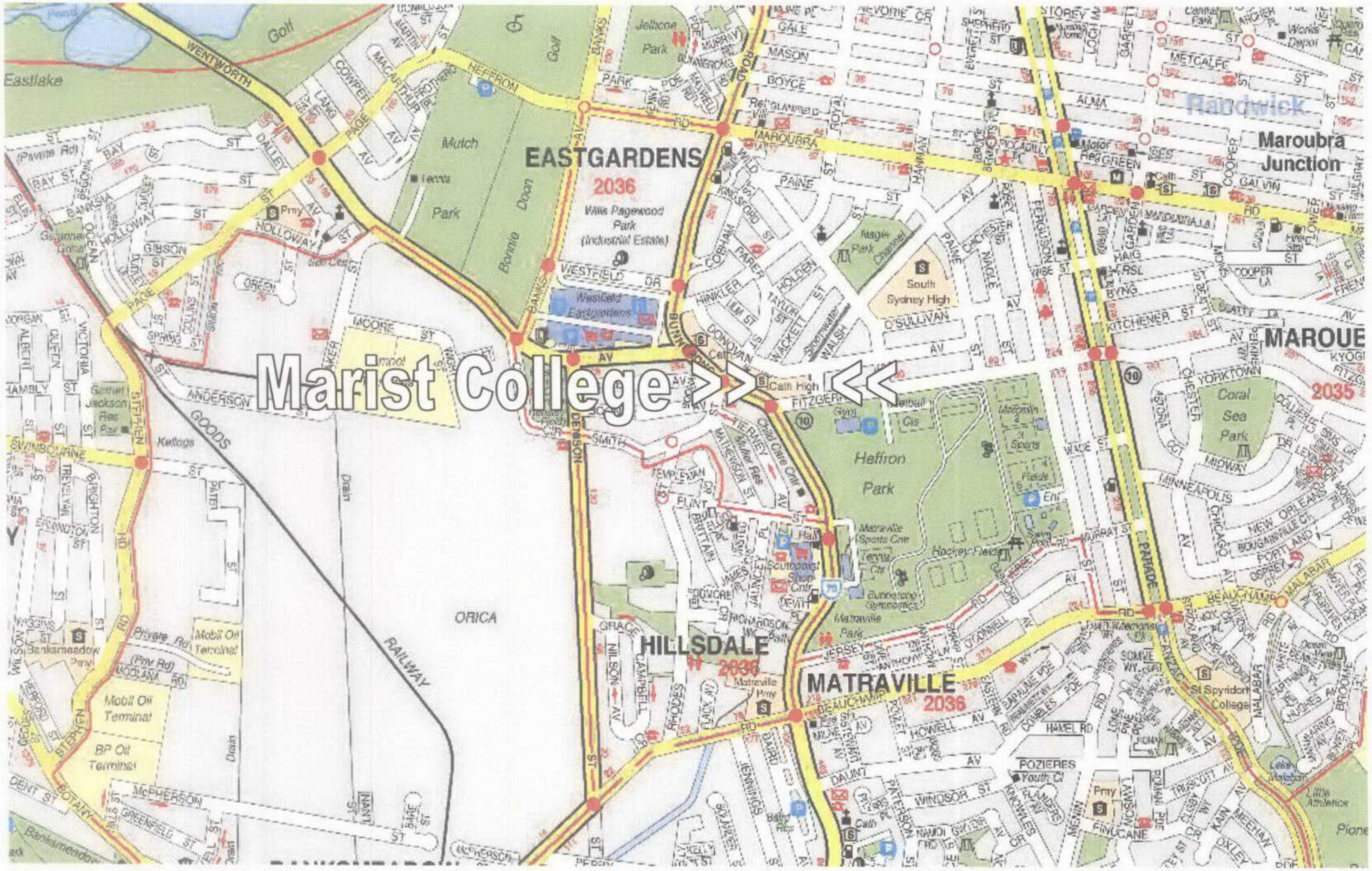
SMEC (1992) Hydrologic and Hydraulic Study of Botany Wetlands, prepared for Sydney Water

(Sydney Water, 2002) Bunnerong to Botany Bay (SWC11) Capacity Assessment

Sydney Water (2002) Bunnerong to Tasman Sea (SWC11AMP) Capacity Assessment

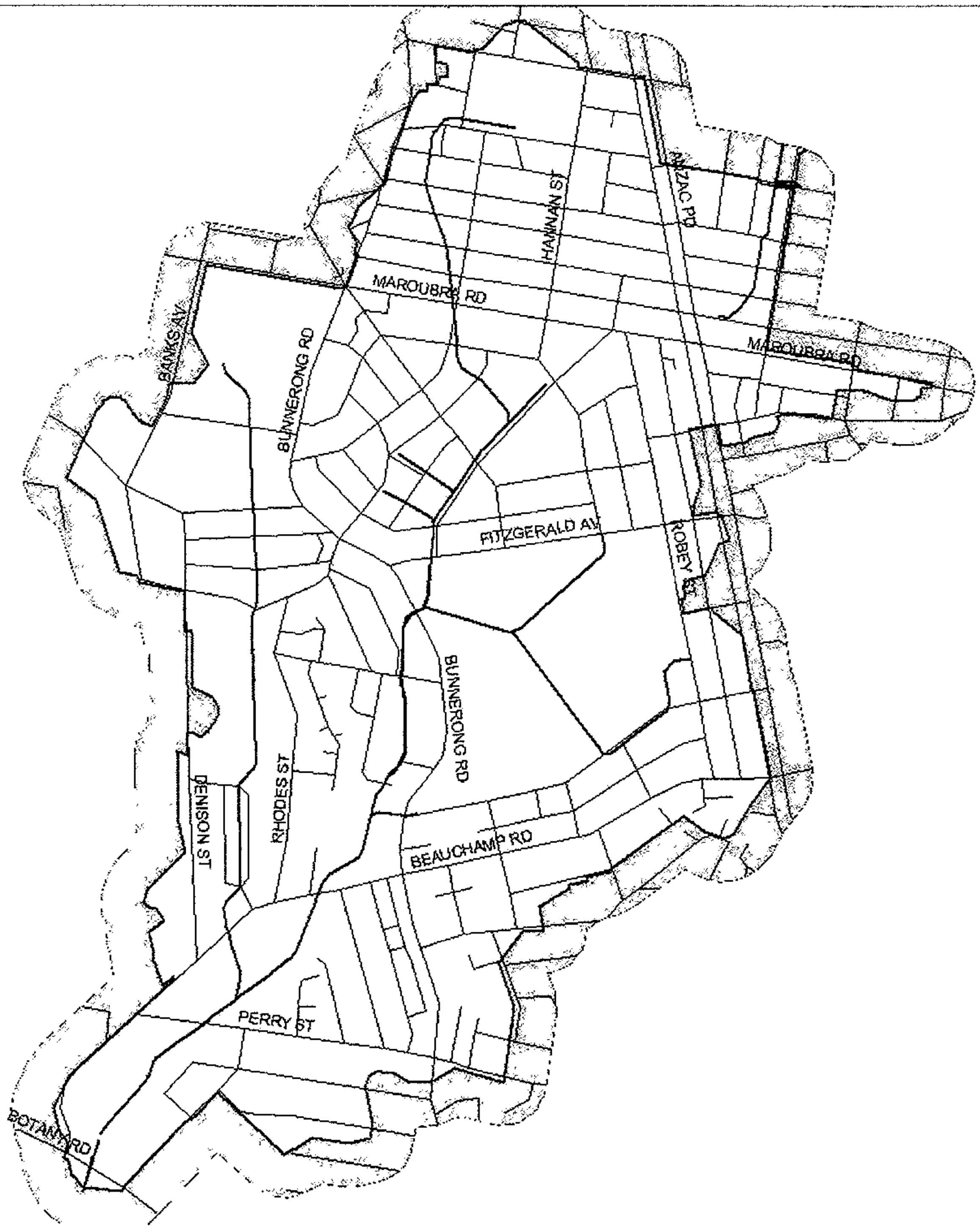
XP Software (*undated*) XP-RAFTS User's Manual, Reference Manual, Belconnen

FIGURES

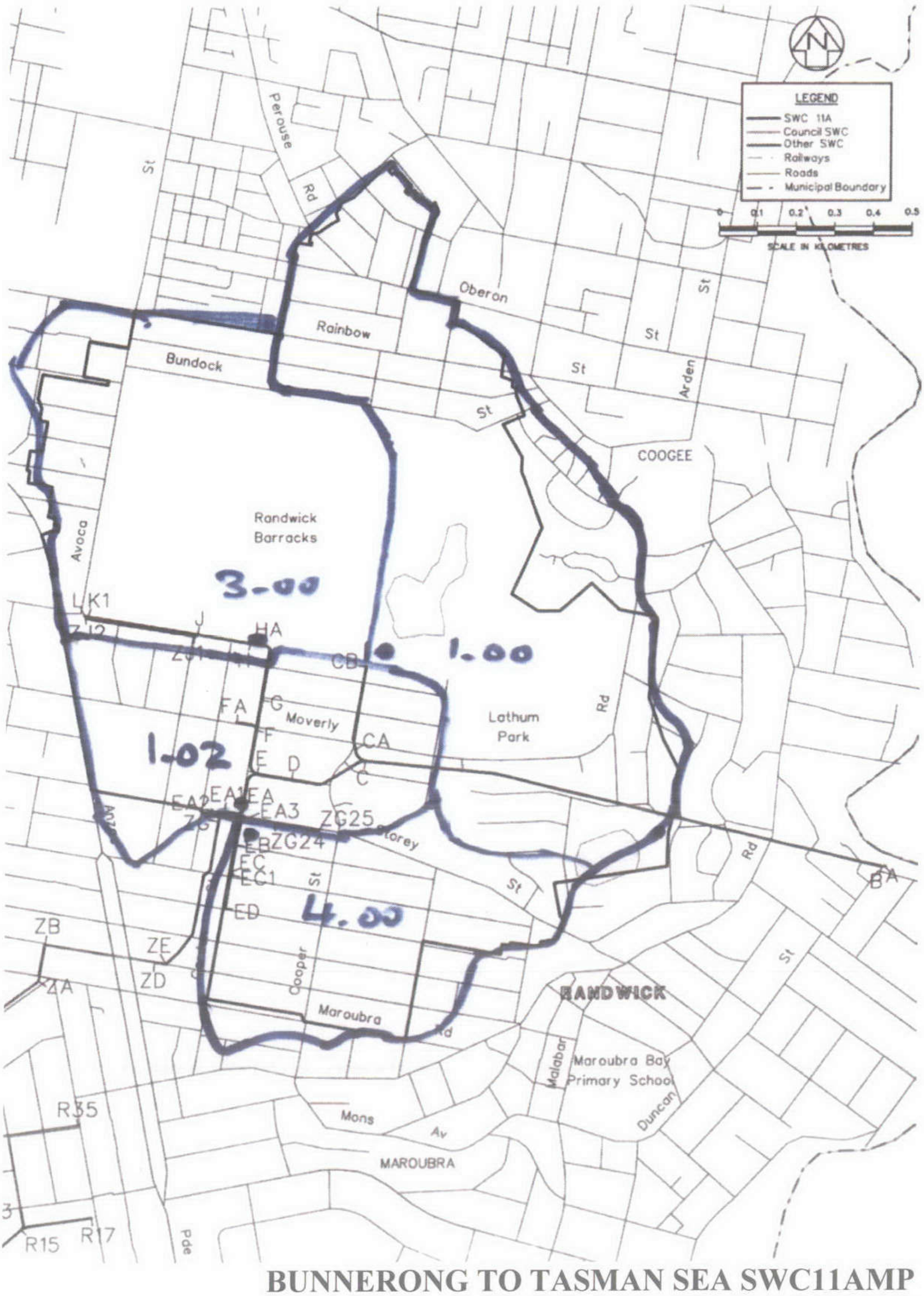


LOCALITY PLAN
FIGURE 1

GROUND DEPRESSION AT MARIST COLLEGE
FIGURE 2

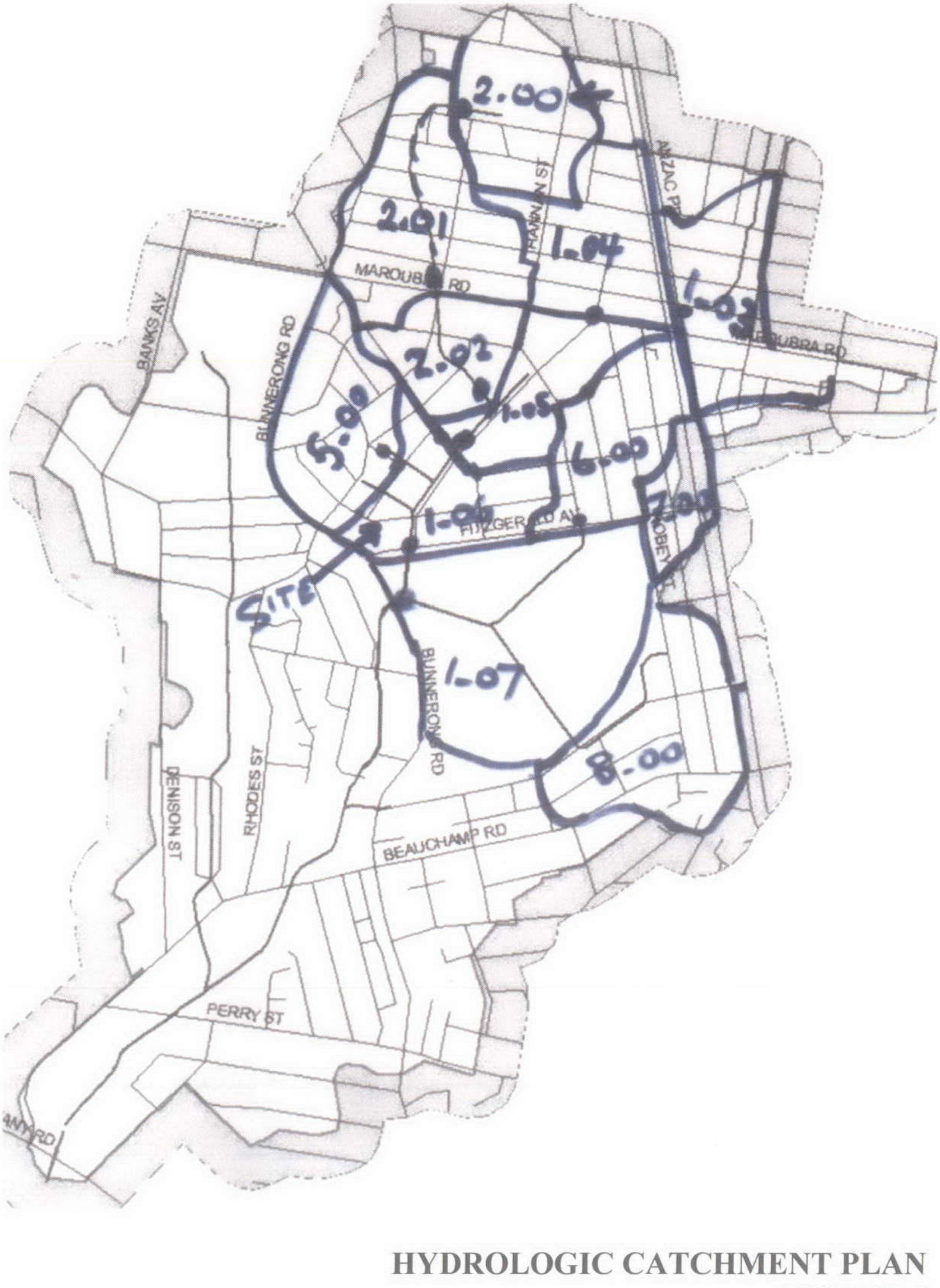


BUNNERONG TO BOTANY SWC11
FIGURE 3

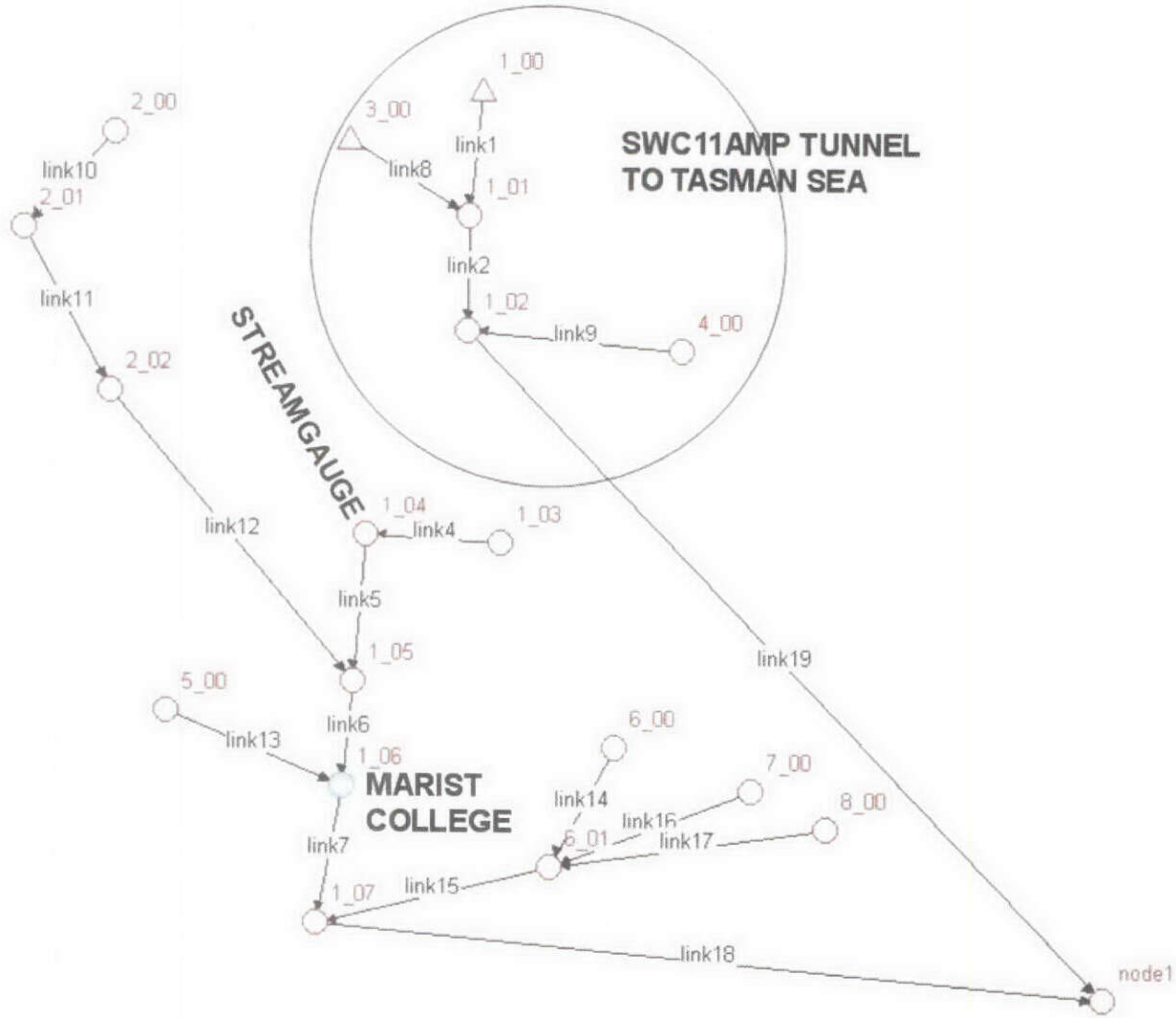


BUNNERONG TO TASMAN SEA SWC11AMP
FIGURE 4

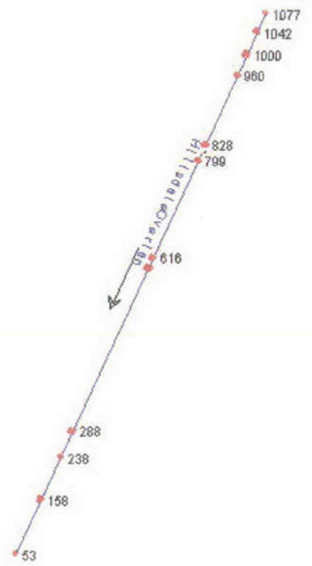
FLOOD RELIEF FLOWPATHS
FIGURE 5

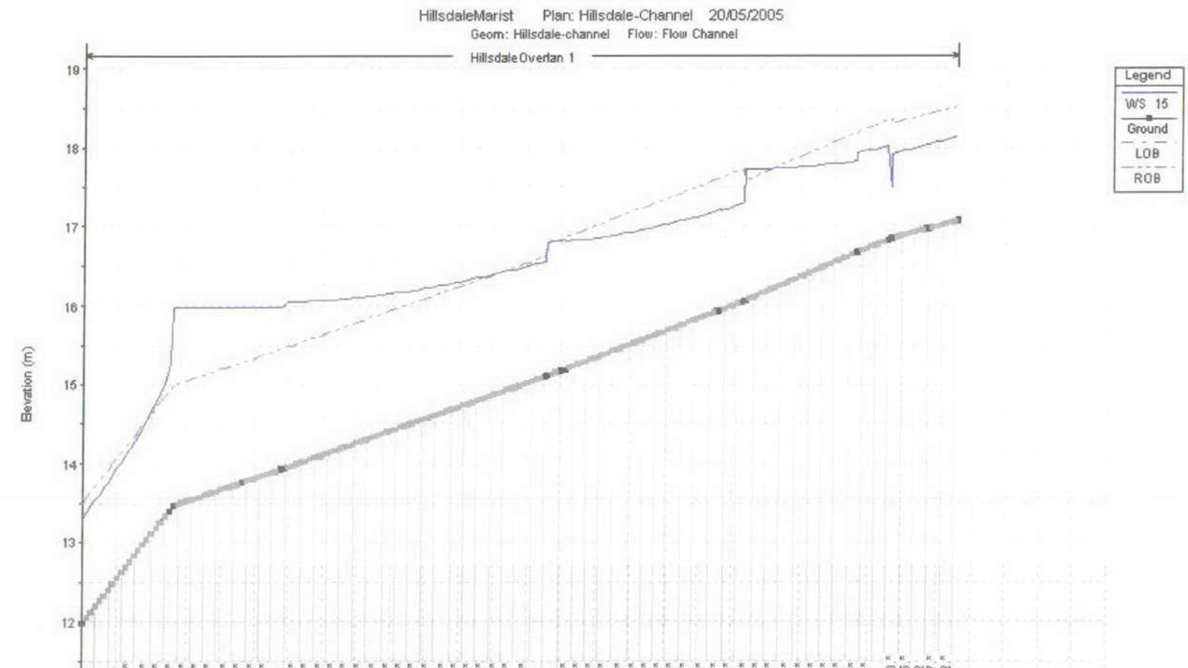


HYDROLOGIC CATCHMENT PLAN
FIGURE 6

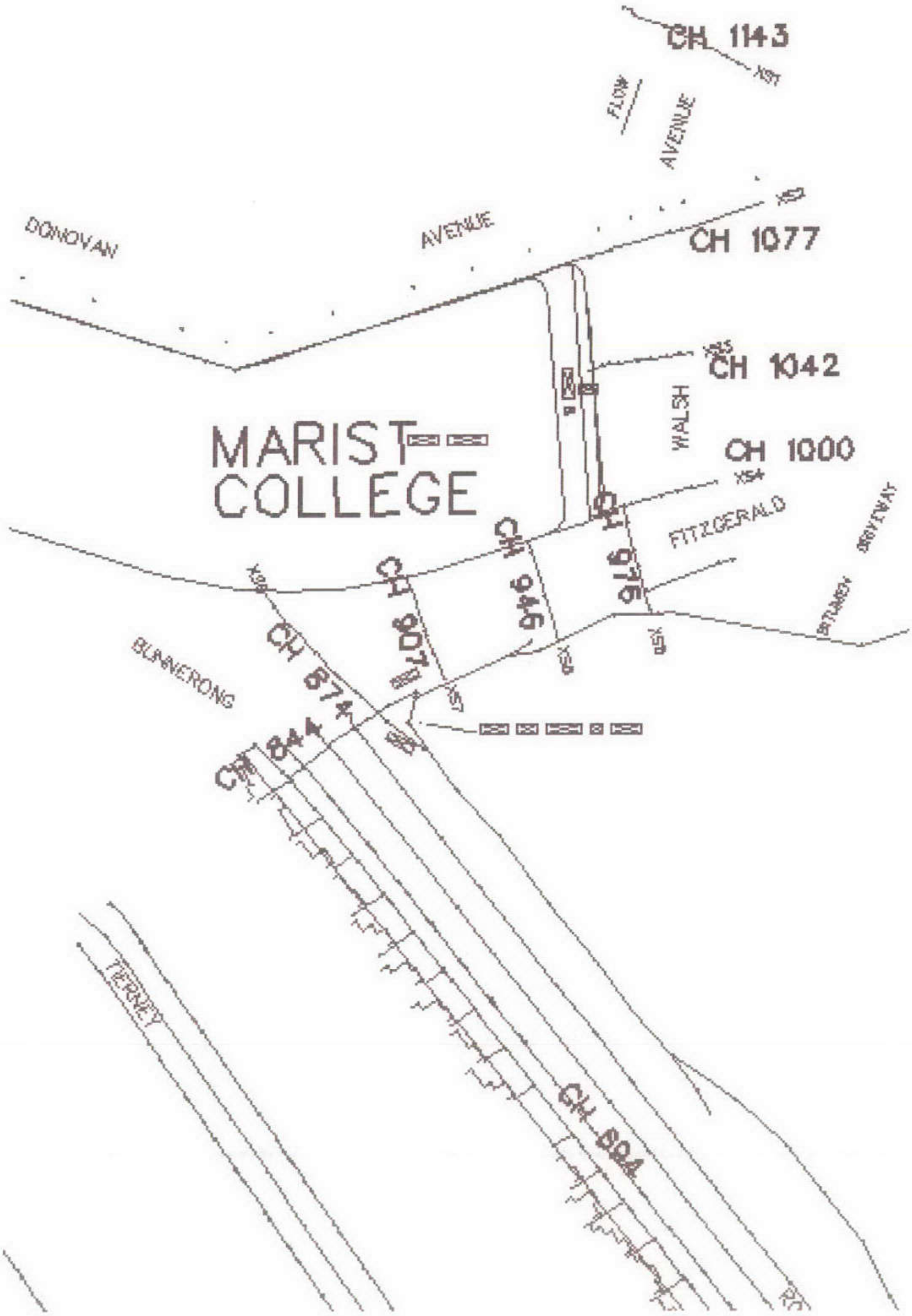


HYDROLOGIC MODEL SCHEMATIC LAYOUT
FIGURE 7

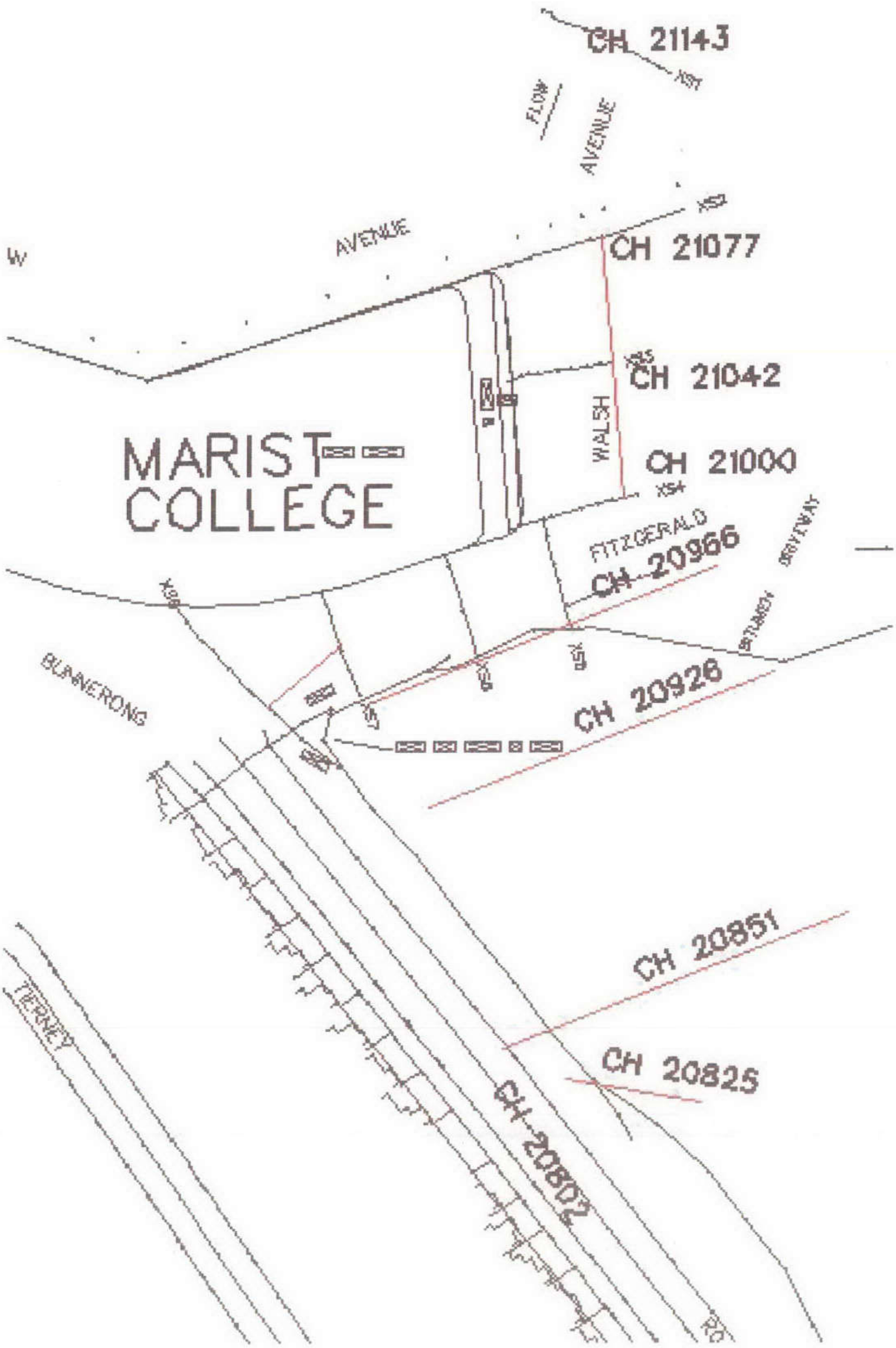




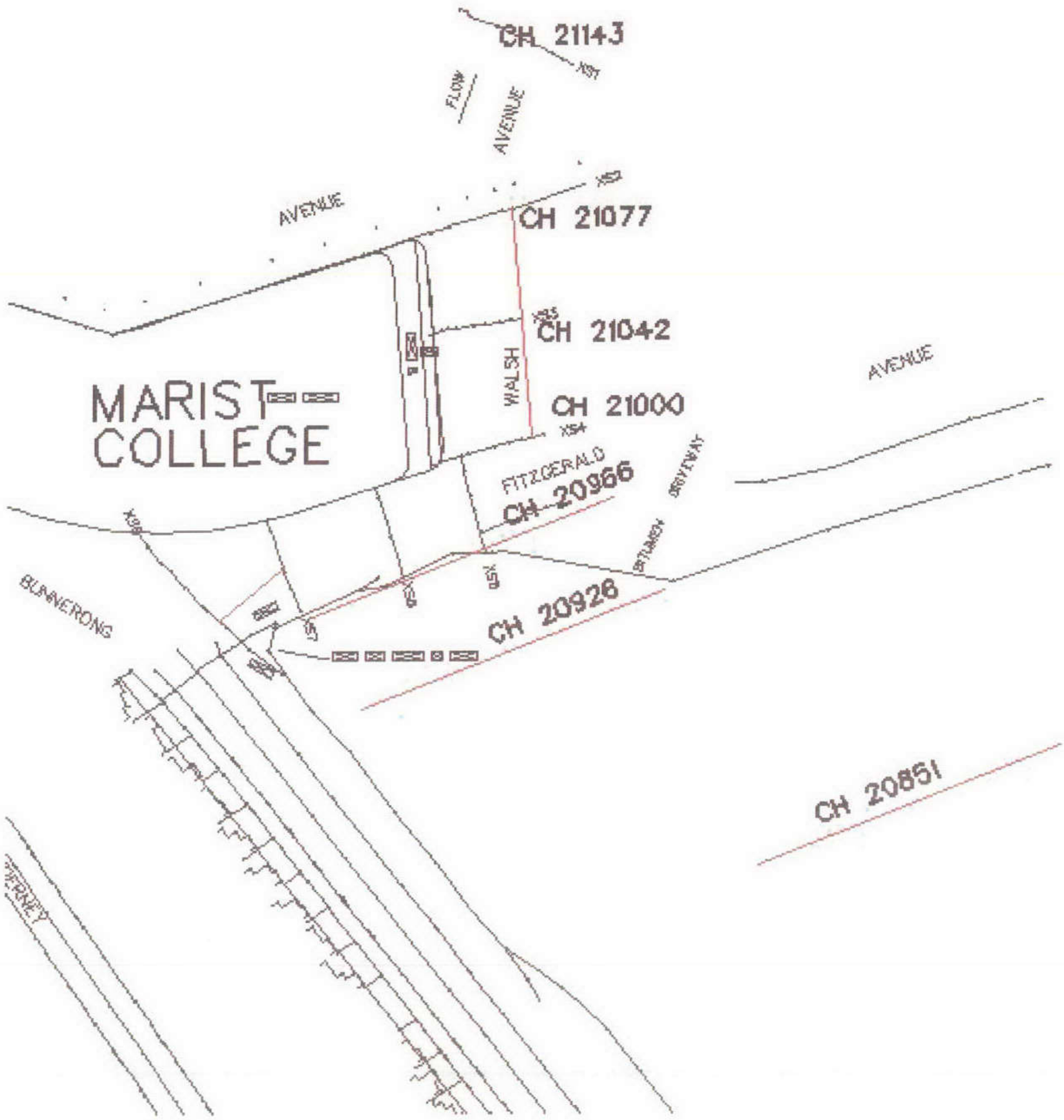
HYDRAULIC MODEL LAYOUT: SWC11
FIGURE 8



HYDRAULIC MODEL LAYOUT: FLOOD RELIEF VIA FITZGERALD AVE
FIGURE 9



HYDRAULIC MODEL LAYOUT: FLOOD RELIEF VIA HEFFRON PARK
FIGURE 10



HYDRAULIC MODEL LAYOUT: FLOOD RELIEF TO HEFFRON PARK LOW PLAYING FIELDS
FIGURE 11

SWC11 DOWNSTREAM OF SITE
PHOTO EXHIBIT A

FITZGERALD AVENUE FLOOD RELIEF FLOWPATH
PHOTO EXHIBIT B

FLOOD RELIEF FLOWPATH THROUGH HEFFRON PARK TO BUNNERONG ROAD
PHOTO EXHIBIT C

FLOOD RELIEF FLOWPATH AT LOW PLAYING FIELDS AT HEFFRON PARK
PHOTO EXHIBIT D

APPENDIX A RAINFALL & STREAMGAUGE DATA

A1 INTENSITY-FREQUENCY-DURATION RAINFALL DATA

Location	BUNNERONG	
2I1 (10.-80.)	41.6	Calc
2I12 (2.-30.)	8.04	Load
2I72 (0.4-15.)	2.49	Save
50I1 (25.-130.)	86.8	Graph
50I12 (5.-50.)	16.1	Print
50I72 (1.-25.)	4.9	
G (0.-0.8)	0.00	
F2 (3.-5.)	4.288	Help
F50 (13.5-18.5)	15.86	Exit

Geographical nam

Estimated Rainfall Factor (R): 3500

Estimated 1:10 storm EI (S10): 2350

ARI \ DUR	5m	6m	10m	20m	30m	1h	2h	3h	6h	12h	24h	48h	72h	1.5h
1	102	96	79	57	46.8	32.0	20.4	15.6	9.84	6.22	4.06	2.59	1.93	24.7
2	131	123	101	74	61	41.6	26.5	20.3	12.7	8.04	5.24	3.33	2.49	32.0
5	165	155	129	96	79	55	34.9	26.5	16.6	10.4	6.79	4.31	3.21	42.2
10	185	174	145	108	89	63	39.8	30.3	18.9	11.8	7.69	4.87	3.63	48.2
20	211	199	166	125	103	73	46.2	35.1	21.9	13.7	8.88	5.62	4.18	56
50	244	231	193	146	122	87	55	41.5	25.8	16.1	10.4	6.59	4.90	66
100	270	255	214	163	136	97	61	46.4	28.8	17.9	11.6	7.33	5.45	74
User	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

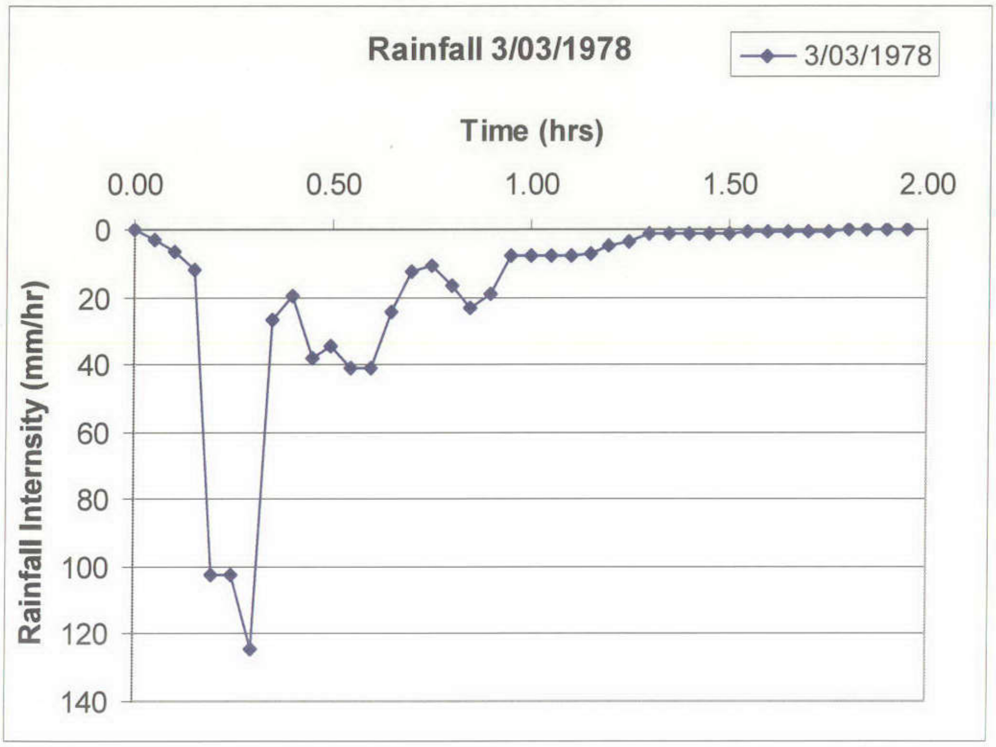
A2 STREAMGAUGE PEAKS

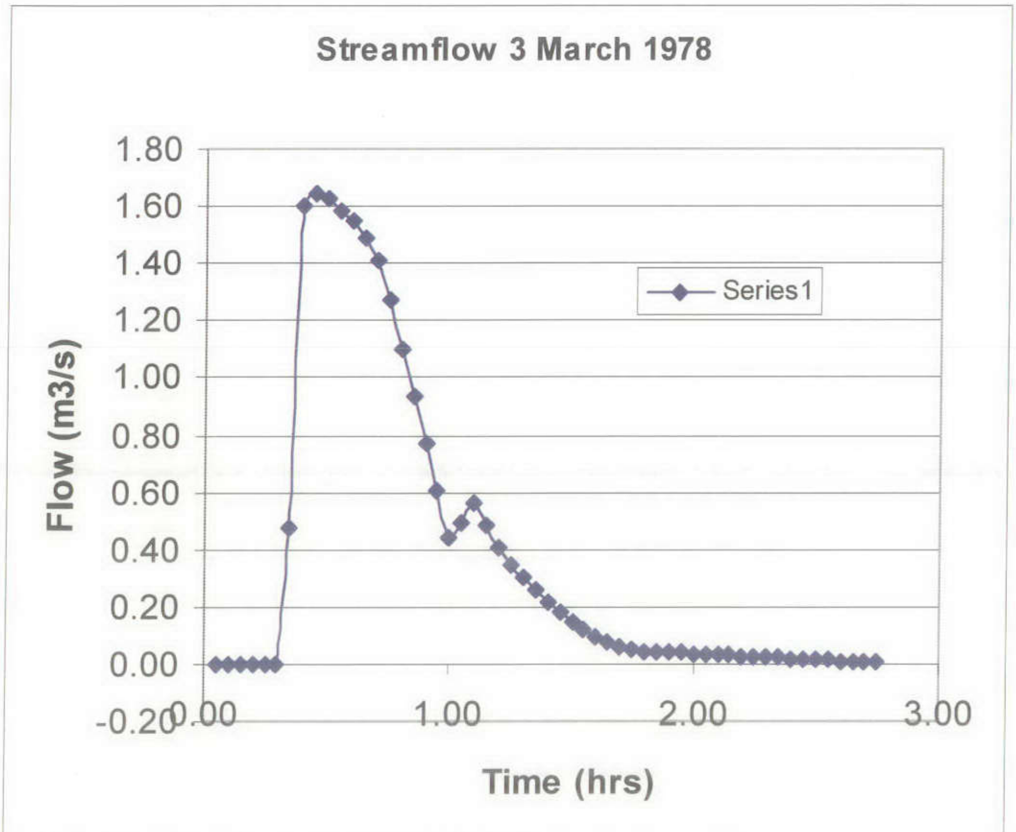
MAROUBRA
SUMMARY OF EVENTS

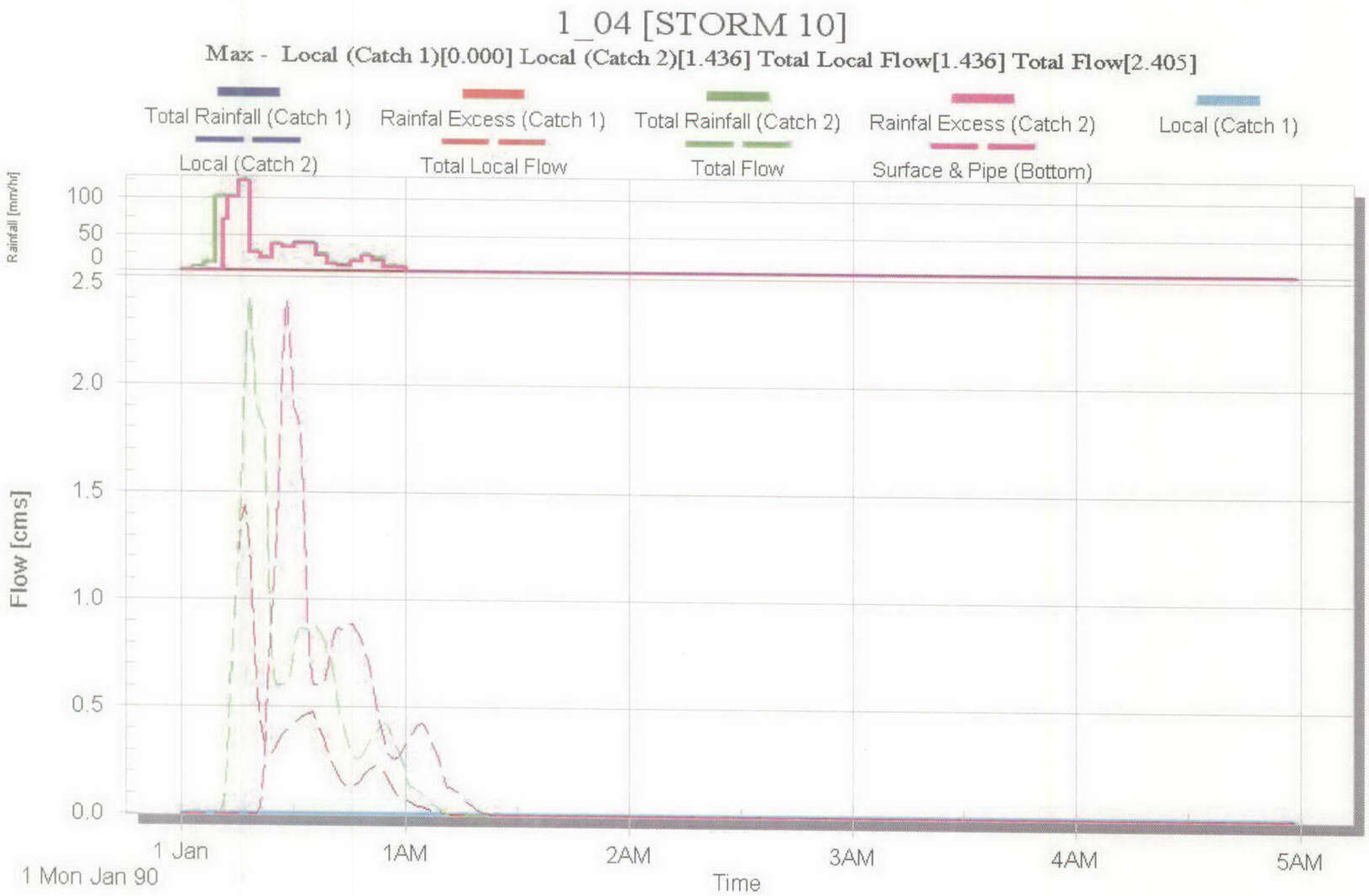
No.	EVENT DATE	TOTAL RAIN (mm)	RUNOFF (mm)	PEAK FI (m^3/s
1	010377	48.16 10	8.20	1.03
2	050377	8.87	1.43	0.56
3	030378	35.66	6.54	1.64
4	170378	6.81	0.67	0.23
5	180378	42.64	8.18	1.55
6	190378	11.25	2.94	0.84
7	270378	5.66	0.85	0.62
8	080478	36.90	5.94	0.66
9	130478	18.90	3.74	0.65
10	180578	11.25	1.70	0.93
11	210578	12.25	2.60	0.83
12	210578B	12.60	2.33	0.86
13	290578	128.07 4	19.20	0.90
14	130678	76.92 6	12.09	1.20
15	190679	40.48	5.73	1.40
16	200679	11.51	1.40	0.43
17	170383	35.46	5.23	2.11
18	180683	5.74	1.00	0.61
19	051184	169.50 2	25.38	1.80
20	061184	3.82	0.71	0.30
21	061184B	18.35	2.84	0.35
22	081184	93.76 6	13.58	1.70
23	111184	33.23	5.48	1.15
24	111284	20.80	4.57	1.29
25	010585	10.44	1.99	1.27
26	081185	22.96	2.76	1.27
27	271285	27.30	5.13	1.36
28	160186	114.81 5	18.45	1.31
29	120486	27.36	3.86	1.61
30	040187	18.68	3.86	1.21
31	030787	15.65	3.22	1.29
32	201087	38.28	7.34	1.13
33	231087	19.73	4.25	1.45
34	130288	84.32 7	12.66	0.94
35	250388	26.32	3.61	1.08
36	020488	136.47 3	23.35	1.27
37	070488	27.89	4.94	1.35
38	280488	227.15 1	46.72	1.41
39	150688	68.83 7	10.31	1.29

A3 GRAPHICAL PRESENTATION OF RAINFALL AND STREAMGAUGE DATA

3 March 1978

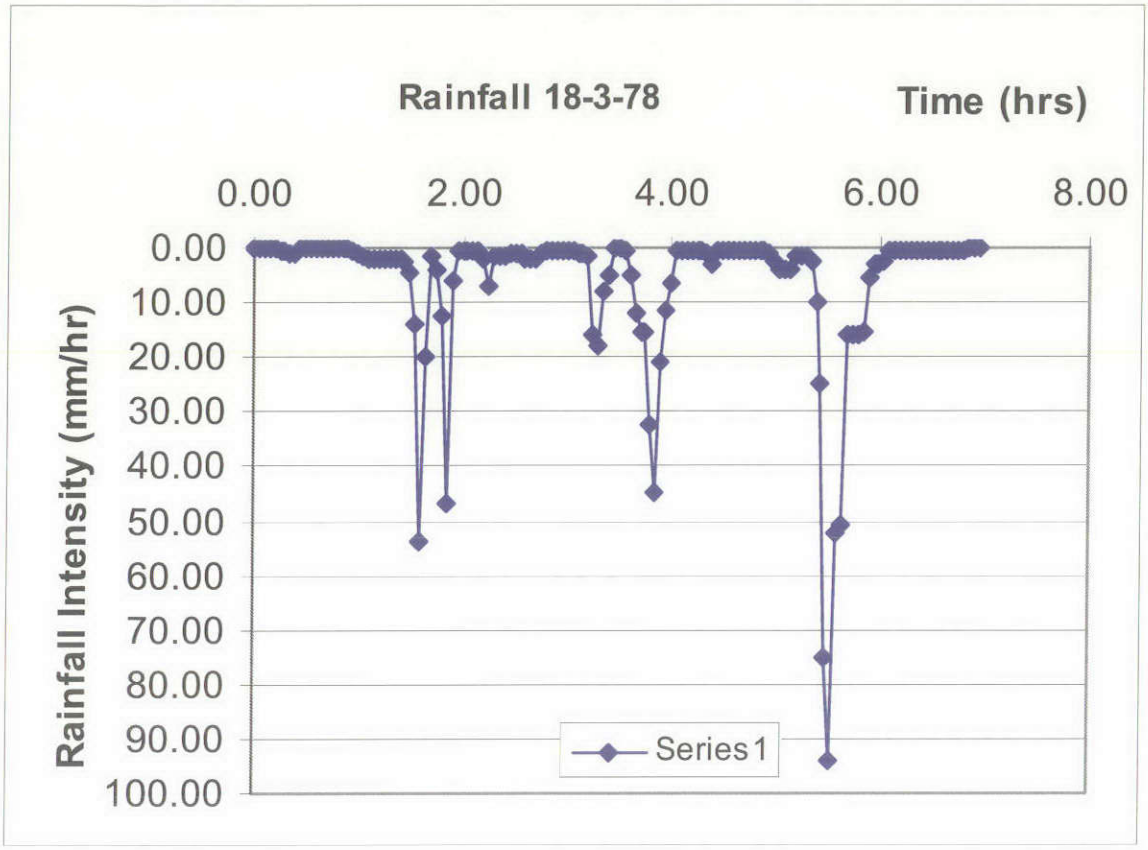


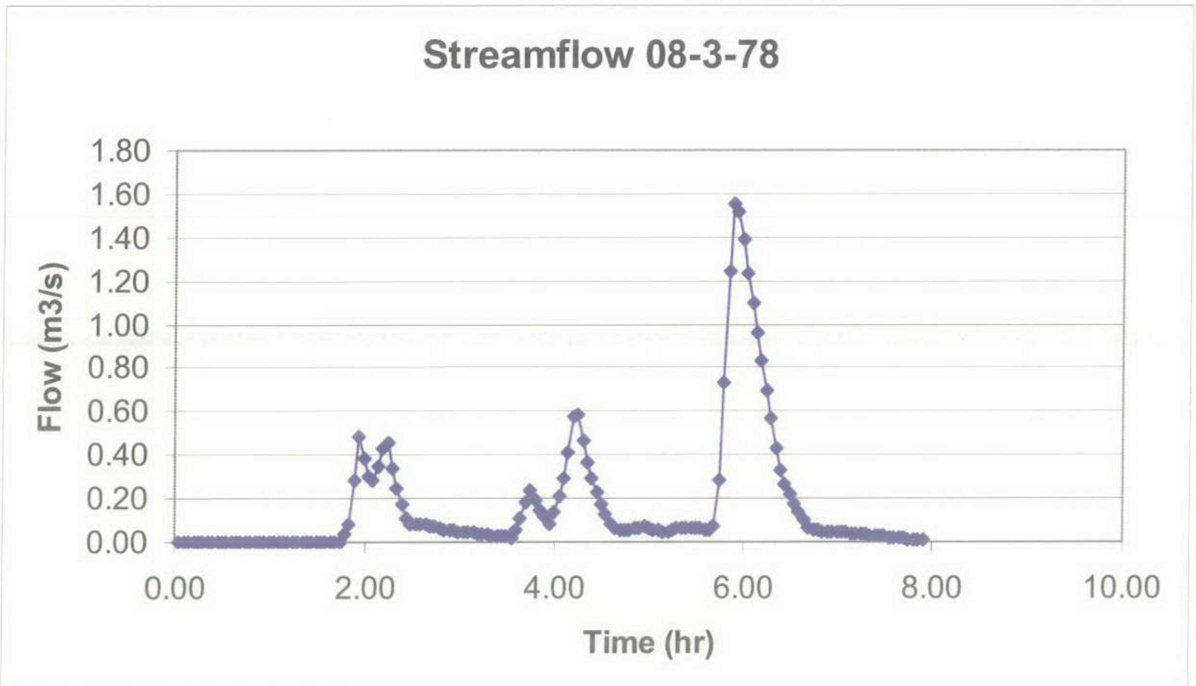


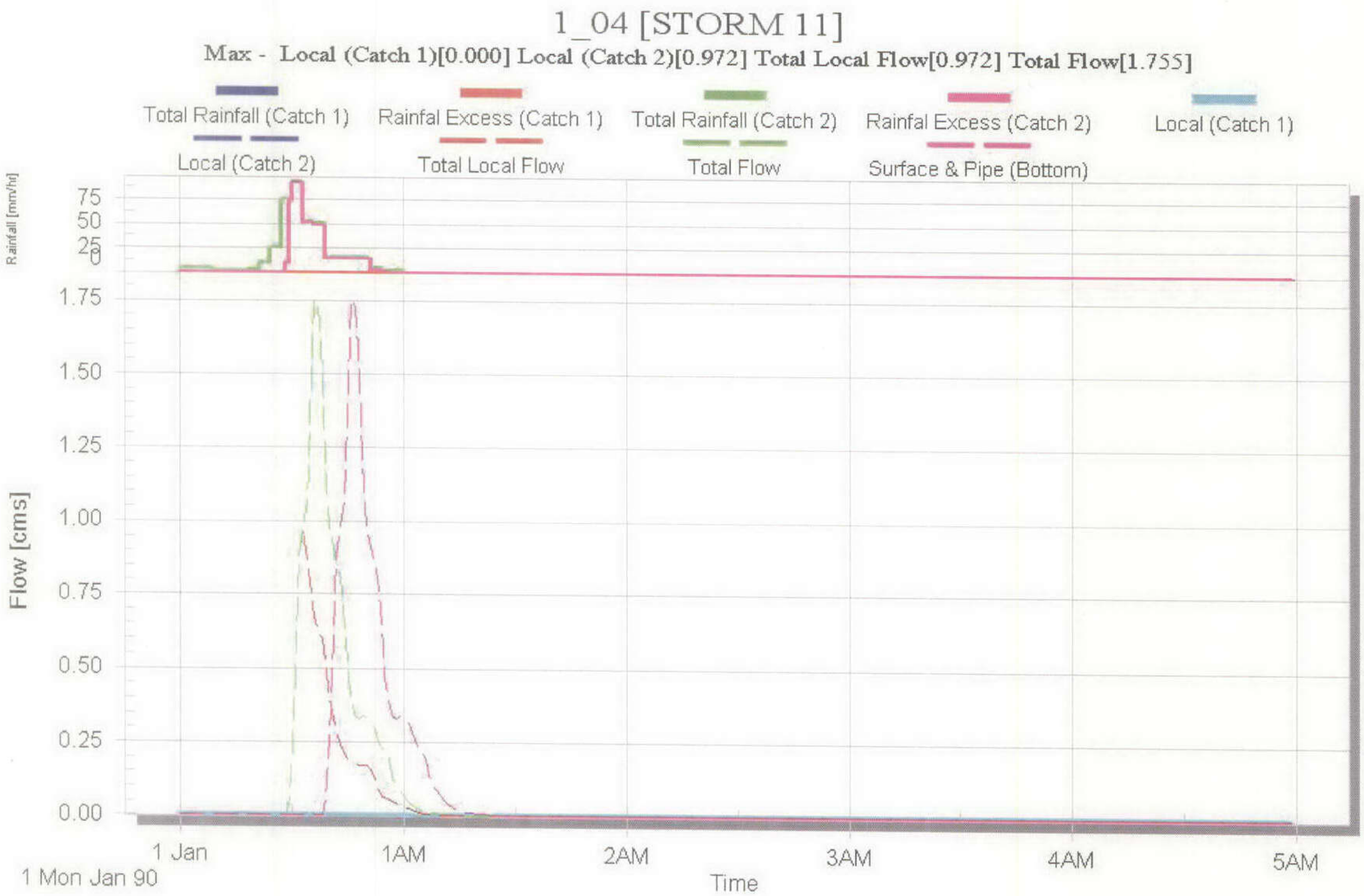


RAFTS CALIBRATION OUTPUT AT GAUGE BASED ON 60 MINUTES PEAK RAINFALL

18 March 1978

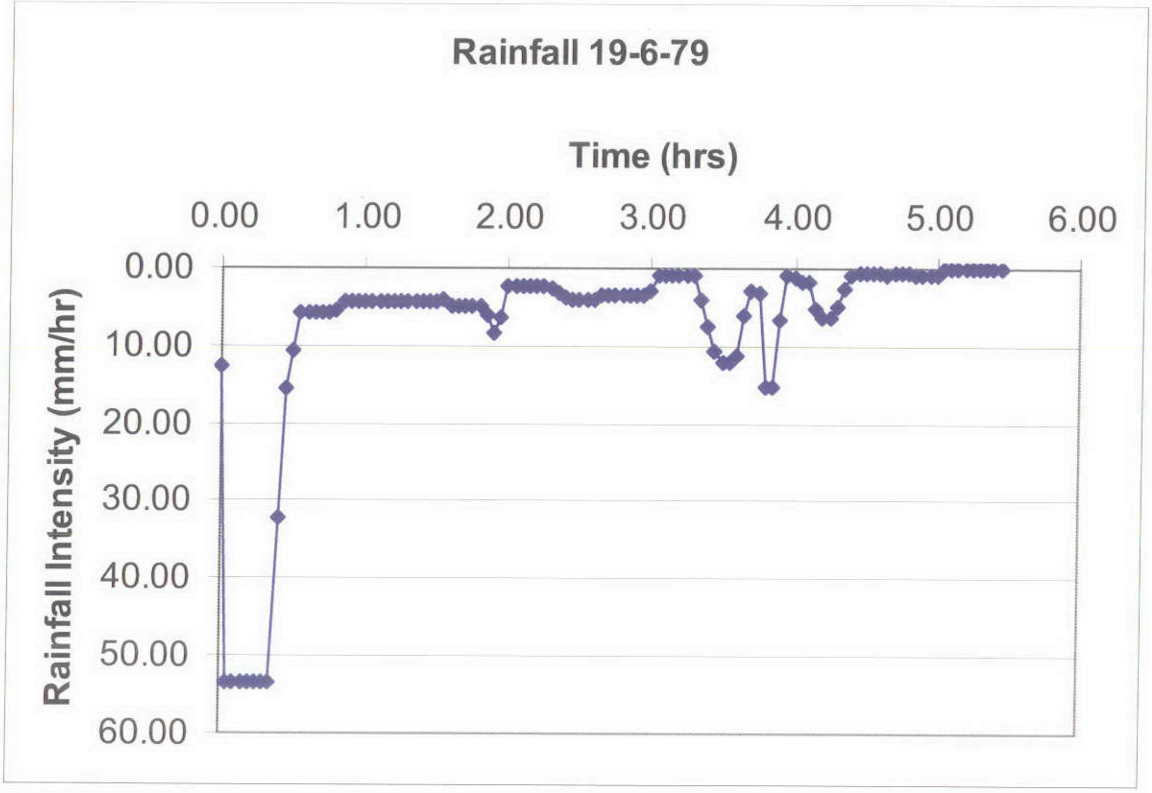




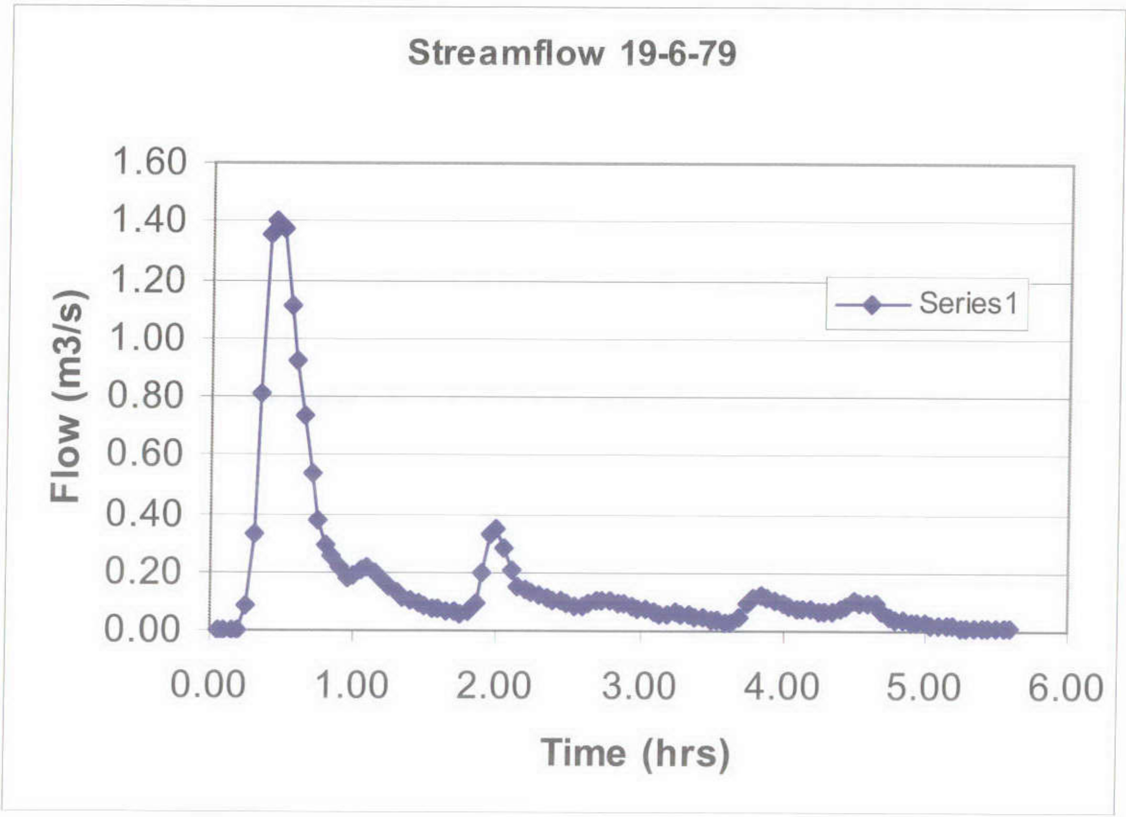


RAFTS CALIBRATION OUTPUT AT GAUGE BASED ON 60 MINUTES PEAK RAINFALL

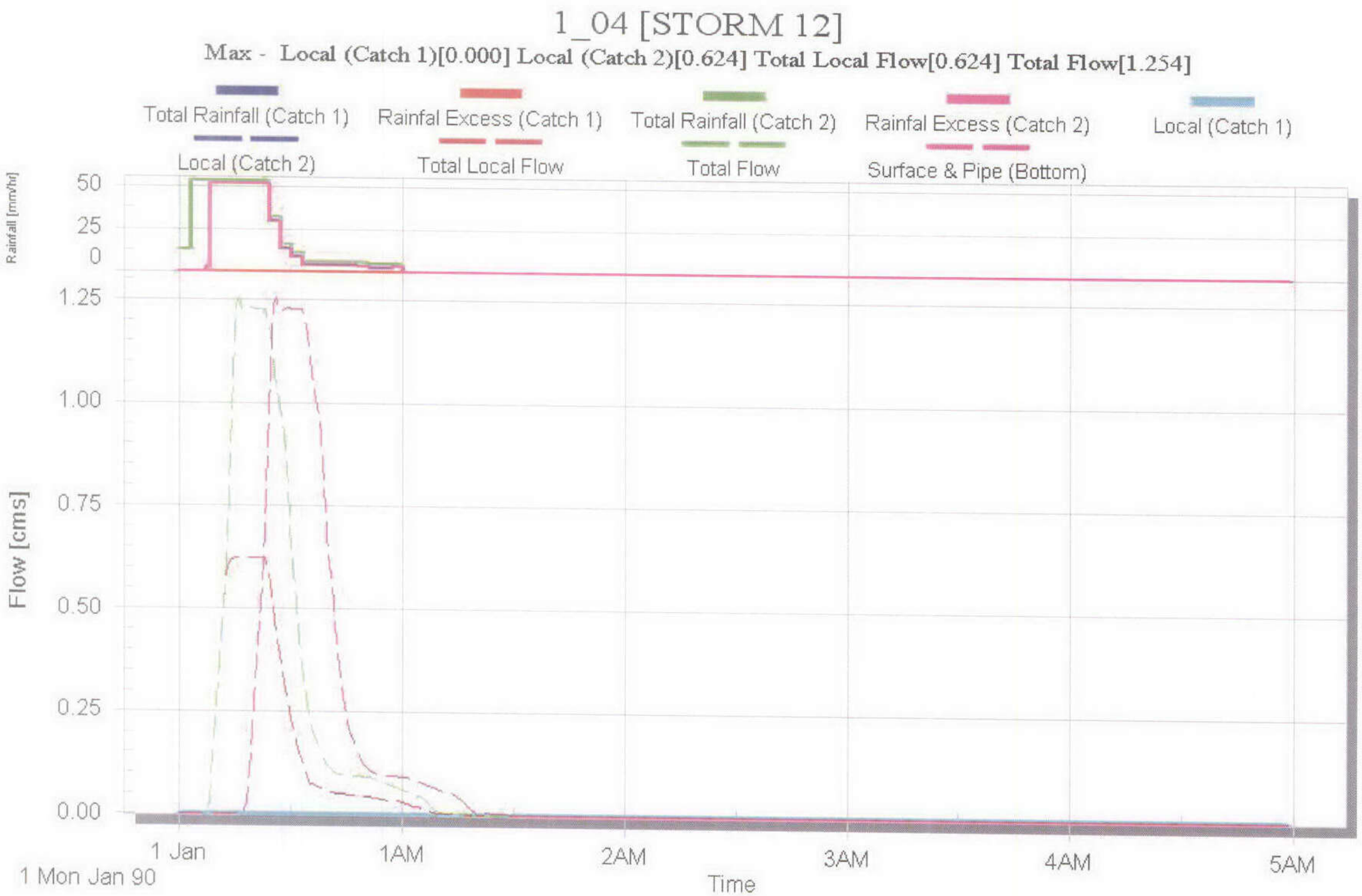
19 June 1979



Rainfall 19-6-79
Time (hrs)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Rainfall Intensity (mm/hr)
0.00
10.00
20.00
30.00
40.00
50.00
60.00

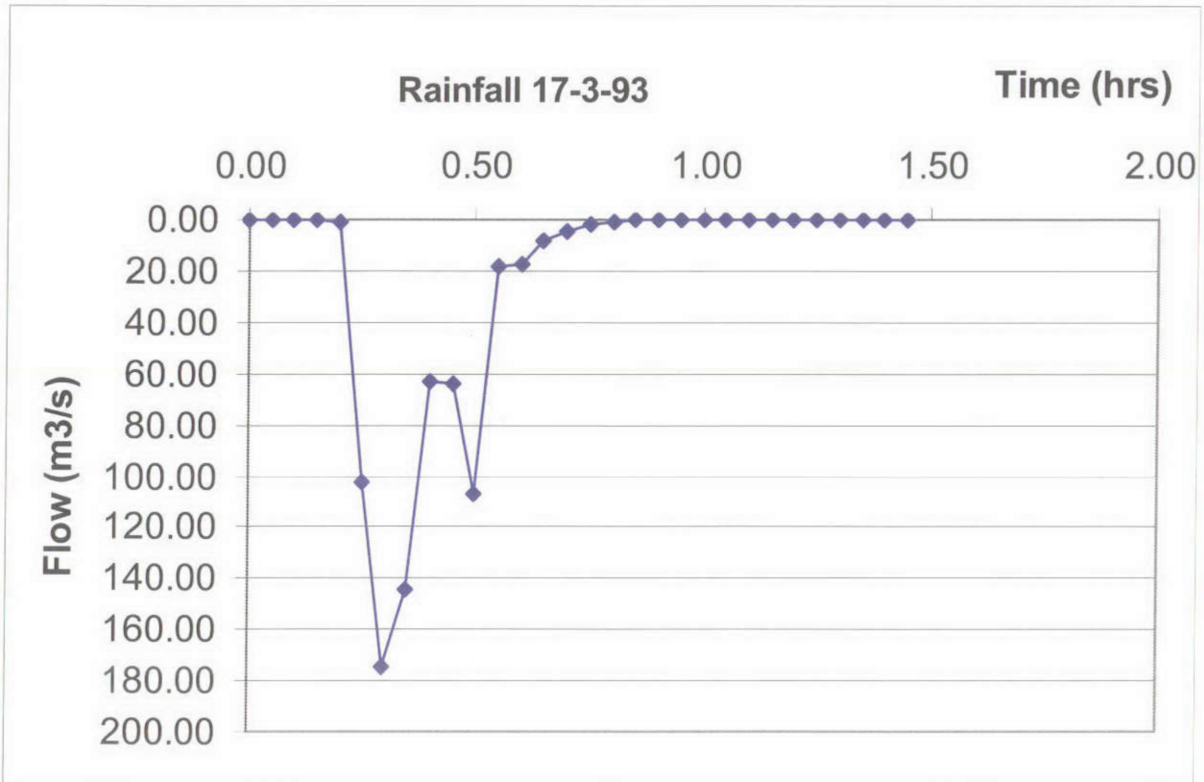


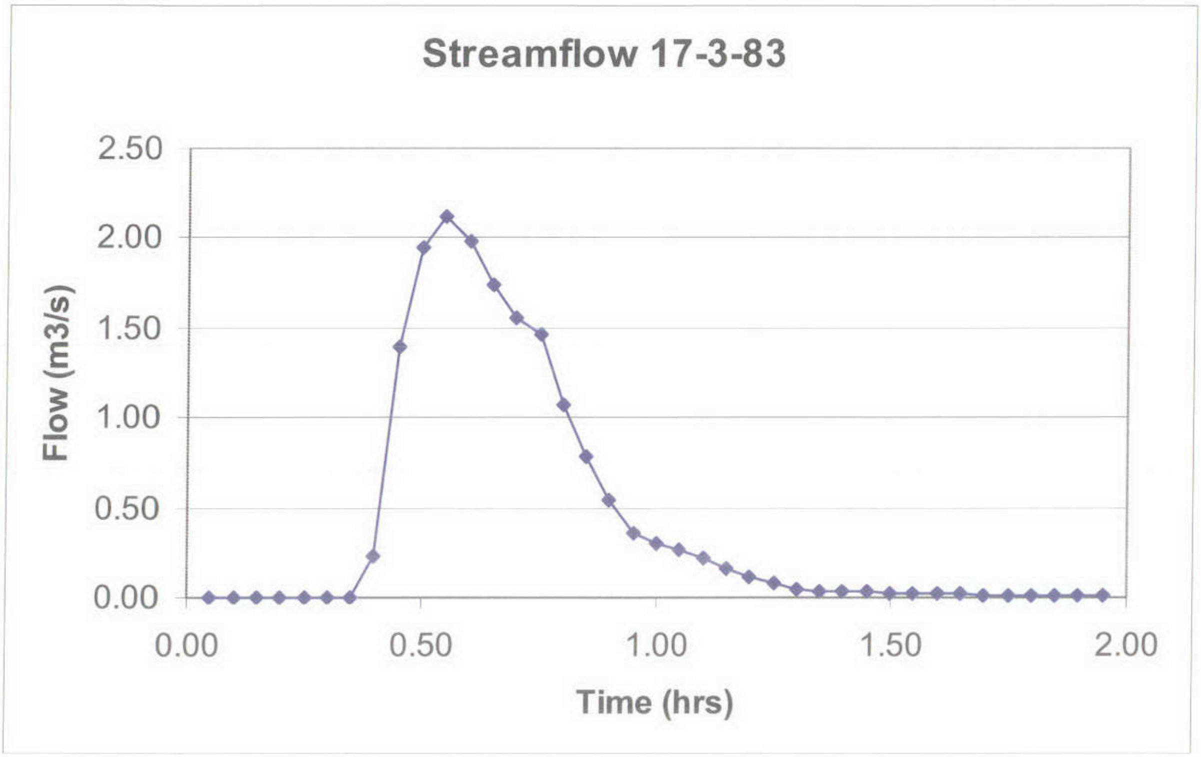
Streamflow 19-6-79
Flow (m3/s)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Series1
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Time (hrs)

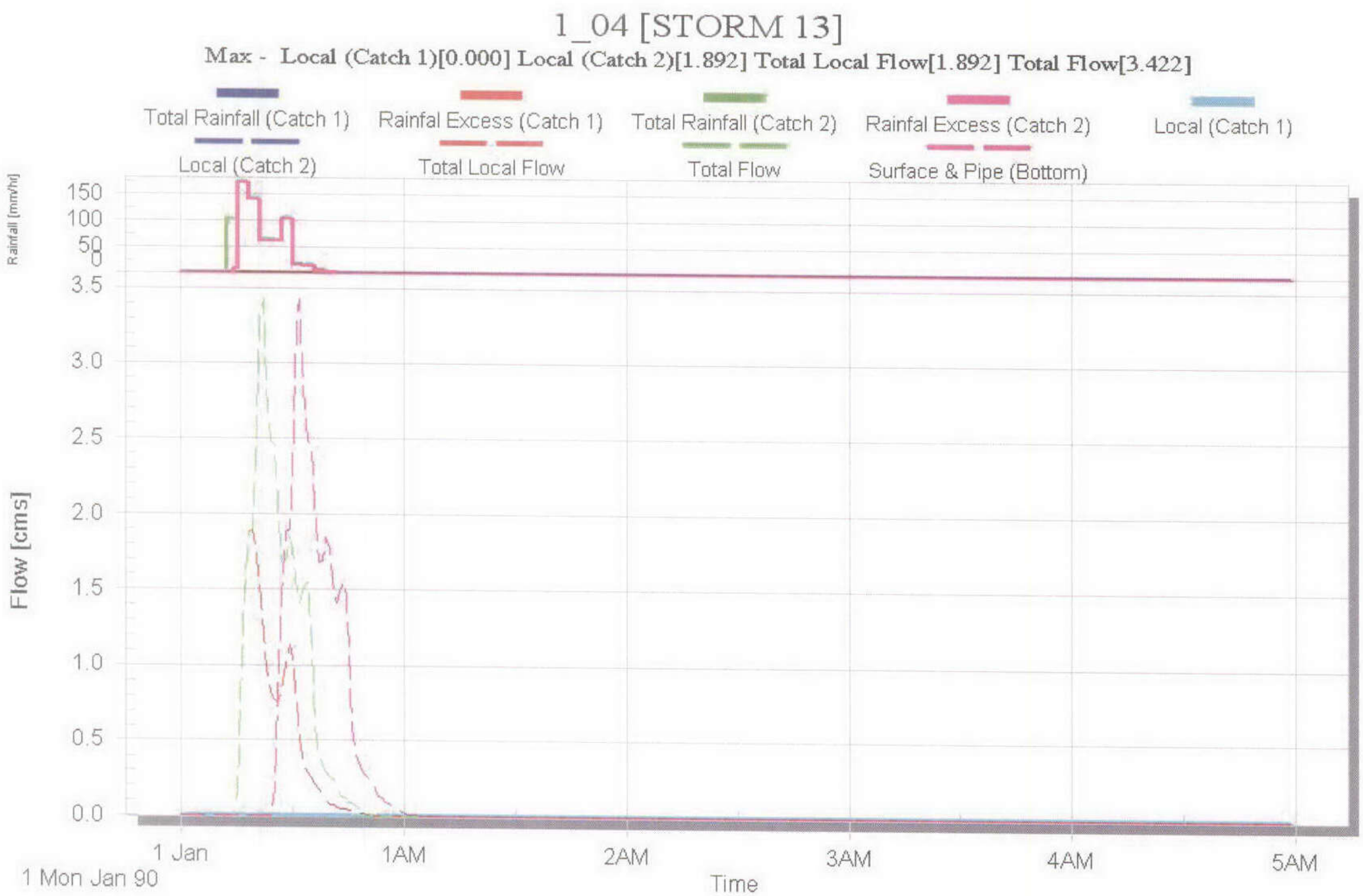


RAFTS CALIBRATION OUTPUT AT GAUGE BASED ON 60 MINUTES PEAK RAINFALL

17 March 1983

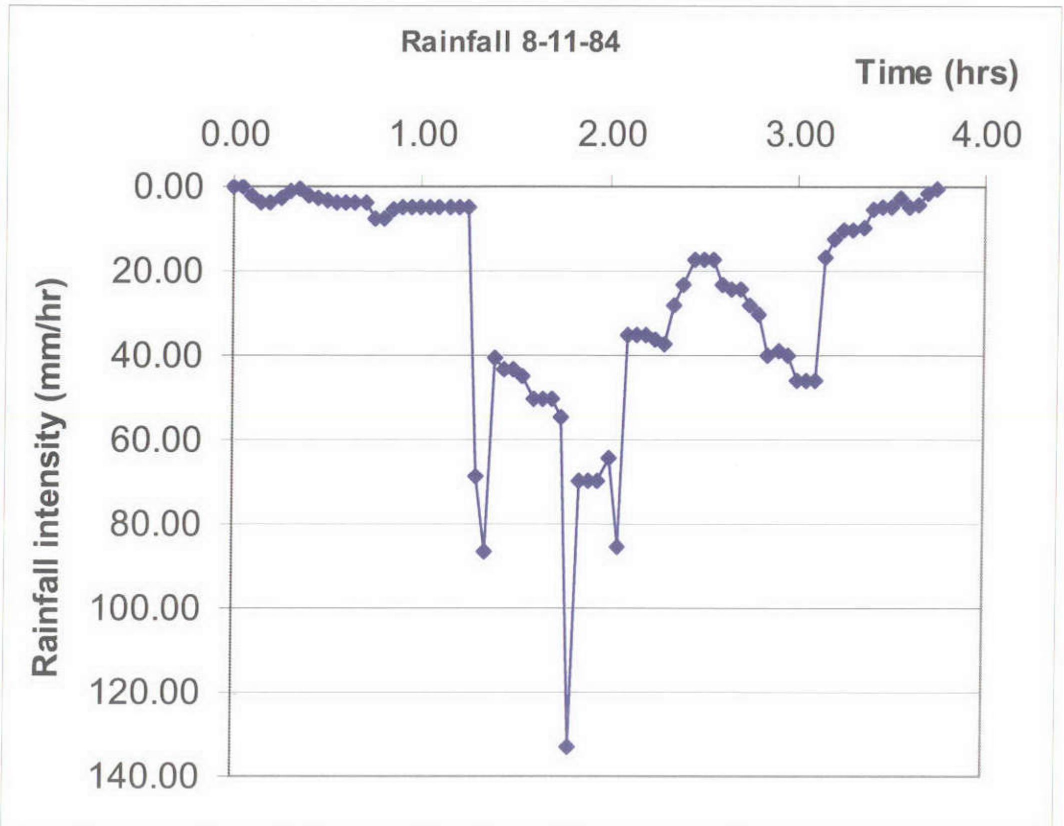


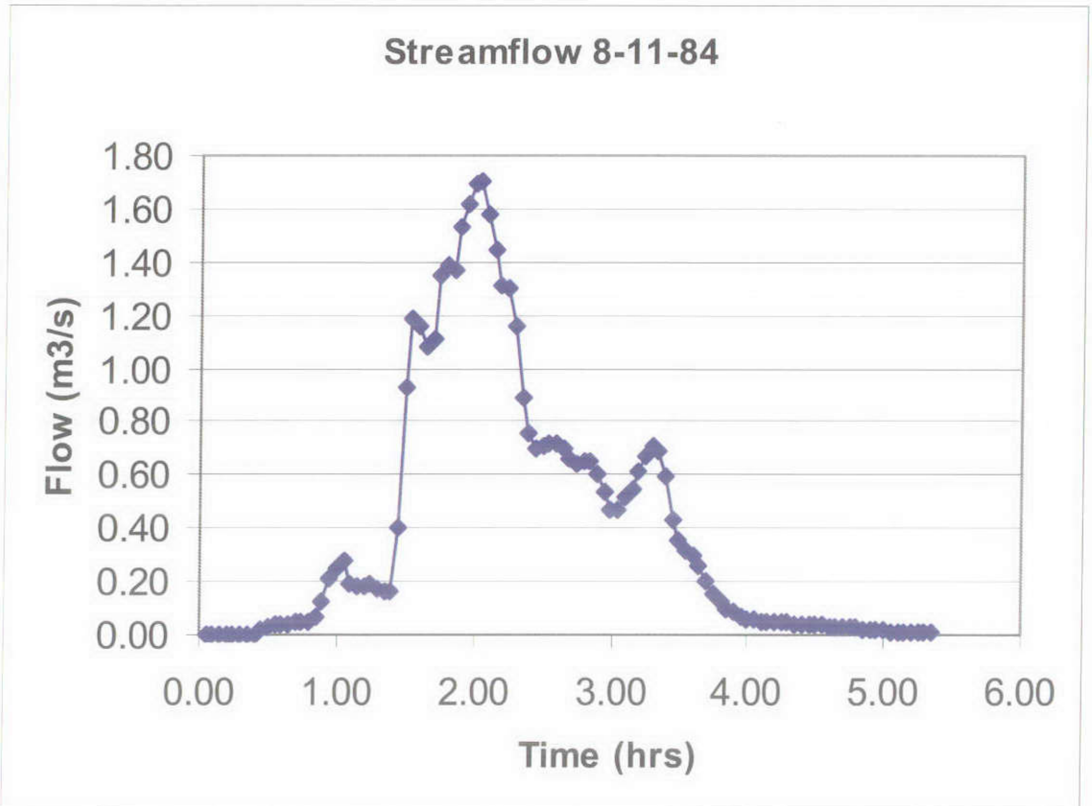


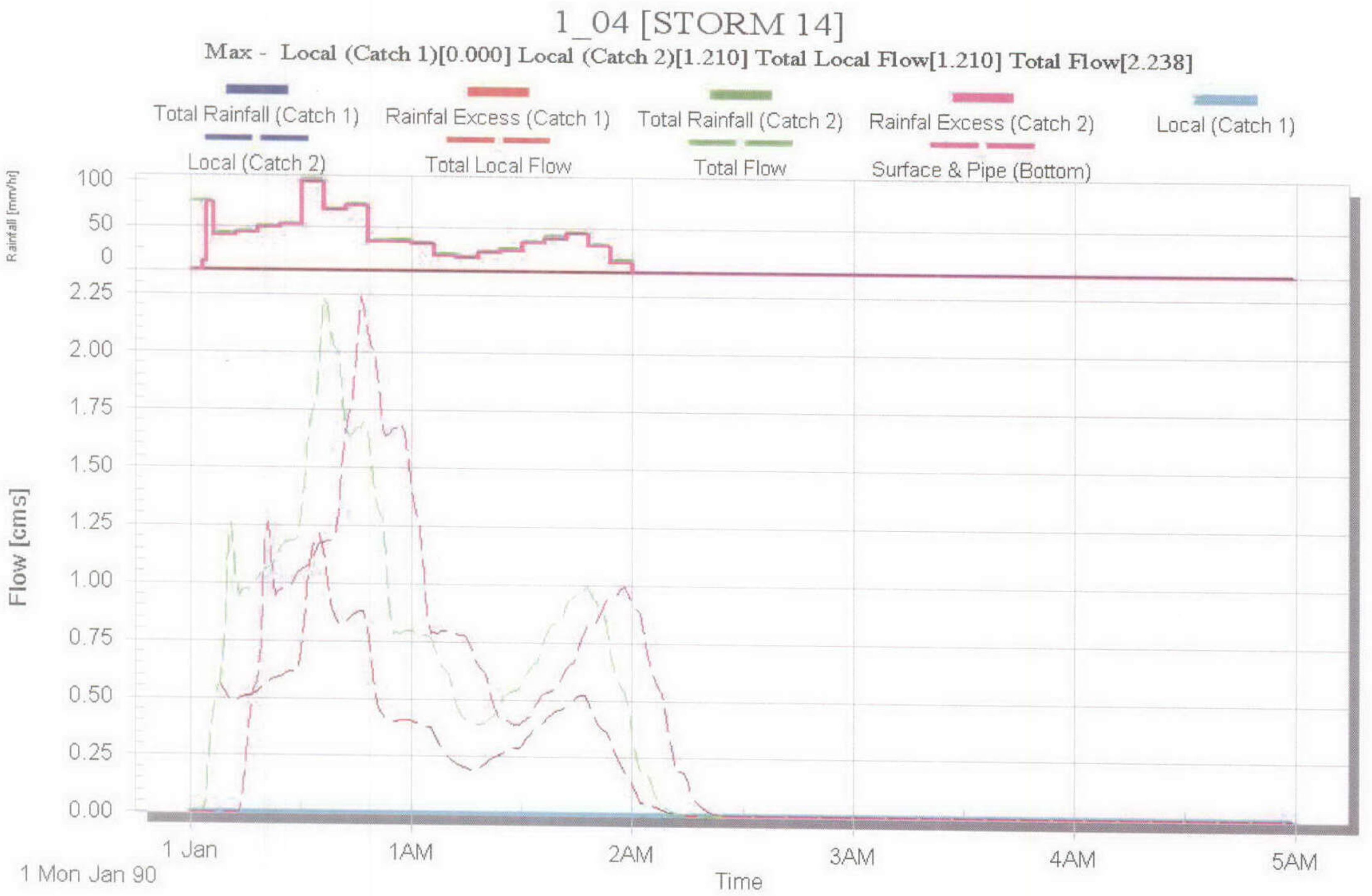


RAFTS CALIBRATION OUTPUT AT GAUGE BASED ON 60 MINUTES PEAK RAINFALL

8 November 1984







RAFTS CALIBRATION OUTPUT AT GAUGE BASED ON 120 MINUTES PEAK RAINFALL

APPENDIX B SURVEY DATA

INSERT ACAD PRINTOUT

APPENDIX C RAFTS MODEL DATA

B2 LINK DEFINITION DATA

Link	Subarea (ha)	Effective Pervious percentage (%)	Effective Impervious percentage (%)	Catchment Slope %	Channel lag (min)
1_00	76.14	75	25	3	4
3_00	52.88	75	25	0.8	0
1_01	0.00001	75	25	1	7
4_00	35.19	75	25	2.8	0
1_02	33.33	75	25	0.4	0
1_03	12.74	75	25	3	5
1_04	13.15	75	25	0.6	10
2_00	16.14	75	25	1.3	12
2_01	19.37	75	25	1.3	1
2_02	8.31	75	25	0.9	2
1_05	9.37	75	25	1.1	6
5_00	14	75	25	0.6	4
1_06	10.34	75	25	0.9	0
6_00	11.43	75	25	0.8	7
7_00	4.6	75	25	1.8	9
8_00	17.46	75	25	1.4	8
6_01	0.00001	75	25	1	4
1_07	32.77	75	25	0.2	0
node1	0.00001	75	25	1	0

BASIN CHARACTERISTICS

LINK 1_00

STAGE	**STORAGE**
mAHD	m3
31	10
31.1	3171
31.2	6644
31.3	10240
31.4	13919
31.5	17660
31.6	21453
31.7	25288
31.8	29161
31.9	33066
32	37000
32.1	40961
32.2	44946
32.3	48953
32.4	52981
32.5	57028
32.6	61094
32.7	65175
32.8	69275
32.9	73389
33	77518

LINK 3_00

STAGE	**STORAGE**
	m3
31	7
31.1	2219.7
31.2	4650.8
31.3	7168
31.4	9743.3
31.5	12362
31.6	15017.1
31.7	17701.6
31.8	20412.7
31.9	23146.2
32	25900
32.1	28672.7
32.2	31462.2
32.3	34267.1
32.4	37086.7
32.5	39919.6
32.6	42765.8
32.7	45622.5
32.8	48492.5
32.9	51372.3
33	54262.6

*Assumed based on performance requiremen

##
Marist
Results for period from 0: 0.0 1/ 1/1990
to 5: 0.0 1/ 1/1990
##

ROUTING INCREMENT (MINS)	=	1.00	
STORM DURATION (MINS)	=	90.	
RETURN PERIOD (YRS)	=	100.	
BX	=	1.5000	
TOTAL OF FIRST SUB-AREAS (ha)		=	367.22
TOTAL OF SECOND SUB-AREAS (ha)		=	122.41
TOTAL OF ALL SUB-AREAS (ha)		=	489.63

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link Label	Catch. Area #1 (ha)	Catch. Area #2	Slope #1 (%)	Slope #2	% Impervious #1 (%)	% Impervious #2	Pern #1	Pern #2	B #1	B #2	Link No.
1_00	76.140	25.380	3.000	3.000	5.000	100.0	.025	.015	.1725	.0069	1.000
3_00	52.880	17.630	.8000	.8000	5.000	100.0	.025	.015	.2760	.0111	2.000
1_01	.00001	0.000	1.000	0.000	0.000	0.000	.025	0.00	0.000	0.000	1.001
4_00	35.190	11.730	2.800	2.800	5.000	100.0	.025	.015	.1195	.0048	3.000
1_02	33.330	11.110	.4000	.4000	0.000	100.0	.025	.015	.3814	.0123	1.002
1_03	12.740	4.250	3.000	3.000	5.000	100.0	.025	.015	.0681	.0027	4.000
1_04	13.150	4.380	.6000	.6000	5.000	100.0	.025	.015	.1545	.0062	4.001
2_00	16.140	5.380	1.300	1.300	5.000	100.0	.025	.015	.1169	.0047	5.000
2_01	19.370	6.460	1.300	1.300	5.000	100.0	.025	.015	.1285	.0052	5.001
2_02	8.310	2.770	.9000	.9000	5.000	100.0	.025	.015	.0994	.0040	5.002
1_05	9.370	3.120	1.100	1.100	5.000	100.0	.025	.015	.0957	.0038	4.002
5_00	14.000	4.670	.6000	.6000	5.000	100.0	.025	.015	.1596	.0064	6.000
1_06	10.340	3.450	.9000	.9000	5.000	100.0	.025	.015	.1114	.0045	4.003
6_00	11.430	3.810	.8000	.8000	5.000	100.0	.025	.015	.1244	.0050	7.000
7_00	4.600	1.530	1.800	1.800	5.000	100.0	.025	.015	.0517	.0021	8.000
8_00	17.460	5.820	1.400	1.400	5.000	100.0	.025	.015	.1173	.0047	9.000
6_01	.00001	0.000	1.000	0.000	5.000	0.000	.025	0.00	0.000	0.000	7.001
1_07	32.770	10.920	.2000	.2000	5.000	100.0	.025	.015	.4298	.0173	4.004
node1	.00001	0.000	1.000	0.000	5.000	0.000	.025	0.00	0.000	0.000	1.003

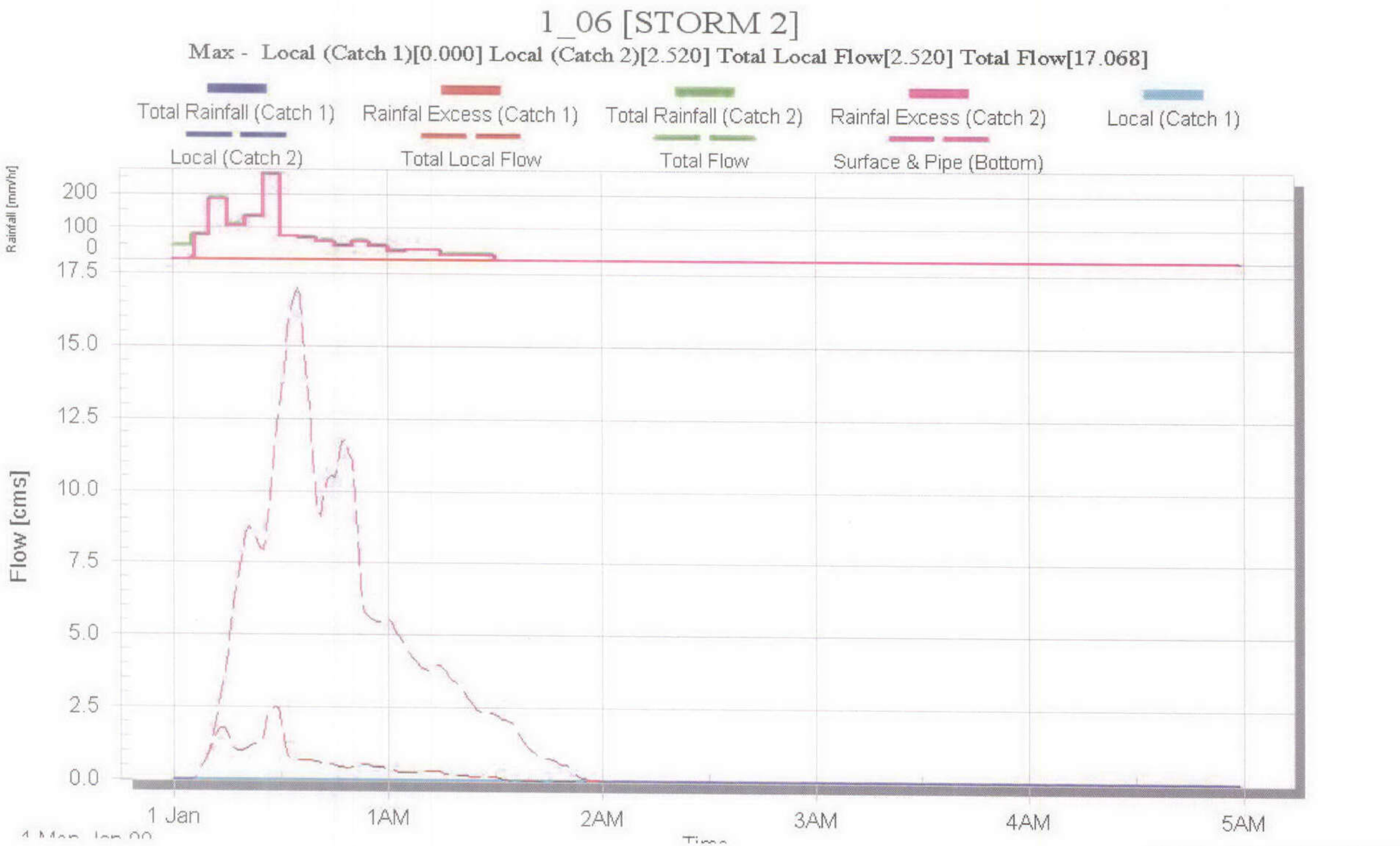
Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	Init. Loss #2	Cont. Loss #1 (mm/h)	Cont. Loss #2	Excess Rain #1 (mm)	Excess Rain #2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
1_00	74.365	100.0	5.000	100.0	2.000	0.000	103.71	18.448	29.00	4.000
3_00	74.365	100.0	5.000	100.0	2.000	0.000	103.71	12.716	30.00	0.000
1_01	74.365	100.0	0.000	100.0	0.000	0.000	0.000	4.280	66.00	7.000
4_00	74.365	100.0	5.000	100.0	2.000	0.000	103.71	8.635	28.00	0.000
1_02	74.365	100.0	5.000	100.0	2.000	0.000	103.71	19.380	30.00	0.000
1_03	74.365	100.0	5.000	100.0	2.000	0.000	103.71	3.162	28.00	5.000
1_04	74.365	100.0	5.000	100.0	2.000	0.000	103.71	4.832	31.00	10.00
2_00	74.365	100.0	5.000	100.0	2.000	0.000	103.71	3.930	29.00	12.00
2_01	74.365	100.0	5.000	100.0	2.000	0.000	103.71	7.040	28.00	1.000
2_02	74.365	100.0	5.000	100.0	2.000	0.000	103.71	9.056	29.00	2.000
1_05	74.365	100.0	5.000	100.0	2.000	0.000	103.71	14.427	30.00	6.000
5_00	74.365	100.0	5.000	100.0	2.000	0.000	103.71	3.378	30.00	4.000
1_06	74.365	100.0	5.000	100.0	2.000	0.000	103.71	17.068	36.00	0.000
6_00	74.365	100.0	5.000	100.0	2.000	0.000	103.71	2.768	29.00	7.000
7_00	74.365	100.0	5.000	100.0	2.000	0.000	103.71	1.126	28.00	9.000
8_00	74.365	100.0	5.000	100.0	2.000	0.000	103.71	4.248	29.00	8.000
6_01	74.365	100.0	0.000	100.0	0.000	0.000	0.000	8.127	37.00	4.000
1_07	74.365	100.0	5.000	100.0	2.000	0.000	103.71	24.400	35.00	0.000
node1	74.365	100.0	0.000	100.0	0.000	0.000	0.000	42.403	30.00	0.000

SUMMARY OF BASIN RESULTS

Link Label	Time to Peak	Peak Inflow (m^3/s)	Time to Peak	Peak Outflow (m^3/s)	Total Inflow (m^3)	Basin Vol. Avail	Basin Vol. Used	Basin Stage Used
1_00	29.00	18.45	63.00	2.308	26312.2	0.0000	16488.2	31.469
3_00	30.00	12.72	62.00	1.977	18279.4	0.0000	10356.6	31.423

SUMMARY OF BASIN OUTLET RESULTS

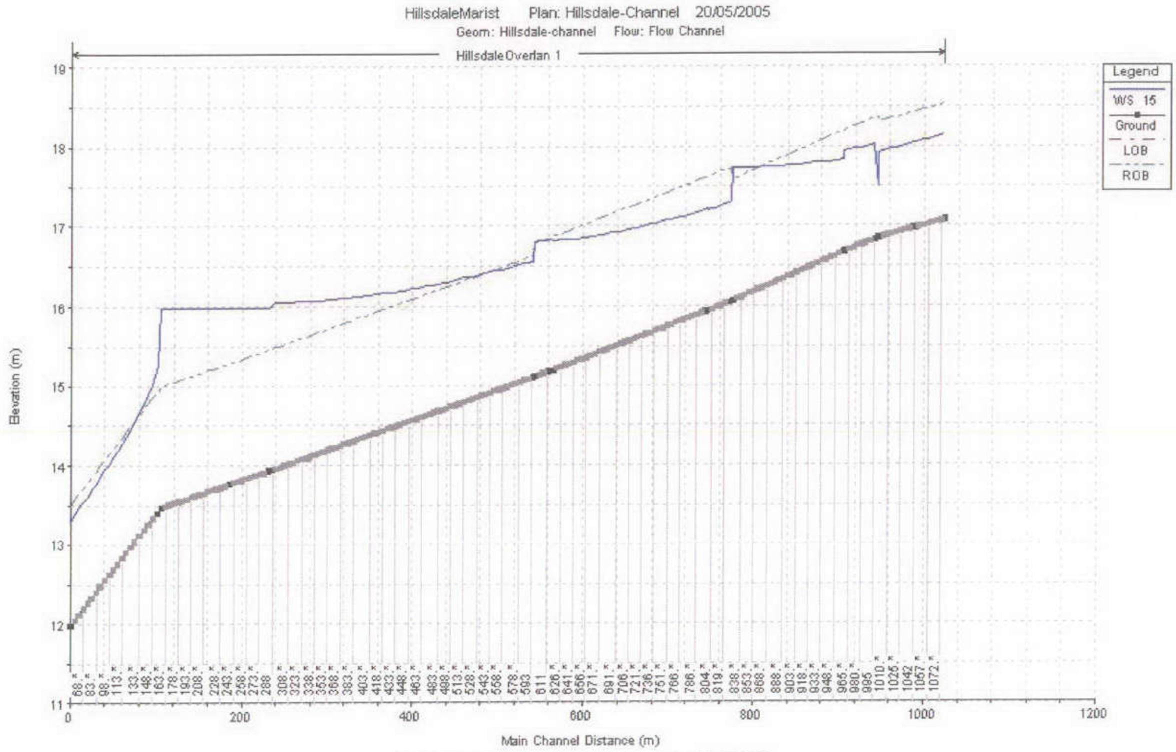
Link Label	No. of	S/D Factor (m)	Dia (m)	Width (m)	Pipe Length (m)	Pipe Slope (%)
1_00	1.0		1.200	0.000	20.000	0.5000
3_00	1.0		1.050	0.000	20.000	0.5000

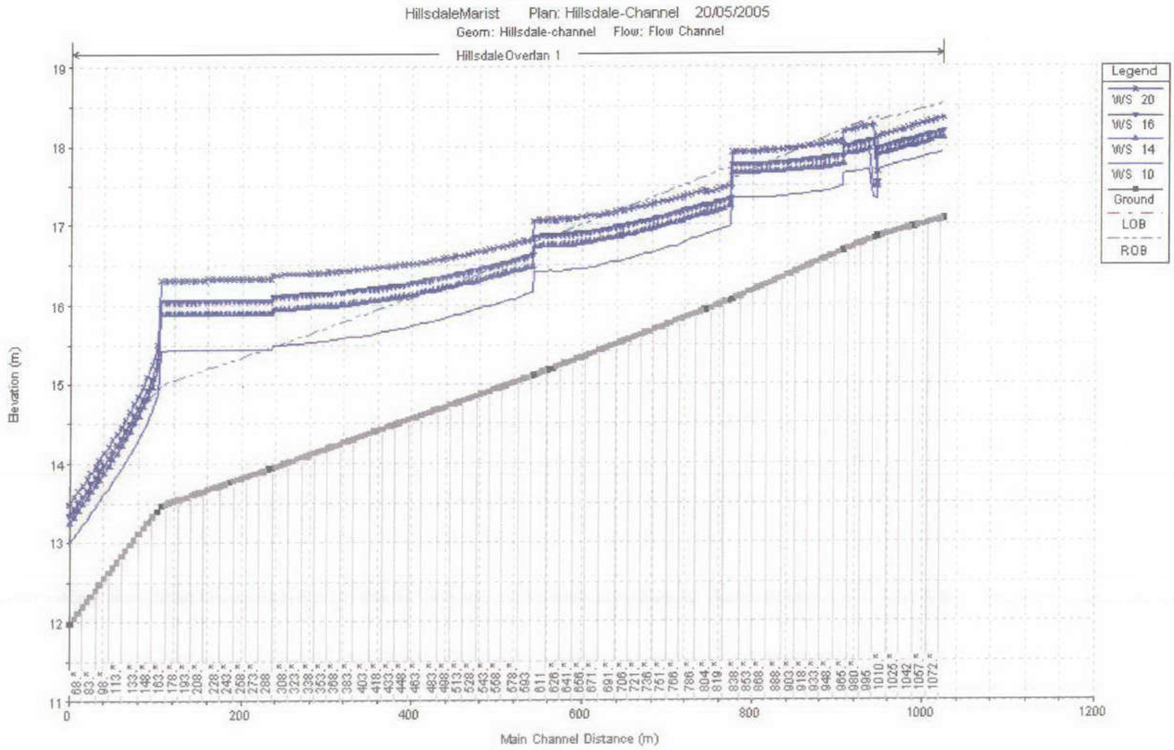


100 YR ARI 90 MINUTE
NODE 1_06 AT MARIST COLLEGE

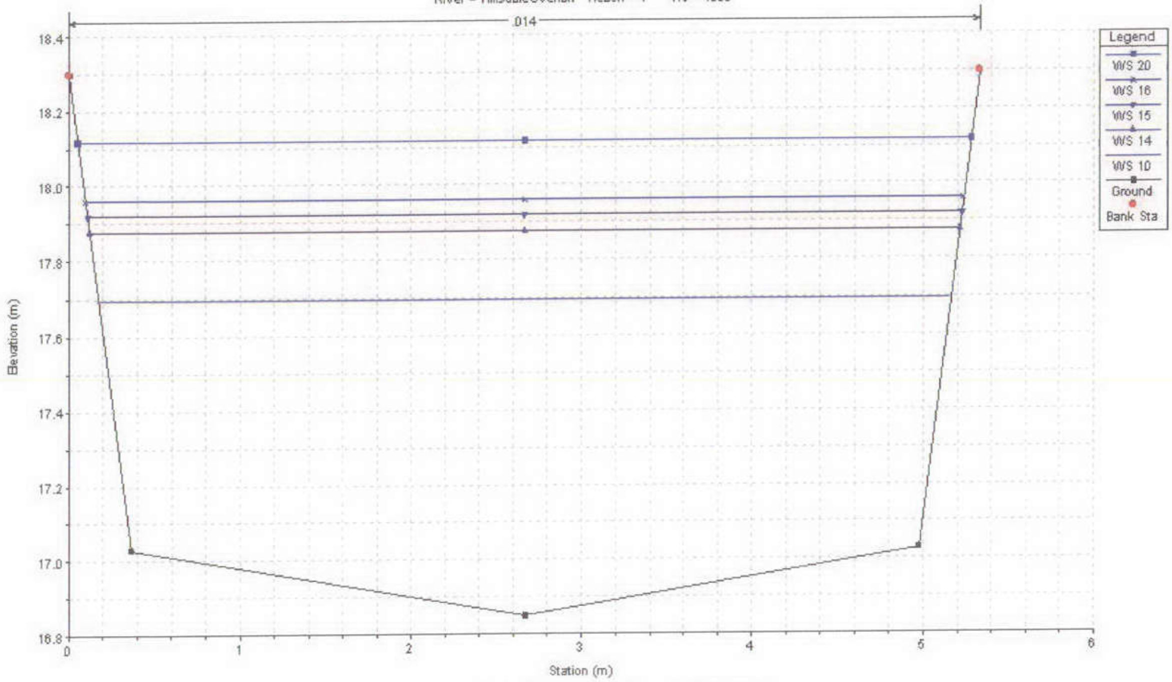
APPENDIX D HYDRAULIC MODEL DATA

D1. SWC11 CULVERT SYSTEM

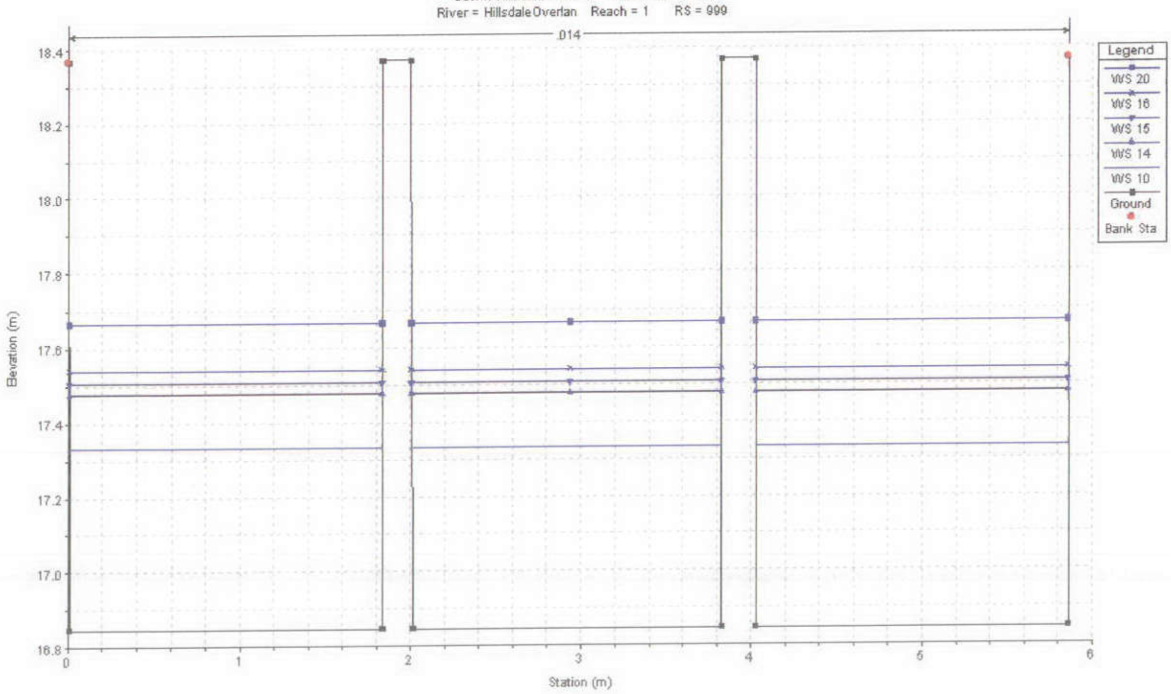

HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
Hillsdale Overlan 1
Legend
WS 15
Ground
LOB
ROB
Elevation (m)
Main Channel Distance (m)

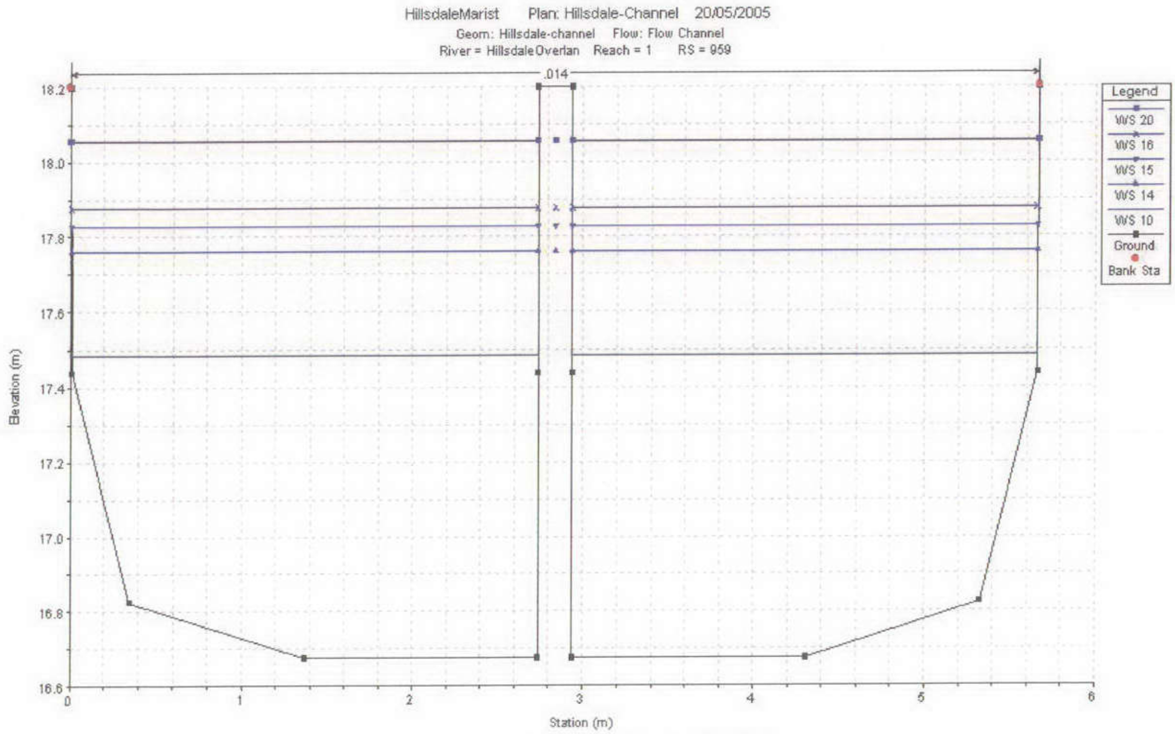

HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
Hillsdale Overlan 1
Legend
WS 20
WS 16
WS 14
WS 10
Ground
LOB
ROB
Elevation (m)
Main Channel Distance (m)

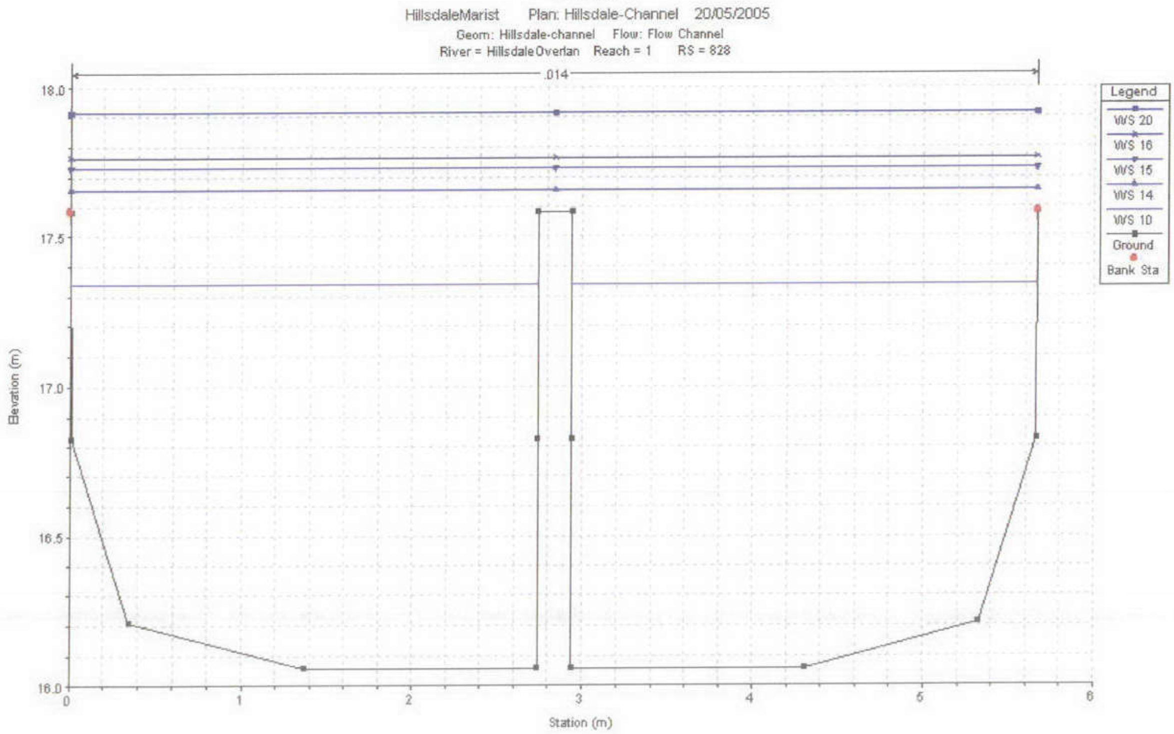
HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 1000

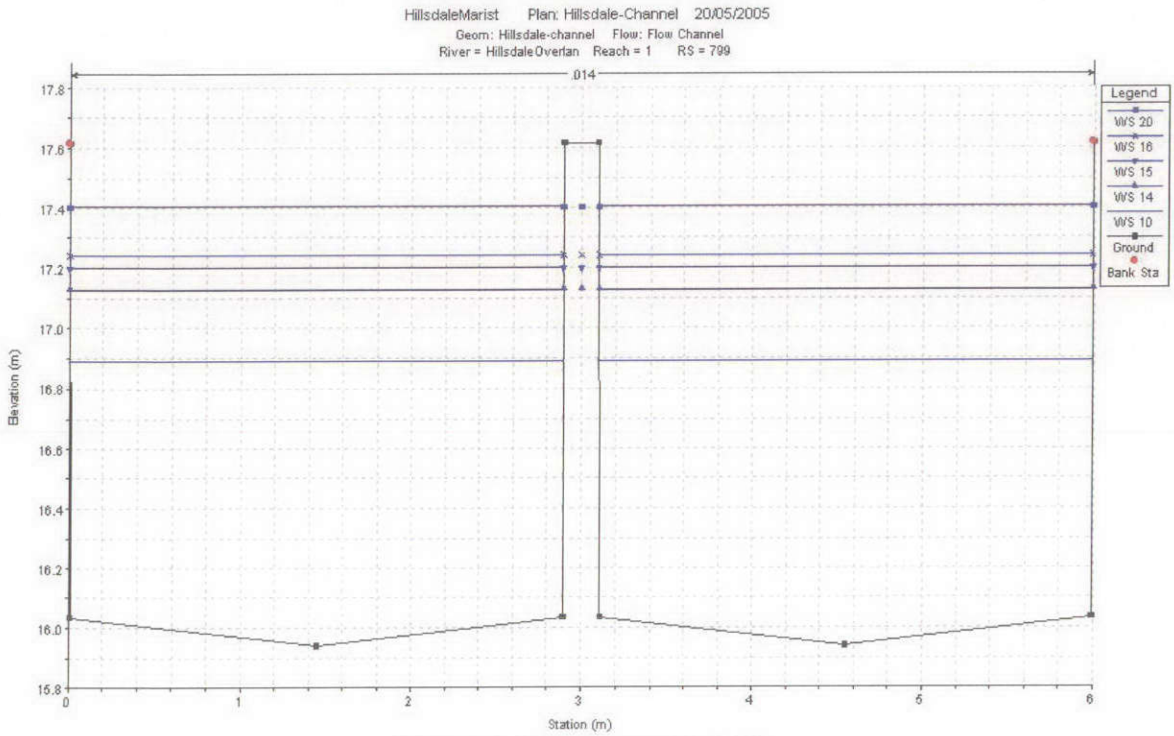


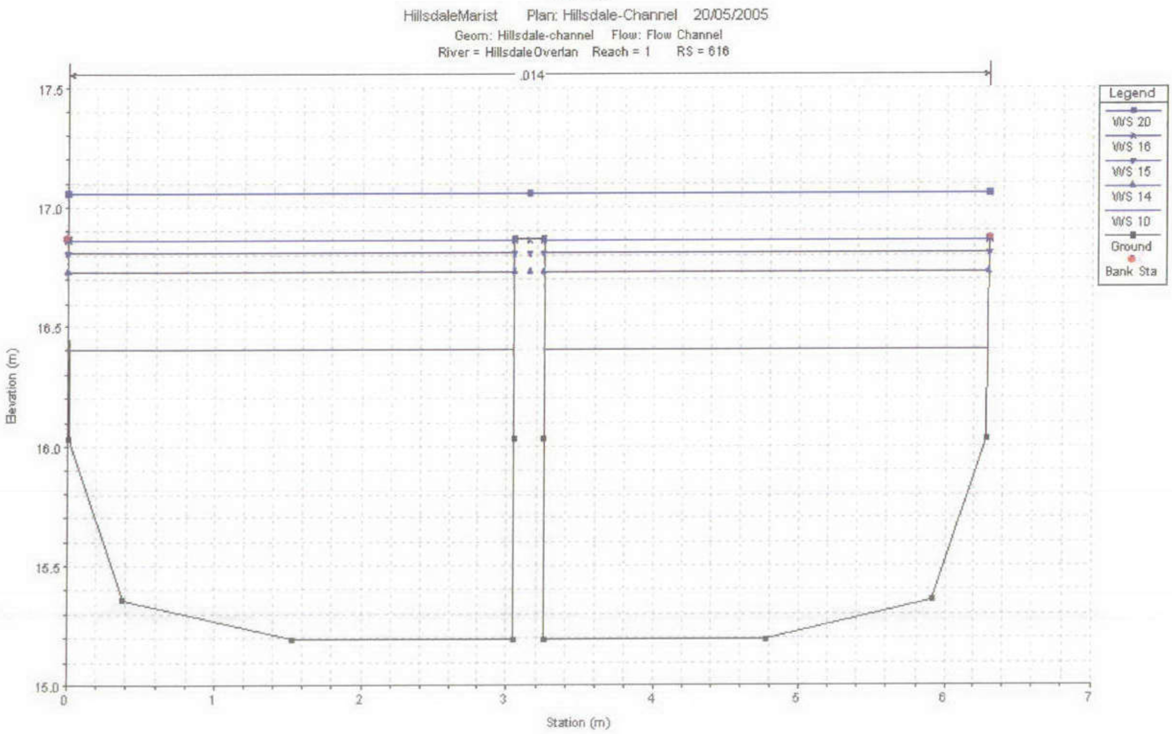
HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 999



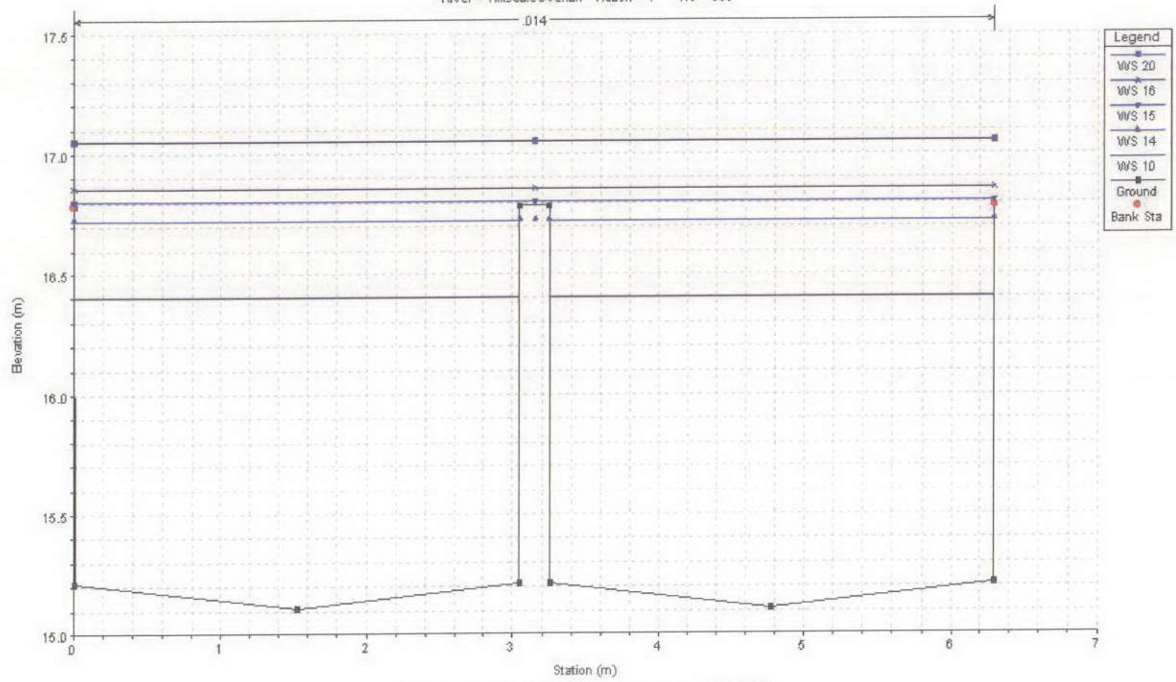

HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 959
.014
Legend
WS 20
WS 16
WS 15
WS 14
WS 10
Ground
Bank Sta
Elevation (m)
Station (m)


HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 828
.014
Legend
WS 20
WS 16
WS 15
WS 14
WS 10
Ground
Bank Sta
Elevation (m)
Station (m)

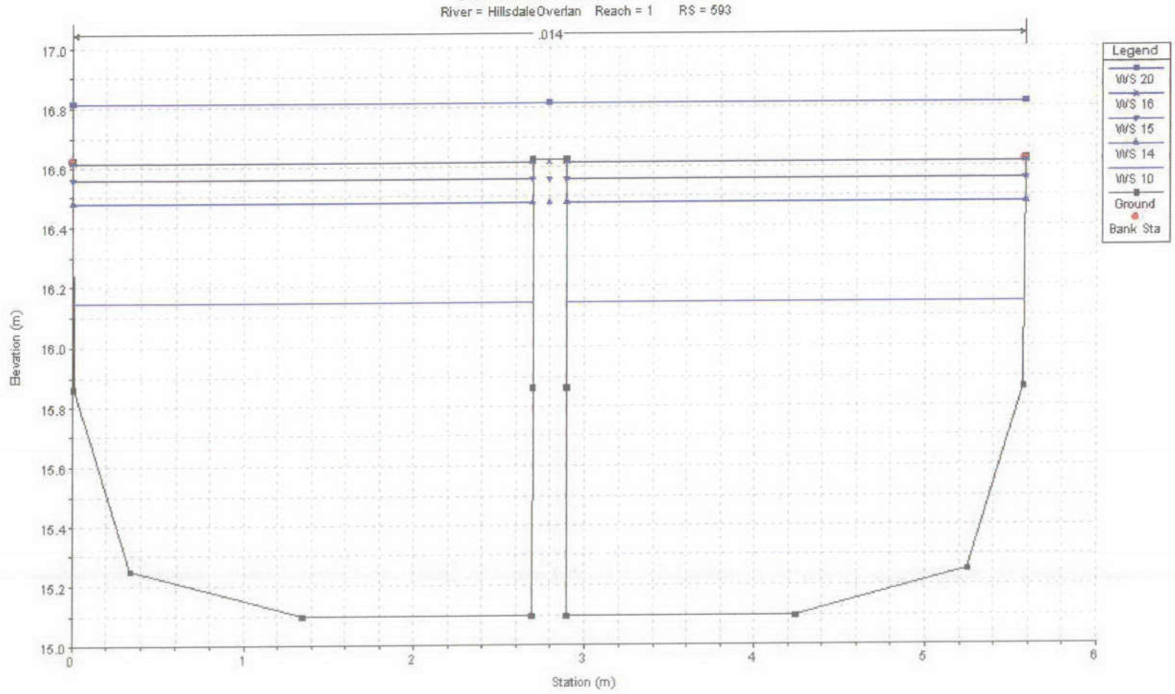

HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 799
.014
Legend
WS 20
WS 16
WS 15
WS 14
WS 10
Ground
Bank Sta
Elevation (m)
Station (m)

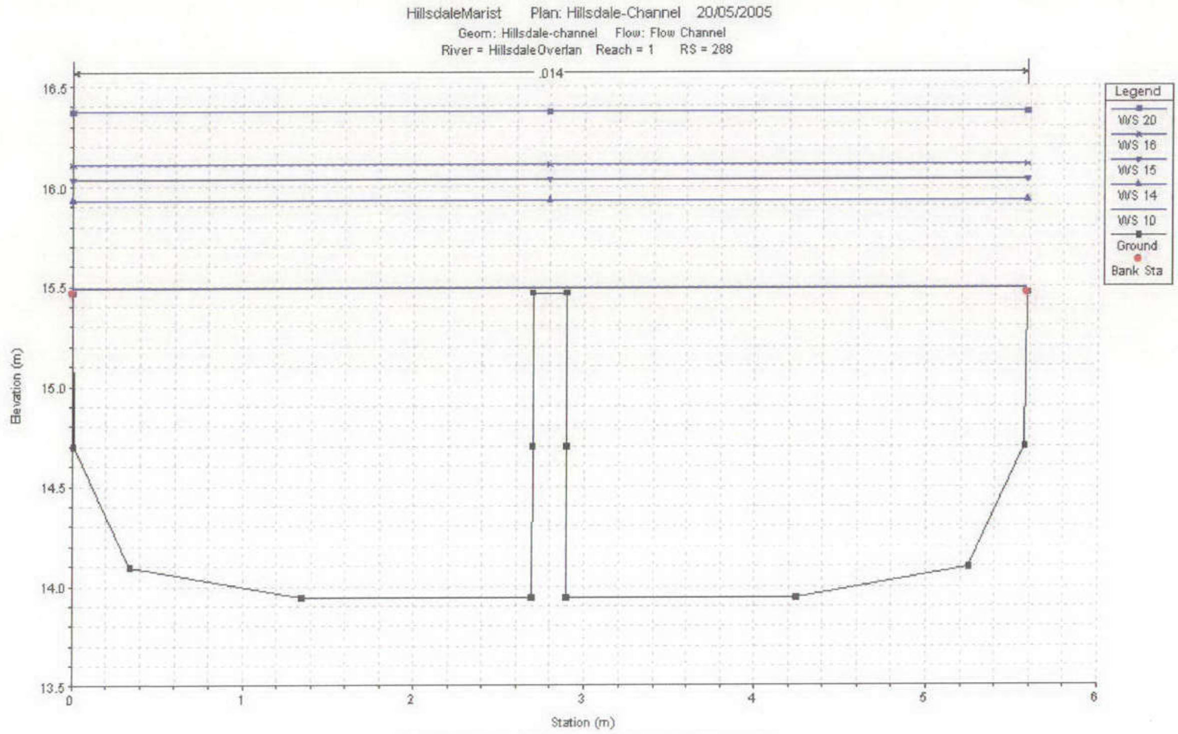

HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 616
.014
Legend
WS 20
WS 16
WS 15
WS 14
WS 10
Ground
Bank Sta
Elevation (m)
Station (m)

HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 596

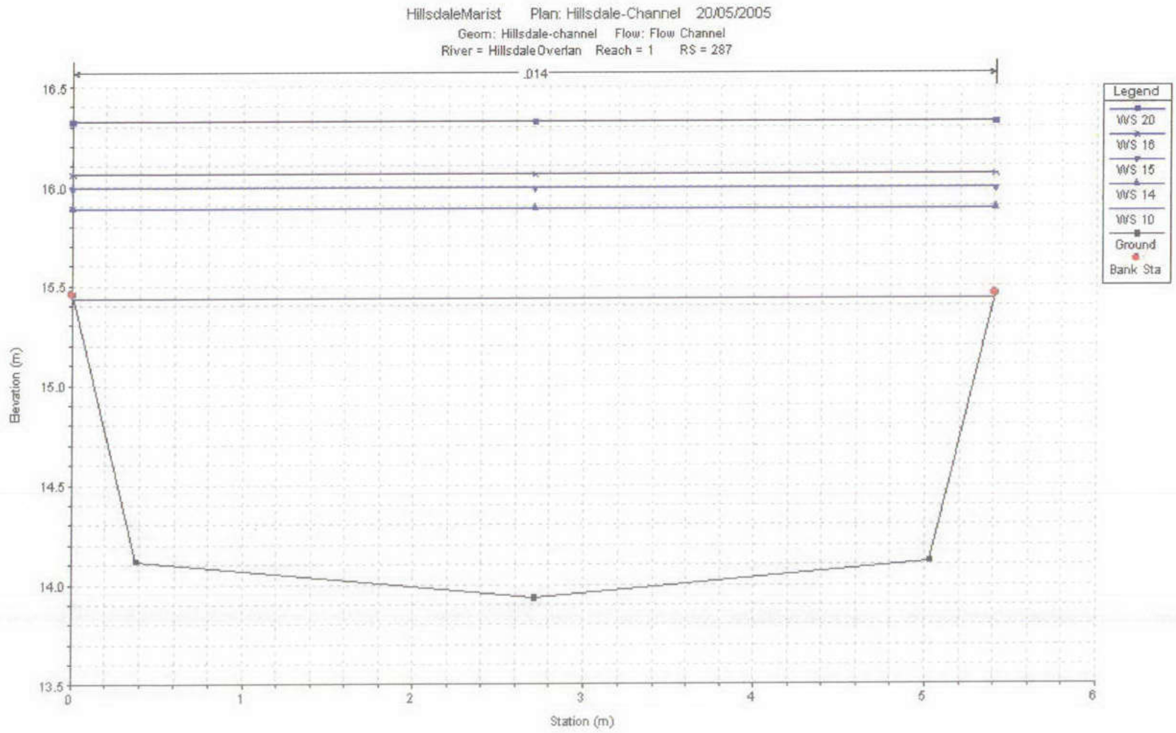


HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 593

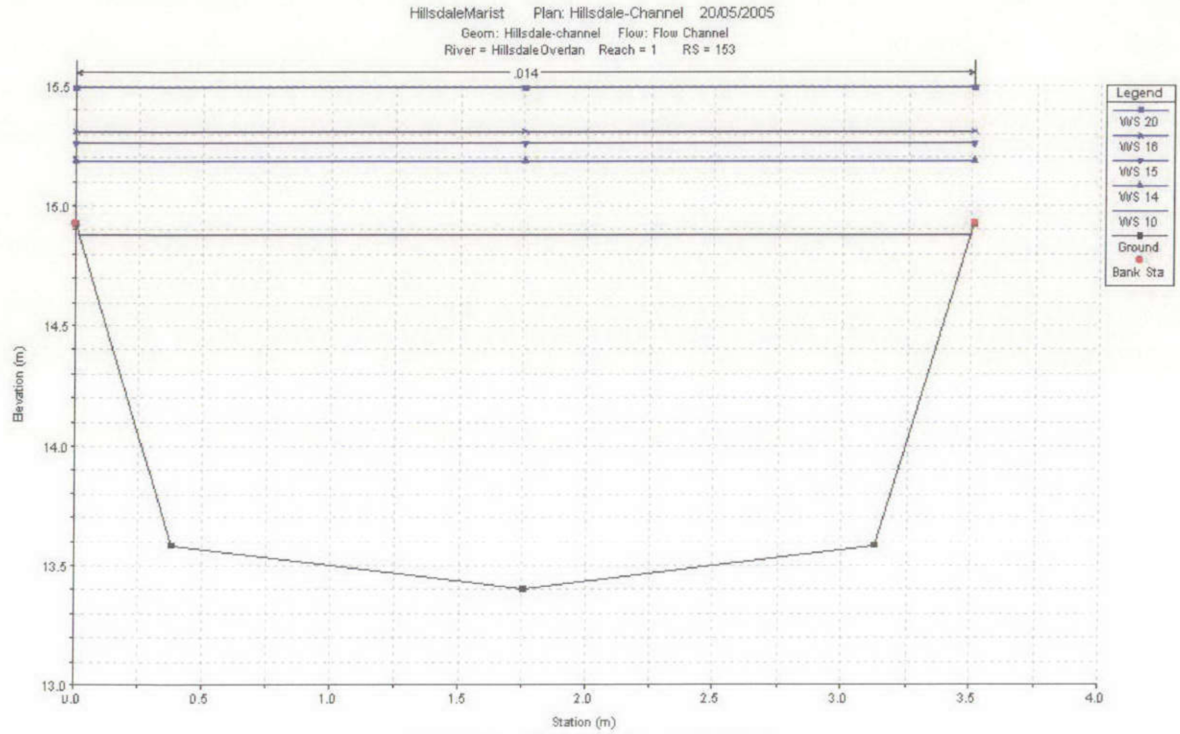


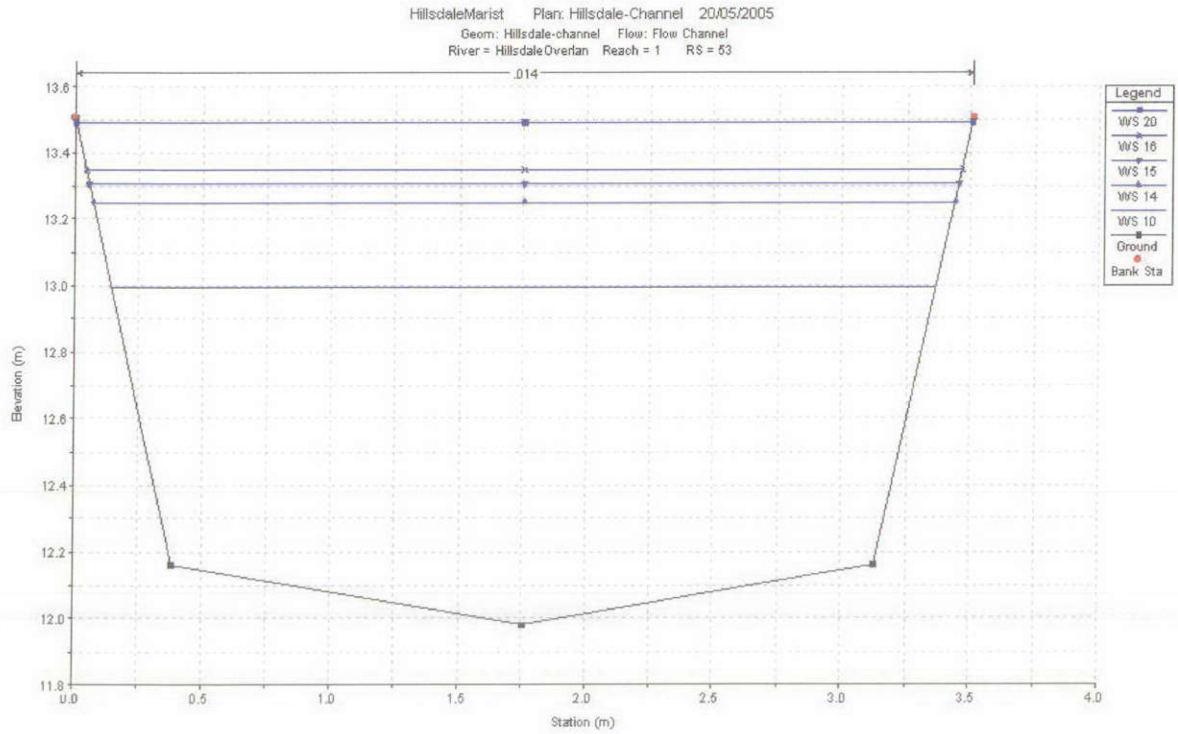


HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 288
.014
Legend
WS 20
WS 16
WS 15
WS 14
WS 10
Ground
Bank Sta
Elevation (m)
Station (m)



HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 287
.014
Legend
WS 20
WS 16
WS 15
WS 14
WS 10
Ground
Bank Sta
Elevation (m)
Station (m)


HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 153
.014
Legend
WS 20
WS 16
WS 15
WS 14
WS 10
Ground
Bank Sta
Elevation (m)
Station (m)
15.5
15.0
14.5
14.0
13.5
13.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0


HillsdaleMarist Plan: Hillsdale-Channel 20/05/2005
Geom: Hillsdale-channel Flow: Flow Channel
River = HillsdaleOverlan Reach = 1 RS = 53
.014
Legend
WS 20
WS 16
WS 15
WS 14
WS 10
Ground
Bank Sta
Elevation (m)
Station (m)
13.6
13.4
13.2
13.0
12.8
12.6
12.4
12.2
12.0
11.8
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

SWC11
HEC-RAS Plan: Channel River: HillsdaleOverlan
Reach: 1

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froud e # Chl
1	1077	10	10	17.08	17.92	17.94	18.32	0.003	2.78	3.6	4.99	1.05
1	1077	14	14	17.08	18.1	18.13	18.6	0.003	3.1	4.51	5.09	1.05
1	1077	15	15	17.08	18.15	18.18	18.66	0.003	3.17	4.73	5.12	1.05
1	1077	16	16	17.08	18.19	18.22	18.72	0.003	3.24	4.94	5.14	1.05
1	1077	20	20	17.08	18.35	18.38	18.96	0.003	3.47	5.76	5.23	1.06
1	1042	10	10	16.98	17.82	17.84	18.21	0.002975	2.77	3.61	4.99	1.04
1	1042	14	14	16.98	18	18.03	18.49	0.00298	3.1	4.52	5.09	1.05
1	1042	15	15	16.98	18.04	18.07	18.55	0.002981	3.17	4.74	5.12	1.05
1	1042	16	16	16.98	18.09	18.12	18.62	0.002982	3.23	4.95	5.14	1.05
1	1042	20	20	16.98	18.24	18.28	18.86	0.002985	3.47	5.77	5.23	1.05
1	1040	10	10	16.97	17.81	17.83	18.21	0.002974	2.77	3.61	4.99	1.04
1	1040	14	14	16.97	18	18.02	18.48	0.002979	3.1	4.52	5.09	1.05
1	1040	15	15	16.97	18.04	18.07	18.55	0.00298	3.17	4.74	5.12	1.05
1	1040	16	16	16.97	18.08	18.11	18.61	0.002981	3.23	4.95	5.14	1.05
1	1040	20	20	16.97	18.24	18.27	18.85	0.002984	3.47	5.77	5.23	1.05
1	1000	10	10	16.85	17.7	17.71	18.09	0.002957	2.77	3.61	4.99	1.04
1	1000	14	14	16.85	17.88	17.9	18.36	0.002968	3.09	4.53	5.09	1.05
1	1000	15	15	16.85	17.92	17.95	18.43	0.00297	3.16	4.74	5.12	1.05
1	1000	16	16	16.85	17.96	17.99	18.49	0.002972	3.23	4.96	5.14	1.05
1	1000	20	20	16.85	18.12	18.15	18.73	0.002978	3.46	5.77	5.23	1.05
1	999	10	10	16.85	17.33	17.54	18.05	0.01259	3.74	2.68	5.48	1.71
1	999	14	14	16.85	17.47	17.72	18.32	0.01214	4.07	3.44	5.48	1.64
1	999	15	15	16.85	17.51	17.76	18.38	0.012075	4.14	3.62	5.48	1.63
1	999	16	16	16.85	17.54	17.8	18.44	0.012023	4.21	3.8	5.48	1.61
1	999	20	20	16.85	17.67	17.95	18.68	0.011905	4.45	4.49	5.48	1.57
1	995	10	10	16.83	17.35	17.52	17.98	0.010477	3.5	2.85	5.48	1.55
1	995	14	14	16.83	17.48	17.7	18.26	0.010901	3.92	3.57	5.48	1.55
1	995	15	15	16.83	18.02	17.74	18.29	0.002504	2.3	6.52	5.49	0.67
1	995	16	16	16.83	18.07	17.78	18.35	0.002549	2.35	6.8	5.49	0.67
1	995	20	20	16.83	18.27	17.93	18.59	0.00275	2.54	7.87	5.49	0.68

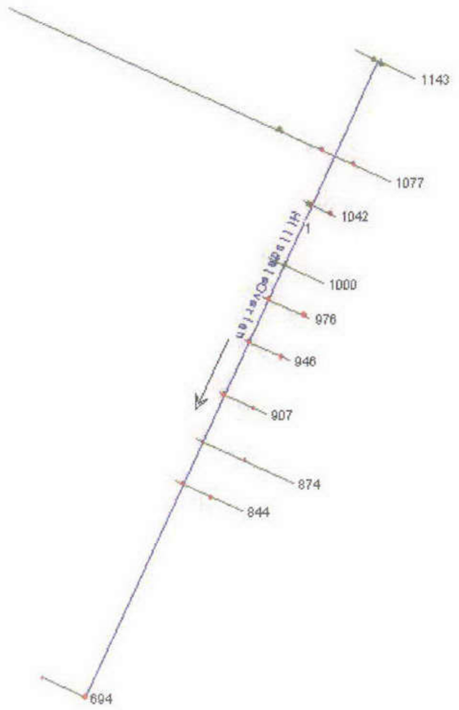
1	960	10	10	16.68	17.64		17.83	0.00195	1.9	5.26	5.48	0.62
1	960	14	14	16.68	17.88		18.11	0.002144	2.13	6.56	5.49	0.62
1	960	15	15	16.68	17.94		18.18	0.002172	2.18	6.89	5.49	0.62
1	960	16	16	16.68	17.99		18.24	0.002241	2.24	7.15	5.49	0.63
1	960	20	20	16.68	18.17		18.48	0.002499	2.45	8.18	5.49	0 64
1	959	10	10	16.68	17 48	17.46	17.81	0.003181	2.54	3.94	5.45	0.95
1	959	14	14	16.68	17.76		18.1	0.002522	2.57	5.45	5.46	0.82
1	959	15	15	16.68	17.83		18.17	0.002405	2.57	5.84	5.46	0.79
1	959	16	16	16.68	17.88		18.23	0.002439	2.63	6.09	5.46	0.79
1	959	20	20	16.68	18.05		18.46	0.002561	2.83	7 06	5.47	0.8
1	958	10	10	16.67	17.48	17.45	17.81	0.003159	2.53	3.95	5.45	0.95
1	958	14	14	16.67	17.76		18.09	0.002505	2.56	5 47	5.46	0.82
1	958	15	15	16.67	17.83		18.16	0.002385	2.56	5.85	5.46	0.79
1	958	16	16	16.67	17.88		18.22	0.00242	2.62	6.11	5.46	0.79
1	958	20	20	16.67	18.05		18.46	0.002549	2.83	7.08	5.47	0.79
1	828	10	10	16.06	17.34		17.46	0.000791	1.53	6.52	5.46	0.45
1	828	14	14	16.06	17.65		17.8	0.000839	1.7	8.25	5.67	0.45
1	828	15	15	16.06	17.73		17.88	0.000832	1.73	8.67	5.67	0.45
1	828	16	16	16.06	17.77		17.93	0.000878	1.8	8.89	5.67	0.46
1	828	20	20	16.06	17.92		18.13	0.00105	2.06	9.73	5.67	0.5
1	827	10	15	16.06	16.99	16.98	17.43	0.003671	2.94	5.1	5.78	1
1	827	14	21	16.06	17.23	17.21	17.76	0.003662	3.23	6.51	5.78	0.97
1	827	15	22.5	16.06	17.3	17.26	17.84	0.003602	3.27	6.89	5.79	0.96
1	827	16	23.5	16.06	17.34	17.29	17.89	0.003559	3.29	7.14	5.79	0.94
1	827	20	27.5	16.06	17.5	17.42	18.09	0.003518	3.41	8.07	5.79	0.92
1	824	10	15	16.04	16.98	16.97	17.42	0.003661	2.94	5.11	5.78	1
1	824	14	21	16.04	17.22	17.19	17.75	0.003654	3.22	6.51	5.78	0.97
1	824	15	22.5	16.04	17.29	17.25	17.83	0.003593	3.26	6.89	5.79	0.95
1	824	16	23.5	16.04	17.33	17.28	17.88	0.00355	3.29	7.15	5.79	0.94
1	824	20	27.5	16.04	17.49	17.41	18.08	0.003509	3.41	8.07	5.79	0.92

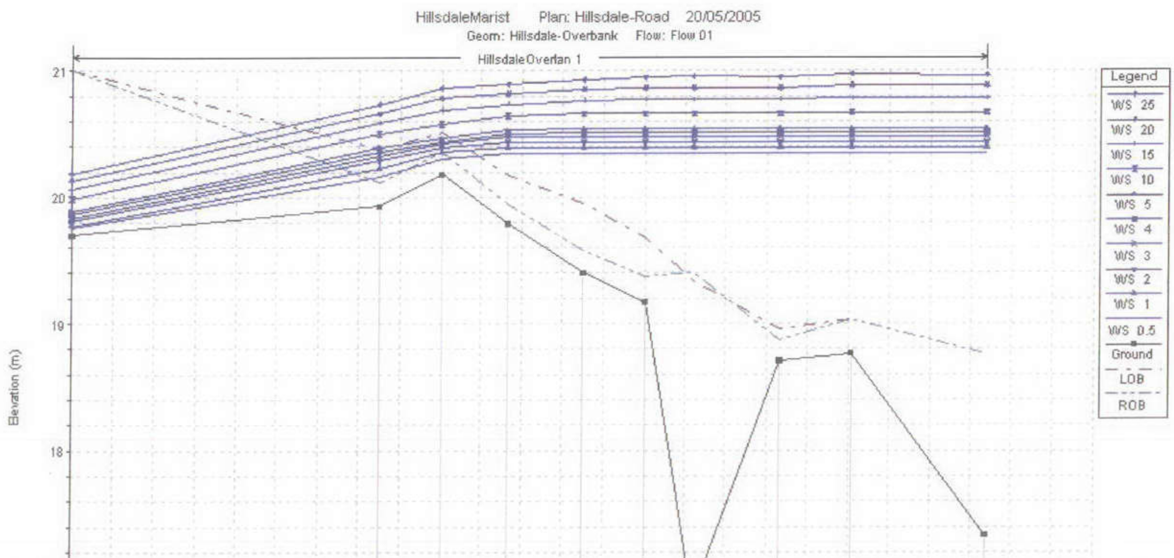
1	799	10	15	15.94	16.89	16.87	17.31	0.003494	2.89	5.2	5.78	0.97
1	799	14	21	15.94	17.13	17.09	17.65	0.003529	3.18	6.6	5.78	0.95
1	799	15	22.5	15.94	17.2	17.14	17.73	0.003466	3.22	6.99	5.79	0.94
1	799	16	23.5	15.94	17.24	17.17	17.78	0.003421	3.24	7.25	5.79	0.92
1	799	20	27.5	15.94	17.4	17.31	17.98	0.003392	3 36	8.18	5.79	0.9
1	798	10	15	15.94	16.88	16.88	17.31	0.003396	2.89	5.2	6.08	1
1	798	14	21	15.94	17.14	17.09	17.63	0.003221	3.11	6.75	6.09	0.94
1	798	15	22 5	15.94	17.21	17.14	17.71	0.003129	3.14	7.17	6.09	0.92
1	798	16	23.5	15.94	17.26	17.18	17.76	0.00307	3 15	7 46	6.09	0.91
1	798	20	27.5	15.94	17.43	17.3	17.96	0.002917	3.22	8.54	6.09	0.87
1	796	10	15	15.93	16.88	16.87	17.3	0.003382	2.88	5.21	6.08	0.99
1	796	14	21	15.93	17.13	17.09	17.63	0.003208	3.11	6.76	6.09	0.94
1	796	15	22.5	15.93	17.2	17.14	17.7	0.003116	3.13	7.18	6.09	0.92
1	796	16	23.5	15.93	17 25	17.17	17.75	0.003057	3.15	7.47	6.09	0.91
1	796	20	27.5	15.93	17.43	17.3	17.95	0.002905	3.21	8.55	6.09	0.87
1	616	10	15	15.19	16.41		16.65	0.001583	2.19	6.84	6.09	0.66
1	616	14	21	15.19	16.73		17.02	0.001572	2.39	8.8	6.09	0.63
1	616	15	22.5	15.19	16.81		17.11	0.001565	2.42	9.29	6.1	0.63
1	616	16	23.5	15.19	16.86		17.17	0.001559	2.44	9.61	6.1	0.62
1	616	20	27.5	15.19	17.06		17.39	0.001521	2.53	10.85	6.3	0.62
1	615	10	15	15.19	16.42		16.64	0.001426	2.08	7.2	6.09	0.61
1	615	14	21	15.19	16.74		17.01	0.001462	2.29	9.16	6.09	0.6
1	615	15	22.5	15.19	16.82		17.1	0.001464	2.33	9.64	6.1	0.59
1	615	16	23.5	15.19	16.88		17.16	0.001489	2.36	9.97	6.3	0.6
1	615	20	27.5	15.19	17.07		17.38	0.001439	2.45	11.21	6.3	0.59
1	611	10	15	15.17	16.42		16.63	0.001386	2.06	7.28	6.09	0.6
1	611	14	21	15.17	16.74		17	0.001432	2.28	9.23	6.09	0.59
1	611	15	22.5	15.17	16.82		17.09	0.001435	2.32	9.72	6.1	0.59
1	611	16	23.5	15.17	16.87		17.15	0.00145	2.34	10.05	6.3	0.59

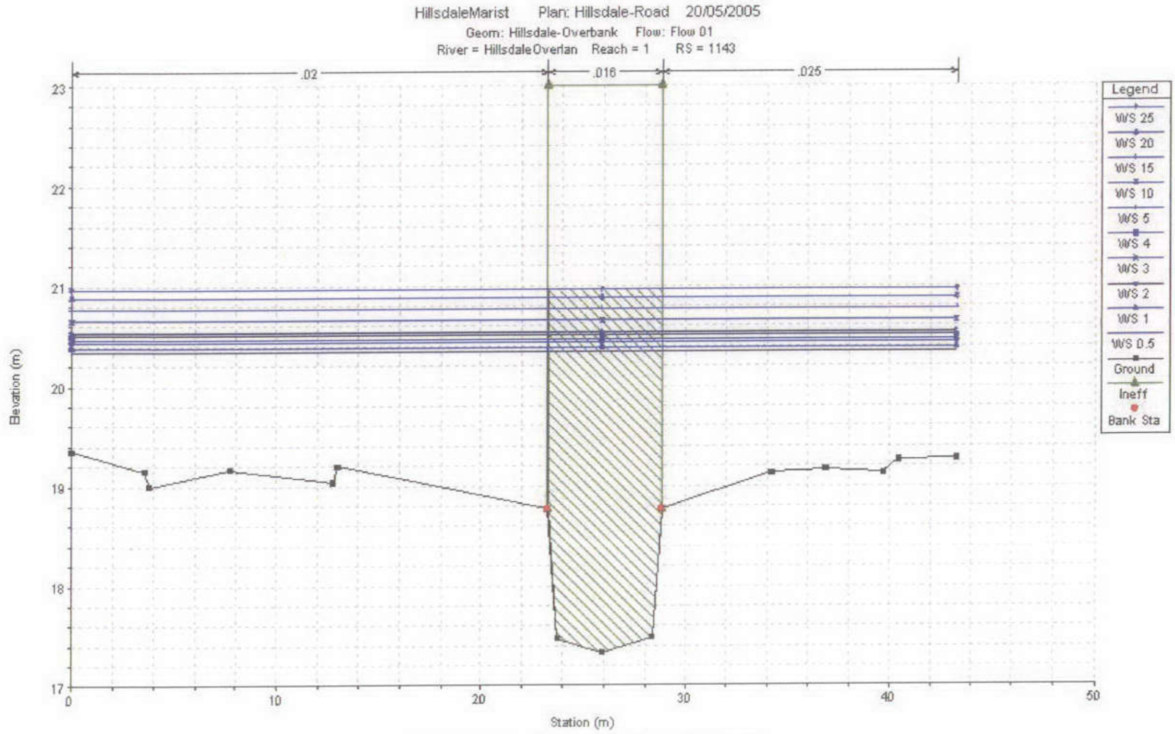
								6				
1	611	20	27.5	15.17	17.07		17.37	0.00141	2.44	11.28	6.3	0.58
1	596	10	15	15.11	16.41		16.61	0.001247	1.98	7.57	6.09	0.57
1	596	14	21	15.11	16.72		16.97	0.001323	2.21	9.51	6.1	0.56
1	596	15	22.5	15.11	16.8		17.06	0.001354	2.25	10	6.3	0.57
1	596	16	23.5	15.11	16.86		17.12	0.001338	2.27	10.33	6.3	0.57
1	596	20	27.5	15.11	17 05		17.34	0.001308	2.38	11.57	6.3	0.56
1	595	10	15	15.11	16.15	16.11	16.58	0.003381	2.91	5.15	5.37	0.95
1	595	14	21	15.11	16.48		16.95	0.00296	3.03	6.94	5.38	0.85
1	595	15	22.5	15.11	16.57		17.04	0.002885	3.05	7.38	5.38	0.83
1	595	16	23.5	15.11	16.62		17.1	0.002838	3.06	7.68	5.39	0.82
1	595	20	27.5	15.11	16.82		17.32	0.002662	3.13	8.8	5 59	0.79
1	593	10	15	15.1	16.14	16.11	16.57	0.003369	2.91	5.16	5.37	0.95
1	593	14	21	15.1	16.48		16.94	0 002947	3.02	6.95	5.38	0 85
1	593	15	22.5	15.1	16.56		17.03	0.002873	3.04	7.39	5.38	0.83
1	593	16	23.5	15.1	16.61		17.09	0.002827	3.06	7.69	5.39	0.82
1	593	20	27.5	15.1	16.82		17.31	0.002649	3.12	8.81	5.59	0.79
1	288	10	15	13.94	15.49		15.67	0.001109	1.91	7.86	5.59	0.51
1	288	14	21	13.94	15.93		16.14	0.000968	2.03	10.33	5.59	0.48
1	288	15	22.5	13.94	16.03		16.25	0.000947	2.06	10.92	5.59	0.47
1	288	16	23.5	13.94	16.1		16.32	0.000935	2.08	11.3	5.59	0.47
1	288	20	27.5	13.94	16.37		16.6	0.000898	2.15	12.78	5.59	0.45
1	287	10	15	13.94	15.44		15.67	0.000948	2.13	7.05	5.4	0.59
1	287	14	21	13.94	15.89		16.14	0.000806	2.22	9.48	5.41	0.53
1	287	15	22.5	13.94	15.99		16.25	0.000788	2.24	10.05	5.41	0.52
1	287	16	23.5	13.94	16.06		16.32	0.000778	2.26	10.42	5.41	0.52
1	287	20	27.5	13.94	16.33		16.6	0.000749	2.32	11.86	5.41	0.5
1	283	10	15	13.92	15.44		15.66	0.00092	2.11	7.12	5.4	0.59
1	283	14	21	13.92	15.89		16.13	0.000789	2.2	9.55	5.41	0.53
1	283	15	22.5	13.92	15.99		16.24	0.000773	2.22	10.12	5.41	0.52

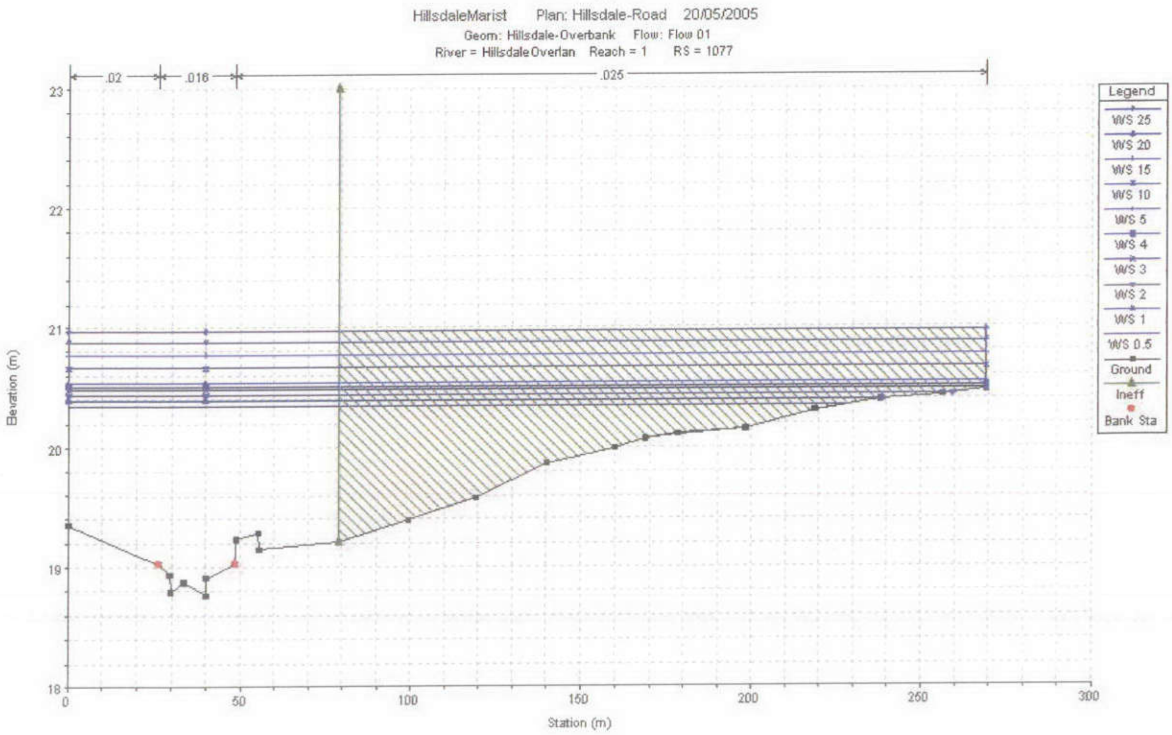
1	283	16	23.5	13.92	16.06		16.31	0.000764	2.24	10.49	5.41	0.51
1	283	20	27.5	13.92	16.33		16.6	0.000737	2.3	11.94	5.41	0.5
1	238	10	15	13.76	15.43		15.61	0.000666	1.88	7.98	5.41	0.49
1	238	14	21	13.76	15.88		16.09	0.000624	2.02	10.41	5.41	0.46
1	238	15	22.5	13.76	15.99		16.2	0.00062	2.05	10.97	5.41	0.46
1	238	16	23.5	13.76	16.05		16.27	0.000618	2.07	11.34	5.41	0.46
1	238	20	27.5	13.76	16.32		16.56	0.000613	2.15	12.78	5.41	0.45
1	158	10	15	13.47	15.43		15.56	0.000407	1.58	9.52	5.41	0.38
1	158	14	21	13.47	15.87		16 03	0.000431	1.76	11.93	5.41	0.38
1	158	15	22.5	13.47	15.98		16.14	0.000437	1.8	12.49	5.41	0.38
1	158	16	23.5	13.47	16.05		16.22	0.000441	1.83	12.86	5.41	0.38
1	158	20	27 5	13.47	16.31		16.5	0.000456	1.92	14.29	5.41	0.38
1	153	10	15	13.4	14.88	14.88	15.5	0.003304	3.49	4.29	3.48	1
1	153	14	21	13.4	15.19	15.19	15.97	0.003531	3.91	5.38	3.51	1.01
1	153	15	22.5	13.4	15.26	15.26	16.07	0.003577	3.99	5.64	3.51	1.01
1	153	16	23.5	13.4	15.31	15.31	16.15	0.003605	4.05	5.81	3.51	1
1	153	20	27.5	13.4	15.49	15.49	16.42	0.003771	4.27	6.44	3.51	1.01
1	53	10	15	11.98	13	13.46	14.52	0.011332	5.46	2.75	3.22	1.89
1	53	14	21	11.98	13.25	13.77	15.01	0.010649	5.87	3.58	3.37	1.82
1	53	15	22.5	11.98	13.31	13.84	15.12	0.010565	5.96	3.77	3.4	1.81
1	53	16	23.5	11.98	13.35	13.89	15.18	0.010413	6	3.92	3.42	1.79
1	53	20	27.5	11.98	13.49	14.07	15.48	0.010405	6.25	4.4	3.5	1.78

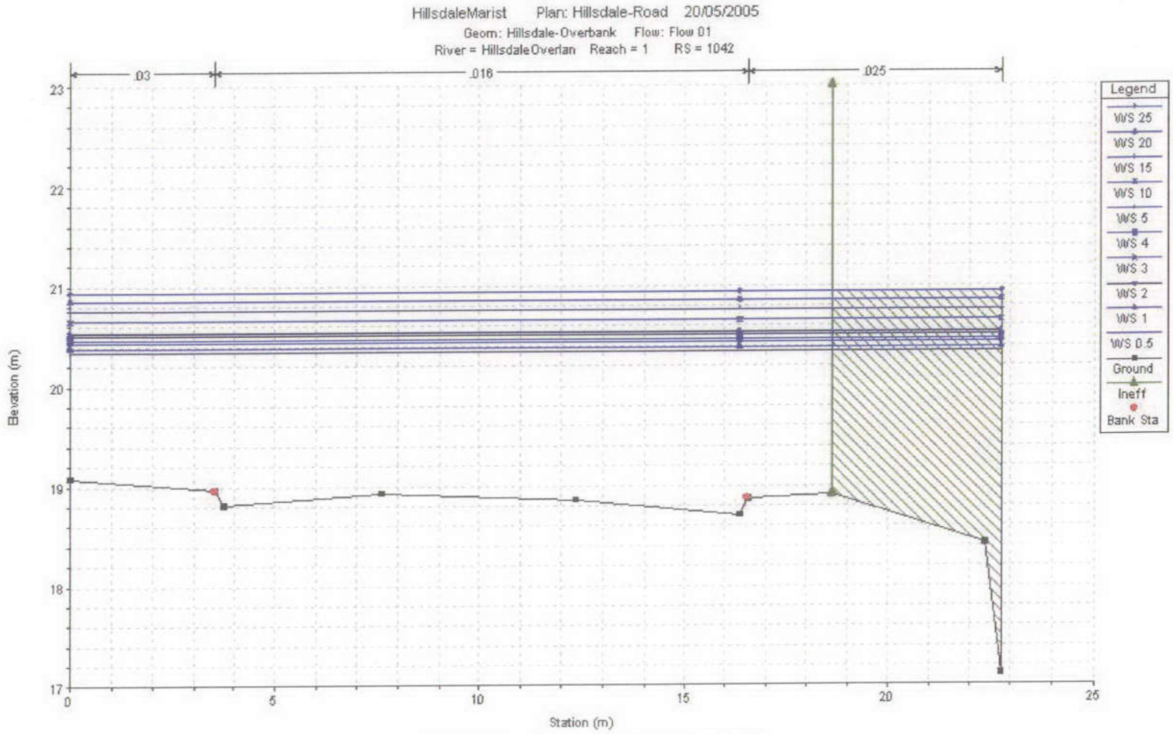
D2. FLOOD RELIEF FLOWPATH VIA FTZGERALD AVENUE

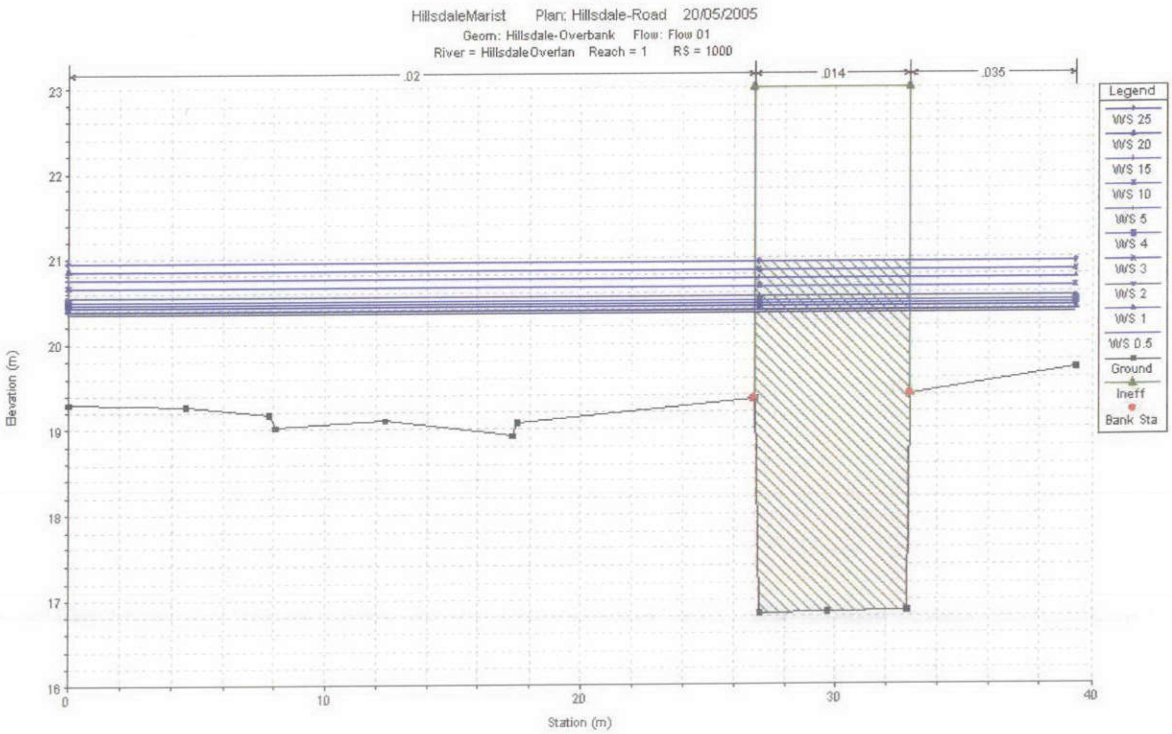


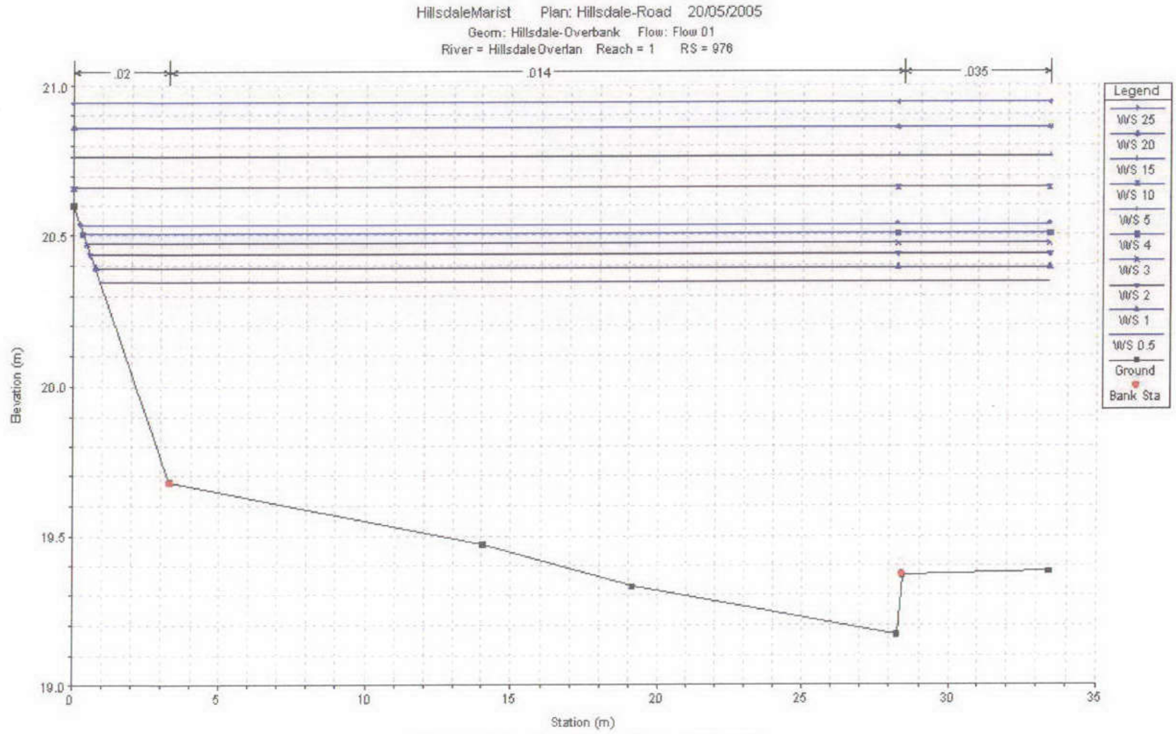


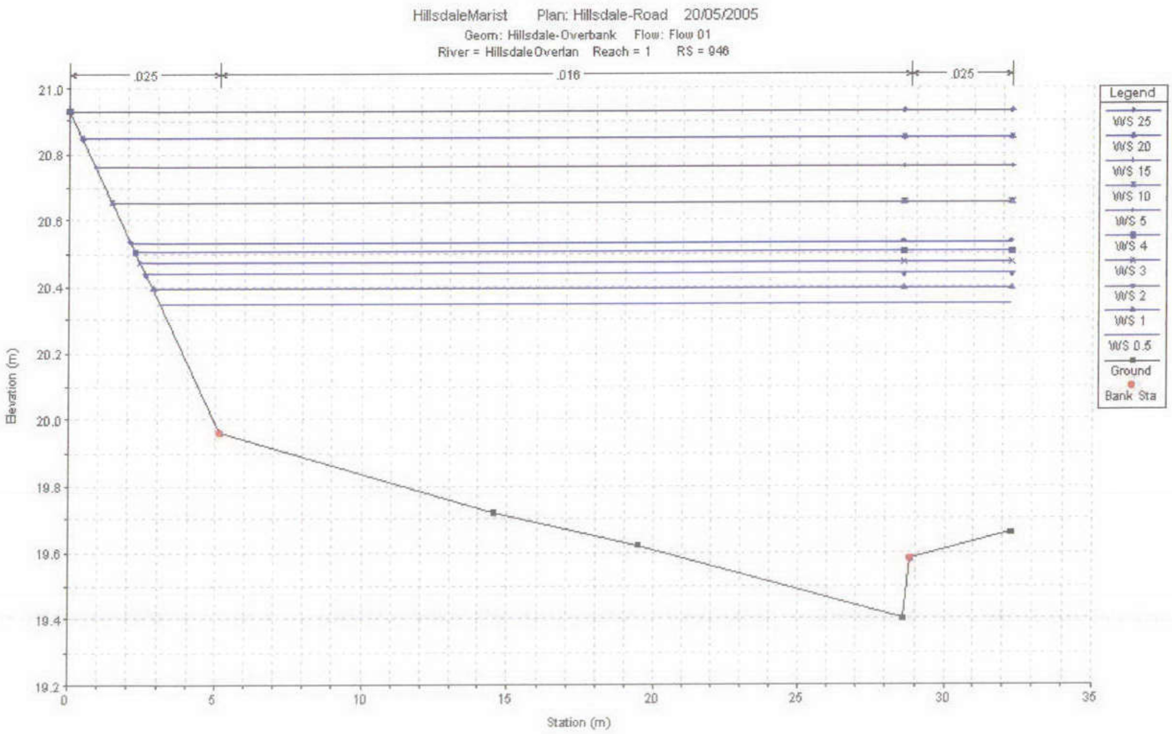

HillsdaleMarist Plan: Hillsdale-Road 20/05/2005
Geom: Hillsdale-Overbank Flow: Flow 01
River = HillsdaleOverlan Reach = 1 RS = 1143
.02
.016
.025
Legend
WS 25
WS 20
WS 15
WS 10
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
17
18
19
20
21
22
23
0
10
20
30
40
50

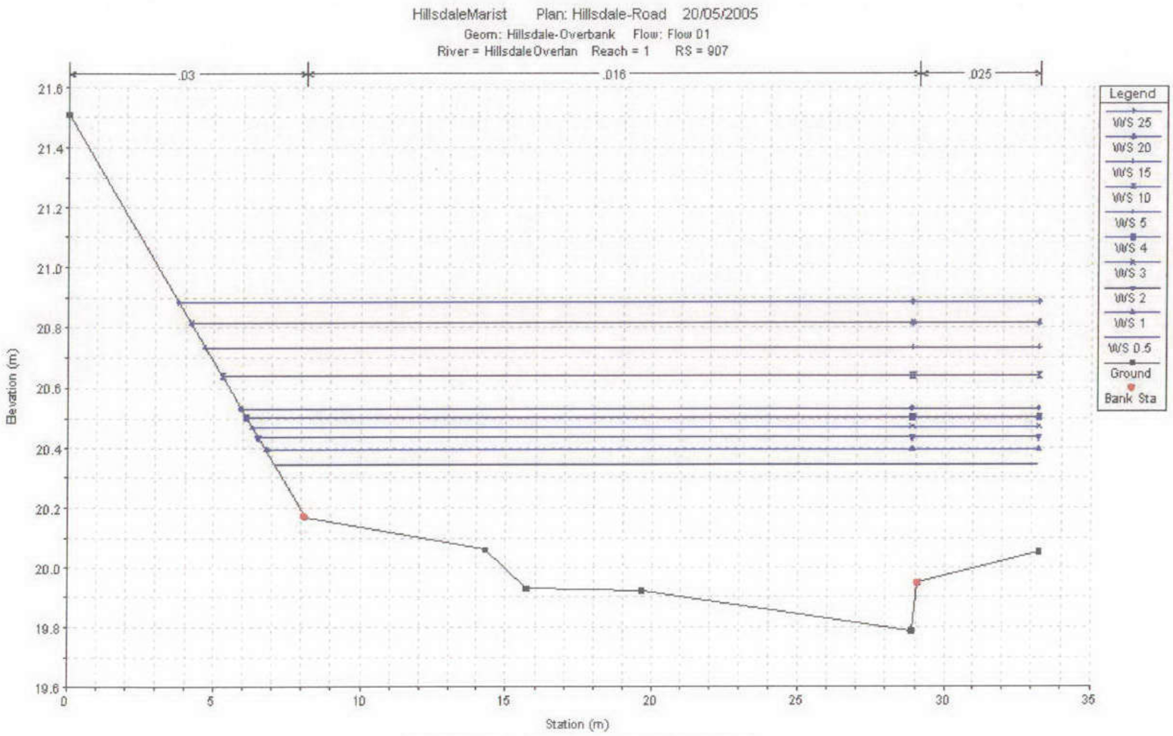

HillsdaleMarist Plan: Hillsdale-Road 20/05/2005
Geom: Hillsdale-Overbank Flow: Flow 01
River = HillsdaleOverlan Reach = 1 RS = 1077
.02
.016
.025
Legend
WS 25
WS 20
WS 15
WS 10
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
18
19
20
21
22
23
0
50
100
150
200
250
300

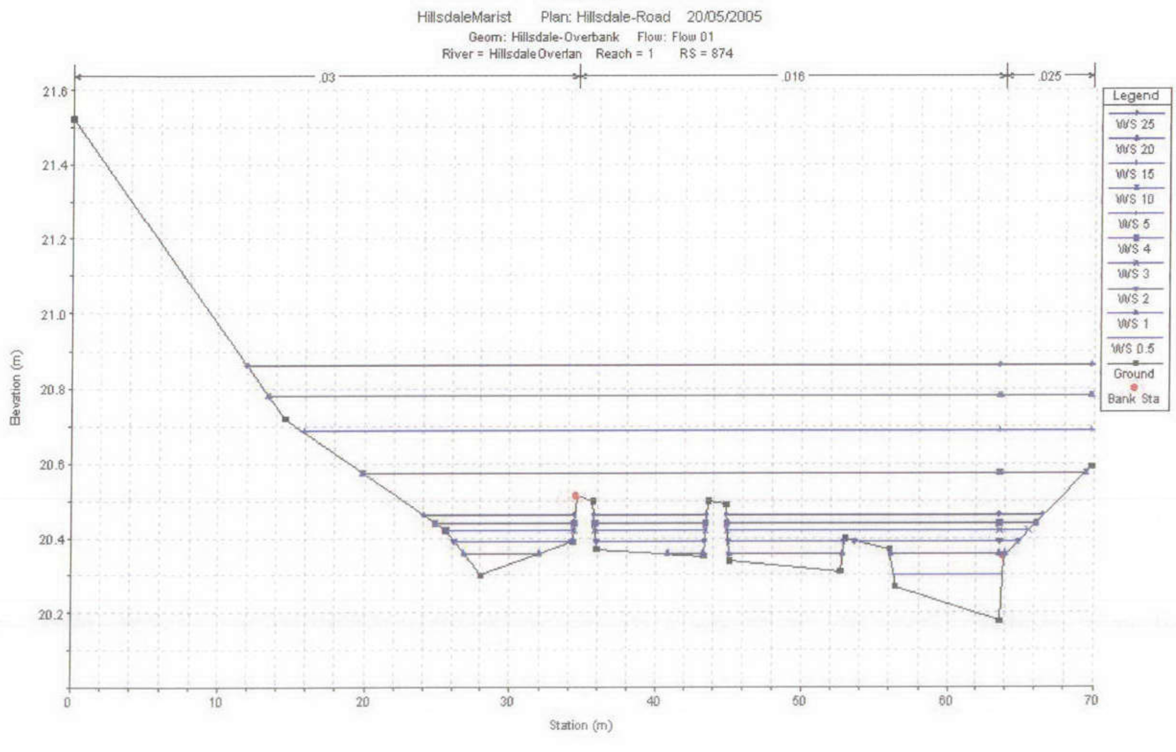

HillsdaleMarist Plan: Hillsdale-Road 20/05/2005
Geom: Hillsdale-Overbank Flow: Flow 01
River = HillsdaleOverlan Reach = 1 RS = 1042
.03
.016
.025
Legend
WS 25
WS 20
WS 15
WS 10
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)

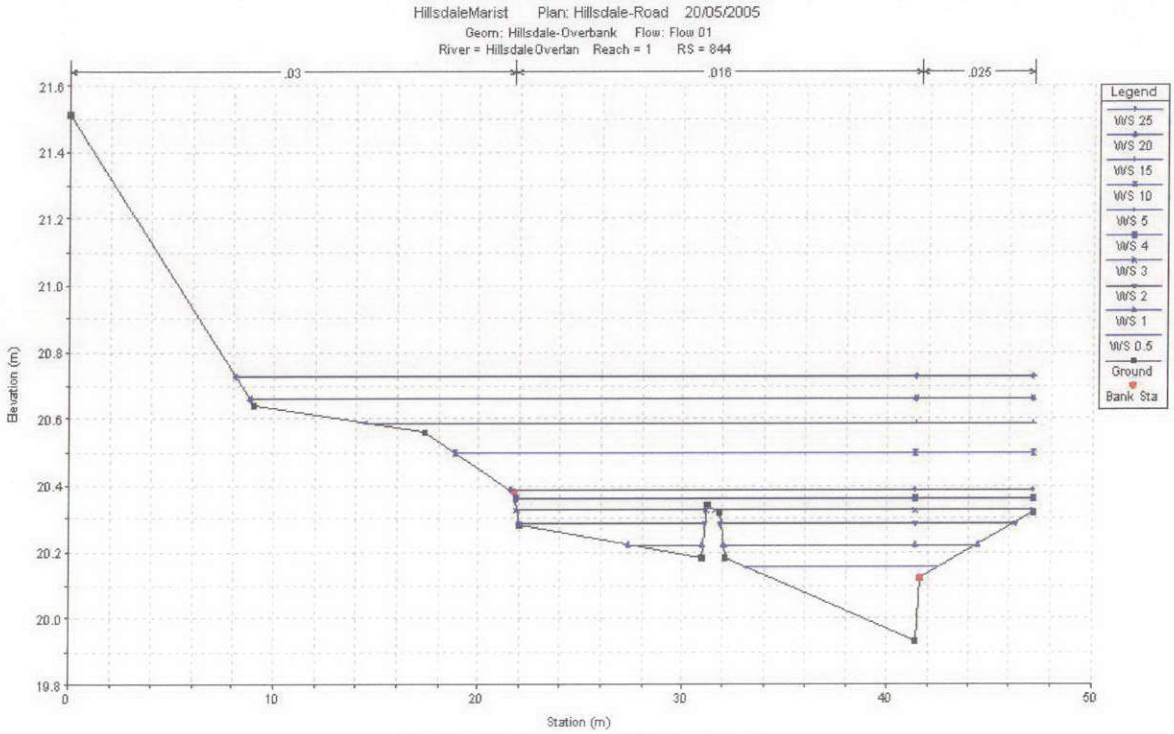

HillsdaleMarist Plan: Hillsdale-Road 20/05/2005
Geom: Hillsdale-Overbank Flow: Flow 01
River = HillsdaleOverlan Reach = 1 RS = 1000
.02
.014
.035
Legend
WS 25
WS 20
WS 15
WS 10
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)


HillsdaleMarist Plan: Hillsdale-Road 20/05/2005
Geom: Hillsdale-Overbank Flow: Flow 01
River = HillsdaleOverlan Reach = 1 RS = 976
.02
.014
.035
Elevation (m)
Station (m)
Legend
WS 25
WS 20
WS 15
WS 10
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Bank Sta

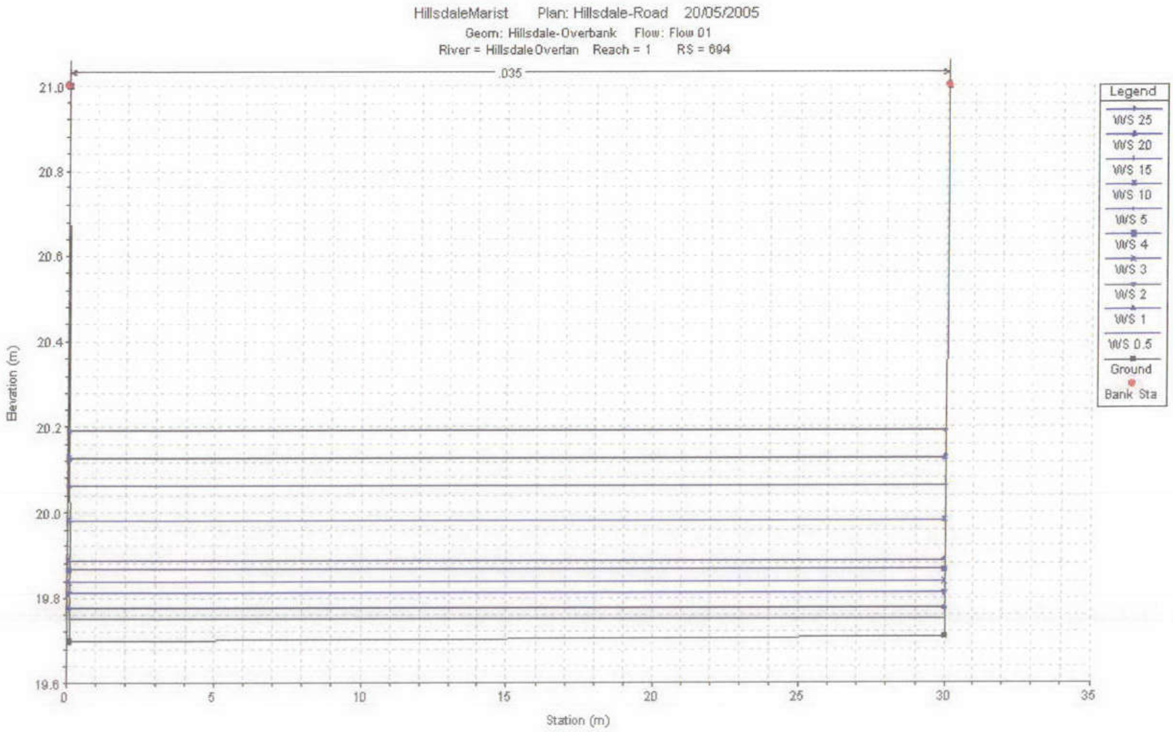

HillsdaleMarist Plan: Hillsdale-Road 20/05/2005
Geom: Hillsdale-Overbank Flow: Flow 01
River = HillsdaleOverlan Reach = 1 RS = 946
.025
.016
.025
Elevation (m)
Station (m)
Legend
WS 25
WS 20
WS 15
WS 10
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Bank Sta


HillsdaleMarist Plan: Hillsdale-Road 20/05/2005
Geom: Hillsdale-Overbank Flow: Flow 01
River = Hillsdale Overlan Reach = 1 RS = 907
.03
.016
.025
Legend
WS 25
WS 20
WS 15
WS 10
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Bank Sta
Elevation (m)
Station (m)


HillsdaleMarist Plan: Hillsdale-Road 20/05/2005
Geom: Hillsdale-Overbank Flow: Flow 01
River = Hillsdale Overlan Reach = 1 RS = 874
.03
.016
.025
Legend
WS 25
WS 20
WS 15
WS 10
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Bank Sta
Elevation (m)
Station (m)



HillsdaleMarist Plan: Hillsdale-Road 20/05/2005
Geom: Hillsdale-Overbank Flow: Flow 01
River = HillsdaleOverlan Reach = 1 RS = 844
.03
.016
.025
Legend
WS 25
WS 20
WS 15
WS 10
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Bank Sta
Elevation (m)
Station (m)



HillsdaleMarist Plan: Hillsdale-Road 20/05/2005
Geom: Hillsdale-Overbank Flow: Flow 01
River = HillsdaleOverlan Reach = 1 RS = 694
.035
Legend
WS 25
WS 20
WS 15
WS 10
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Bank Sta
Elevation (m)
Station (m)

FLOOD RELIEF OVERLAND FLOWPATH VIA FITZGERALD AVENUE

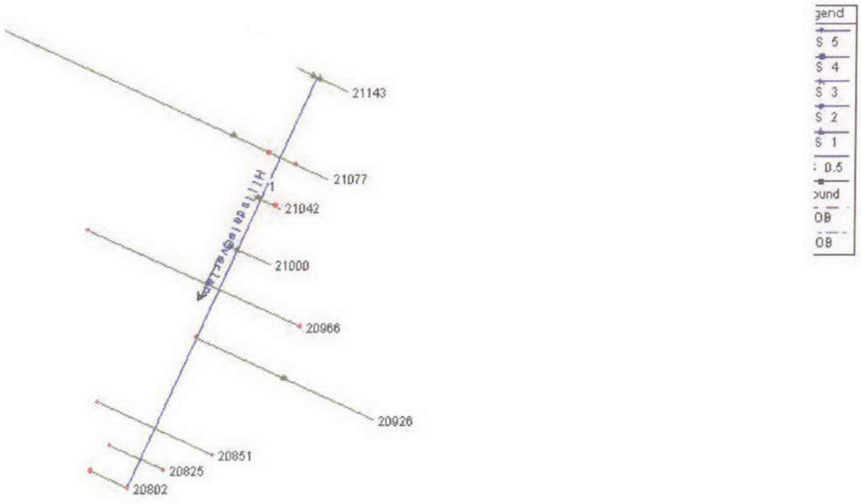
HEC-RAS Plan: Hillsdale-Rd River: HillsdaleOverlan
Reach: 1

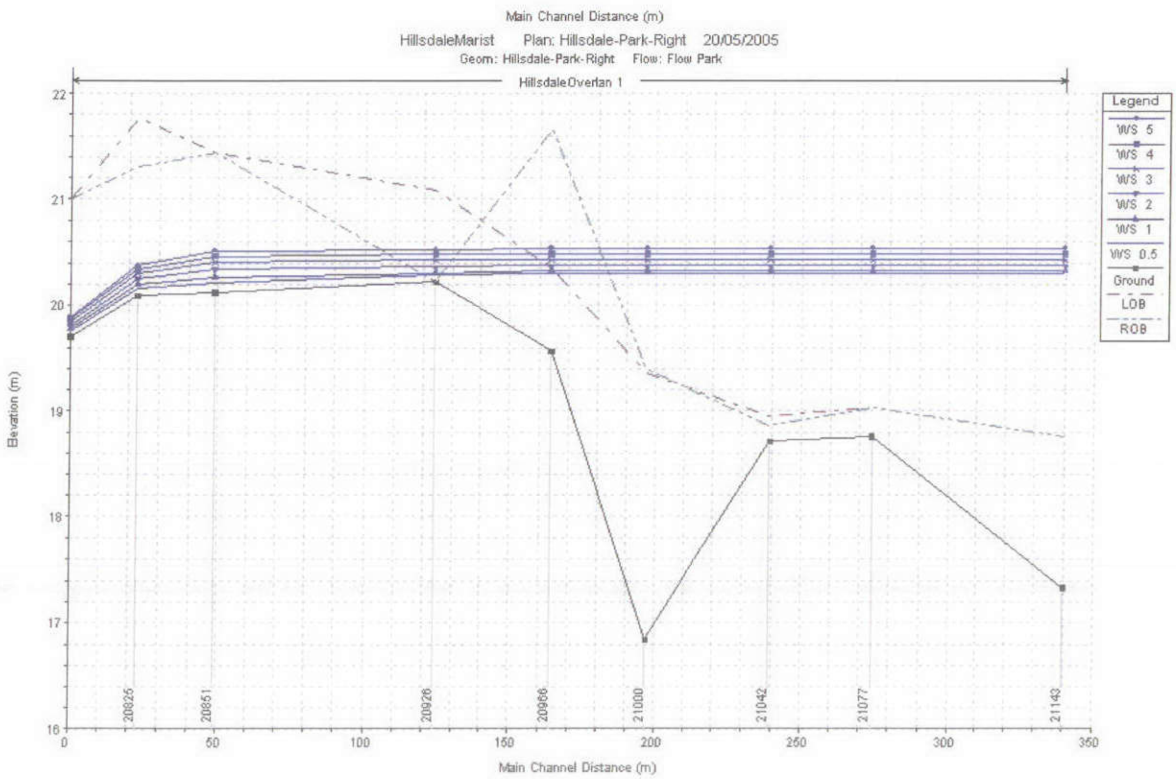
Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
1	1143	0.5	6	17.33	20.57	19.2	20.57	0.000003		56.11	43.3	0
1	1143	1	1	17.33	20.39	18.99	20.39	0		49.51	43.3	0
1	1143	2	2	17.33	20.44	19.06	20.44	0.000001		51.3	43.3	0
1	1143	3	3	17.33	20.48	19.11	20.48	0.000001		52.68	43.3	0
1	1143	4	4	17.33	20.51	19.15	20.51	0.000002		53.93	43.3	0
1	1143	5	5	17.33	20.54	19.19	20.54	0.000003		55.06	43.3	0
1	1077	0.5	6	18.76	20.57	19.1	20.57	0.000001	0.07	115.13	269.47	0.02
1	1077	1	1	18.76	20.39	18.92	20.39	0	0.01	101.27	238.74	0
1	1077	2	2	18.76	20.44	18.98	20.44	0	0.03	105.03	259.23	0.01
1	1077	3	3	18.76	20.48	19.02	20.48	0	0.04	107.92	269.47	0.01
1	1077	4	4	18.76	20.51	19.05	20.51	0	0.05	110.55	269.47	0.01
1	1077	5	5	18.76	20.54	19.08	20.54	0	0.06	112.92	269.47	0.01
1	1042	0.5	6	18.71	20.56	19.12	20.57	0.000006	0.22	31.21	22.75	0.05
1	1042	1	1	18.71	20.39	18.94	20.39	0	0.04	27.99	22.75	0.01
1	1042	2	2	18.71	20.44	18.98	20.44	0.000001	0.08	28.88	22.75	0.02
1	1042	3	3	18.71	20.47	19.02	20.48	0.000002	0.12	29.55	22.75	0.03
1	1042	4	4	18.71	20.51	19.06	20.51	0.000003	0.16	30.16	22.75	0.04
1	1042	5	5	18.71	20.54	19.09	20.54	0.000005	0.19	30.71	22.75	0.05
1	1000	0.5	6	16.84	20.56	19.33	20.57	0.000006		44.17	39.38	0
1	1000	1	1	16.84	20.39	19.14	20.39	0		38.4	39.38	0
1	1000	2	2	16.84	20.44	19.2	20.44	0.000001		39.97	39.38	0
1	1000	3	3	16.84	20.48	19.24	20.48	0.000002		41.18	39.38	0
1	1000	4	4	16.84	20.51	19.28	20.51	0.000003		42.27	39.38	0
1	1000	5	5	16.84	20.54	19.31	20.54	0.000004		43.26	39.38	0
1	976	0.5	6	19.17	20.56		20.57	0.000006	0.19	36.05	33.25	0.06
1	976	1	1	19.17	20.39		20.39	0	0.04	30.36	32.63	0.01
1	976	2	2	19.17	20.44		20.44	0.000001	0.07	31.91	32.8	0.02
1	976	3	3	19.17	20.47		20.48	0.00000	0.1	33.1	32.93	0.03

								2				
1	976	4	4	19.17	20.51		20.51	0.000003	0.13	34.18	33.05	0.04
1	976	5	5	19.17	20.54		20.54	0.000005	0.16	35.15	33.15	0.05
1	946	0.5	6	19.4	20.56		20.57	0.00002	0.26	25.25	30.33	0.09
1	946	1	1	19.4	20.39		20.39	0.000001	0.05	20.15	29.42	0.02
1	946	2	2	19.4	20.44		20.44	0.000004	0.1	21.54	29.67	0.04
1	946	3	3	19.4	20.47		20.48	0.000007	0.14	22.61	29.86	0.05
1	946	4	4	19.4	20.51		20.51	0.000011	0.18	23.58	30.03	0.06
1	946	5	5	19.4	20.54		20.54	0.000015	0.22	24.45	30.19	0.08
1	907	0.5	6	19.79	20.55		20.56	0.000093	0.43	15.34	27.44	0.18
1	907	1	1	19.79	20.39		20.39	0.000008	0.1	10.93	26.45	0.05
1	907	2	2	19.79	20.44		20.44	0.000022	0.18	12.15	26.73	0.08
1	907	3	3	19.79	20.47		20.47	0.000039	0.25	13.08	26.94	0.11
1	907	4	4	19.79	20.5		20.51	0.000056	0.31	13.92	27.13	0.14
1	907	5	5	19.79	20.53		20.54	0.000075	0.37	14.66	27.29	0.16
1	874	0.5	6	20.18	20.48	20.47	20.55	0.004564	1.24	5.67	41.01	0.99
1	874	1	1	20.18	20.36	20.36	20.39	0.005699	0.79	1.37	23.29	0.96
1	874	2	2	20.18	20.39	20.39	20.43	0.005964	0.9	2.49	34.9	1.01
1	874	3	3	20.18	20.42	20.42	20.47	0.005046	0.98	3.46	37.03	0.97
1	874	4	4	20.18	20.44	20.44	20.5	0.005077	1.1	4.17	38.36	1
1	874	5	5	20.18	20.46	20.46	20.52	0.004699	1.17	4.97	39.78	0.99
1	844	0.5	6	19.93	20.41	20.35	20.46	0.001669	1.04	6.29	26.21	0.65
1	844	1	1	19.93	20.22	20.15	20.24	0.001421	0.59	1.8	16.07	0.53
1	844	2	2	19.93	20.29	20.23	20.31	0.001556	0.68	3.15	23.52	0.57
1	844	3	3	19.93	20.33	20.27	20.36	0.001593	0.8	4.1	24.85	0.6
1	844	4	4	19.93	20.36	20.3	20.4	0.001616	0.88	4.93	25.36	0.61
1	844	5	5	19.93	20.39	20.33	20.43	0.00166	0.97	5.62	25.58	0.64
1	694	0.5	6	19.7	19.91	19.86	19.96	0.010013	0.98	6.11	29.93	0.69
1	694	1	1	19.7	19.77	19.75	19.79	0.010006	0.48	2.08	29.91	0.58
1	694	2	2	19.7	19.81	19.78	19.83	0.010008	0.63	3.15	29.92	0.62

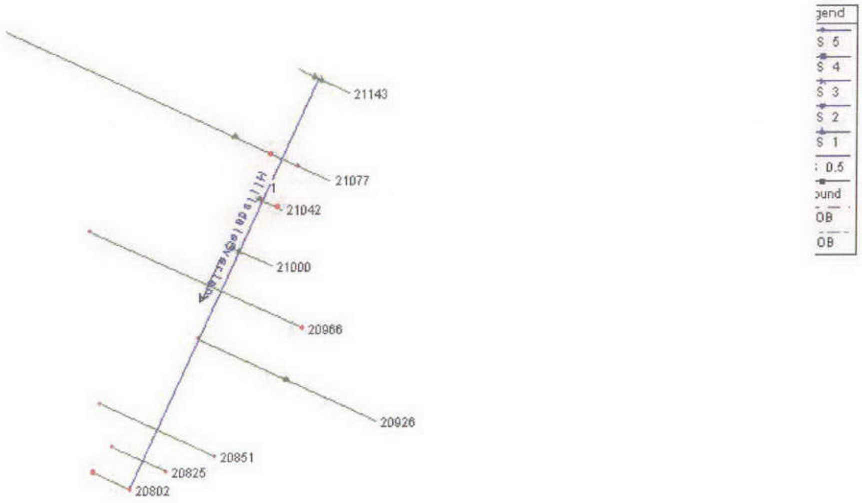
1	694	3	3	19.7	19.84	19.81	19.87	0.010001	0.75	4.02	29.92	0.65
1	694	4	4	19 7	19.86	19.83	19.9	0.010003	0.84	4.78	29.92	0.67
1	694	5	5	19.7	19.89	19.85	19.93	0.010001	0.91	5.47	29.93	0.68

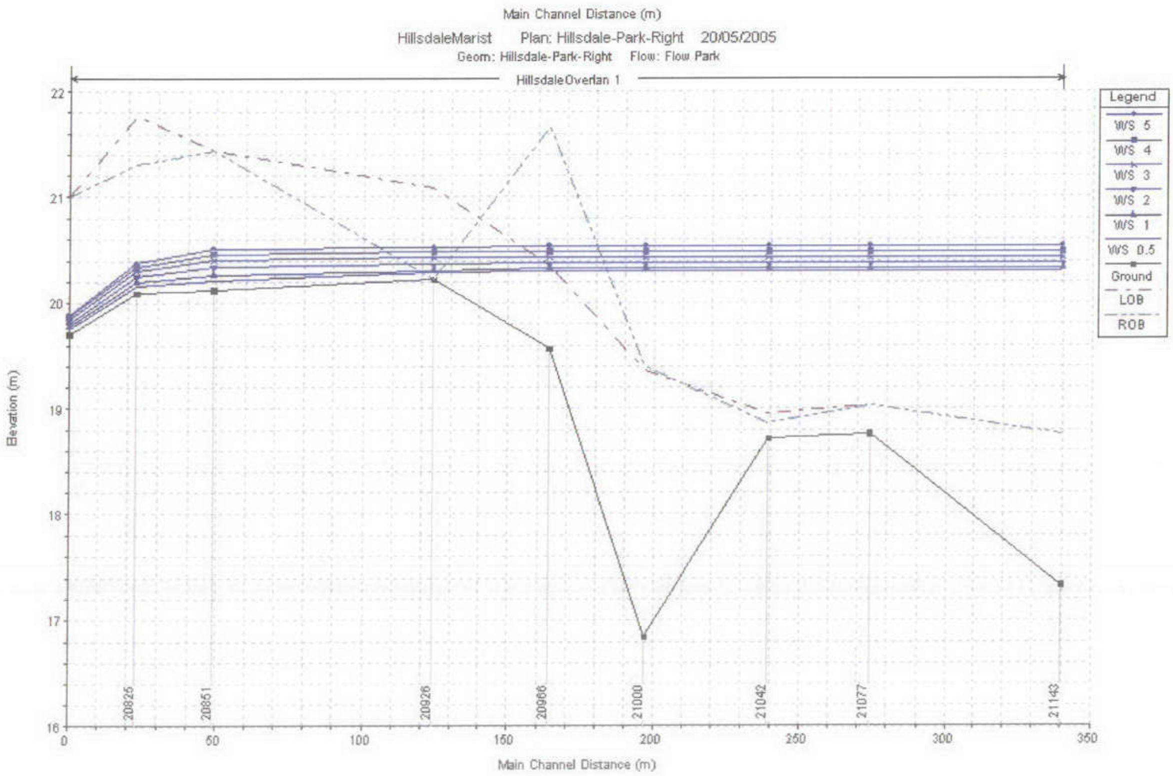
D3. FLOOD RELIEF FLOWPATH VIA HEFFRON PARK TO BUNNERONG ROAD

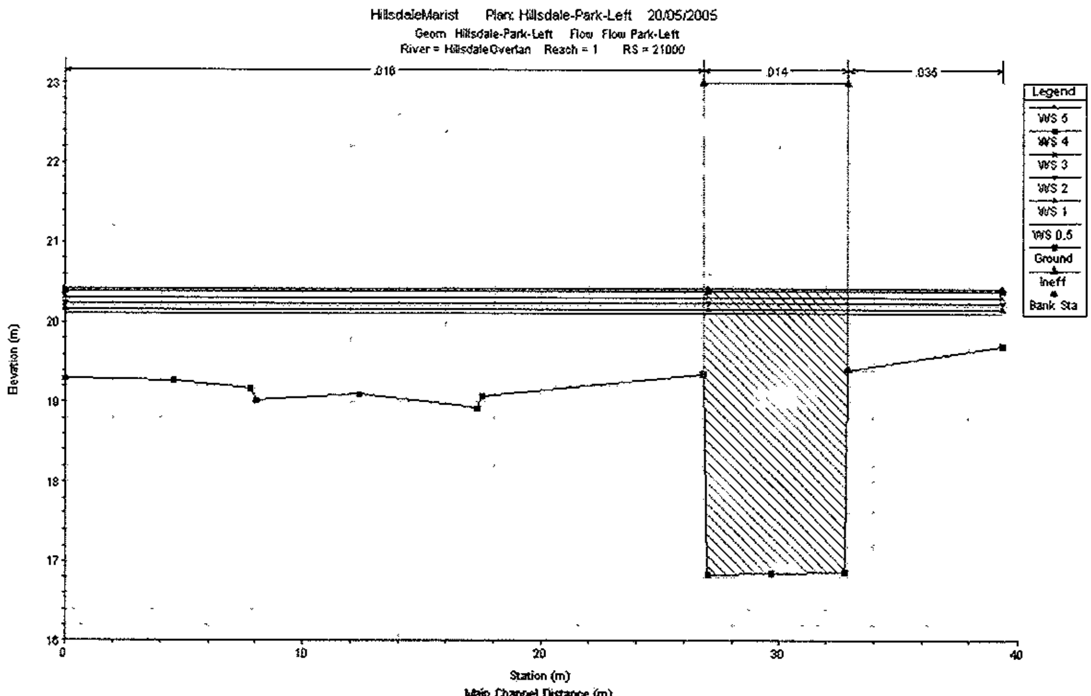


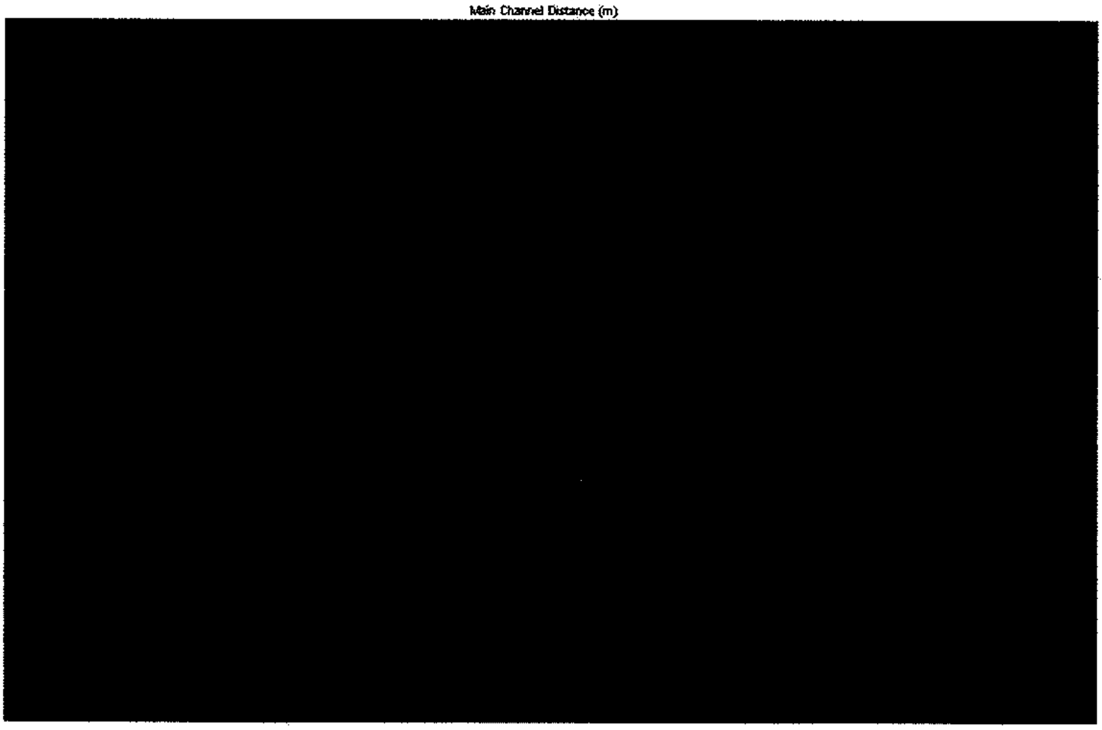


D3. FLOOD RELIEF FLOWPATH VIA HEFFRON PARK TO BUNNERONG ROAD

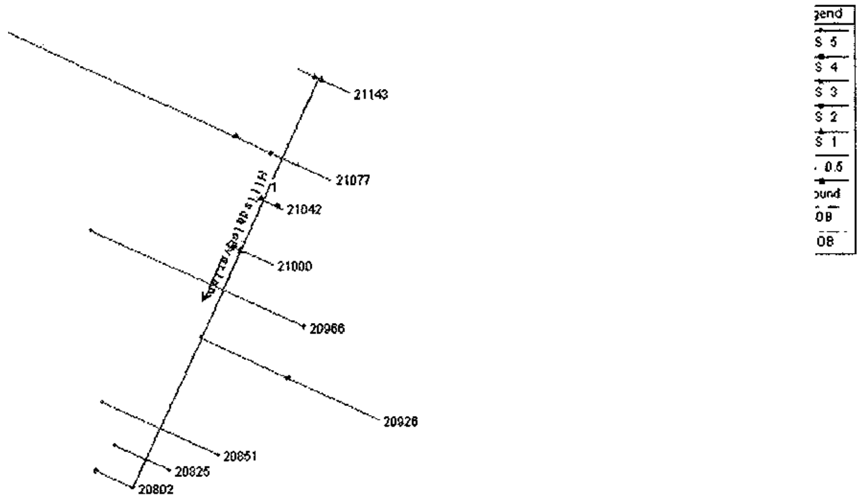


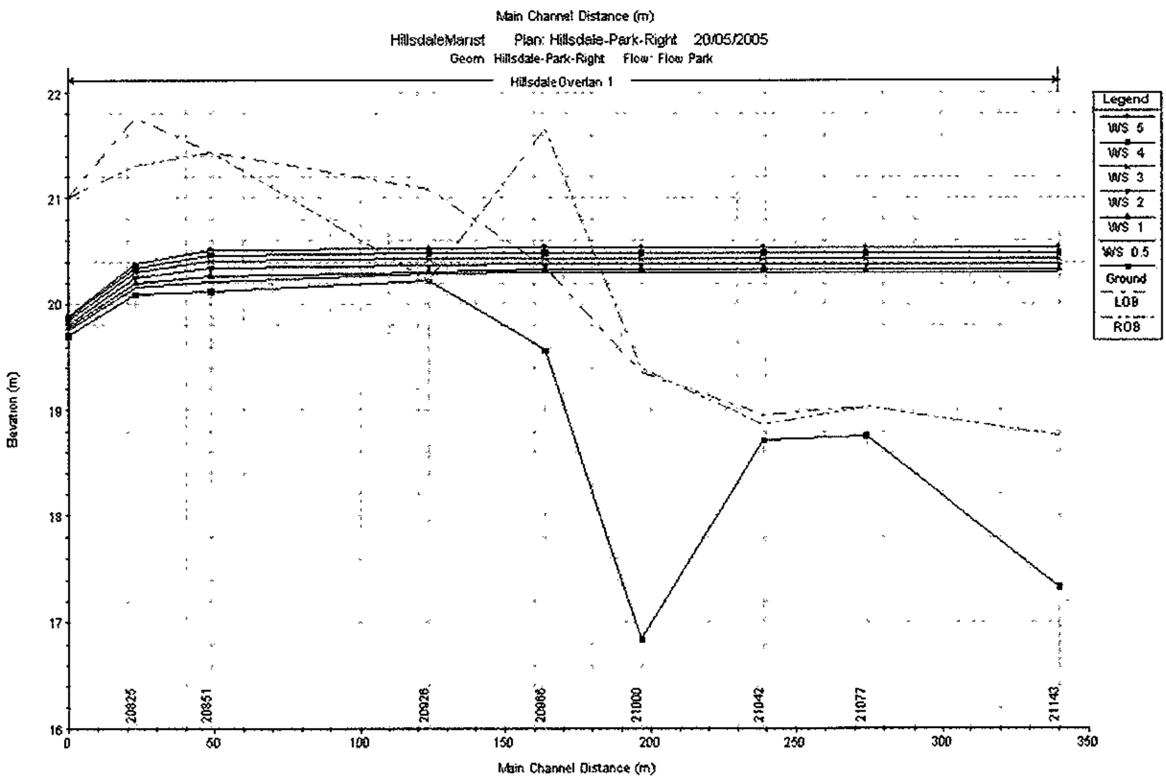


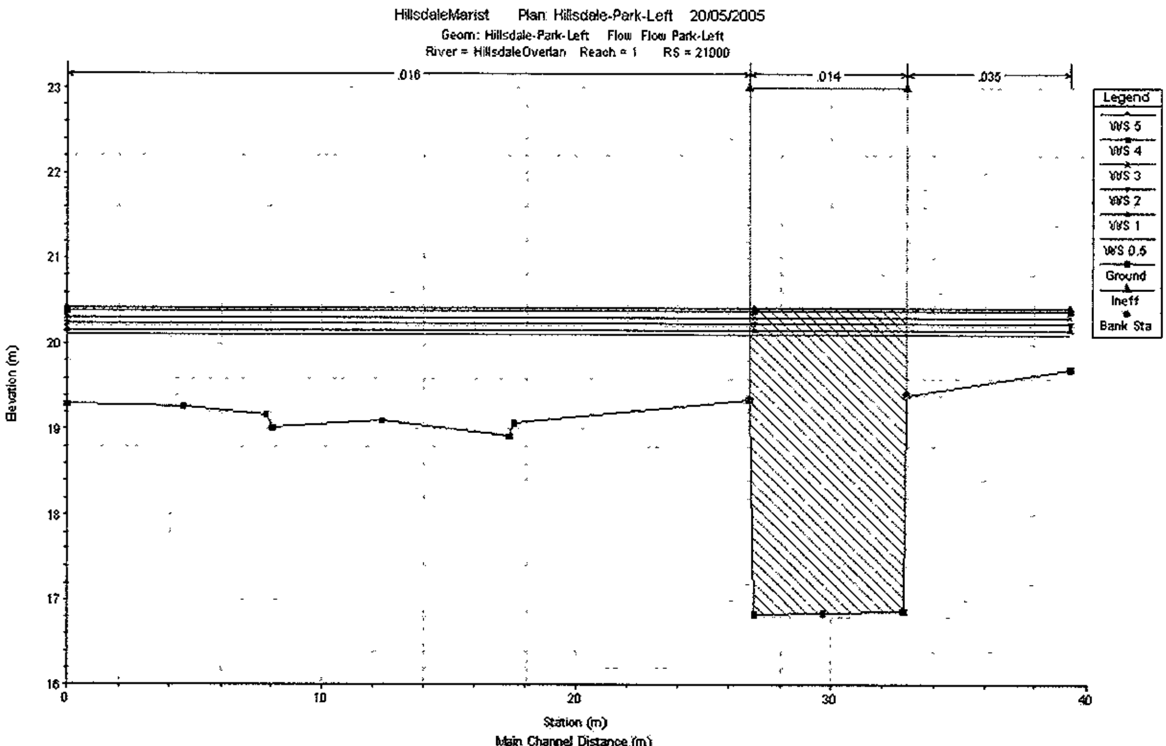

HillsdaleMarist Plan: Hillsdale-Park-Left 20/05/2005
Geom Hillsdale-Park-Left Flow Flow Park-Left
River = HillsdaleOverlan Reach = 1 RS = 21000
.016
.014
.035
Legend
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
Main Channel Distance (m)
0
10
20
30
40
16
17
18
19
20
21
22
23

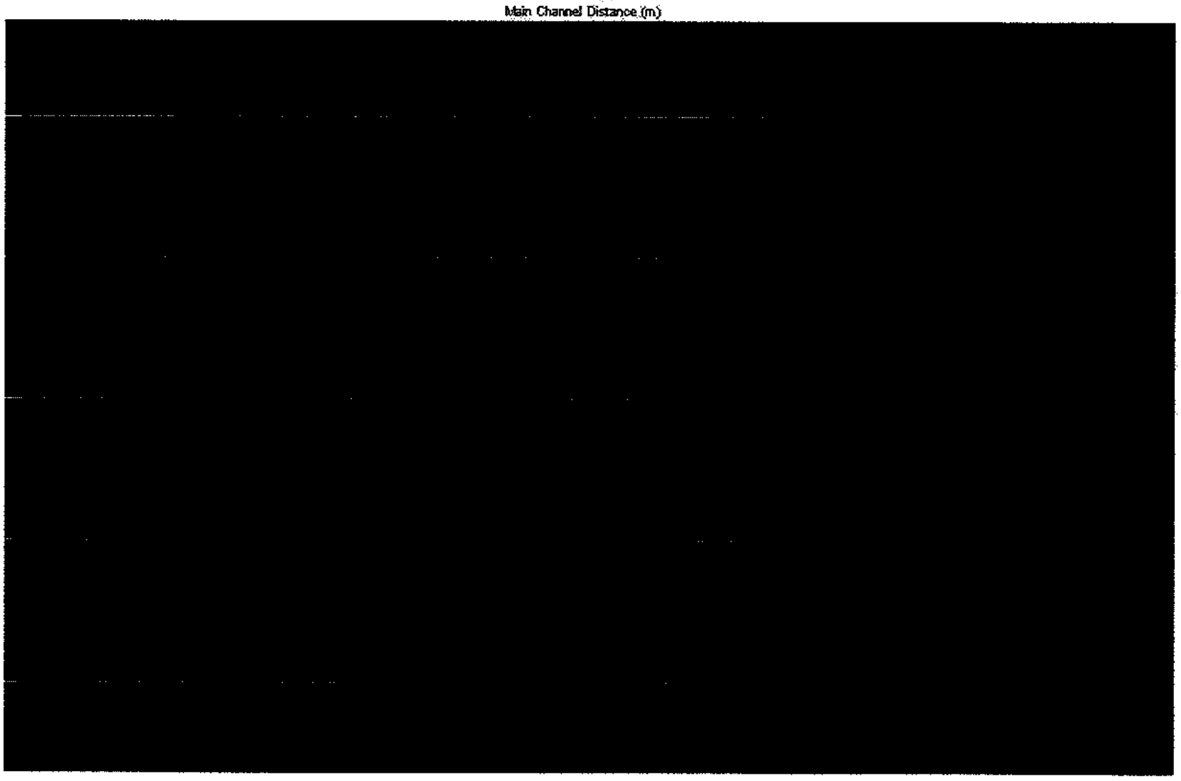


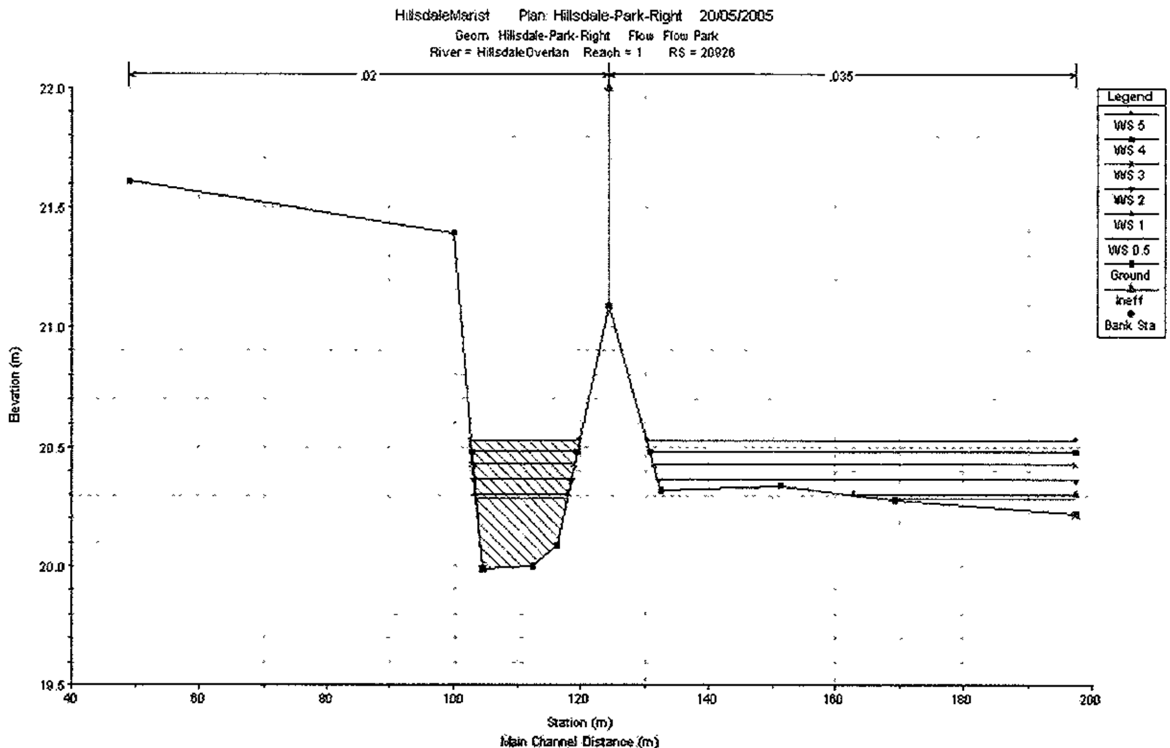
D3. FLOOD RELIEF FLOWPATH VIA HEFFRON PARK TO BUNNERONG ROAD






HillsdaleMarist Plan: Hillsdale-Park-Left 20/05/2005
Geom: Hillsdale-Park-Left Flow: Flow Park-Left
River = HillsdaleOverlan Reach = 1 RS = 21000
.016
.014
.035
Legend
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
Main Channel Distance (m)
23
22
21
20
19
18
17
16
0
10
20
30
40





[redacted]

Station (m)
Main Channel Distance (m)

[redacted]

Station (m)
Main Channel Distance (m)

[redacted]

Station (m)
Main Channel Distance (m)

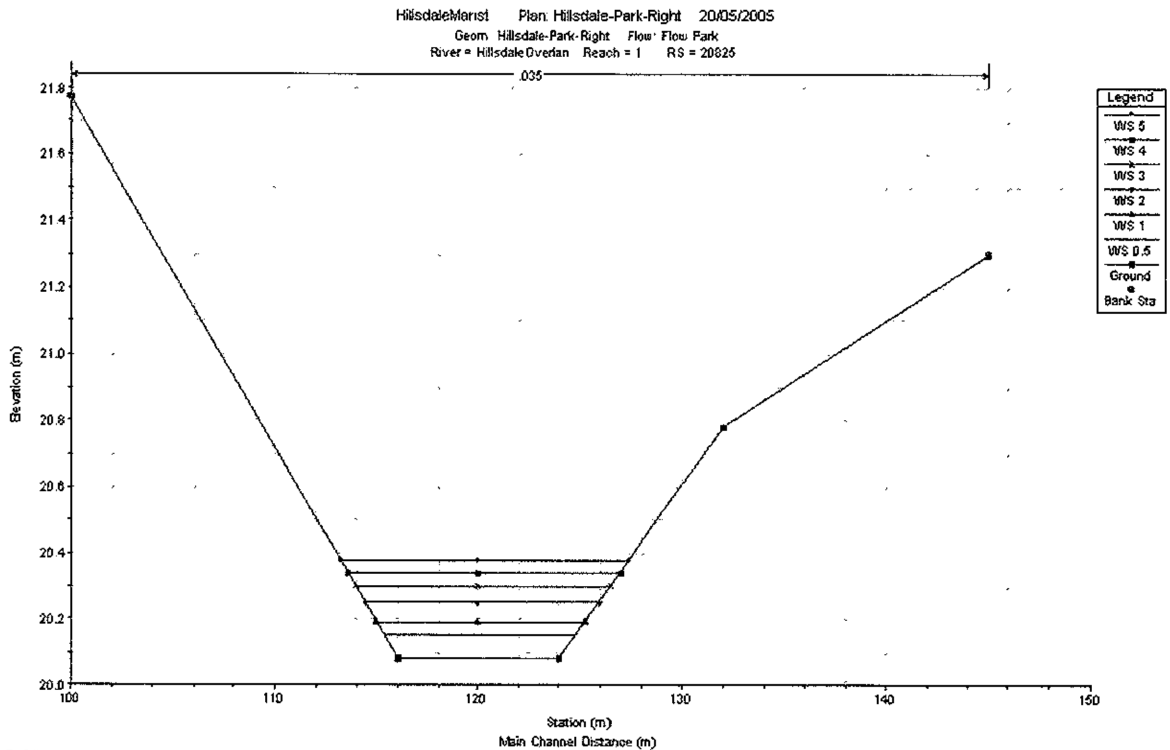
[redacted]

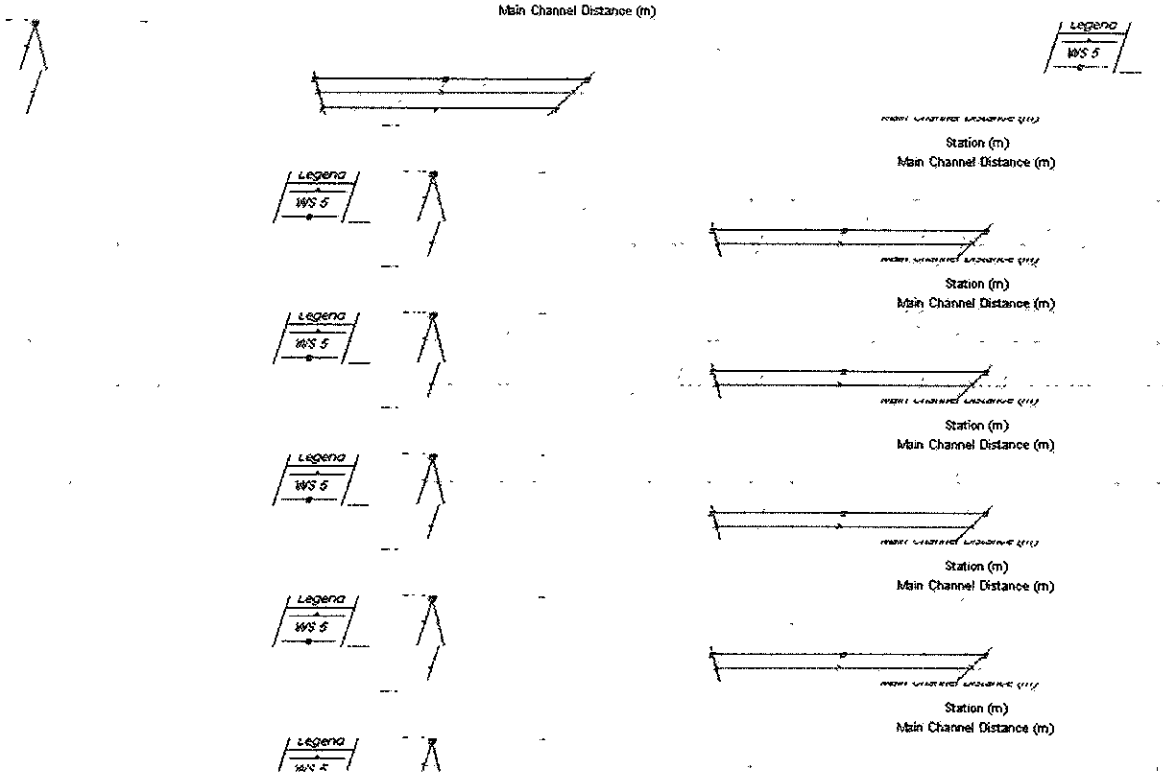
Station (m)
Main Channel Distance (m)

[redacted]

Station (m)
Main Channel Distance (m)

[redacted]


HillsdaleMarist Plan: Hillsdale-Park-Right 20/05/2005
Geom: Hillsdale-Park-Right Flow: Flow Park
River = Hillsdale Overlan Reach = 1 RS = 20825
.035
Legend
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Bank Sta
Elevation (m)
21.8
21.6
21.4
21.2
21.0
20.8
20.6
20.4
20.2
20.0
100
110
120
130
140
150
Station (m)
Main Channel Distance (m)


Legend
WS 5
Station (m)
Main Channel Distance (m)
Legend
WS 5
Station (m)
Main Channel Distance (m)
Legend
WS 5
Station (m)
Main Channel Distance (m)
Legend
WS 5
Station (m)
Main Channel Distance (m)
Legend
WS 5
Station (m)
Main Channel Distance (m)
Legend

FLOOD RELIEF OVERLAND FLOWPATH VIA HEFFRON PARK

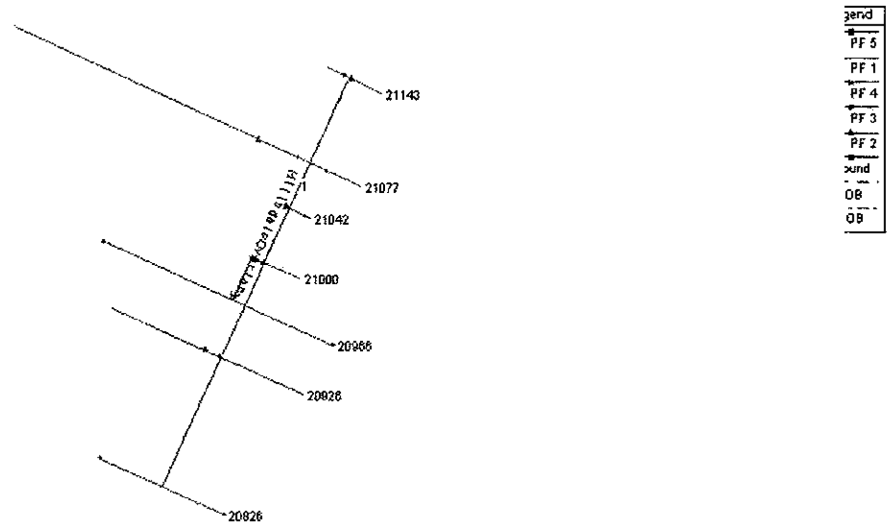
HEC-RAS Plan: Park-Right River: HillsdaleOverlan

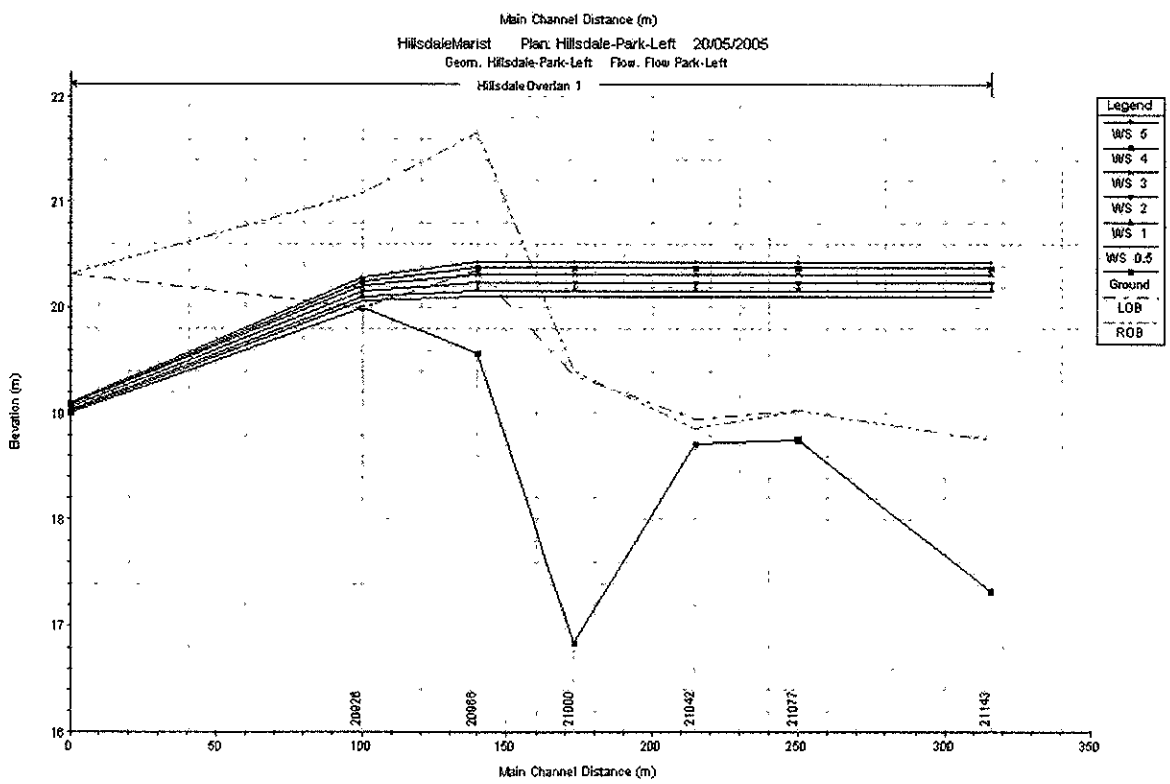
Reach: 1

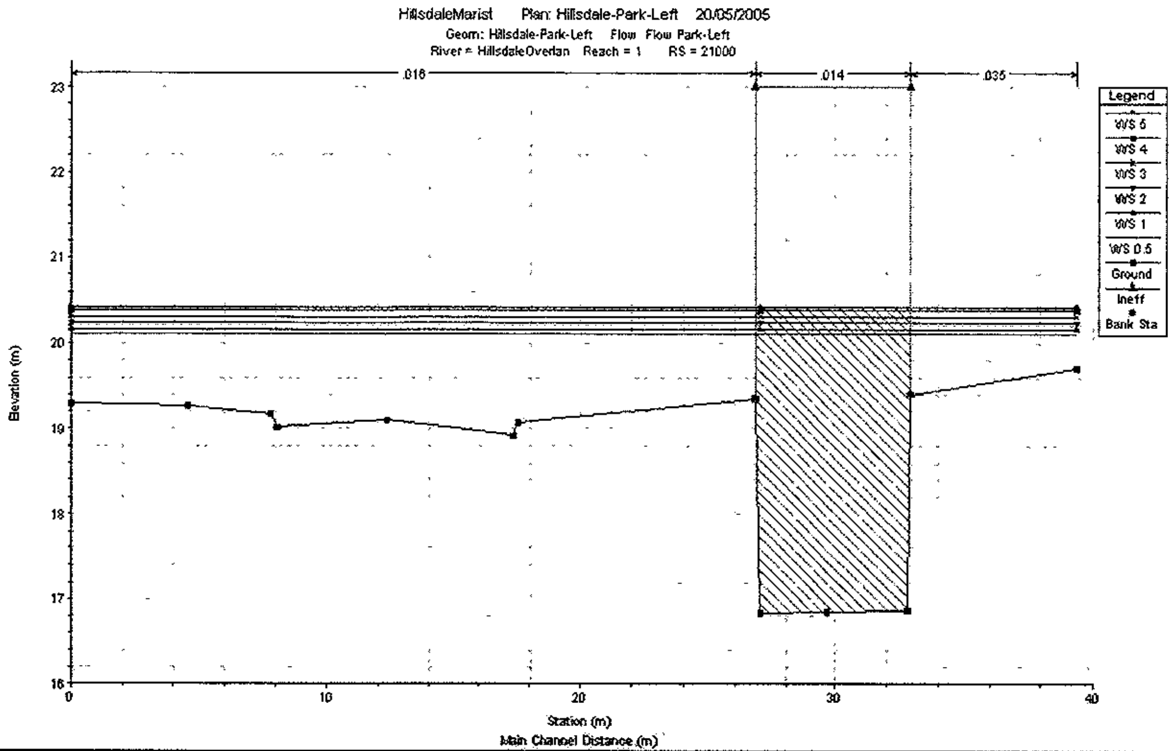
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	21143	0.5	6	17.33	20.58	19.2	20.58	0.000003		56.7	43.3	0
1	21143	1	1	17.33	20.33	18.99	20.33	0		47.05	43.3	0
1	21143	2	2	17.33	20.37	19.06	20.37	0.000001		48.84	43.3	0
1	21143	3	3	17.33	20.43	19.11	20.43	0.000001		51.09	43.3	0
1	21143	4	4	17.33	20.49	19.15	20.49	0.000002		53.16	43.3	0
1	21143	5	5	17.33	20.54	19.19	20.54	0.000003		55.01	43.3	0
1	21077	0.5	6	18.76	20.58	19.1	20.58	0.000001	0.07	116.37	269.47	0.02
1	21077	1	1	18.76	20.33	18.92	20.33	0	0.01	96.13	224.35	0
1	21077	2	2	18.76	20.37	18.98	20.37	0	0.03	99.88	234.6	0.01
1	21077	3	3	18.76	20.43	19.02	20.43	0	0.04	104.6	257.41	0.01
1	21077	4	4	18.76	20.49	19.05	20.49	0	0.05	108.92	269.47	0.01
1	21077	5	5	18.76	20.54	19.08	20.54	0	0.06	112.81	269.47	0.01
1	21042	0.5	6	18.71	20.58	19.12	20.58	0.000006	0.22	31.51	22.75	0.05
1	21042	1	1	18.71	20.33	18.94	20.33	0	0.04	26.78	22.75	0.01
1	21042	2	2	18.71	20.37	18.98	20.37	0.000001	0.08	27.66	22.75	0.02
1	21042	3	3	18.71	20.43	19.02	20.43	0.000002	0.12	28.77	22.75	0.03
1	21042	4	4	18.71	20.49	19.06	20.49	0.000003	0.16	29.78	22.75	0.04
1	21042	5	5	18.71	20.54	19.09	20.54	0.000005	0.19	30.68	22.75	0.05
1	21000	0.5	6	16.84	20.58	19.33	20.58	0.000004		44.69	39.38	0
1	21000	1	1	16.84	20.33	19.14	20.33	0		36.24	39.38	0
1	21000	2	2	16.84	20.37	19.2	20.37	0.000001		37.81	39.38	0
1	21000	3	3	16.84	20.43	19.24	20.43	0.000001		39.78	39.38	0
1	21000	4	4	16.84	20.49	19.28	20.49	0.000002		41.59	39.38	0
1	21000	5	5	16.84	20.54	19.31	20.54	0.000003		43.21	39.38	0
1	20966	0.5	6	19.56	20.58		20.58	0.000023	0.1	63.01	108.28	0.04
1	20966	1	1	19.56	20.33		20.33	0.000003	0.03	37.87	88.28	0.01
1	20966	2	2	19.56	20.37		20.37	0.000008	0.05	42.15	92.45	0.02
1	20966	3	3	19.56	20.43		20.43	0.00001	0.06	47.78	97.18	0.03

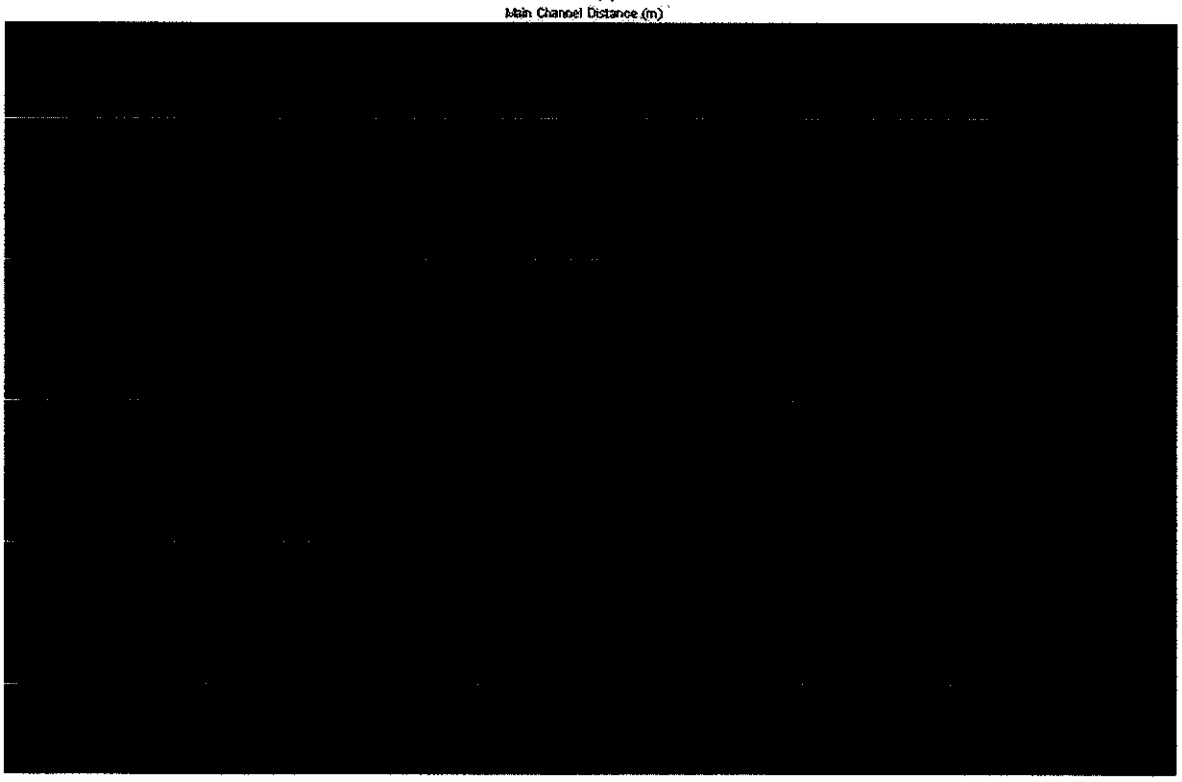
								3				
1	20966	4	4	19.56	20.49		20.49	0.000017	0.08	53.18	101.52	0.03
1	20966	5	5	19.56	20.54		20.54	0.00002	0.09	58.23	105.42	0.04
1	20926	0.5	6	20.22	20.57	20.38	20.58	0.000702	0.32	18.72	85.32	0.19
1	20926	1	1	20.22	20.3	20.3	20.32	0.033754	0.65	1.53	49.3	0.99
1	20926	2	2	20.22	20.36	20.33	20.37	0.007301	0.42	4.73	80.79	0.5
1	20926	3	3	20.22	20.43	20.35	20.43	0.002074	0.34	8.84	82.14	0.3
1	20926	4	4	20.22	20.48	20.36	20.49	0.001183	0.32	12.47	83.32	0.24
1	20926	5	5	20.22	20.53	20.37	20.53	0.000862	0.32	15.73	84.37	0.21
1	20851	0.5	6	20.12	20.56		20.56	0.000104	0.17	36.32	85.33	0.08
1	20851	1	1	20.12	20.26	20.14	20.26	0.000143	0.09	11.09	81.66	0.08
1	20851	2	2	20.12	20.34		20.34	0.000116	0.11	17.99	82.68	0.08
1	20851	3	3	20.12	20.41		20.41	0.000109	0.13	23.48	83.48	0.08
1	20851	4	4	20.12	20.46		20.47	0.000105	0.14	28.25	84.17	0.08
1	20851	5	5	20.12	20.51		20.52	0.000104	0.15	32.48	84.78	0.08
1	20825	0.5	6	20.08	20.41	20.41	20.54	0.019317	1.59	3.78	14.89	1.01
1	20825	1	1	20.08	20.19	20.19	20.24	0.026043	0.98	1.02	10.32	1
1	20825	2	2	20.08	20.25	20.25	20.32	0.02324	1.2	1.67	11.57	1.01
1	20825	3	3	20.08	20.3	20.3	20.39	0.021312	1.33	2.26	12.59	1
1	20825	4	4	20.08	20.34	20.34	20.44	0.020619	1.44	2.79	13.43	1.01
1	20825	5	5	20.08	20.38	20.38	20.49	0.019894	1.52	3.29	14.2	1.01
1	20802	0.5	6	19.7	19.91	19.86	19.96	0.010013	0.98	6.11	29.93	0.69
1	20802	1	1	19.7	19.77	19.75	19.79	0.010006	0.48	2.08	29.91	0.58
1	20802	2	2	19.7	19.81	19.78	19.83	0.010008	0.63	3.15	29.92	0.62
1	20802	3	3	19.7	19.84	19.81	19.87	0.010001	0.75	4.02	29.92	0.65
1	20802	4	4	19.7	19.86	19.83	19.9	0.010003	0.84	4.78	29.92	0.67
1	20802	5	5	19.7	19.89	19.85	19.93	0.010001	0.91	5.47	29.93	0.68

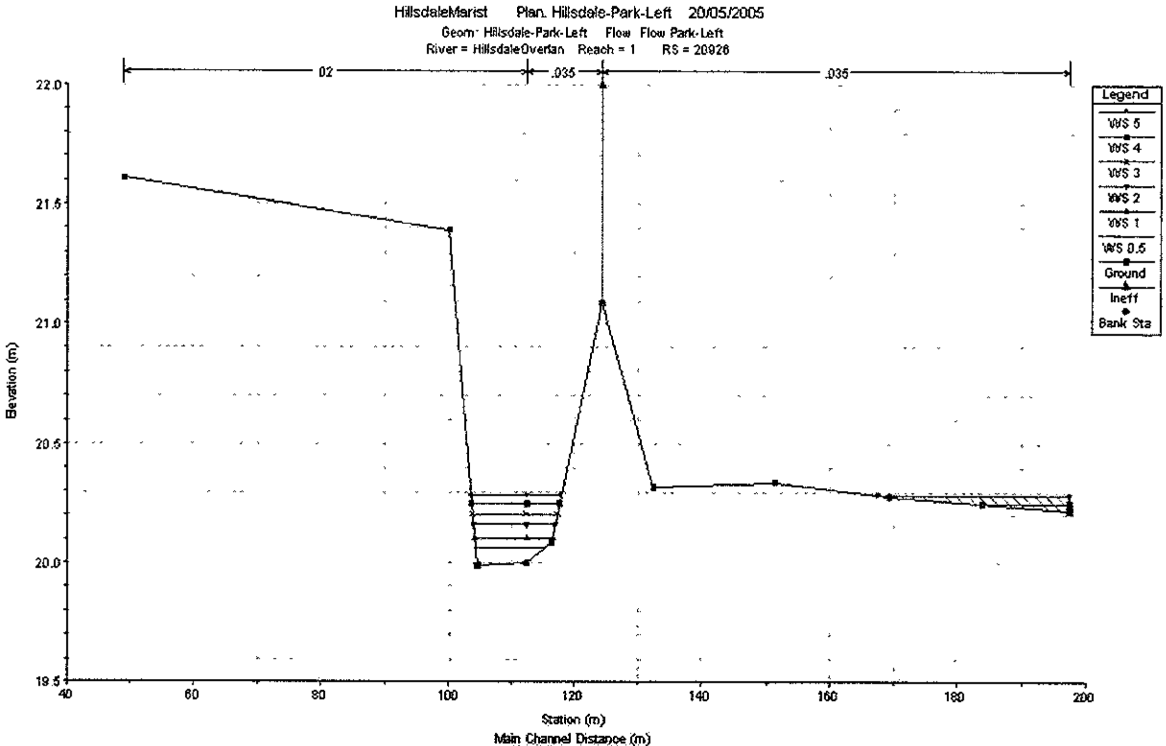
D4. FLOOD RELIEF FLOWPATH TO HEFFRON PARK LOW PLAYING FIELDS

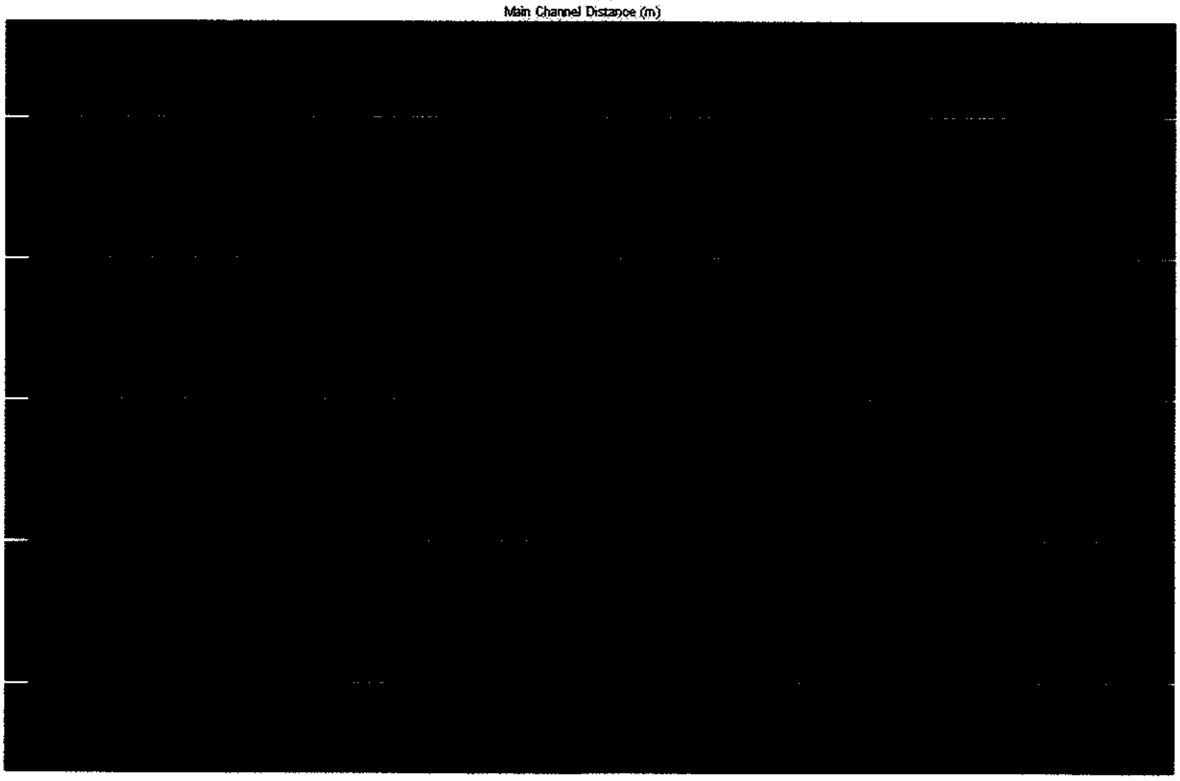





HillsdaleMarist Plan: Hillsdale-Park-Left 20/05/2005
Geom: Hillsdale-Park-Left Flow: Flow Park-Left
River = HillsdaleOverlan Reach = 1 RS = 21000
.016
.014
.035
Legend
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)
Main Channel Distance (m)




HillsdaleMarist Plan. Hillsdale-Park-Left 20/05/2005
Geom: Hillsdale-Park-Left Flow Flow Park-Left
River = HillsdaleOverlan Reach = 1 RS = 20926
.02
.035
.035
Legend
WS 5
WS 4
WS 3
WS 2
WS 1
WS 0.5
Ground
Ineff
Bank Sta
Elevation (m)
22.0
21.5
21.0
20.5
20.0
19.5
40
60
80
100
120
140
160
180
200
Station (m)
Main Channel Distance (m)



FLOOD RELIEF OVERLAND FLOWPATH TO HEFFRON PARK LOW PLAYING FIELDS

HEC-RAS Plan: Park-Left River: HillsdaleOverlan

Reach: 1

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
1	21143	0.5	8	17.33	20.57	19.24	20.57	0.000006		56.2	43.3	0
1	21143	1	1	17.33	20.16	18.99	20.16	0		40.74	43.3	0
1	21143	2	2	17.33	20.24	19.06	20.24	0.000001		43.93	43.3	0
1	21143	3	3	17.33	20.31	19.11	20.31	0.000002		46.54	43.3	0
1	21143	4	4	17.33	20.37	19.15	20.37	0.000002		48.82	43.3	0
1	21143	5	5	17.33	20.43	19.19	20.43	0.000003		50.88	43.3	0
1	21077	0.5	8	18.76	20.57	19.14	20.57	0.000001	0.09	115.32	269.47	0.02
1	21077	1	1	18.76	20.16	18.92	20.16	0	0.02	82.9	199.69	0
1	21077	2	2	18.76	20.24	18.98	20.24	0	0.03	89.59	211.08	0.01
1	21077	3	3	18.76	20.31	19.02	20.31	0	0.04	95.05	221.42	0.01
1	21077	4	4	18.76	20.37	19.05	20.37	0	0.05	99.84	234.47	0.01
1	21077	5	5	18.76	20.43	19.08	20.43	0.000001	0.06	104.15	255.28	0.02
1	21042	0.5	8	18.71	20.56	19.17	20.57	0.000011	0.3	31.23	22.75	0.07
1	21042	1	1	18.71	20.16	18.94	20.16	0	0.05	23.67	22.75	0.01
1	21042	2	2	18.71	20.24	18.98	20.24	0.000001	0.09	25.24	22.75	0.02
1	21042	3	3	18.71	20.31	19.02	20.31	0.000003	0.13	26.52	22.75	0.03
1	21042	4	4	18.71	20.37	19.06	20.37	0.000004	0.17	27.63	22.75	0.04
1	21042	5	5	18.71	20.43	19.09	20.43	0.000006	0.2	28.64	22.75	0.05
1	21000	0.5	8	16.84	20.57	19.37	20.57	0.000007		44.21	39.38	0
1	21000	1	1	16.84	20.16	19.14	20.16	0		30.67	39.38	0
1	21000	2	2	16.84	20.24	19.2	20.24	0.000001		33.48	39.38	0
1	21000	3	3	16.84	20.31	19.24	20.31	0.000002		35.77	39.38	0
1	21000	4	4	16.84	20.37	19.28	20.37	0.000003		37.76	39.38	0
1	21000	5	5	16.84	20.43	19.31	20.43	0.000004		39.56	39.38	0
1	20966	0.5	8	19.56	20.57		20.57	0.000044	0.13	61.44	107.82	0.06
1	20966	1	1	19.56	20.16		20.16	0.000011	0.04	23.84	80.22	0.02
1	20966	2	2	19.56	20.24		20.24	0.00002	0.07	30.76	83.84	0.03
1	20966	3	3	19.56	20.31		20.31	0.000026	0.08	36.62	86.9	0.04
1	20966	4	4	19.56	20.37		20.37	0.000032	0.1	42.02	92.34	0.05
1	20966	5	5	19.56	20.43		20.43	0.000036	0.11	47.14	96.66	0.05
1	20926	0.5	8	20	20.38	20.38	20.54	0.005977	0.91	5	81.18	0.56
1	20926	1	1	20	20.1	20.1	20.15	0.008057	0.38	1.14	12.48	0.51
1	20926	2	2	20	20.16	20.16	20.23	0.007207	0.54	1.87	13.11	0.53
1	20926	3	3	20	20.21	20.21	20.3	0.006814	0.64	2.49	13.63	0.54
1	20926	4	4	20	20.25	20.25	20.36	0.006499	0.72	3.06	27.67	0.55
1	20926	5	5	20	20.29	20.29	20.41	0.006288	0.78	3.58	44.37	0.55
1	20826	0.5	8	19	19.13	19.1	19.16	0.010002	0.74	10.79	81.62	0.65
1	20826	1	1	19	19.04	19.02	19.04	0.010001	0.32	3.08	80.47	0.53
1	20826	2	2	19	19.06	19.04	19.07	0.010001	0.43	4.68	80.71	0.57
1	20826	3	3	19	19.07	19.05	19.09	0.010004	0.5	5.97	80.9	0.59
1	20826	4	4	19	19.09	19.06	19.1	0.010001	0.56	7.1	81.07	0.61
1	20826	5	5	19	19.1	19.07	19.12	0.010014	0.62	8.12	81.22	0.62