Whangarei District Council

Ngunguru Stormwater Catchment Management Plan

Final Report

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GHD LIMITED
First Floor, Merial Building
Putney Way, Manukau City
Telephone: 261 1400 Facsimile: 262 8340

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Glossary

The glossary provided herein relates to general terminology. Detailed explanations of more technical terms are contained within the text.

ARI	Average Recurrence Interval
AMC	Antecedent Moisture Content.
NRC	Northland Regional Council.
Attenuation	Reduction in peak discharge due to storage and lagging effects.
Calibration	Procedure of adjusting the parameters of a model in order to reproduce observations.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Datum	Unless stated otherwise, all levels are referred to in terms of metres (m) above Department of Survey & Land Information (which corresponds to about mean sea level).
Design Flood	The flood selected as a basis for design of flood control works.
Design Floor Level	A minimum flood level specified as part of a building control programme.
Detention Storage	Storage that captures some inflow for subsequent release compared with a retention storage that captures flow for soakage into the ground.
Development	The erection of a building or the carrying out of work; or the use of land or a building for work; or the subdivision of land. Usually associated with an increase in urbanisation.
Discharge or Flow Rate	Volume of water passing a given point during a specified time interval. It is to be distinguished from the speed of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flood Hazard	Potential for flooding or erosion due to stormwater runoff.
Flood Management Plan	Programme to lessen the damaging effects of floods, maintain and enhance natural values, and make effective use of related water and land resources in the catchment.
Floor Level	Floor level is taken to be the top of the structural floor.
Floodplain	The portion of a valley, adjacent to open watercourse, which is covered with water when the watercourse overflows during floods.
Flood Standard	The flood selected for planning purposes.

Flood Storage	Those parts of the Floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Freeboard	Additional clearance above estimated flood level to allow for uncertainty.
Habitable Floor Levels	A living area such as a lounge room, dining room, rumpus room, kitchen, bedroom etc.
HF	Habitable Floor
Hydraulic	The term given to the study of water flow in a river, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph which shows how the discharge changes with time at any particular location
Hydrology	The term given to the study of the rainfall and runoff process.
Hyetograph	Graph illustrating the variation of rainfall intensity with time (same as storm profile).
Mathematical Computer Models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are run on computers due to the complexity of the mathematical relationships. It is noted that these are not physical models.
MHWS	Mean High Water Spring Tide level
NHF	Non Habitable Floor
Overland Flow Path	Is the route along which stormwater will flow where it cannot be taken by a piped system.
Peak Discharge or Peak Flow Rate	The maximum discharge occurring during a flood event.
Primary, Secondary and Trunk drainage	Primary drainage is the initial conveyor of flow (e.g. a pipe); secondary drainage is the route taken by flows when the primary drainage capacity is exceeded (e.g. overland flow path) and trunk drainage is a combination of these (e.g. detention reservoir).
Revetment	Rock used to prevent erosion
Runoff	The amount of rainfall, which actually ends up as stream flow, also known as rainfall excess.
Stormwater Flooding	Inundation resulting from the inability of urban stormwater drainage works to handle runoff.
Time of Concentration	Generally described as the time taken for a water particle to travel from the furthermost point of the catchment to the outlet.

Urbanisation	Land use associated with the establishment of residential, industrial or commercial properties in an area.
Urban Land	Land zoned as residential, industrial, commercial, business or related zonings.
Verification	Comparison of simulated or modelled values and observation without altering any model parameters.
Water Surface Profile	A longitudinal plot showing the flood levels at any given location along a watercourse.
WDC	Whangarei District Council
XP-SWMM	Specialised computer software program used to analyse stormwater drainage systems.

References

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6. Huber W.C and Dickinson R.E (1992): Stormwater Management Model, Version 4:Users Manual.

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1. Introduction

1.1 Brief and Scope

GHD Limited, formerly Manukau Consultants Ltd (MCL) have been commissioned by Whangarei District Council (WDC) to prepare a Stormwater Catchment Management Plan for Ngunguru Township. The plan is intended to address matters listed in Appendix 5 of the Proposed Regional Water and Soil Plan for Northland (Variation) (reference 2).

A draft copy of the Catchment Management Plan will form the basis of consultation with various interested parties. Their input will be incorporated into the final plan. The final, updated plan will form the basis of an application to the Northland Regional Council for a comprehensive discharge consent.

As a function of the catchment management planning exercise, WDC also intends to evaluate the local stormwater reticulation system to determine areas of insufficient capacity causing flooding and identify upgrading requirements.

1.2 Background

WDC has a statutory obligation to apply for resource consent for the discharge of stormwater from Ngunguru Township (Resource Management Act 1991) and the stormwater catchment management plan will be used as supporting information to the resource consent application.

The stormwater catchment management plan will also be used by WDC as:

- A management document in the evaluation of new developments within the catchment in terms of flooding, erosion and stormwater quality issues.
- A resource document in the preparation of WDC's Stormwater Capital Works and Maintenance programmes.

1.3 Historical Flooding & Previous Catchment Studies

Based on the results of a public questionnaire survey undertaken as part of this study, residents reported that most incidents of stormwater flooding in Ngunguru occurred during 1999, mostly between June and August. Very few flooding and drainage problems prior to 1999 were reported. Based on the results of the questionnaire, consultation with Northland Regional Council staff and site investigations by GHD staff, the following factors appear to have contributed to these problems:

- A general increase in development in the Ngunguru Township;
- Unusually high rainfall during June, July and August 1999;
- Deficiencies in the drainage system.

According to information supplied by WDC, a stormwater catchment study of Ngunguru has never been undertaken. The Whangarei County Council undertook a basic study of a part of the Township, the proposed Ngunguru Drainage Scheme, in October 1980. This study identified the main catchment and subcatchment areas, and the 100 and 5 year ARI flows for the Waiotoi Road sub-catchment areas only. Analysis of other parts of the Township appears to have been excluded.

Ngunguru's most recent major flooding incident occurred on 11 March 1997. At this time a number of properties adjacent to the tidal drain west of Waiotoi Rd were flooded with salt water. Mr Brye Blackhall of 23-25 Waiotoi Rd, a retired civil engineer, who was at his property when the incident occurred, believes that this event was caused by a 'tidal surge' up the Waiotoi Rd drain from the Ngunguru Estuary rather than heavy rainfall coinciding with an exceptionally high tide. While flooding at this time caused habitable floor flooding at only one property, extensive damage to gardens, trees (including an orchard) and grass areas (particularly the Ngunguru Golf Course) occurred as a result of this event.

As requested by Whangarei District Council, GHD have undertaken a simplified analysis of this problem and have outlined proposed remedial works for WDC's preferred option in this report.

Fresh water flooding of the Waiotoi Rd area has also occurred on a number of occasions. However, this has been less severe than the above salt water flooding incident. Analysis for freshwater flooding of the Waiotoi Rd area is included in this report. Fresh water flooding occurred most recently, during the course of this study on 11 December 2000.

2. Present Situation

2.1 Catchment Overview & Geology

This stormwater catchment management study of Ngunguru focuses on flooding, drainage, water quality and erosion problems in a 420-hectare catchment area that discharges to the Ngunguru Estuary / River.

Current land use in Ngunguru Township falls into the following two categories:

- Developed areas (urban) – 55 hectares;
- Undeveloped areas (zoned residential/commercial/open space (reserves & parks) – 132 hectares;
- Other land (coastal countryside & countryside) – 233 hectares.

Land zoned for urban development generally follows the Ngunguru coastline, while rural zoned land tends to be located inland away from the coast. A sharp increase in the development of the higher ridge areas in the upper part of the catchment has occurred in recent years. This trend is continuing at present.

Ngunguru's stormwater runoff presently discharges to the Ngunguru Estuary via approximately 30 separate stormwater outfalls (both pipes and open drains). Piped outfalls range in size from 300mm to 900 mm diameter. Most catchments originate in the hills to the east and include both rural and urban zoned land, although a few small catchments include urban land only.

The geology of Ngunguru can be classified as follows:

- Undifferentiated alluvium of Holocene age;
- Greywacke and Argillite with chert and associated manganese of Permian to Jurassic age (Waipapa group).

2.2 Future Development

According to the Whangarei District Council Proposed Planning Maps (1998), land in the Ngunguru Catchment area zoned for residential development falls is either 'Living 1' or 'Living 3'. The minimum allowable net site area for "Living 1" is 500 m^2, and for 'Living 3' is 2500 m^2. A small area of land (approximately 4500 m^2) on Ngunguru Rd and Waoitoi Rd is zoned for commercial development.

2.3 Drainage System - General

Developed areas of Ngunguru Township are generally serviced by piped stormwater drainage systems while undeveloped and rural areas tend to be serviced by open drains. Some existing parts of the drainage system, such as the drain adjacent to Waiotoi Rd are affected by high tides.

Consideration of high tide levels has therefore been taken into account in the design of systems in these areas. A MHWS tide level of 1.0m has been used for this purpose based on recent tide data.

In order to obtain sufficient information for a comprehensive analysis of the drainage system, the WDC supplied spreadsheet (which included details of manholes and pipes) was supplemented by additional survey where necessary. This focused on parts of the piped drainage system for which no information was available and for culverts and open drains.

3. Consultation

3.1 Drainage Survey Feedback

Catchment wide consultation was carried out by means of a drainage questionnaire posted to all Ngunguru residents in January 1999. A total of 181 responses were received which can be summarised as follows:

Major (habitable)	3
Minor (non habitable)	18
Property / Section	41
Street	20
None	99

A review of the received questionnaire responses, together with site inspections by GHD staff, indicated that a variety of flooding problems have occurred in Ngunguru. Some of the causes of the problems reported included the following:

- Salt water flooding due to inadequate stopbanks along tidal drains and flood gates;
- Uncontrolled runoff from Ngunguru Rd (inadequate street drainage system);
- Development of the upper catchment areas without adequate improvement of the stormwater drainage system;
- Inadequate piped drainage systems.

Plan 16194/00/01 shows the location of properties in the catchment from which responses were received. A tabulated summary of the responses is included in Appendix 3.

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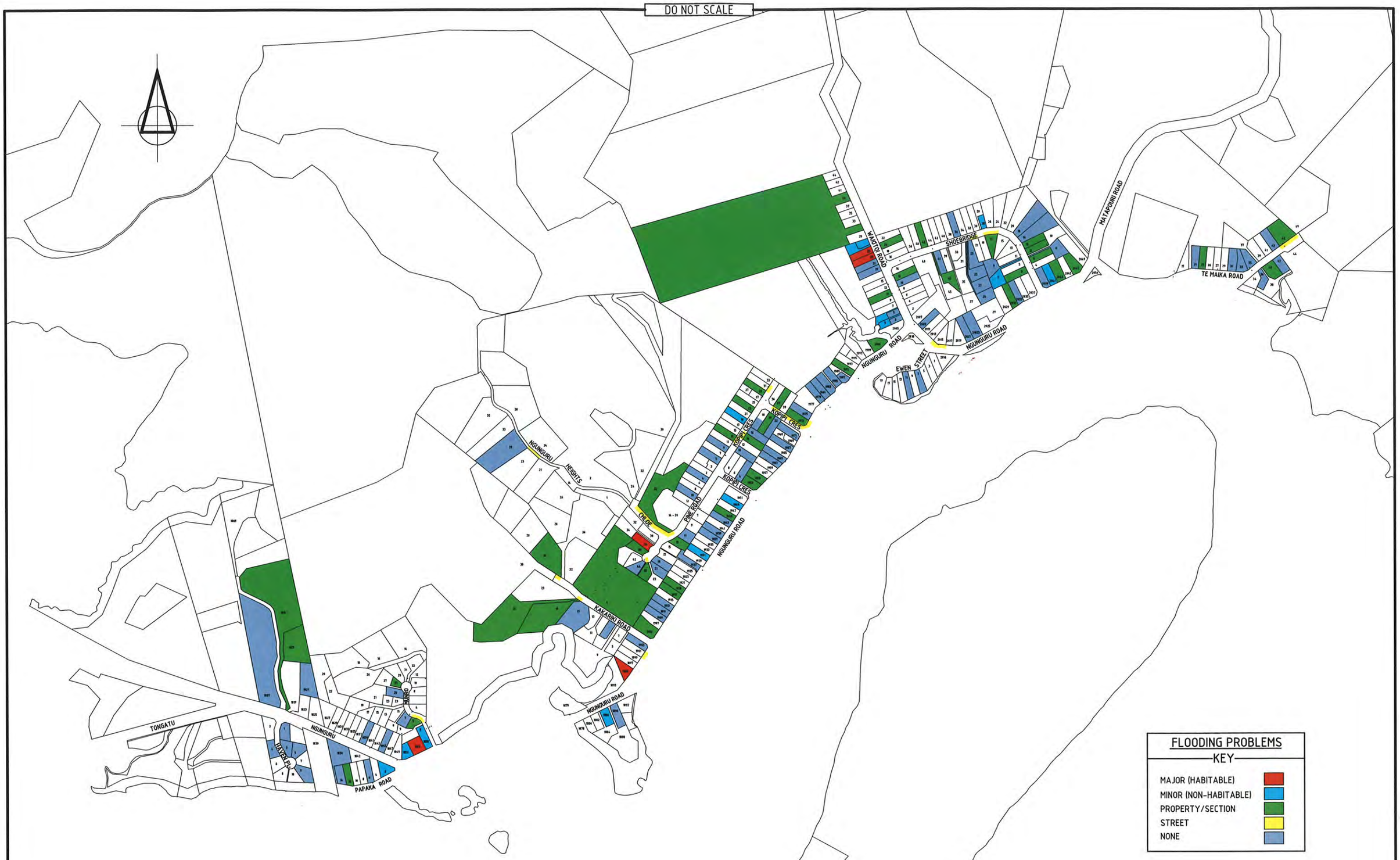

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Drawing File No. S:\51\16194\ACAD\NGUNGURU SURVEY RESPOND (V1)

GHD
MANAGEMENT ENGINEERING ENVIRONMENT
Putney Way, Manukau City, Auckland, 1702
Telephone (09) 261 1400 Facsimile (09) 262 8340
Email: auckmail@ghd.co.nz
GHD Limited

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Client and Job: WHANGAREI DISTRICT COUNCIL
NGUNGURU CATCHMENT STUDY

Title: STORMWATER DRAINAGE SURVEY FEEDBACK

Size: A1 | Drg. No. 16194/00/00 | Rev

4. Hydrology

4.1 Rainfall Intensities

The rainfall depth-duration-frequency data shown in the table below was used to estimate rainfall depths in Ngunguru in this study. The data was obtained from the HIRDS computer program (NIWA), which interpolates intensity/duration/frequency figures between NIWA rain gauge sites throughout New Zealand. All rainfall depths are in millimetres.

ARI	AEP	10min	20min	30min	1 hr	2 hr	6 hr	24 hr
5	20%	23	34	42	61	82	133	241
50	2%	37	53	67	96	126	203	369

The rainfall depths above were converted into hourly intensities for use in the rational formula, which was used to estimate runoff in the study. The final hourly intensities as used in the study are tabulated below:

ARI	AEP	10min	20min	30min	1 hr	2 hr	6 hr	24 hr
5	20%	138	102	84	61	41	22	10
50	2%	222	159	134	96	63	34	15

4.2 Rational Formula

The standard form of the rational formula as shown below was used in the study:

$$Q = C*I*A / 360$$

Where:

Q = Discharge (m^3/s)

C = Runoff Coefficient

I = Intensity (mm/hr)

A = Catchment Area (hectares)

Runoff coefficients for the study were adopted from standard engineering values. For the existing development scenario an overall runoff coefficient was developed for each land use area based on a sample of properties and their respective roof, driveway and garden areas. For the future development scenario, maximum allowable coverage based on the Proposed District Plan (1997) was used. The following values were developed:

Type of Surface	Existing	Future
Living 1	0.48	0.6
Living 3 (lower catchment – flat areas)	0.3	0.46
Living 3 (upper catchment steep areas)	0.35	0.51
Pasture, grass and open space areas:	0.35	0.51
Impervious areas (roads, etc.):	0.85	0.85

4.3 Catchment Areas and Discharges

The following catchment areas and discharges were calculated for the major catchments within the study area. Catchment letters are as detailed on plan 16194/00/03.

Catchment	SW Line or Final Culvert in Catchment	Area (hectares)	Discharge	
			5 yr. ARI	50 yr. ARI
A	PC1	6.03	0.37	0.70
B	PC5	16.35	0.93	1.70
C	Line A	0.5	0.092	0.148
D	Line C	1.98	0.348	0.557
E	Line B	0.49	0.091	0.146
F	Lines D, E , EA & DA	3.72	0.67	1.07
G	PC7	16.74	1.01	1.87
H	PC11	20.29	1.20	2.23
I	Line H	1.41	0.26	0.42
J	Line F	1.80	0.32	0.52
K	Line J	0.77	0.14	0.23
L	Line K	0.47	0.086	0.14
M	Line L	1.54	0.27	0.43
N	Line O	3.13	0.49	0.78
O	Line M	0.49	0.09	0.14
P	Line N	0.69	0.12	0.20
Q	Line P	0.68	0.16	0.26
R	Line Q	0.2	0.04	0.06
S	PC13	4.49	0.27	0.51

Catchment	SW Line or Final Culvert in Catchment	Area (hectares)	Discharge	
T	No culvert data	1.93	0.25	0.41
U	Line S	1.46	0.26	0.42
V	Line R	2.11	0.33	0.53
W	PC15	32.31	1.88	3.47
X	Line U	0.35	0.07	0.106
Y	Line V	0.71	0.13	0.21
Z	Line W	0.69	0.13	0.21
AA	Line X	4.08	0.73	1.18
AB	PC17	25.2	1.57	2.6
AC	PC18	0.78	0.055	0.11
AD	Line Y	4.23	0.57	0.91
AE	Line Z	0.71	0.12	0.19
AF	Line ZA	0.96	0.153	0.246
AG	Line ZB	0.58	0.098	0.157
AH	Un-named	0.17	0.06	0.09
AI	PC19	4.85	0.29	0.55

5. Hydraulics

5.1 Overview

Basic hydraulic analysis without consideration of backwater effects was used for the majority of the stormwater drainage system. The exception was for the 19 culverts in the Ngunguru Township area considered in this study. These were analysed using a simplified XP-SWMM model to take into account tidal effects.

5.2 Basic Analysis

The standard Colebrook-White formula was used to calculate pipe capacities for the piped drainage system, as presented in the Wallingford Hydraulic Charts (Ref. 1). A 'k' value (pipe roughness) of 1.5 mm was used for all pipes under 1.0 m diameter, while a value of 0.6 mm was used for pipes greater than 1.0 m diameter (in accordance with GHD practice).

Appendix D includes a spreadsheet showing the calculation process that was used for the piped drainage system.

It should be noted that the above analysis method did not take account of tidal effects (as per the brief and tender offer, except where specifically indicated.

Capacities of open drains were calculated using the Manning formula, based on cross-section data provided by WDC. The following Manning's roughness values were adopted:

Open drains and natural watercourses	0.04
Culvert Overflows across Roads	0.02 – 0.03
Culverts	0.015

5.3 Detailed Analysis with SWMM

5.3.1 Brief Overview of XP-SWMM

A computer model is a mathematical representation of the hydraulic and hydrologic processes of a catchment. This representation is capable of simulating the response of a catchment to changing rainfall and catchment conditions based on data provided by the modeller.

The computer model used in this study was XP-SWMM. This software program was developed from the United States Environmental Protection Authorities (USEPA) Stormwater Management Model (SWMM). For a further description, details, principles and an algorithm of this model, see Ref. 9.

Since the 1970s, SWMM has been used to analyse, design and manage catchment behaviour throughout the United States and many other countries. A large amount of literature is therefore available on SWMM's capabilities and applications.

XP-SWMM can simulate the rainfall-runoff process using a number of different techniques. Laurensons method was selected for this particular study.

5.3.2 *Run-off Flow and Transport Network*

A computer model of a stormwater drainage system generally represents channels, pipes and overland flow paths as nodes and links. Links are conduits and nodes are junctions.

Links are assigned; cross-sections, invert levels and lengths by the modeller. Nodes are assigned to the ends of each link. The actual elevation of the stream invert is assigned to each node along with inflow hydrographs, storage and/or outfall characteristics.

5.4 Application in this Study

In this study XP-SWMM was used to model the culverts and open drainage systems that discharge to the Ngunguru estuary within the confines of Ngunguru Township. In order to simplify the analysis the following simplifications were made:

- Flows at each node were determined separately using the rational formula;
- To allow for a single model run for all 19 culverts and their associated open drains, a hypothetical tidal channel with sufficient capacity to accept flows from these systems without any significant change in depth was included in the model. Each drainage system discharged to this channel (see Appendix 4).
- A constant tide of RL 1.0m corresponding to MHWS was used to simulate the worst case scenario.

One of the main benefits of using XP-SWMM to model the culvert channel systems was that it considered the overall effect of a series of culverts/channels and their impact on each other. Typically culverts and channels are analysed in isolation without any consideration of the effect of backwater on the culvert/channel system as a whole.

5.5 Verification of Model

The data generated by the XP-SWMM model was checked for accuracy against manual calculations using standard 'inlet control' and 'outlet control' nomograms for culverts. This process showed satisfactory agreement between the two methods.

6. Drainage System –Flooding Problems & Solutions

6.1 Minor Problems

Table 6.1 below outlines the problems and proposed remedial options for Ngunguru by catchment. For clarification of catchment and stormwater line designations, reference can be made to the drawings at the end of this section. For details of the hydrologic and hydraulic analysis, reference can be made to Appendix 3.

6.2 Assumptions / Notes

The following items refer to Table 6.1 and the analysis undertaken as part of this catchment study:

- For catchments with culverts and open drains modelling with XP-SWMM was undertaken to determine the required upgrades. Modelling of the culvert and channel system was not a requirement of the brief. For this reason only essential reaches and nodes for each catchment were included in each model.
- A pipe stress of up to105% was considered acceptable before upgrading the pipe was considered necessary. This figure has been used by GHD on other projects in the Auckland region. A figure greater than 100% was adopted to take into account pressure effects that are ignored in the standard drainage system analysis procedure as used for this project. A value of 105% also reduces the risk of undertaking non-essential upgrades.
- The priority ranking given in Table 6.1 (1,2 or 3) was determined from a subjective assessment of each problem including the potential impact on each property, the risk to members of the public and the expected frequency of the flooding event.
- Upgrades shown in bold and blue denote pipe reaches that have been sized for the 50 yr ARI design flow.
- Allowance for the 50 yr ARI flow in the pipe system or culvert was made only where there was no clear overland flow path or where the overland flow path would only operate after the onset of property flooding (habitable or non-habitable floor).

Table 6.1: Summary of Catchment Characteristics, Problems and Proposed Remedial Options

Catchment	Drainage System	Catchment Description	Area (ha)	Zoning	Drainage Survey Results*	Results of Analysis	Clear Overland Flow Path **	Design Flow (50/5yr)?	Existing Upgrade Requirements	Total Cost	Future Upgrade Requirements (as for 5 yr ARI except where specified here)	Total Cost	Priority	General Comments
A	Open drains and culverts (PC1).	• Forested & steep upper catchment; • Flat lower catchment (mostly paddock);	6.03	Liv 3	No problems	No major problems. Road elevation significantly higher than ground level at culvert inlet – flooding of paddock areas likely in extreme event.	Yes	50	None			N/A	N / A	• No data available downstream of Ngunguru Rd. • Overflow to catchment B expected for flood level above RL 2.0 (approx.) – expected for 50 yr ARI.
B	Open drains and culverts (PC2, PC3, PC4 & PC5)	• Forested & steep upper catchment; • Flat lower catchment (mostly paddock). • Main channel passes through 4 pipe culverts; • Discharges to mangrove swamp area.	16.35	Liv 3	Section flooding only.	Flooding of paddock areas and road over Culvert PC2 expected in 50 yr. ARI event. Preliminary modelling indicates that a flood depth of 200-400 mm is likely at Culvert PC2.	Yes	50	The area upstream of Ngunguru Rd is a low-lying natural flood plain area and reducing flood levels significantly would not be cost effective. Prelim. Modelling indicates that the flood levels at PC2 could be reduced to RL 2.35m (400 mm deep) for the future development scenario and RL 2.11m (200 mm deep) for the existing development scenario by undertaking the following: • Installing an additional 900mm dia. culvert at PC3; • Enlarging the channel between PC2 and PC3 by excavating the banks of the channel from 1v:1h to 1v:3h (or a section with an equivalent area) – increase x-sectional area by 0.7 m^2 (approx.).			$12,600 $4,000,	2	Prelim. Modelling indicates that upgrading culvert PC4 (Ngunguru Rd) would have a practically negligible effect on flood levels at culvert PC2. Note: The pond/dam at No. 1807 Ngunguru Rd was not considered in the analysis.
C	Single 300 mm dia. pipe to outlet at beach (Line A).	• Close to fully developed; • Moderately steep; • Discharges directly to beach.	0.58	Liv 1	No problems	No problems reported in survey. Analysis indicates that present pipe system requires for reticulation of all properties in the catchment.	Yes	5	• Cesspit to Outlet: upgrade to 450	$22,050	• Cesspit to Outlet: upgrade to 525	$26,250	3	No reported problems – upgrade only required in the future when more properties are directly connected to the system. It was assumed that the existing system carries runoff from the road reserve only.
D	Pipe system (Line C).	• Mostly developed; • Includes part of Ngunguru Road; • Discharges directly to beach.	1.98	Liv 1	NHF flooding - 1	Analysis indicates that the existing system is significantly undersized. No clear overland flowpath due to presence of Ngunguru Rd.	No	5/50	MH6001-MH6004: 450 MH6004-MH6002: 450 MH6002-MH6003: 600 **MH6003-Outlet: 675** **Install additional cesspits at MH 6002 for overland flow.**	$38,808 $29,547 $10,710 **$19,992** **$7,000**	MH6004-MH6002: 525 **MH6003-Outlet: 750**	$35,175 **$23,520**	2	Problems in Catchment F may be related. Amount of overland flow indicates that upstream properties may not be connected to the system – connection of these is recommended.
E	Pipe system (Line B).	• Close to fully developed; • Discharges directly to beach / estuary.	0.49	Liv 1	S flooding – 1	Existing pipe to beach undersized for 5 yr ARI storm. Overland flowpath across Papaka Rd appears to be below HF & NHF levels.	Yes	5	Cesspit to Outlet: 375 Install additional cesspit	$8,618 $2,000	Cesspit to Outlet: 450	$10,055	3	

Catchment	Drainage System	Catchment Description	Area (ha)	Zoning	Drainage Survey Results*	Results of Analysis	Clear Overland Flow Path **	Design Flow (50/5yr)?	Existing Upgrade Requirements	Total Cost	Future Upgrade Requirements (as for 5 yr ARI except where specified here)	Total Cost	Priority	General Comments
F	Pipe system (Lines D, DA, E & EA).	• Close to fully developed; • Discharges directly to beach / estuary.	3.72	Liv 1	NHF flooding – 2 HF flooding – 1 S flooding - 2	Line D under-capacity. Line DA requires additional cesspit capacity. Overland flows due to a lack of house connections may be adding to problem. The foot bridge was not included in the system analysis for this catchment. However, based on the measured and estimated dimensions, calculations indicate that the bridge could affect upstream flows from Lines E & D in a 50 year ARI event. The potential for blockage is also high due to a fence upstream of the bridge and the bridge deck itself. Maintenance of the drain is essential to the performance of the system.	No	5/50	MH6000-MH6079: 375 MH6079-MH6078: 525 **MH6078-Outlet: 900** **Install additional superpits on Line DA for overland flow.** **Enlarge existing open drain downstream of Line D (by 1.0 m^2 – x-sectional area) and re-grade to estuary.** **Widen channel under bridge to at least 2.0-m and raise bridge deck to create a channel depth of at least 0.6-m. Due to livestock, regular cleaning and re-forming of the drain is also recommended.**	$27,594 $30,975 **$28,350** **$7,000** **$2,000** **$1,000**	MH6000-MH6079: 450 MH6079-MH6078: 600 **MH6078-Outlet: 1050** **Enlarge existing open drain downstream of Line D (by 1.5 m^2 – x-sectional area) and re-grade to estuary**	$32,193 $37,170 **$34,125** **$3,000**	1	It is recommended that upgrading works for Catchments D and F be undertaken together. Connection of all properties to the system is recommended.
G	Open drains and culverts (PC6A, PC6B, PC7).	• Mostly undeveloped; • Large areas of bush and paddock; • Gradual development of Ngunguru Heights; • Discharges to Catchment H.	16.74	Liv 3	S flooding – 3	Flooding of properties upstream of culverts PC6A and PC6B is recommended.	No	50	Preliminary modelling indicates that flood levels up-stream of culverts PC6 and PC7 at Kakariki Rd (RL 3.25m) are above the floor level of No. 30 Kakariki Rd (FL 2.91m). This is caused primarily by culvert PC7, which is undersized. The following works are therefore recommended for both the existing and future development scenarios: • Upgrade culvert PC7 to a dual 900 mm dia, culvert; The above measure would reduce flood levels at PC6A to RL 2.48m for the existing development scenario. For the future development scenario an additional measure is required: • Upgrade culverts PC6A & B to 675 mm dia. Culverts. Preliminary modelling indicates that the above measures will lower the flood level at PC6A to RL 2.72m for the future development scenario. While this is below the recommended 500 mm freeboard, this is considered sufficient as storage effects have not been considered fully in the model (see 'comments').	$15,120 $11,000	1	The storage area upstream of culvert PC6 was not taken into account in the prelim. model. It is likely that flood levels at PC6 would be slighter lower than given here if this storage were taken into account.
H	Open drains and culverts (PC8, PC9, PC10, and PC11).	• Mostly undeveloped; • Large areas of bush and paddock; • Gradual development of Ngunguru Heights and adjacent ridges; • Receives flows from catchments G, I & K. • Discharges to mangrove swamp north of Ngunguru Rd.	20.29	Liv 3	S flooding – 1; Problem with flooding of 30-38 Pine Rd during extreme events. Residents want separate line to beach for Ngunguru Heights SW.	Flooding between culverts PC9 and PC11 expected. Remedial works required. Possible options include new line to beach, upgrading of existing system, on-site detention tanks and construction of a detention dam.	No	50	Further investigation and analysis required to establish the best option. See main report **Section 6.3 Major Problems** for further details (proposed option is upgrading of system between PC8 and Ngunguru Estuary).				1	

Catchment	Drainage System	Catchment Description	Area (ha)	Zoning	Drainage Survey Results*	Results of Analysis	Clear Overland Flow Path **	Design Flow (50/5yr)?	Existing Upgrade Requirements	Total Cost	Future Upgrade Requirements (as for 5 yr ARI except where specified here)	Total Cost	Priority	General Comments
I	Three pipe systems that discharge to watercourse though single outlet (Lines G, H & I).	• Fully developed (Ngunguru Retirement Village); • Discharges to Catchment G upstream of culvert PC 11.	1.41	Liv 1	S flooding – several sites within retirement village.	No problems as a result of Line I. This line has sufficient capacity for the 5 yr ARI future flow. Reports by local residents suggest that the elevated water level upstream of Kakariki Rd (due to the undersized PC11) backs up flow in the local reticulation system for the retirement village causing some flooding of village properties. This problem will be rectified when the existing culvert is upgraded (Catchment H).	Yes	5	No upgrading works required.		No upgrading works required.		N / A	The first pipe reach of Line I (MH6007 to MH6006.1) and Line G were not included in the study due to a lack of data.
J	Pipe system (Line F).	• Close to fully developed; • Very flat area; • Flat grades on existing SW line; • Low lying area in retirement village. • Discharges to mangrove swamp behind Ngunguru Rd.	1.80	Liv 1	S flooding – 2 properties.	Kakariki Rd acts as a dam to the overland flowpath for this catchment. The non-habitable floor levels of two dwellings in the flow path are RL2.67m and RL2.68m respectively. The Kakariki Rd level is RL 2.76m (approx.). Therefore, in an extreme event, ponding in this overland flowpath could occur with likely flooding of these buildings. Flooding of habitable floors is not expected. Nos. 1895-1901 Ngunguru Rd receive runoff from Ngunguru Rd. HF flooding occurred at No. 1895 in the winter of 1999.	Yes	50	To provide 50 yr ARI flood protection to the existing garages in the overland flow path upstream of this line, upgrading Line F for the 50 year ARI event would be required. **Cesspit to MH6075: 675** **MH6075 to MH6074: 675** **MH6074 to Outlet: 675** **Additional cesspits in flowpath.** Construct a new SW system (225 mm dia.) along the footpath from Nos. 1895-1901 Ngunguru Rd with a combination of strip drains and cesspits with an outlet at MH6074.	**$22,134** **$13,066** **$43,911** **$7,000** $45,000	**Cesspit to MH6075: 750** **MH6075 to MH6074: 750** **MH6074 to Outlet: 750**	**$26,040** **$15,372** **$51,660**	2	Preliminary investigation indicates that upgrading Line F may be difficult due to the close proximity of dwellings. However, preliminary investigation indicates that a route to the estuary is possible. Further investigation at design stage is recommended. A number of properties along Ngunguru Rd have experienced flooding problems caused by runoff from Ngunguru Rd – a combination strip and cesspit drainage system connected to Line F is recommended to alleviate this problem (see photo 5).
K	Pipe system (Line J).	• Fully developed; • Discharges to Catchment H open channel downstream of PC 10. • Affected by flooding from Catchment H.	0.77	Liv 1	HF flooding – 1; S flooding – 2.	Existing system is adequate for 5 yr ARI flow. The flooding problems reported for this catchment (and as summarised at left) are caused by overflows from Catchment H. Solutions to these problems are dealt with in Section 6.3.	Yes	5	No upgrading works required.	N/A	MH6061 to Outlet: 375	$18,900	3	The flooding of Nos. 36 & 38 Pine Rd is caused by overflows from the main drainage system draining Catchment H. This problem is dealt with separately in Section 6.3.1. The section flooding of No. 25 Pine Rd was a maintenance problem caused by blockage of the cesspit adjacent to this property.
L	Pipe system (Line K).	• Close to fully developed; • Some local depressions behind fore dune area (Ngunguru Rd); • Natural overland flow path towards Kakariki Rd; • Discharges directly to beach / estuary.	0.47	Liv 1	NHF flooding – 1	No natural overland flowpath directly to beach. In extreme flood event some ponding in localised depressions and possible overflow to Catchment J. Present system has sufficient capacity carry 50 year ARI flow. Reported NHF flooding of one property was caused by runoff from the reconstructed Ngunguru Rd.	No	50	Diversion of portion of Catchment J to Line K recommended (connection of properties 1919-1923 Ngunguru Rd to Line K including cesspits in overland flowpath). This will reduce flows to Line F, which is under-capacity. • 100 m of 300 dia RCRRJ pipe • New cesspits	$22,500 $7,000	As for existing.		2	See main report (Section 6) for more details Note: a clear overland flowpath for this catchment does not exist. However, Line K has sufficient capacity to carry the 50 yr ARI flow. Recommend that the drainage system along Ngunguru Rd be improved. A combination strip and cesspit drainage system connected to Line K is recommended to alleviate this problem (see photo 5).

Catchment	Drainage System	Catchment Description	Area (ha)	Zoning	Drainage Survey Results*	Results of Analysis	Clear Overland Flow Path **	Design Flow (50/5yr)?	Existing Upgrade Requirements	Total Cost	Future Upgrade Requirements (as for 5 yr ARI except where specified here)	Total Cost	Priority	General Comments
M	Pipe system (Line L).	• Close to fully developed; • Discharges directly to beach / estuary.	1.54	Liv 1	NHF flooding – 1; S flooding 1; problems with flow from Kopipi Reserve to adjoining properties & flow from Ngunguru Rd.	Analysis indicates that portions of Line L are significantly undersized, with consequent flooding in parts of the catchment (as reported by residents).	No	5/50	Upgrade lines as required (subject to confirmation of analysis results). MH6059 to MH 6060: 525 MH6060 to MH 6070: 525 **MH6070 to Outlet: 750** **Additional cesspits in Kopipi Crescent to MH6070 and in Kopipi Reserve to MH6060.**	 $15,120 $17,010 **$30,000** **$9,000**	 MH6059 to MH 6060: 600 MH6060 to MH 6070: 600 **MH6070 to Outlet: 900**	 $30,240 $34,020 **$56,700**	1	As the calculated flows are significantly larger than the calculated pipe capacities it is recommended that upgrading of this system be considered a high priority.
N	Pipe system (Line O).	• Steep bush above relatively flat developed sections; • No separate drainage system for bush areas; • Discharges to Catchment S outlet channel.	3.13	Liv 1 & Liv 3.	NHF flooding – 1; S flooding – 3; Complaints of overland flows from bush area.	Recommend property by property approach to flooding caused by SW from bush areas. SW needs to be directed away from houses to the public SW system (improve private drainage). NHF flooding at left caused by groundwater seepage and surface runoff from hillside (see notes/comments section for more details of remedial options).	Yes	5	MH6055 to MH6054: 750	$40,320	MH6031 to MH6057: 375 MH6057 to MH6055: 525 MH6055 to MH6054: 825	$8,694 $44,100 $45,360	3	Solutions to the flooding caused by bush areas were considered. The most appropriate solution was considered to be solving the problem on a house by house basis. Construction of cut-off drains connected to swales / cesspits discharging to the main line (Line O) or a similar arrangement would appear to be the most appropriate solution.
O	Pipe system (Line M)	• Close to fully developed; • Discharges directly to beach.	0.49	Liv 1	S flooding – 1	No major problems; parts of system undersized. No clear overland flowpath to beach. Recommend upgrading last reach (MH6067 to outlet) of Line M for 50 yr ARI and remainder of system for 5 yr ARI.	No	5/50	MH6067 to MH6066: 450 **MH6066 to Outlet: 450** Install additional cesspits at ponding areas and in overland flowpath.	$14,553 **$11,025** $7,000	MH6067 to MH6066: 525 **MH6066 to Outlet: 525**	$17,325 **$13,125**	3	
P	Pipe system (Line N)	• Close to fully developed; • Discharges directly to beach / estuary.	0.69	Liv 1	No problems	No major problems; parts of system undersized. No clear overland flowpath to beach. Recommend upgrading last reach (MH6053 to outlet) of Line N for 50 yr ARI and remainder of system for 5 yr ARI.	No	5/50	**MH6053 to Outlet: 525** Install additional cesspits at ponding areas.	**$21,000**	MH6028 to MH6065: 375 MH6027 to MH6053: 375 **MH6053 to Outlet: 600**	$6,804 $5,292 **$25,200**	3	
Q	Pipe system (Line P)	• Close to fully developed; • Discharges directly to beach / estuary.	0.68	Liv 1 & Bus 3	S flooding – 1	Most of this catchment has no formal drainage system. Line Q, which drains Ngunguru Rd, does not require upgrading.	Yes	5	No upgrading works required.	N/A	No upgrading works required.	N/A	N / A	Some properties within catchment may discharge to open channel adjacent to sports complex.
R	Pipe System (Line Q).	• Close to fully developed; • Discharges directly to beach / estuary.	0.2	Liv 1	None	No problems identified.	Yes	5	No upgrading works required.	N/A	No upgrading works required.	N/A	N / A	Line Q may receive only flows from Ngunguru Rd.

Catchment	Drainage System	Catchment Description	Area (ha)	Zoning	Drainage Survey Results*	Results of Analysis	Clear Overland Flow Path **	Design Flow (50/5yr)?	Existing Upgrade Requirements	Total Cost	Future Upgrade Requirements (as for 5 yr ARI except where specified here)	Total Cost	Priority	General Comments
S	Open drains and culverts.	• Steep bush in upper catchment; • Grassed playing fields / golf course in lower catchment; • Receives flows from Catchment N; • Discharges to tidal drain parallel to Waiotoi Rd.	4.49	Open space & small area of Liv 1.	S flooding – 1 (tidal flooding during event of 11/3/1997).	No major problems, although flooding of playing field areas due to culvert PC12 expected – this flooding is unlikely to cause any property damage. Overtopping of culvert PC13 is also expected for the 50 yr ARI event.	Yes	50	Although flood levels at culverts PC 12 and PC13 (RL2.9m and RL2.23m respectively-future development scenario) are expected to be above overflow levels (RL2.8m and RL2.16m), upgrading of these culverts is not recommended at this time. Although some flooding is likely to occur, it is unlikely that any significant damage to properties will occur. The habitable floor level at No. 33 Kopipi Crescent, which is likely to be worst affected by the flooding, is RL2.93m – this is well above the expected flood level of RL2.23m).			N/A	N/A	The capacity of the drain is adequate when maintained in good condition. However, at the present time uncontrolled growth of mangroves in this drain is impeding flows and this could create a flooding issue in an extreme storm event. Clearing of mangroves and silt in the main channel is therefore necessary to ensure that the required capacity of the drain is maintained. See Section 11.2 for more details.
T	Open drains and culverts.	• Low-lying (most likely former mangrove swamp area); • Mostly paddock with developed area along Waiotoi Rd. • Discharges via existing culvert and tide gate to tidal drain; • Protected from tidal drain by stopbank at RL 1.9.	1.93	Liv 1 & small area of open space.	HF flooding – 1; NHF flooding – 1; flooding caused by overflows from tidal drain downstream of Waiotoi Rd box culvert.	Data for SW system not available. No problems originating within this catchment reported. Problems in this catchment are related to salt water flooding and the growth of mangroves in the tidal drain downstream of the adjacent Waiotoi Rd bridge. For solutions see Sections 7 and 11.			N/A				N/A	According to local residents this catchment has received flows from Catchment W in the past. However, this has been infrequent and is related to problems within Catchment W.
U	Pipe system (Line S)	• Drains portion of Waiotoi Rd and small housing area; • Last reach of Line S receives flows from Catchment V; • Discharges to tidal drain.	0.23	Liv 1 & Road	S flooding – 1	This system receives flows from Waiotoi Rd. According to residents, properties do not currently discharge directly to this line. However, some upgrading works are still required.	Yes	5	MH6022 to MH6023: 375	$30,618	*MH6046 to MH6047: 675*	*$7,140*	3	Line R-S1, which links MH6046 with MH6047, is included under this catchment.
V	Pipe System (Line R).	• Mostly developed; • Discharges directly to beach / estuary. • At MH6046 flow divided between Line S and Line R.	2.41	Liv 1 and Open Space.	S flooding – 3	Upgrading of most of this line is required for both the existing and future development scenarios. It is likely that the section flooding of three properties, as reported at left is the result of the undersized pipe system for this catchment.	No	5	MH6038 to MH6039: 525 MH6039 to MH6040: 525 MH6040 to MH6041: 525 MH6041 to MH6042: 600 MH6042 to MH6043: 525 MH6043 to MH6020: 600 MH6020 to MH6044: 600 MH6044 to MH6045 : 600 MH6045 to MH6024: 675 MH6049 to Outlet: 825	$13,125 $3,675 $15,225 $6,930 $7,350 $10,080 $762 $14,490 $23,562 $37,800	MH6038 to MH6039: 600 MH6039 to MH6040: 525 MH6040 to MH6041: 600 MH6041 to MH6042: 675 MH6042 to MH6043: 600 MH6043 to MH6020: 675 MH6020 to MH6044: 675 MH6044 to MH6045: 750 MH6045 to MH6024: 750 MH 6024 to MH6048: 750 MH6049 to Outlet: 900	$15,750 $3,675 $18,270 $7,854 $8,820 $11,424 $864 $19,320 $27,720 $21,000 $45,360	2	At MH6046 Line R has two outlets – one discharges to Line S at MH6047, the other continues to MH6025. In the analysis it was assumed that flow is split between these outlets in proportion to their x-sectional areas. The natural overland flow path for line R upstream of MH6046 is also located at this point. It is therefore recommended that line R-S1, which connects MH6046 to MH6047 be upgraded for the 50 yr ARI event.

Catchment	Drainage System	Catchment Description	Area (ha)	Zoning	Drainage Survey Results*	Results of Analysis	Clear Overland Flow Path **	Design Flow (50/5yr)?	Existing Upgrade Requirements	Total Cost	Future Upgrade Requirements (as for 5 yr ARI except where specified here)	Total Cost	Priority	General Comments
W	Open drains and culverts.	• Steep upper catchment with mostly bush cover; • Paddock in lower catchment; • Discharges to tidal drain parallel to Waiotoi Rd.	32.31	Country -side	Flooding of properties in Catchments V & T; complaints of growth of mangroves in channels.	Analysis supports local reports by residents suggesting that the capacity of the channel downstream of PC15 has become significantly reduced by the growth of mangroves. In addition, analysis indicates that PC14, a privately installed pipe, is under-capacity. These restrictions in the drainage system have resulted in flooding of properties in Catchments V & T.	Yes	50	It is recommended that measures be undertaken to address the growth of mangroves in the tidal channel downstream of culvert PC15. Continued growth of these mangroves will further compromise the capacity of the system and put properties along Waiotoi Rd at greater risk of flooding. Modelling indicates that improvement of the channel to a Manning's 'n' of 0.03 would significantly reduce the flood risk. Any works in the channel would require consent from NRC. In addition, upgrading of culvert PC14 is required. However, prior to undertaking any design or physical works, it is recommended that an investigation into the channel upstream of this culvert be undertaken. The surveyors who undertook this work indicated that there are additional culverts upstream of culvert PC14, which appear to be private, as WDC records do not have any details of anything upstream of culvert PC14. • Modelling indicates that upgrading PC14 to at least a 600 mm dia. pipe would be required. • Clear mangroves and deposited silt to provide a clean, unconstricted drain.			$34,000	2	• Flooding in this catchment in the past has resulted in flooding of Waiotoi Rd properties. • Section 7 of this report discusses tidal flooding problems related to this catchment.
X	Pipe system (Line U).	• Close to fully developed; • Discharges directly to Ngunguru beach / estuary.	0.35	Liv 1 & open space.	No Problems	The existing pipe system has sufficient capacity to pass the 50 yr ARI flow for the future development scenario.	Yes	5	No upgrading required.	N/A	No upgrading required.	N/A	N / A	
Y	Pipe system (Line V).	• Close to fully developed; • Discharges directly to beach / estuary.	0.71	Liv 1 & open space.	Street flooding only.	The natural overland flow path for this catchment is across Ngunguru Rd. However, it is expected that this flow will be spread out and will not cause any serious erosion. Some regrading of the berm along the northern side of Ngunguru adjacent to Nos. 2015 and 2017 to direct flow to the existing cesspit adjacent to No. 2017 may also be required to eliminate street flooding.	Yes	5	Regrade berm in front of Nos. 2015 & 2017 Ngunguru Rd. Installation of an additional cesspit connected to the existing manhole (Line V) may also may be required.	$500 $2,000	MH6051 to Outlet: 375	$13,230	3	Some consideration should be given to diverting flows to Line U in Catchment X, which is only 29% stressed under the 50 yr ARI event.
Z	Pipe system (Line W).	• Partially developed; • Discharges directly to beach / estuary.	0.69	Liv 1	No Problems.	To eliminate the possibility of overflow across Ngunguru Rd and the likely erosion associated with this overflow upgrading for the 50 yr ARI event would be required.	Yes	50	Inlet to Outlet: 375	$7,560	As for existing			A clear overland flow path for this catchment does not appear to exist. Overflow to catchment AA may occur – however, catchment AA does not have a natural overland flowpath itself.
AA	Pipe system (Line X).	• Mostly developed; • Ponding areas in vicinity of 6 & 12 Shoebridge Crescent. • Discharges directly to beach; • Overland flow path 0.5m above ponding area.	4.08	Liv 1	S flooding – 8; NHF flooding – 2.	Analysis indicates that all reaches of Line X are undersized for both existing and future flows. However, a possibility exists for the re-establishment of an overland flow path to Catchment AB.	No	50	Section 8 of this report provides further details of problems in this catchment.					

Catchment	Drainage System	Catchment Description	Area (ha)	Zoning	Drainage Survey Results*	Results of Analysis	Clear Overland Flow Path **	Design Flow (50/5yr)?	Existing Upgrade Requirements	Total Cost	Future Upgrade Requirements (as for 5 yr ARI except where specified here)	Total Cost	Priority	General Comments
AB	Open drains and culverts (PC16 & PC17).	• Steep upper catchment with mostly bush cover; • Open paddock in lower catchment; • Discharges directly to beach / estuary.	27.66	Country side	No problems reported in drainage questionnaire survey. Recent overflow to Catchment AA resulted in NHF flooding of one property.	See Section 8 for further details of this area.								
AC	Open drains and culverts (PC18).	• Steep & mostly forested; • Drains to open channel along Matapouri Rd; • Discharges directly to beach / estuary;	0.78	Coastal country side	No problems	Prelim. Modelling indicates that upstream flood levels at culvert PC18 (RL3.60m – future dev.) would be below the overflow level on Te Maika Rd of (RL3.7m).	No	50	No upgrading works required.	N/A	No upgrading works required.	N/A		
AD	Open drains and pipe system (Line Y).	• Steep forested upper catchment; • Open paddock and playing fields in lower catchment; • Discharges directly to beach / estuary.	4.23	Coastal Country side & Liv 1	No problems	No problems.	Yes	5	No upgrading works required	N/A	No upgrading works required.	N/A		
AE	Open drains and pipe system (Line Z).	• Steep forested upper catchment; • Developed sections in lower catchment; • Discharges directly to beach / estuary.	0.71	Coastal Country -side & Liv 1	S flooding – 1	No problems.	Yes	5	No upgrading works required	N/A	No upgrading works required.	N/A		
AF	Open drains and pipe system (Line ZA).	• Steep forested upper catchment; • Developed sections in lower catchment; • Discharges directly to beach / estuary.	0.96	Coastal Country -side & Liv 1	No problems	No problems.	Yes	5	No upgrading works required	N/A	No upgrading works required.	N/A		
AG	Open drains and pipe system (Line ZB).	• Steep forested upper catchment; • Developed sections in lower catchment; • Discharges directly to beach / estuary.	0.58	Coastal Country -side & Liv 1	No problems	Existing pipe system undersized for future development flows.	Yes	5	No upgrading works required	N/A	MH6015 to Outlet: 375	$15,725	3	

Catchment	Drainage System	Catchment Description	Area (ha)	Zoning	Drainage Survey Results*	Results of Analysis	Clear Overland Flow Path **	Design Flow (50/5yr)?	Existing Upgrade Requirements	Total Cost	Future Upgrade Requirements (as for 5 yr ARI except where specified here)	Total Cost	Priority	General Comments
AH	Pipe system (Line ZC)	• Road drainage system only; • Discharges to open channel downstream of Catchment AI.	0.17	Road reserve	Some road flooding	Analysis indicates that the existing system has sufficient capacity for both the existing and future development flows.	Yes	5	No upgrading works required.	N/A	No upgrading works required.			
AI	Open drains and culverts (PC19).	• Steep forested upper catchment; • Open paddock in lower catchment; • Discharges to estuary via mangrove swamp area. • Receives flows from Catchment AH and large catchment to NE (outside study area boundary).	4.85	Coastal country side & Liv 1.	S flooding – 1	Preliminary modelling indicates that a flood level of RL 1.62m would occur for a 50-yr ARI event compared to an overflow level for Te Maika Rd of RL1.60m. Flooding of the one section listed at left (45 Te Maika Rd) was not considered to be of sufficient severity to require upgrading of culvert PC19.	No	50	No upgrading works required.			N/A	N / A	No floor levels were available for the dwelling at 45 Te Maika Rd. Flooding of the section was not considered to be of sufficient severity to require upgrading of culvert PC19.

* HF – Habitable Floor
NHF – Non-Habitable Floor
S – Section

**The responses given in this column are based on: (1) Whether the overland flowpath will operate without flooding any habitable or non-habitable floors for the 50 yr ARI, or (2) The overland flowpath will not operate for the 50 yr ARI event, but potential ponding levels are estimated to be below house floor levels.

6.3 Major Problems

6.3.1 *Chloe Place to Ngunguru Estuary*

Reported Flooding:

Habitable Floors – 1 Property

Non-Habitable Floors – 1 Property

Sections – 5 Properties

Description of Existing System

Runoff from Catchment H is collected through a system of open drains and minor culverts to a point north-west of Chloe Place where flows pass through a 900 mm dia. culvert (PC8) under a right of way and discharge into an open drain that runs in an easterly direction adjacent to Chloe Place. Flows then enter a 1050 mm dia. culvert under Chloe Place (PC9) which discharges to a short length of open drain before re-entering a sealed 1050 half round pipe with extended sides (PC10) – roughly equivalent to a full 1050 mm dia. pipe (see Photo 14). PC10 discharges to an open drain west of No. 38 Pine Road and downstream of No. 36 Pine Rd (Photo 8). This drain follows the northern boundary of the Ngunguru retirement village passing under a local access bridge to a property north of the drain and receives flows from Catchments G, I and K before discharging through a 1050 mm dia culvert (PC11) under Kakariki Rd (Photo 6). PC11 discharges to an open drain (Photo 7) which flows into a mangrove area of the Ngunguru estuary.

Problem

Increasing development upstream of the channel / culvert system that flows from Chloe Place to the Ngunguru Estuary via Kakariki Rd has resulted in increased stormwater flows and consequent flooding problems. Several properties adjacent to the channel / culvert system reported flooding. The Ngunguru Retirement Village has reported flooding problems related to this system to WDC on a number of occasions. XP-SWMM modelling of this system for the 50-year design storm (future development scenario) indicates that several parts of this system are undersized. Two remedial options for the protection of properties in this area were investigated.

Note: The measures specified below are based on future design flows. Where a particular measure is not required under existing design flows this is clearly stated.

Option 1

Refer to drawing 16194/00/10 for a graphic presentation of the upgrade requirements for Option 1. The basic requirements area as follows:

Driveway upstream of Chloe Place (PC8)

(Not required for existing design flows)

Modelling indicates that the existing 900 mm dia. culvert (PC8) under the right of way (ROW) to Nos. 20-24 Chloe Place is undersized for the 50 year ARI event. Overtopping of the ROW would therefore be expected, with erosion of the driving surface likely. As this road is not of major importance, upgrading the existing culvert would depend on other factors. It is expected that access would not be affected except in the case of significant erosion. Two options exist:

1) Install a new 1050 mm dia. pipe to pass flows from the eastern portion of catchment H (**$14,000**).
2) Upgrade the right of way by constructing a controlled overflow weir with erosion protection (**$5,000**).

Culverts PC 9 & 10

(Not required for existing design flows)

- Install an additional 1050 mm dia. culvert from the inlet of PC9 to the outlet of PC10 (**$60,000**).
- Remove existing inlet grill and replace with a grill of a design that will eliminate or minimise the possibility of blockage.

Note: An alternative here would be to remove the existing pipe and replace it with a larger pipe or box culvert with a cross-sectional area equivalent to a dual 1050mm dia. pipe culvert.

PC 10 to Driveway Bridge

- Upgrade existing channel to trapezoidal section 2 m base width, 1v: 2h side slope - left bank, 1v: 2h side slope - right bank (increase x-sectional area by 2.0 m^2) or equivalent (note: option is dependent on maintenance of channel slopes in good condition) (**$3,500**).

Channel under Driveway Bridge

- Enlargement of the channel section under the bridge is recommended. Further investigation would be required to determine whether this would be possible (**$2,000**).

Channel downstream of Bridge to Junction with Main Branch of Catchment G

- Enlarge existing channel to trapezoidal section, 2 m base width, 1v: 1h side slope – left bank, 1v: 2h side slope – right bank or equivalent section (approx. existing section: 2 m base width, 1v: 1h side slope – both sides) (**$1,500**).

Catchment G / H Junction to PC 11

- Enlarge existing channel to trapezoidal section, 2 m base width, 1v: 1h side slope – left bank, 1v: 2h side slope – right bank or equivalent section (approx. existing section: 2 m base width, 1v: 1h side slope – both sides) (**$7,000**).

Culvert PC11

This culvert is a major bottleneck in the system. Upgrading this culvert in the near future is therefore recommended.

- Upgrade existing 1050 mm dia. culvert to a 2.0 m wide by 1.0 m high box culvert with constructed inlet and outlet structures (wing walls) (**$45,000**).

Downstream of Culvert PC11 to Ngunguru Estuary

The existing channel is a major bottleneck in the efficient performance of this system. Upgrading this channel is required. An important part of the correct functioning of this system is the outlet through the mangrove area to the estuary. Maintenance of this outlet is required if the system is to function as designed. It is recommended that an accurate survey of the existing channel be undertaken prior to design to confirm cross section dimensions, as the dimensions used in this analysis were estimates.

- Enlarge existing channel to trapezoidal section, 2.5 m base width, 1v: 2h side slopes or adopt equivalent section. Regrade channel evenly from culvert PC11 to estuary with grade of at least 0.2% (increase cross sectional area by $7m^2$ (approx.)) (**$10,000**).

Construction Sequence

It is recommended that the design of the entire system be undertaken prior to the upgrading of any sections of the drainage system. This will allow for consultation with affected parties and identification of the most appropriate option based on detailed survey and further analysis. Following this it is considered that staged construction would be possible. Item 2 (see plan

16194/00/10) is considered to be the most important element of the upgrading work, while items 1, 2 and 3 would follow with Item 5 being last.
Construction should generally proceed from downstream to upstream.

Option 2

Note: Option 2 has been considered for future design flows only. A detailed cost estimate has not been prepared for Option 2. However, it is expected that costs for Option 2 would be well in excess of Option 1 due to the length of new pipe involved. Details of Option 2 have therefore been prepared to present an alternative to upgrading the existing system that may be considered during the design phase.

The main features of this option are as follows:

Channel downstream of PC10 to Bridge

- Upgrade to a trapezoidal section, 1.4 m base width (existing), 1v: 1h side slope – left bank and 1v: 2h side slope right bank or adopt equivalent section.

Culvert PC11

- Upgrade culvert as for Option 1.

Channel Downstream of PC11

- Upgrade channel as for Option 1

Chloe Place to Beach – New Pipe

The main feature of this option would be a new pipe culvert system from the inlet of PC9 to the beach. A preliminary investigation of this option indicates that a possible route would be from the inlet of PC9 to the top of the right of way (ROW) on Pine Rd, and from here along the ROW under Ngunguru Rd to the beach.

Problems with this route would be the elevation of the ROW at Pine Rd relative to its elevation at the low point between Ngunguru Rd and Pine Rd, which would require a deep excavation. In addition, a retaining wall along No. 17 Pine Rd adjacent to the ROW would make open excavation difficult indicating that an alternative technique such as micro tunnelling would be required. While this does not negate the possibility of this option, it does make this option more expensive.

Preliminary modelling of this pipeline based on a single straight section of pipe directly to the beach indicates that a 750 mm dia. pipe would be adequate. In order to ensure that existing culvert / channel system from Chloe Place to Kakariki would continue to receive flow (and thereby continue to support the ecosystems associated with this system), the new 750 mm dia pipe could be

designed so as to accept high flows only. This would also minimise potential erosion of the beach at the proposed outlet.

6.4 Conclusion

Based on an assessment of a range of factors, it is considered that Option 1 would be the most appropriate solution to the current flooding problems in this area. Option 1 would be less expensive than Option 2 and would require less disruption to local residents.