GOSFORD CITY COUNCIL

KARIONG AREA
Drainage Investigation

Prepared by
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Verification Sheet

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KARIONG AREA
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FOREWORD

The State Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of the local government. The State Government subsidises flood mitigation works to alleviate existing flood problems and provides specialist technical advise to assist Councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through the following four sequential stages:

1. Flood Study

   Determines the nature and extent of the flood problem.
2. Floodplain Management Study

   Evaluates management options for the catchment in respect of both existing and proposed development.
3. Floodplain Management Plan

   Involves formal adoption by Council of a plan of management for the catchment.
4. Implementation of the Plan

   Construction of flood mitigation works to protect existing development and use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Kariong Drainage Investigation constitutes the first three stages of the management process for this catchment. AWT Engineering Pty Ltd has prepared this study for Gosford City Council.

1 SUMMARY

In July 2000, Gosford City Council undertook investigation of the following:

- the extent of stormwater flooding associated with Council owned infrastructure;
- the extent of structural defects in the stormwater system; and
- the development of a Drainage Management Plan which outlines works required to mitigate the risk of flooding and to repair structurally defective infrastructure in the Kariong Catchment.

Kariong is located approximately five kilometres west of the Gosford Central Business District. The catchment is bounded by the Pacific Highway to the north and Brisbane Water National Park to the east, south and west. The majority of the catchment drains to Mooney Mooney Creek, which is a tributary of the Hawkesbury River.

This report comprises three main investigation stages, namely:

1. Drainage Study, which identifies:
   - the causes and extent of the existing drainage problems by estimating the catchment runoff and then assessing the flow capacity of the existing drainage system,
   - the extent of structural defects of the drainage infrastructure,
2. Drainage Management Study, which identifies:
   - various drainage strategies or mitigation works to address the existing flooding problems,
3. Drainage Management Plan, which defines:
   - recommended plan of works best suited to resolve the flooding problems.

In Stage 1, the Drainage Study, a hydrologic/hydraulic computer model was established for the catchment. The model was used to determine the following:

- 5 year, 10 year, 20 year and 100 year ARI design peak flows;
- flow contained in the existing pipe system; and
- overland flow in terms of quantity, velocity and depth.

It was found that, in general, the existing drainage system met the Council's standard for pipe drainage. Where the pipe system was determined to be below Council's standard, the excess flow was tested against safe overland flow depth and velocity. It was determined that for the 100 year ARI storm event, overland flows in the lower reaches of the catchment generally exceeded what is considered to be a safe flow depth times velocity multiple

The mitigation works considered in this study included:

- pipe and culvert amplification;
- extension of drainage lines;
- additional stormwater pits; and
- new drainage lines.

The standard of flood protection to be afforded to the area was based on Council's latest specification for the design of stormwater drainage works and the specification for pedestrian and vehicle safety in overland flow paths.

Stage 1 of the study included the inspection of all pipes equal to and greater than 900 mm diameter with the aid of Closed Circuit Television (CCTV).

The CCTV inspections detected significant defects including the following:

- open joints (greater than the pipe wall thickness);
- leaking joints;
- direct break ins with small diameter pipes and poor sealing of joints;
- intrusion of small pipes by more than 100 mm into the larger pipe and causing loss of hydraulic capacity;
- cracked pipes, both circumferential and longitudinal; and
- tree root invasion via open pipe joints.

Individual components of works have been costed and given an order of priority to assist Council in preparing a Works Program for the area. The construction works have been estimated to cost approximately $1.1M.

An "Exhibition Draft" report was prepared in October 2001 and was advertised during December 2001 and January 2002 for public review and comment. The comments received from the public led to the inclusion of additional drainage works recommended for construction. The cost of construction works was re-estimated and determined to cost approximately $1.2M.

2 INTRODUCTION

2.1 OBJECTIVES

The objectives of this report are set out below:

Stage 1 – Drainage Study:

- Identify the nature and extent of the existing drainage problems by:
  - ~ assessing the flood history of the catchment;
  - ~ estimating catchment runoff;
  - ~ assessing the capacity of the existing drainage system;
  - ~ determining overland flow paths and areas of ponding;
  - ~ determine faulty/damaged sections of underground conduits;
  - ~ determine areas of erosion and sedimentation;
  - ~ determine likely sources of gross pollutants; and
  - ~ determine likely sources of nutrients.

Stage 2 – Drainage Management Study:

- Identify various drainage strategies or mitigation works to address the existing flooding problems within the catchment.
- Identify strategies to fix faulty/damaged sections of underground conduits.
- Identify drainage strategies to mitigate erosion and sedimentation.
- Identify works to trap gross pollutants and nutrients.

Stage 3 – Drainage Management Plan:

- Identify the optimal scheme of works and/or measures which best meet Council's aims and objectives of minimising the extent of the flooding problem to an acceptable standard (houses to be flood free in a 100 year ARI event).
- Identify the optimal method of underground conduit repair.
- Identify the optimal works and measures to prevent erosion, sedimentation.
- Identify the optimal works and measures to trap gross pollutants and nutrients.

2.2 STUDY AREA

The majority of the study area is located within the catchment of Piles Creek, which is a tributary of Mooney Mooney Creek, and a minor portion of the study area is located within the catchment of Coorumbine Creek. The study area is fully developed and consists of predominantly low-density residential development. Some neighbourhood business developments exist within the study areas. The undeveloped areas within the catchment are mainly National Parks.

The Kariong catchment is located approximately five kilometres west of the Gosford City Central Business District (CBD). The catchment is bounded by the Pacific Highway to the north and Brisbane Water National Park to the east, south and west. The catchment lies between 150 and 200 metres above sea level and is mostly founded on Hawkesbury sandstone.

Woy Woy Road, an arterial road linking the Woy Woy peninsula with the Pacific Highway, traverses the catchment in a north south direction.

3 DATA COLLECTION

A comprehensive search was undertaken to collect the following information:
- contours;
- cadastral data;
- Council's drainage records;
- rainfall data;
- ground survey;
- resident questionnaires; and
- Closed Circuit Television (CCTV) inspection data.

3.1 CONTOURS

Contour details covering all of the study area were provided by Council in digital format. This data was used to define catchment boundaries for each drainage system.

3.2 CADASTRAL DATA

Cadastral data including road and property boundaries, lot numbers and deposit plan numbers were provided in digital format by Council. This data was used to define catchment study limits.

3.3 COUNCIL'S DRAINAGE DATA

Council made available drainage design drawings and work as executed drawings for the study area. This information covered approximately 75% to 80% of the area. Ground level and invert level data were extracted from these drawings for use later in setting up the hydrologic/hydraulic computer models.

Council's Global Information System (GIS) provided digital details on drainage infrastructure location and details on individual pipe diameters and length. This data covered approximately 80% of the study area.

3.4 GROUND SURVEY

Surveyors Johnson Partners were commissioned in February 2001 to provide ground level spot heights in the retarding basins adjacent to Langford Drive and Gilford Street and to provide stormwater pit cover levels and invert levels for where design or work as executed drawings were not available. This data was used to supplement the Council provided drainage data and in constructing the hydrologic/hydraulic computer models. The data was also used to update Council's GIS database. Electronic transfer of data between Gosford Council and AWT Engineering carried out the latter.

3.5 RAINFALL DATA

Design rainfall data for Kariong (Woy Woy Zone) were obtained from Council's Specification for Stormwater Drainage Works (Reference 1). A table outlining the design rainfall intensities is provided in table on the following page.

Table 1 Design Rainfall Intensities (mm/h)

Duration	**Woy Woy Zone (Council)**			
	5 year ARI	10 year ARI	20 year ARI	100 year ARI
6 minutes	141	158	181	232
10 minutes	116	131	149	192
20 minutes	86	97	111	143
30 minutes	70	79	91	118
1 hour	48	55	63	82
2 hours	32.2	36.8	42.3	55.5
3 hours	25.3	28.7	33.2	43.7
6 hours	16.6	18.9	22.0	29.0

Source: Woy Woy Design Rainfall Intensities from Council's Stormwater Drainage Specification

3.6 RESIDENT QUESTIONNAIRES

Resident questionnaire forms were delivered to households in those areas that had previously experienced drainage problems. The forms were delivered in early December 2000 and of the 120 forms distributed, 18 (15%) were returned.

The resident questionnaire forms have been supplied to Council under a separate cover (Attachment B).

3.7 CLOSED CIRCUIT TELEVISION (CCTV)

The pipeline inspection company, Pipe Eye Services Pty Ltd, was commissioned in February 2001 to CCTV all pipes greater than or equal to 900 mm diameter. Approximately 3000 metres of pipes were CCTVed and the information captured on videotapes. A report on the condition of the pipes was provided as part of this survey.

The videotapes and conditions reports were provided to Council under a separate cover.

4 HYDROLOGIC AND HYDRAULIC MODELLING

4.1 GENERAL

The hydrologic/hydraulic model adopted for this study was influenced by:
- the quality of the available drainage infrastructure data; and
- the quantity of the available drainage infrastructure data.

During the data collection phase of this study, all of the following drainage infrastructure data was collected:
- pipe sizes;
- pipe lengths;
- pit grate levels;
- pit invert levels;
- location of pipes and pits; and
- topographic details of retarding basins.

The data collected was considered to be good and the latest urban drainage hydrologic/hydraulic model, DRAINS, was adopted. The DRAINS model is capable of utilising all of the data and is considered to be superior to its predecessor ILSAX as it is capable of modelling pipes when under pressure flow.

There are a number of trunk drainage systems in Kariong each with its own outfall. A number of smaller drainage systems also exist with direct discharge into Brisbane Water National Park. To enable better management of the hydrologic/hydraulic modelling the study area was sub-divided into four (4) main catchments (refer to Figure 2), these being:
- Arunta Avenue Catchment (which includes the sub-catchments of Jackson Street and Old Mount Penang Road);
- Belsham Road Catchment;
- Casey Crescent Catchment; and
- Truscott Avenue Catchment.

Details of the existing drainage system in each of the four catchments are shown on Figures 3a to 3d.

4.2 MODEL PARAMETERS

Prior to running the model, model parameters are required. A number of methods are used to determine model parameters. These methods include, in order of preference:
- calibrating the model for at least two historical storm events and then testing the parameters against a third storm event, or
- adopting model parameters from an adjacent catchment that has well documented historical flood data, or
- adopting model parameters from catchments with similar characteristics as the study area.

The study area and its adjacent catchments had very little recorded historical flood data and for this reason model parameters from catchments with similar characteristics to the study area were used. Gosford City Council has prepared numerous urban drainage studies using the ILSAX hydrologic model. The DRAINS model parameters from these studies were assessed and, the parameters adopted for this study are shown in the table below.

Table 2: DRAINS Model Parameters

Soil Type	Paved Area Depression Storage (Initial Loss)	Grassed Area Depression Storage (Initial Loss)	Antecedent Moisture Content
2	1 mm	1 mm	3

4.3 SUB-CATCHMENT AREAS

The DRAINS model for the study area is made up of a number of sub-catchment areas (refer to Figures 4a to 4d). Each sub-catchment is joined to an immediately downstream sub-catchment area by a pipe or channel reach. Relevant details of each sub-catchment area required for the model include:

- times of concentration; and
- percentage of impervious and pervious area.

The minimum time of concentration adopted for the study was 6 minutes, as recommended in the 1978 Edition of Australian Rainfall and Runoff. The minimum time was applied to all impervious areas. The times of concentration for pervious areas was estimated using the kinematic wave method described in Council's Specification for Design of Stormwater Drainage Works.

A list of the DRAINS model input data including pipe, pit and retarding basin data and sub-catchment areas are presented in Appendix A.

4.4 HYDRAULICS

The DRAINS model calculates the hydraulic grade lines throughout the stormwater reticulation system and estimates the magnitude of overflows. The hydraulic analysis are dependent on a number of catchment controls, these include:

- outlet water level;
- overland flow paths;
- retarding basins; and
- sag points and associated flood storage capacities.

4.4.1 Outlet Water Level

The study area is at an elevation of between 150 metres and 200 metres above sea level. The majority of the study area drains into Piles Creek with the rest draining into Coorumbine Creek. Both Piles Creek and Coorumbine Creek fall steeply away from the study area and as such have no adverse hydraulic impact on the capacities of the pipe drainage system.

For the hydraulic analyses of the system it has been assumed that the drains have a free outfall.

4.4.2 Overland Flow Paths

When the existing drainage system capacity is exceeded the excess flow is generally transferred to the next downstream inlet pit. The route the excess flow takes is termed as the overland flow path. In most cases the overland flow path is a roadway, however in certain instances it could be:

- drainage easements;
- private property;
- grassed swales;
- open drains; or
- watercourses.

In this study, the overland flow paths are generally roadways and these are accounted for in the DRAINS model by inputting the road cross section and specifying a time of travel for the overland flow. Generally the overland flow travel time was specified as one minute.

4.4.3 Retarding Basins

Retarding basins are drainage structures employed to mitigate peak flows leaving the catchment. The basin temporarily stores the stormwater and its associated peak flow and releases the stormwater at a controlled rate.

4.4.4 Sag Points

Sag points are isolated low points within each catchment. These points can only drain with the assistance of an underground drainage system. Where the underground drainage system is insufficient in capacity, these sag points fill with stormwater and act as mini detention basins. The storage capacities of these sag points are generally small, less than 1000 cubic metres and their impacts on reducing peak flows are negligible, that is, less than two percent. Where the impacts of the sag points are small, the DRAINS model recommends leaving the detention basin out of the model. For the catchments in this study, the storage at sag points is accounted for by providing a storage volume in the sag pit equivalent to the sag point volume. The model then estimates the actual volume of water stored at the sag for each modelled storm event. This data can then later be used to estimate the flood level at each sag point.

4.4.5 Existing System Performance

The DRAINS model for each catchment was run for the 5, 10, 20 and 100 year ARI storm events. Storms durations ranging from 6 minutes to 2 hours were run to determine the worst case storm for each ARI. The worse case model results for each ARI are presented in a separate cover.

The following criteria has been adopted to measure the performance of the existing drainage system:

- Minor overflows – flows less than 200 litres per second
- Medium overflows – flows between 200 and 600 litres per second
- Major overflows – flows greater than 600 litres per second

Overflows have also been converted to depths, and where overflow depths exceed road gutter depths (150 mm), these have been documented on Figures 4a to 4d.

4.4.6 Arunta Avenue Catchment

The DRAINS model results for Arunta Avenue Catchment are provided in the table on below.

Table 3: DRAINS Model Results – Arunta Avenue Catchment

5 year ARI	10 year ARI	20 year ARI	100 year ARI
Minor overflows occur at Gilford St, Hart Cl and Turnbull Ave.	Minor overflows occur at Gilford St, Turnbull Ave, Jedda St, Arunta Ave and Taranna Rd.	Minor overflows occur in Langford Dr., Jedda St and Arunta Ave.	Minor overflows occur in Jedda St and Carringa Rd.
Medium overflows occur at Tracie Cl and Jarrah Dr.	Medium overflows occur at Hart Cl and Tracie Cl.	Medium overflows occur at Gilford St, Hart Cl, Turnbull Ave and Taranna Rd.	Medium overflows occur at Brittany Cr, Jessina St, Gilford St, Turnbull Ave, Langford Dr, Arunta Ave, and Taranna Rd.
-	Major overflow occurs at Jarrah Dr.	Major overflows occur at Tracie Cl and Jarrah Dr.	Major overflows occur at Hart Cl, Tracie Cl and Jarrah Dr.

Rates of flow in Jarrah Drive for the 100 year storm reached a maximum of 1.44 cubic metres per second and maximum depths of 240 mm. This is 90 mm above the top of kerb level. For the 100 year storm event depths of overflow were generally less than 100 mm, the exception being flow across Curringa Road which reached a depth of 220 mm.

4.4.7 Belsham Road Catchment

The DRAINS model results for Belsham Road Catchment are tabled below.

Table 4: DRAINS Model Results – Belsham Road Catchment

5 year ARI	10 year ARI	20 year ARI	100 year ARI
Minor overflows occur in Vaisey Cl.	Minor overflows occur in Conroy Cres and Belsham Rd.	Minor overflows occur in Conroy Cres.	-
-	Medium overflows occur in Vaisey Cl.	Medium overflows occur at Mitchell Rd South and Vaisey Cl.	Medium overflows occur at Vaisey Cl, Conroy Cres, Carmel Cres and Belsham Rd.
-	Major overflow occurs in Mitchell Dr, between Belsham Rd and the northern end of Mitchell Dr.	Major overflow occurs in Mitchell Dr between, Belsham Rd and the northern end of Mitchell Drive.	Major overflows occur in Mitchell Dr, from Vaisey Cl to the northern end of Mitchell Dr.

Rates of flow in Mitchell Drive for the 100 year storm reached a maximum of 4.4 cubic metres per second and maximum depths of 300 mm. This is 150 mm above the top of kerb level. This results in a velocity by depth multiple greater than 0.4 m^2/s and is therefore in excess of the upper limit for pedestrian safety.

4.4.8 Casey Crescent Catchment

The DRAINS model results for Casey Crescent Catchment are tabled below.

Table 5: DRAINS Model Results - Casey Crescent Catchment

5 year ARI	10 year ARI	20 year ARI	100 year ARI
Minor overflows occur in Conroy Cres West and Langford Dr West.	Minor overflows occur in Casey Cres.	Minor overflows occur in Langford Dr East.	Minor overflows occur in Thurling Ave.
-	Medium overflows occur in Conroy Cres West, Carmel Cres and Langford Dr West.	Medium overflows occur Conroy Cres, Carmel Cres and Casey Cres.	Medium overflows occur in Langford Dr East.
-	-	Major overflow occurs in Langford Dr.	Major overflows occur in Conroy Cres, Carmel Cres and Langford Dr West.

The greatest rate of overflow in this catchment occurs in a drainage reserve downstream of Dean Place. For the 100 year storm, the overland flow reached a maximum of 1.4 cubic metres per second and a maximum depth of 160 mm. This results in a velocity by depth multiple of approximately 0.4 m^2/s, which is the upper limit for pedestrian safety.

For the 100 year storm event, the depth of overland flow in the street gutters is generally less than 200 mm.

4.4.9 Truscott Avenue Catchment

The DRAINS model results for Truscott Avenue Catchment are tabled on the following page.

Table 6: DRAINS Model Results – Truscott Avenue Catchment

5 year ARI	10 year ARI	20 year ARI	100 year ARI
Minor overflows occur in Oaks St, Benkari Ave and Truscott Ave South.	Minor overflows occur in Maher Cl, Howe Pl, Langford Dr and Risdon Cres.	Minor overflows occur in Cutcheon St, Rees St and Barclay Cl.	Minor overflows occur in Cutcheon St, Whitehead Cl and Barclay Cl,
-	Medium overflows occur in Oaks St, Benkari Ave and Truscott Ave south	Medium overflows occur in Maher Cl, Hempstalk Cres, Howe Pl, Oaks St, Benkari Ave and Truscott Ave.	Medium overflows occur in Hempstalk Cres, Howe Pl and Rees St.
-	-	Major overflow occurs in Langford Dr.	Major overflows occur between Old Woy Woy Rd and Kari Cl and in Maher Cl, Oaks St, Langford Dr and Benkari Avenue.

The greatest rate of overflow in this catchment occurs in Langford Drive near Oaks Street. For the 100 year storm, the overland flow reached a maximum of 2.15 cubic metres per second and a maximum depth of 165 mm. This results in a velocity by depth multiple of approximately 0.4 m2/s, which is the upper limit for pedestrian safety.

For the 100 year storm event, the depth of overland flow in the street gutters is generally less than 200 mm.

5 RESIDENT QUESTIONNAIRES

Resident questionnaire forms were distributed to 120 households in the catchment. The households were selected on the basis of previously reported drainage problems and a study of the contours for each catchment also identified potential drainage problem areas.

The forms were delivered in early December 2000 and of the 120 forms distributed, 18 (15%) were returned.

The resident questionnaire forms have been supplied to Council under a separate cover (Attachment B).

The questionnaires identified 4 main areas of drainage problems (Figure 7). These being at:

- Jarrah Drive – Old Mt. Penang area, Area A
- Tudawali Crescent - Arunta Avenue area, Area B
- Foster Close and Woodley Close area, Area C
- Maher Close and Percy Joseph Avenue area, Area D

Area A - Jarrah Drive

Three resident questionnaires were received from this area with all three reporting past flooding experience. This supports the hydraulic modelling which identified that the pipe drainage system in the Jarrah Drive area surcharges (overflows) for the 5 year ARI storm event.

Area B - Tudawali Crescent - Arunta Avenue area

Four resident questionnaires were received from this area with all reporting past flooding experience. However, all four questionnaires also indicated that since the construction of additional drainage systems in the area, they had not experienced further flooding. This supports the hydraulic modelling which shows that the drainage system in the Arunta Avenue area can cope adequately for all storms up to the 100 year ARI event.

Area C - Foster Close and Woodley Close area

Two resident questionnaires were received from this area. One questionnaire identified minor backyard flooding due to a lack of inter-allotment drainage whilst the other questionnaire mentioned that the drainage problem had been addressed by Council. The hydraulic modelling was established to mainly investigate the existing trunk drainage system and therefore would not detect drainage problems at the inter-allotment level.

Area D - Maher Close and Percy Joseph Avenue area

Four resident questionnaires were received from this area. Three were received from Maher Close and one from Percy Joseph Avenue. The questionnaire received from Percy Joseph Avenue reported no incidents of flooding. The main drainage problem for Maher Close residents was runoff from the National Park. The hydraulic modelling shows that overland flows of up to almost one cubic metre per second for the 100 year storm event could be expected in Maher Close.

6 CLOSED CIRCUIT TELEVISION (CCTV)

The pipeline inspection company Pipe Eye Services Pty Ltd, was commissioned in February 2001 to CCTV all pipes greater than or equal to 900 mm diameter. Approximately 3000 metres of pipes were CCTVed and the information captured on videotapes. The locations of the pipes surveyed are shown on Figures 6a and 6b.

The videotapes and conditions reports by Pipe Eye Services Pty Ltd were provided to Council under a separate cover.

The full analyses of the faults in the pipelines are attached as Appendix C.

A list, of the common faults, is as follows:

- Direct connection of small pipes to the trunk drains. These usually consisted of 100 mm diameter sub-soil drains and roof drainage lines. The break into the larger pipes leaves the reinforcement exposed, leading to rusting of the reinforcement and weakening of the pipe. The holes created in the trunk drain for the direct connection were usually oversized and this allows groundwater and sediments to flow into the trunk drain. Consequences of this are loss of backfill material and conveyance of sediments into the receiving watercourse. Additionally, the 100 mm diameter pipes were often installed such that 200 mm to 500 mm of the smaller pipe intruded into the trunk drain and adversely affected the hydraulic performance of the trunk drain.
- Leaking pipe joints between Pit A8 and Pit A22. Flush joint pipes were installed in this section of drainage line and these allow groundwater and sediments to drain into the pipe. The loss of backfill has resulted in adjacent pipes being displaced relative to each other.
- All pipes are manufactured with a lifting hole which are sealed with a concrete block before placement of backfill. On average between 30 and 40 percent of all lifting holes were not watertight and allowed both groundwater and sediments to flow into the trunk drain.

The structural condition of the pipes surveyed were generally in good condition except for a few cases of circumferential cracks and one case where there was significant pipe damage in the 450 mm pipe located under Woy Woy Rd. This is shown as pipe G11 to G12 on Figure 6a.

7 DRAINAGE MANAGEMENT STUDY

This section of the study reviews the behaviour and performance of the existing drainage system for the 5 year, 10 year, 20 year and 100 year storm events. The existing system performance is compared with the drainage standard set out in Council's specification for drainage design for a residential area and drainage management works are proposed.

The existing drainage systems are shown on:

- Figure 3a – Arunta Avenue Catchment;
- Figure 3b – Belsham Rd Catchment;
- Figure 3c – Casey Crescent Catchment; and
- Figure 3d – Truscott Avenue.

Council's drainage standards for a residential area are set out in the following table:

Table 7: Council's Drainage Standards

Drainage Situation	Design Flood Average Recurrence Interval	Excess Flow Passage
1. Residential streets and catch drains with overflow or bypass along the street.	10 Year	The 100 year flood to be confined to carriageway, pathway or reserve.
2. Residential streets and catch drains at low points with overflow along public reserves and pathways.	10 Year	The 100 year flood to be confined to carriageway, pathway or reserve.
3. Residential streets and catch drains at low points with drainage lines traversing building allotments or other locations where surface flow may cause property damage.	Generally 20 year, but 100 year if there is no escape route	The 100 year flood edge of stream is to be shown on the plans so that appropriate easement width and treatment of escape route can be determined.
4. Major system traversing developed areas (residential, commercial or industrial). Major systems are defined as those having catchment areas in excess of 15 ha. Or having 50 year ARI runoffs in excess of 3 m^3/s whichever is the lesser.	Generally 50 year, but 100 year if there is no escape route	The 100 year flood edge of stream is to be shown on the plans so that appropriate easement width and treatment of escape route can be determined.

7.1 ARUNTA AVENUE CATCHMENT

In section 4.4.6 it was noted that minor sections of the existing drainage system, in this catchment, fail to meet the design requirements in "Drainage Situation 2" as set out in Council's Specification for Drainage Design. However, a more detailed study of the impacts of the under-capacity sections of pipelines shows that the overland flows for up to the 100 year storm event do not pose a pedestrian safety hazard. The velocity times depth multiple is less than 0.4 m^2/s.

7.1.1 Old Mount Penang Road Sub-Catchment

In Jarrah Drive, the floodwater during a 100 year storm event has been estimated to overtop the kerb by 90 mm. The overland flowpath downstream of the Jarrah Drive low point is via private property.

Recommended drainage works, for this catchment, are:

- provide an additional 675 mm diameter pipe between Jarrah Drive and Pacific Highway;
- provide additional collection in Jarrah Drive (up to 4 extended kerb inlet pits); and
- create a drainage easement/overland flowpath through Lot 59 in DP 250926 and Lot 2 in DP 581761.
- The estimated cost of works is $50,000.

OR

- provide a retarding basin in the existing park; and
- create a drainage easement/overland flowpath through Lot 59 in DP 250926 and Lot 2 in DP 581761.
- The estimated cost of works is $50,000.

7.2 BELSHAM ROAD CATCHMENT

In this catchment, parts of the existing drainage system fail to meet:

- the design requirements in "Drainage Situation 2" as set out in Council's Specification for Drainage Design; and
- the need for the overland flows "velocity times depth multiple" to not exceed 0.4 m^2/s, which is upper the limit for pedestrian safety.

The recommended drainage works, for this catchment, are:

- duplicate existing pipeline in Mitchell Drive between Belsham Rd and northern end of Mitchell Drive. Estimated cost of works is $430,000.

7.3 CASEY CRESCENT CATCHMENT

In section 4.4.8 it was noted that minor sections of the existing drainage system for this catchment fail to meet the design requirements in "Drainage Situation 2" as set out in Council's Specification for Drainage Design. However, a more detailed study of the impacts of the under-capacity sections of pipelines shows that the overland flows for up to the 100 year storm event do not present a pedestrian safety hazard - velocity times depth multiple is less than 0.4 m^2/s.

Council has previously received reports of flooding in the Woodley Close – Foster Close area. Flooding was caused mainly by flows coming off the basketball courts in the Kariong School grounds. To address this problem, it is recommended that Council provides additional drainage in Foster Close to intercept runoff from basketball courts before it flows across the road and into the Public Reserve on the low side of Foster Close. The estimated cost of works is $25,000.

Council has received reports of groundwater problems in the Carmel Crescent, however, this issue was outside the scope of this study and has not been addressed.

7.4 TRUSCOTT AVENUE CATCHMENT

In section 4.4.9 it was noted that minor sections of the existing drainage system for this catchment fail to meet the design requirements in “Drainage Situation 2” as set out in Council’s Specification for Drainage Design. The drainage model results are supported by comments received from the public, following the advertising of the Draft Exhibition report in December 2001 – January 2002. The public comments stated that considerable volumes of surface stormwater runoff originated from the grounds of the Kariong Public School and caused nuisance flooding in Truscott Avenue. It is therefore recommended that additional pipework and stormwater collection pits be provided in Truscott Avenue. The estimated cost of the works is $160,000.

The resident interviews showed that there are excessive overland flows from Brisbane Water National Park that drain into properties fronting Maher Close. There are existing cut-off drains that divert runoff into Maher Close. In large storm events the cut-off drain capacity is exceeded and the overflow drains into the rear yards of properties fronting Maher Close. To mitigate this problem it is recommended that Council enlarge the cutoff drain and/or provide a levee to at least 20 year capacity. The estimated cost of works is $8,000.

8 WATER QUALITY

8.1 GENERAL

The quality of stormwater that flows off a developed catchment is very much governed by its land usage, ie its zoning. The Kariong drainage catchment has a total area of 210 hectares and is primarily zoned Residential 2 (a). Recent studies on the main pollutant and typical loads conveyed by stormwater for an urbanised area are provided in the table below.

Table 8: Typical Pollutant Loads in Urban Stormwater

Pollutant	Dry Weather Concentration	Wet Weather Event Mean Concentration
Gross Pollutants & Gravel	*	*
Suspended Solids (mg/L)	1 – 350	20 – 1000
Nutrients:		
Total Phosphorous (mg/L)	0.001 – 2.200	0.12 – 1.60
Total Nitrogen (mg/L)	0.1 – 11.6	0.6 – 8.6

(Source: Suspended Solids and Nutrients from EPA's Managing Urban Stormwater – Strategic Framework 'Draft', September 1996)

* Variable and very much dependant on individual catchments. Could potentially reduce over the coming years due to the EPA's current education program.

The CCTV work that was carried out for this study highlighted copious amounts of sediment and building rubble in the drain in Woy Woy Rd (Reference Line A on Figure 6b). There has been recent sub-division work and new homes constructed in the area upstream of this drain and this is the most likely source of the sediments and building rubble.

The video tapes from the CCTV work carried out in the rest of the study area shows that the pipes are relatively free of sediments. Vegetation matter, in the form of large twigs and roots, were common in the section of drain located beneath the retarding basins in the Truscott Avenue catchment. In one pit the vegetation debris caused a loss of about 20% of the pipe inlet area.

A visual inspection of the wetland downstream of Kariong Oval and at the northern end of Mitchell Drive shows that gross pollutants in the form of soft drink containers, food packaging, paper, etc. was finding its way into the wetland.

The four (4) wetlands located immediately west of and adjacent to the study area (Casey Crescent Catchment) were found to be in good condition following a visual inspection in April 2001. At the end of the stormwater pipe conveying flow to the wetland, a headwall and trash rack was installed. At the time of inspection the trashracks and the wetlands were generally clean of debris and the water in the wetland was free of floating algae.

8.2 WATER QUALITY RECOMMENDATIONS

The following actions/works have been recommended to improve water quality:

- provide vegetation/debris trap at inlet to the retarding basin pipe drainage system upstream of Langford Drive and between Hempstalk Crescent and Oaks Street;
- provide a gross pollutant trap immediately upstream of the wetland in the Recreation Reserve and at the northern end of Mitchell Drive; and
- enforce Council's erosion and sediment controls on land sub-dividers and home constructers.

9 WATER SENSITIVE URBAN DESIGN

Traditionally, urban stormwater management has concentrated on stormwater drainage and flood protection to accommodate the expected increase in stormwater discharge due to the catchment urbanisation. (Wong and Eadie, 2000) Water Sensitive Urban Design (WSUD) is a relatively new concept which aims at managing urban stormwater within an ecological and sustainable framework where wastewater and stormwater are recycled and potable supplies are conserved. The principles of WSUD are based on total catchment water management and implementation of best practices currently used in the water industry. Key elements of WSUD can be integrated into the planning, design, construction, management and landscaping of individual homes, factories, precincts and industrial estates, eg reuse of stormwater in groundwater recharge, toilet flushing, for irrigation and in hot water supply systems. (Stormwater Industry Association, 2000 and Coombes et al, 2000).

The cost of upsizing existing and rebuilding aging stormwater infrastructure can be costly for large catchments, so by making WSUD features part and parcel of development applications, it may be possible for Council to minimise the stormwater impact of new developments. In making it mandatory for new developments to retain and recycle most stormwater at the source the amount of stormwater that enters already deficient network will be reduced. This therefore reduces the amount Council needs to spend upgrading the stormwater infrastructure. Besides large cost savings WSUD also provides significant environmental benefits.

For WSUD to be successful it will be necessary for Regulators and Authorities to amend policies on:

- the quality of stormwater that can be discharged from a development site; and
- the quantity of stormwater runoff that is permitted to be discharged from a development site.

Reduced stormwater discharge from a development site, could be achieved by reuse and reduced runoff via clever landscaping, water tanks, roof gardens, bio-retention, rainsaver gutters, groundwater recharge, etc..

The rate of implementation of WSUD is controlled by Regulators and Authorities and by financial incentives. Roof gutters are on average replaced every 15 to 20 years on domestic dwellings. Financial incentives to replace existing gutters with more expensive rainsaver gutters and water tanks will be required to encourage uptake of the concept by developers and home owners.

Research has shown that WSUD can reduce the quantity of runoff from a residential sub-division by about 50% and potable water consumption by a similar percentage. The reduction in potable water demand can delay the need to upgrade water mains by up to 18 years. (Coombes et al, 2000-reference 3) This should provide an incentive to both water supply authorities and consumers.

Council's Development Control Plan for Kariong might be amended to include a guide for the re-development of the area and recommend:

Water conservation to:

Minimise the use of reticulated water on site through conservation practices and reuse of rainwater.

All new developments are to include water saving devices such as dual flush toilets, tap aerators, spring return taps and low water use dishwashers and washing machines.

Site Drainage and Stormwater Control:

Development should be designed to ensure maximum rain water infiltration on site by minimising paved areas and providing stormwater drainage systems that promote natural infiltration.

All new developments to include rainwater tanks and/or rainsaver gutters. Stormwater stored in such devices is not to be used for consumption but to be used for irrigation, toilet flushing, car washing etc..

Council might consider providing a financial incentive to residents who implement WSUD from the savings it would make by not having to upgrade its existing infrastructure.

10 COSTING OF WORKS

Each component of the drainage works recommended to upgrade the drainage system standard to Council's latest standard, improve water quality and repair structurally defective sections of the drainage system, were costed, and this is represented in Appendix D. A summary of the costs for each of the four sub-catchments is tabled below.

Table 9: Cost of Works

Catchment	Proposed Work	Cost
Arunta Avenue	Upgrade drainage line between Jarrah Drive and Pacific Highway and provide additional pits in Jarrah Drive, or provide a retarding basin in Jarrah Park. This excludes the cost of acquiring a drainage easement between Jarrah Drive and Pacific Highway.	$50,000
	Fix leaking pipe joints between Langford Drive and Taranna Rd (340 metres at $350/metre).	$140,000
Belsham Road	Duplicate pipe drainage system in Mitchell Drive between Belsham Rd and northern end of Mitchell Drive.	$430,000
	Provide and maintain a GPT in the Recreational Reserve adjacent to Mitchell Drive.	$50,000
Casey Crescent	Provide drainage in Foster Close.	$25,000
Truscott Avenue	Upgrade existing cutoff drain and levee at the rear of properties fronting Maher Close.	$8,000
	Provide a trash rack at the entrance to the pipe system under the retarding basins.	$70,000
	Replace existing 375mm and 450mm pipes across Woy Woy Rd with a single 900mm culvert. Reconstruct pit over existing 900mm pipe to accommodate new pipe connection and to improve inlet hydraulics.	$25,000
	Provide additional drainage in Truscott Avenue	$160,000
General Repairs in all four catchments	Seal leaky pipe joints and bung holes (pipe lifting holes).	$100,000
	Trim all agricultural pipe connections into trunk mains, paint exposed reinforcement with coal tar epoxy and mortar spalled concrete with epoxy cement.	$50,000
	Repair cracked pipes with epoxy cement.	$50,000
Wetland Maintenance (Casey Street and Truscott Avenue catchments)	Maintain existing wetlands.	$20,000 per annum

11 DRAINAGE MANAGEMENT PLAN

The drainage management plan (Figure 8) presented in this report has been selected on the basis of:

- meeting Council's latest specification for the design of stormwater drainage works;
- providing protection to the environment by recommending the installation of gross pollutant traps and trash racks and the enforcement of Council's Erosion and Sediment control policy;
- providing protection of public and private assets by recommending and prioritising maintenance works on the existing drainage infrastructure; and
- promoting the conservation of natural resources by recommending the adoption of the principles of Water Sensitive Urban Design.

The upgrade works recommended in the management plan have been ranked ie. given a priority based on returned questionnaires and historical knowledge of areas most likely to be flooded in a storm event. The following table outlines the proposed works and their priority.

Table 10: Proposed Drainage Works

Item	Proposed Works	Priority
A	Construct a retarding basin in Jarrah Park and acquire a drainage easement over the existing 525 mm pipe between Jarrah Drive and Pacific Highway. **Cost $50,000.**	HIGH
B	Fix leaking pipe joints between Langford Drive and Taranna Road. **Cost $140,000.**	MEDIUM - HIGH
C	Duplicate pipe system in Mitchell Drive, between Belsham Road and the north end of Mitchell Drive. **Cost $430,000.**	LOW
D	Provide and maintain a Gross Pollutant Trap in the Recreational Reserve adjacent to Mitchell Drive. **Cost $50,000.**	LOW - MEDIUM
E	Provide additional drainage in Foster Close. **Cost $25,000.**	HIGH
F	Upgrade existing cut off drain and levee at rear of properties fronting Maher Close. **Cost $8,000.**	HIGH
G	Provide and maintain a trash rack at the entrance to the retarding basin between Hempstalk Crescent and Oaks Street. **Cost $70,000.**	MEDIUM
H	Replace existing 375 mm and 450 mm pipes across Woy Woy Road with a 900 mm pipe. Reconstruct pit on the western side of Woy Woy Road. **Cost $25,000.**	HIGH
J	Provide additional drainage in Truscott Avenue. **Cost $160,000**.	HIGH
General Works		
•	Seal leaky pipe joints and bung holes. **Cost $100,000.**	MED
•	Trim all small diameter uPVC pipes intruding into the trunk drainage pipes. Remove rust from exposed reinforcement and paint with coal tar epoxy. Repair spalled concrete around reinforcement. **Cost $50,000.**	MED
•	Repair cracked pipes with epoxy cement. **Cost $50,000.**	HIGH
Maintenance Works		
	Maintain existing wetlands in Casey Cres and Truscott Ave Catchments. **Cost $20,000 per annum.**	HIGH

12 REFERENCES

1. P Coombs, G Kuczera, J Argue and J Kalma,
Costing of Water Cycle Infrastructure Savings Arising from Water Sensitive Urban Design Source Control Measures
WSUD Conference, Melbourne, August 2000

2. Department of Housing
Kariong, Upper Catchment Drainage
May 1990

3. Gosford City Council
Specification for the Drafting and Design of Stormwater Drainage Works and Roadworks
Revised Edition September 1993

4. The Institute of Engineers, Australia
Australian Rainfall and Runoff – A Guide to Flood Estimation
Revised Edition 1987

13 GLOSSARY OF TERMS

Afflux
Change in water surface profile due to head losses due to changes in channel cross-section, alignment or obstruction.

Annual Exceedance Probability (AEP)
Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded: it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but relatively large.

Australian Height Datum (AHD)
A common national plane of sea level corresponding approximately to mean sea level.

Average Recurrence Interval (ARI)
The expected or average value of the time period between exceedances of a given event magnitude.

Catchment
The area draining to a site. It always relates to a particular location and may include catchments of tributary streams as well as the main stream.

Designated Flood
See flood standard.

Detention Basin
A temporary storage that fills during a storm event and effectively throttles flow out in order to reduce the peak discharge.

Discharge
The rate of flow of water measured in terms of volume over time. It is to be distinguished from velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.

Flood Hazard
Potential for damage to property or persons due to flooding.

Flood Standard
The flood selected for planning purposes. The selection should be based on an understanding of flood behaviour and the associated flood risk. It should also take into account social, economic and ecological considerations.

Hydraulic Grade Line (HGL)
This line indicates the water levels in a drainage system for a given flow. It represents the piezometric head and is a direct measure of the static pressure in the flow.

Hydraulics
The term given to the study of water flow in a watercourse or piped drainage system, in particular, the evaluation of flow parameters such as stage (or water level) and velocity.

Hydrograph
A graph that shows how the discharge varies with time at any particular location.

Hydrology
The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.

IFD Data
Intensity – Frequency – Duration data provides average rainfall intensities for a range of average recurrence intervals and design storm durations based on historical data.

Management Plan
A document including as appropriate, both written and diagrammatic information describing how a particular area of land is to be managed to achieve defined objectives. It may also include description and discussion of various issues, problems, special features and values of the area, the specific management measures that are to apply, and the means and timing by which the plan will be implemented.

Mathematical/Computer Models
The mathematical representation of the physical processes involved in runoff and streamflow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff and streamflow.

Peak Discharge
The maximum discharge occurring during a flood event.

Probability
A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation, see Annual Exceedance Probability.

Rational Method
A statistical method for use in estimating design flows. It is used to estimate a peak flow of a selected ARI from an average rainfall intensity of the same ARI.

Runoff
The amount of rainfall that actually enters the drainage system or watercourse; also known as rainfall excess.

Stormwater Flooding
Inundation resulting from the incapacity of an urban stormwater drainage system to handle runoff.

Tailwater Level

The level in some downstream receiving water or control structure which influences water levels in the upstream system.

Water Surface Profile

A longitudinal plan showing the flood stage at any given location along a watercourse or drainage system.

FIGURE 1
LOCALITY MAP

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SCALE 1:150000

0 2.0 4.0 6.0 8.0 10.0km

FIGURE 2
SITE PLAN

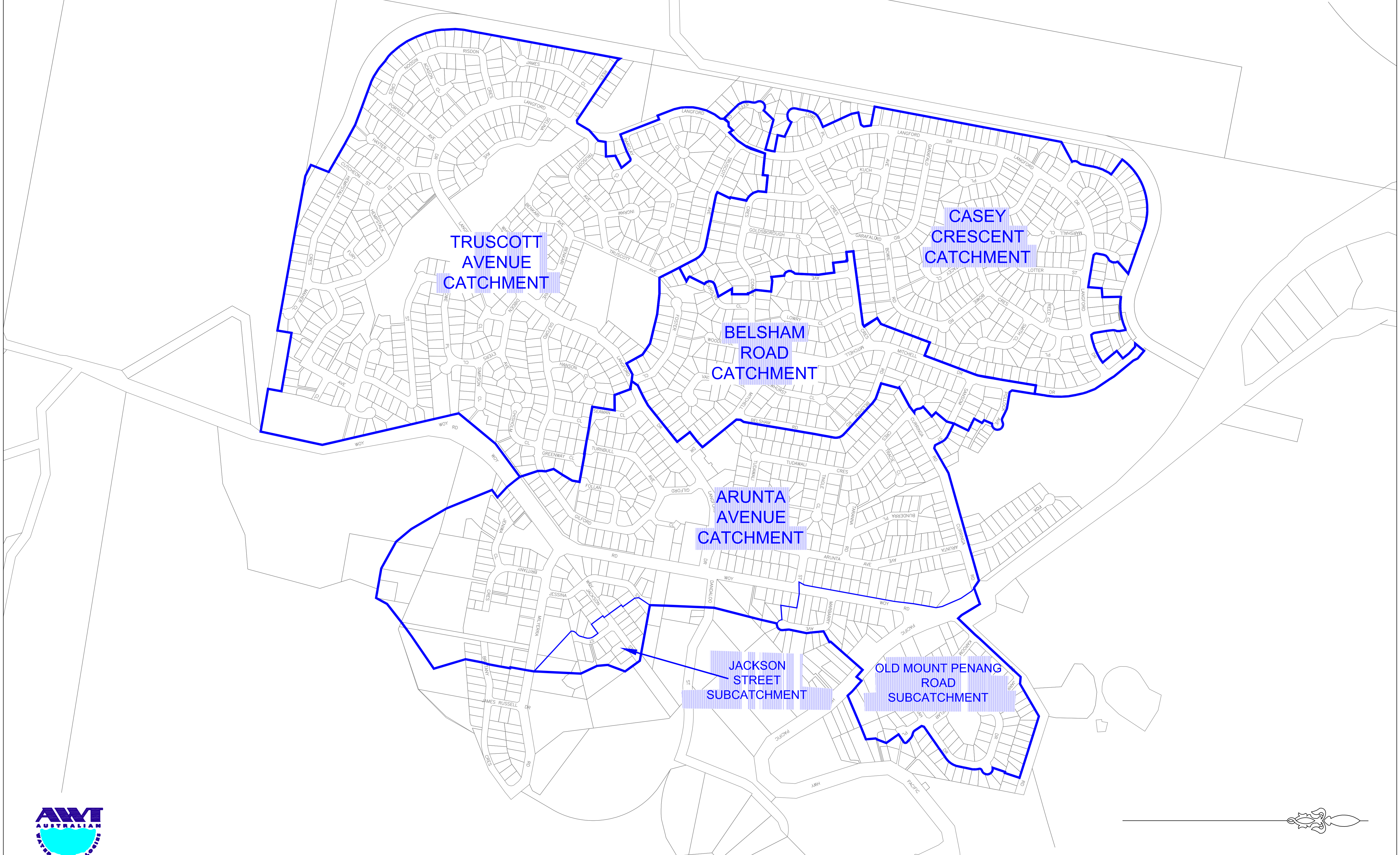

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FIGURE 8
DRAINAGE MANAGEMENT PLAN

ITEM	PROPOSED WORKS	PRIORITY	COST	SOURCE OF FUNDING
A	Construct a retarding basin in Jarrah Park and acquire a drainage easement over the existing 525 mm pipe between Jarrah Drive and Pacific Highway.	HIGH	$50,000	Council General Funds
B	Fix leaking pipe joints between Langford Drive and Taranna Road	MED-HIGH	$140,000	General Works
C	Duplicate pipe system in Mitchell Drive between Belsham Road and north end of Mitchell Drive.	LOW	$430,000	S.94
D	Provide and maintain a Gross Pollutant Trap in the Recreational Reserve adjacent to Mitchell Drive.	LOW-MED	$50,000	S.94
E	Provide additional drainage in Foster Close.	HIGH	$25,000	S.94
F	Upgrade existing cut off drain and levee at rear of properties fronting Maher Close.	HIGH	$8,000	S.94
G	Provide and maintain a trash rack at the entrance to the retarding basin between Hempstalk Crescent and Oaks Street.	MEDIUM	$70,000	S.94
H	Replace existing 375 mm and 450 mm pipes across Woy Woy Road with a 900 mm pipe. Reconstruct pit on the western side of Old Woy Woy Road.	HIGH	$25,000	S.94
J	Provide additional drainage in Truscott Avenue.	HIGH	$160,000	S.94
General Works				
	* Seal leaky pipe joints and bung holes (pipe lifting holes),	MED	$100,000	General Works
	* Trim all small diameter uPVC pipes intruding into the trunk drainage pipes. Remove rust from exposed reinforcement and paint with coal tar epoxy. Repair spalled concrete around reinforcement,	MED	$50,000	General Works
	* Repair cracked pipes with epoxy cement.	HIGH HIGH	$18,000 $32,000	General Works S.94
Maintenance Works				
	* Maintain existing wetlands in Casey Crescent and Truscott Avenue Catchments,	MED	$20,000 p.a.	General Works
		TOTAL	$1,178,000	

WATER SENSITIVE URBAN DESIGN (WSUD)

Gosford City Council might consider introducing, in the Kariong area, some of the principles of water sensitive urban design. The residents might be encouraged to:

- install rain water tanks;
- install rain saver gutters; and
- reuse stormwater for car washing, toilet flushing and the watering of gardens.

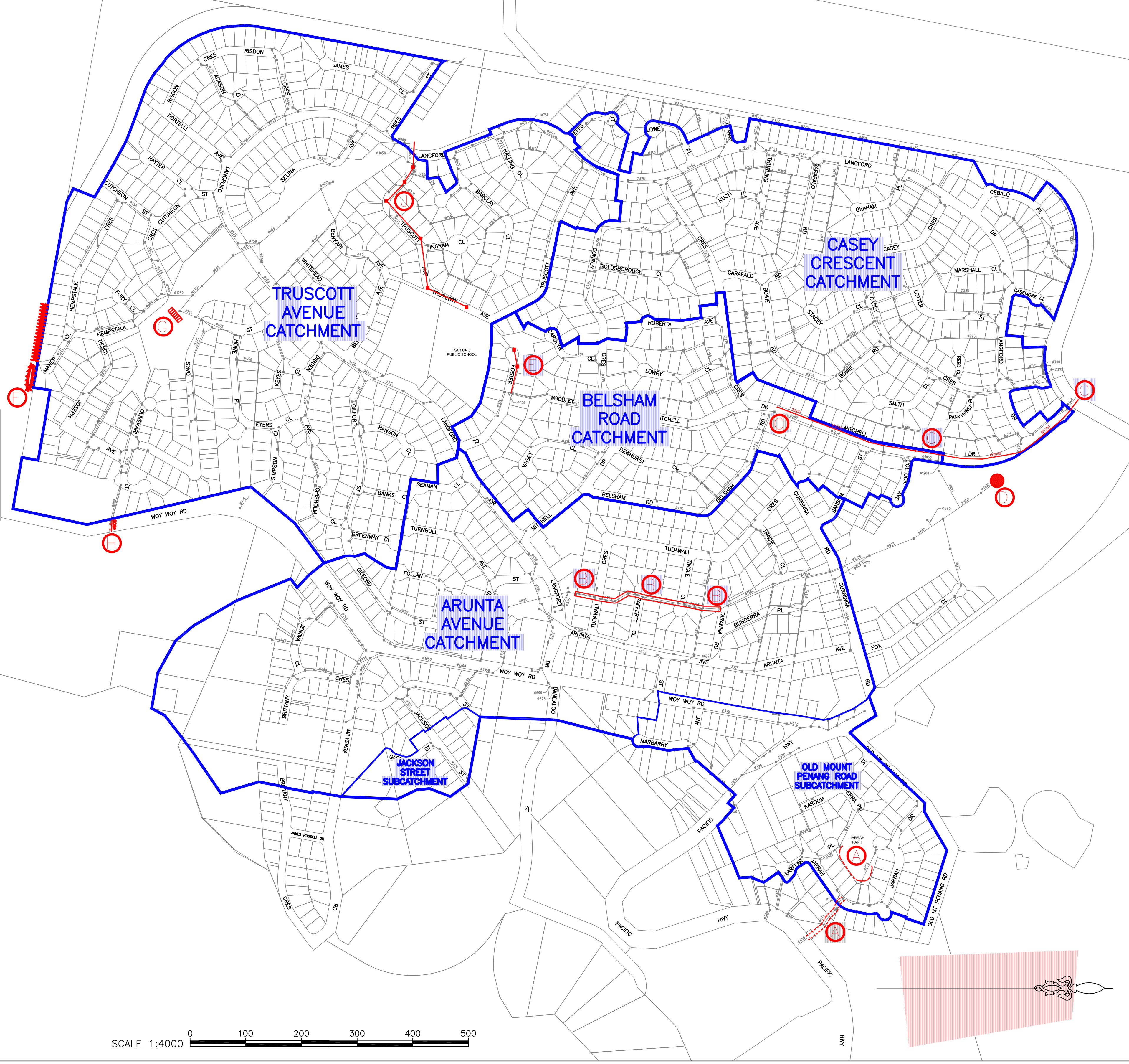

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FIGURE 7
RESIDENT INTERVIEW RESPONSES

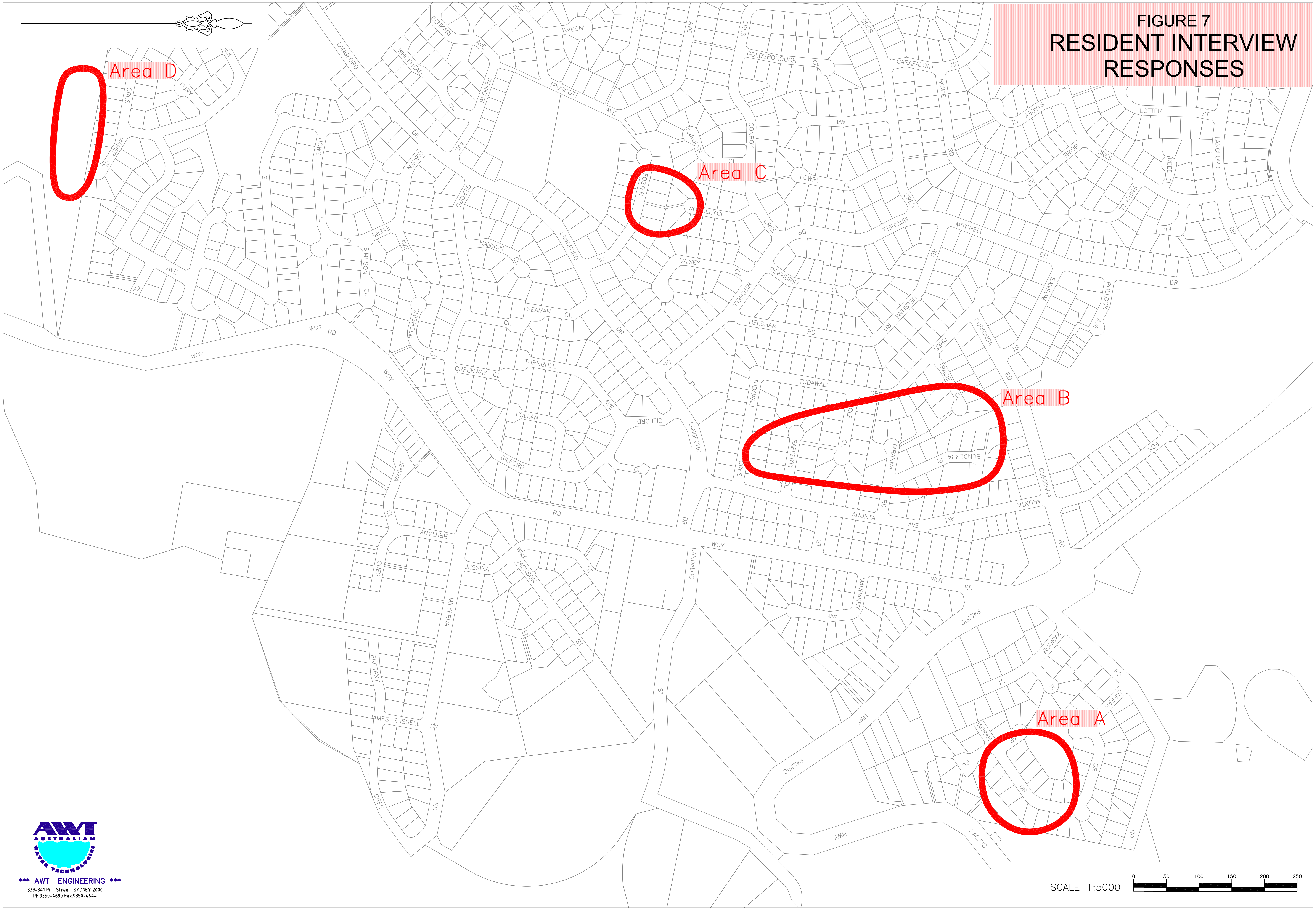

FIGURE 6b
CCTV COVERAGE
Sheet 2 of 2

COMMENTS – LINE E

Section From	Section To	Pipe Diameter (mm)	Total Length (m)	Chainage (m)	Description of Defect	Ranking of Defect	Recommended Works
E03	E06	900	33	28.5	– poor small pipe connection at obvert – reo. Exposed	M	clean around pipe connection and repair with epoxy cement
				32.7	– damaged pipe lifting hole	L	clean pipe lifting holes and seal with epoxy cement
E06	E07	900	38	16.2	– poor small pipe connection at obvert – reo. Exposed	M	clean around pipe connection and repair with epoxy cement
				16.4	– open pipe joint – medium	M	clean pipe joint and seal with epoxy mortar
				17.2	– poor small pipe connection at obvert – reo. Exposed	M	clean around pipe connection and repair with epoxy cement
				18.9	– poor small pipe connection near obvert – reo. Exposed	H	clean around pipe connection and repair with epoxy cement
E01	E05	1050	48	35.5	– poor small pipe connection near obvert – reo. Exposed	H	clean around pipe connection and repair with epoxy cement
				50.0	– log obstructs upstream inlet to culvert	H	remove obstruction and install a trash rack
E02	E04	1050	48	32.0	– poor small pipe connection near side – reo. Exposed	H	clean around pipe connection and repair with epoxy cement
				48.3	– debris obstructs upstream inlet to culvert	H	remove obstruction and install a trash rack

COMMENTS – LINE F

Section From	Section To	Pipe Diameter (mm)	Total Length (m)	Chainage (m)	Description of Defect	Ranking of Defect	Recommended Works
F06	F12	1200	47	0.0 – 1.0	– silt along pipe invert	L	remove silt from pipe invert
F06	F05	600	54	33 & 35.6	– substantial seepage via pipe lifting holes	M	clean pipe lifting holes and seal with epoxy cement
				53.5	– poor pipe to pit connection, pipe reo. rusting and exposed.	H	clean exposed reo. and repair pipe with epoxy mortar
F05	F04	1050	34		– no major problems, so OK	–	
F04	F03	600	49	0.1	–circumferential crack, reo. rusted & significant seepage	H	clean exposed reo. and repair pipe with epoxy mortar
				4.5	– seepage at pipe joint, also at Chainages 31.0, 33.6, 36.5, 38.6, 41.1	M	clean pipe joint and seal with epoxy mortar
				5.0	– poor small pipe connection – reo. Exposed	M	clean around pipe connection and repair with epoxy cement
				34.0	– spalled concrete at pipe obvert	M	clean area and repair with epoxy cement
F03	F02	1050	29	1.5 – 6.3	– 3 small pipe connections, rust staining pipe	L	monitor the situation
F02	F01	1050	2	0.0	– debris at mouth of upsteam opening (Pit F02)	H	remove debris – good location for dry GPT at outlet
F06	F07	1350	53	1.0	– debris in pipe	L	remove debris
F07	F08	600	70	18.2	– pipe broken near invert	H	clean area and repair with epoxy cement
				30.9	– seepage at pipe joint, also at Chainages 38.5, 50.0 and 52.9	M	clean pipe joint and seal with epoxy mortar
				67.7	– significant seepage via pipe joint	H	clean pipe joint and seal with epoxy mortar
				70.1	– debris at pit	M	remove debris
F08	F09	1050	29	0.0 – 20.0	– debris along pipe invert – sand bags, gravel, etc.	H	remove debris
				11.5	– obstruction (tree root/branch) in pipe	H	remove debris
				26.7	– significant seepage via pipe joint	H	clean pipe joint and seal with epoxy mortar
F13	F12	900	35	11.6	– intruding ag pipe, reo exposed	H	trim intruding pipe, clean reo. and repair with epoxy cement
				29.0	– 150mm service pipe (watermain ?) through top of pipe	H	check if service pipe is live, if not remove service pipe and repair stormwater pipe
F10	F11	600	7	7.0	– roots at upstream opening (F11)	H	remove vegetation and install a trash rack at pipe entry
F10	F09	750	26		– no major problems, so OK	–	

COMMENTS – LINE G

Section From	Section To	Pipe Diameter (mm)	Total Length (m)	Chainage (m)	Description of Defect	Ranking of Defect	Recommended Works
G05	G06	900	24	24.5	– tree roots in Pit G06	H	remove tree roots from Pit G06
G06	G07	900	14	14.5	– twigs in Pit G07	H	remove vegetation matter from Pit G07
G07	G08	900	22	0.1	– circumferential crack in pipe	M	clean crack and repair with epoxy cement

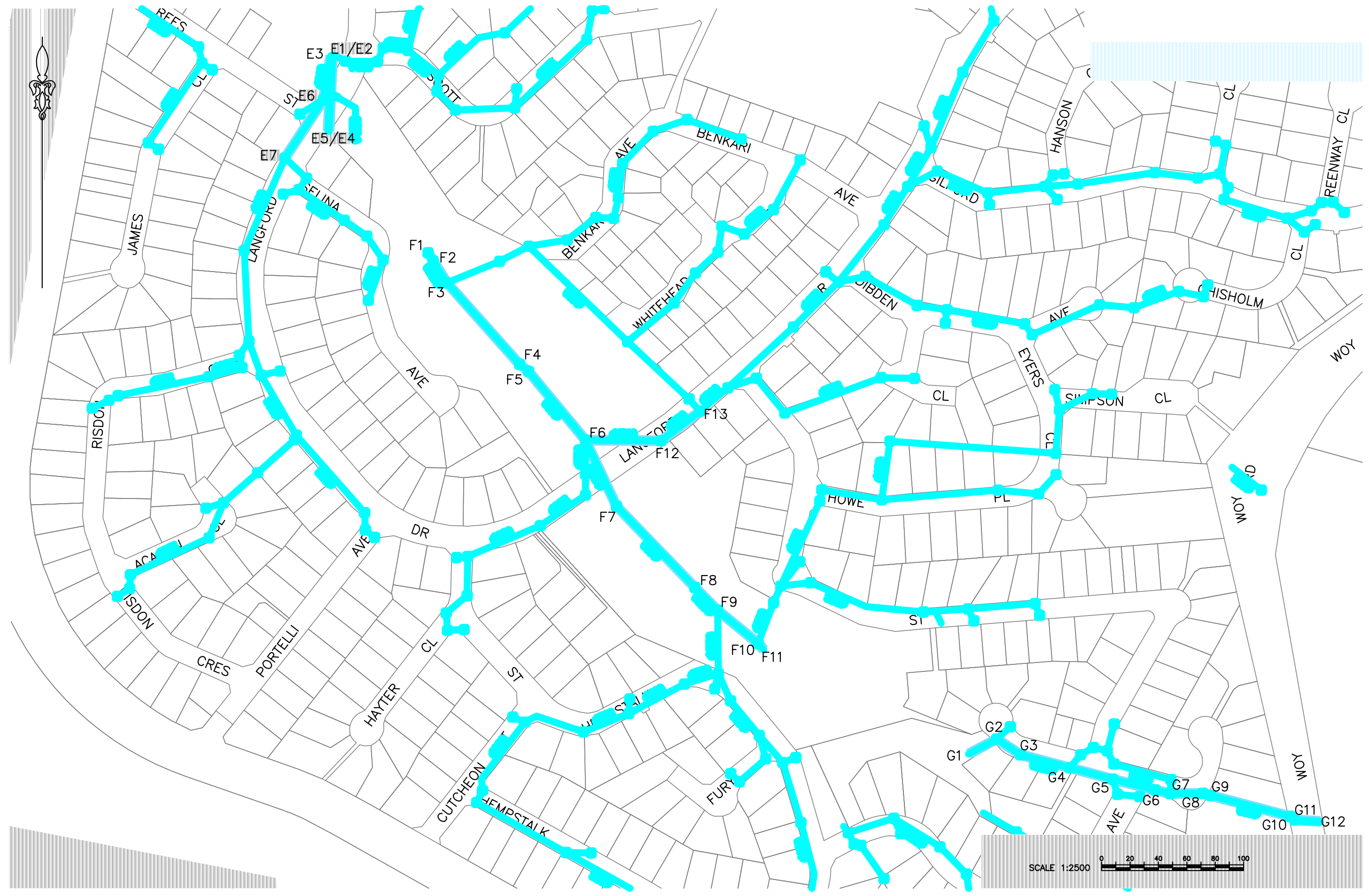

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FIGURE 6a
CCTV COVERAGE
Sheet 1 of 2

COMMENTS – LINE A

Section From	Section To				Description of Defect		Recommended Works
A27	A28	1200	56.2	5.3	– circumferential crack at top of pipe	L	monitor the situation
				27.9	– hole in conduit at top of pipe and aggregate exposed	M	clean and repair with epoxy cement
A28	A29	1050	61	51.4	– sign of rust on pipe wall (seepage ?)	L	monitor the situation
A29	A30	1050	60	0.0	– pit invert slightly rough	L	epoxy cement render pit invert
				19.4	– ag. pipe intrudes 400 mm	M	trim ag. Pipe and seal around ag. Pipe
				52.6	– sign of rust on pipe wall (seepage ?)	L	monitor the situation
				60.0	– some debris in pit	M	clean pit
A30	A31	900	17	0.6	– debris in pipe	M	clean pipe
				17.8	– debris at incoming Ø375mm (Pit A31)	M	clean pit
A31	A32	900	30		– no major problems, so OK		
A27	A26	1350	34		– no major problems, so OK	–	
A26	A25	1500	61		– no major problems, so OK		
A25	A24	1650	59	59.2	– small amount of debris in pit, pipe OK	L	clean pit
A19	A20	900	34	4.5 – 34.0	– seepage via pipe joints and pipe lifting hole	H	epoxy cement render pipe joints and pipe lifting hole
				11.0	– poor Ø100mm connection, reinforcement exposed	M	clean and repair with epoxy cement
					– damage in Pit A20 (exposed reinforcement)		clean and repair with epoxy cement
A20	A21	900	8	0.5	– clear debris	M	clean pipe
				0.0 – 8.0	– coarse aggregate & debris on invert	M	clean pipe
A21	A22	900	50	0.0 – 50.0	– sand & coarse aggregate on invert	M	clean pipe
				20.0	– logitudinal crack at top of pipe	L	monitor the situation
				32.2	– spalled concrete, reo. exposed, seepage	H	clean and repair with epoxy cement
				49.4	– break at top of pipe, seepage	H	clean and repair with epoxy cement
				50.0	– blocked pipe leaking	H	clean and repair with epoxy cement
A19	A18	900	8	6.9	– minor seepage via pipe joint	L	clean and repair with epoxy cement
A18	A15	900	71	3.7	– seepage via pipe lifting hole	L	clean and repair with epoxy cement
				7.7	– Ø100mm connection intrudes 100mm	M	trim intruding pipe & seal around intruding pipe
				12.5 – 41.0	– substantial seepage via most pipe joints	H	clean and repair with epoxy cement
				24.9	– break in conduit (exposed reinforcement)	H	clean and repair with epoxy cement
				25.8	– debris at badly damaged joint (concrete)	H	clear debris and repair with epoxy cement
				26.5	– break in conduit (exposed aggregate)	H	clean and repair with epoxy cement
				27.5	– intruding plastic pipe	M	trim intruding pipe & seal around intruding pipe
				40.4 – 44.1	– pipe joint damage at invert	H	clean and repair with epoxy cement
A15	A14	900	9		– no major problems, so OK	–	
A14	A13	900	32.7	6.4 – 32.7	– substantial seepage via most pipe joints	H	clean and repair with epoxy cement
				27.2	– fine roots opening pipe joint	H	clear roots and repair with epoxy cement
				30.7	– intruding small dia. ag & plastic pipes	H	trim intruding pipes & seal around intruding pipes
				32.7	– CCTV survey abandoned because of intruding pipe	H	trim intruding pipe & seal around intruding pipe
A09	A10	1050	9		– no major problems, so OK	–	
A10	A11	1050	32	0	– mass of roots at mouth of conduit (Pit A10)	H	clear roots and repair with epoxy cement
				3.3	– fine roots coming through pipe joint	H	clear roots and repair with epoxy cement
				3.3	– open joint and noticable seepage	H	clean and repair with epoxy cement
				32.7	– cross connection obstructing pipe opening in Pit A11	H	check cross connection & trim intruding pipe
A09	A08	1200	95	1.3	– roots at joint	H	clear roots and repair pipe joint with epoxy cement
				5.8	– intruding concrete pipe	H	trim intruding pipe & seal around intruding pipe
				8.3	– roots at joint	H	clear roots and repair pipe joint with epoxy cement
				11.2 – 16.1	– mass roots at joints	H	clear roots and repair pipe joint with epoxy cement
				29.7	– intruding pipes	M	trim intruding pipes & seal around intruding pipes
				95	– roots in Pit A08	M	clear roots and repair pit with epoxy cement
A08	A07	1350	94	0	– break in conduit (exposed reinforcement)	M	clean and repair with epoxy cement
				14.8	– pipe connection	M	clean around connection and mortar with epoxy cement
				56.7	– intruding pipes at CH56.7 and CH 56.8	H	trim intruding pipes & seal around intruding pipes
A13	A14	900	30	1.7	– pipe joint displaced – medium	H	repair displaced pipe joint
				6.9	– pipe joint displaced – large	H	repair displaced pipe joint
				14 – 30.1	– leaking joints between CH14.0 and CH30.1	M	clean and repair with epoxy cement
				17.6 – 19.7	– intruding pipes at CH17.6 and CH19.7	H	trim intruding pipes & seal around intruding pipes
				23.72	– pipe joint displaced – large	H	repair displaced pipe joint
				28.5	– pipe joint displaced – medium	M	repair displaced pipe joint
A13	A12	900	7		– no major problems, so OK	–	
A12	A11	1050	30	5.7 – 30.1	– most joints leak between CH5.7 and CH30.1	M	clean pipe joints and mortar with epoxy cement
				16.3 & 22.9	– fine roots at joints	M	remove roots and epoxy mortar point of root entry
				30.1	– small dia. pvc pipe running through Pit A11	H	check pipe and remove/ re-route
A2	A1	1200	40		– no major problems, so OK	–	
A2	A3	1050	77		– intruding pipes at CH34.2, CH45.1, CH66.1 and CH 72.5	L	trim intruding pipes & seal around intruding pipes
A3	A4	1050	76		– intruding pipes at CH19.8, CH21.3, CH46.5 and CH 74.0	L	trim intruding pipes & seal around intruding pipes
A4	A5	1200	64		– no major problems, so OK		
A6	A5	825	84	2.5 – 84.4	– most joints leak between CH2.5 and CH84.4	M	clean pipe joints and mortar with epoxy cement
A6	A7A	1200	59		– no major problems, so OK	–	
A7A	A7	1200	31	23.7 & 25.4	– broken conduit at CH23.7 and CH25.4	M	repair broken conduit with epoxy cement
A34	A33	1050	13	1.4	– debris (including silt) in pipe	H	clean pipe
				13.1	– water level is 40% past CH13.1	H	unblock downstream pipe
A33	A22				– pipe not CCTV surveyed permanently full of water	H	pipe to be unblocked

COMMENTS – LINE B

Section From	Section To				Description of Defect		Recommended Works
B02	B01	1350	20	0 – 20	– pipe appears structurally OK, but water level in pipe high in pipe due to blocked downstream pipe	H	unblock downstream pipe
B02	B03	1050	3	2.8	– infiltration	M	clean and seal pipe
B03	B04	1050	76	28.4	– fine roots at pipe joint	H	clean pipe joints and mortar with epoxy cement
				39.5	– mass roots at pipe joint	H	clean pipe joints and mortar with epoxy cement
				40.0	– debris caught in mass roots	H	remove debris

COMMENTS – LINE C

Section From	Section To				Description of Defect		Recommended Works
C06	C07	1200	74		– no major problems, so OK		
C07	C08	1200	83	64 & 74	– infiltration via pipe lifting hole	–	seal pipe lifting hole with epoxy mortar
C06	C05	1200	91	69.5 & 70.8	– cracked pipe – significant seepage	M	clean pipe cracks and mortar with epoxy cement
				76.9	– differential settlement & crcked pipe at invert	M	clean pipe cracks and mortar with epoxy cement
				90.8	– defective ag pipe connection	L	trim intruding pipe & seal around intruding pipe
C05	C03	1350	60	58.9	– defective small pipe connection	L	trim intruding pipe & seal around intruding pipe
C03	C02	1350	49		– no major problems, so OK	–	
C02	C01	1350	171		– intruding pipes at CH34.2, CH105.1, CH134.3 and CH171.0	L	trim intruding pipes & seal around intruding pipes
				34.4	– seepage through pipe	M	clean seepage area and seal with epoxy cement
				34.6	– spalled concrete	M	clean spalled area and repair with epoxy cement
				155.5	– pipe damaged at invert, concrete chipped	M	clean damaged area and repair with epoxy cement
				160.0	– open pipe joint – seepage via joint	M	clean pipe joint and seal with epoxy cement
C01	C01A	1350	107	17.5 – 26.1	– leaking pipe lifting holes – significant infiltration drippers	M	clean pipe lifting holes and seal with epoxy cement
				26.1	– intruding 150 mm pipe, by 20 mm	L	clean around pipe and seal with epoxy cement
				35.0	– seepage via pipe joint	M	clean pipe joint and seal with epoxy cement
				73.6	– leaking pipe lifting holes	L	clean pipe lifting holes and seal with epoxy cement
A06	C01A	1200	57		– no major problems, so OK	–	

COMMENTS – LINE D

Section From	Section To				Description of Defect		Recommended Works
D06	D07	1050	87		– no major problems, so OK	–	
D07	D08	900	68	50.0 – 57.2	– four leaking pipe joints	L	clean pipe joints and seal with epoxy cement
D08	D09	900	44	0.3	– minor circumferential crack	L	clean crack and seal with epoxy cement
				12.0	– open pipe joint	L	clean pipe joint and seal with epoxy cement
D06	D05	1050	24	22.7	– minor circumferential crack	L	clean crack and seal with epoxy cement
D05	D04	1050	19		– no major problems, so OK	–	
D04	D03	1050	58	35.6	– suspect pipe joint	L	monitor the situation
D03	D02	1050	39	3.9 – 31	– suspect pipe joints at Ch 3.9, Ch 28.7 and Ch 31	L	monitor the situation
D02	D01	1200	30	3.5	– infiltration at pipe joint	L	clean pipe joint and seal with epoxy cement
				11.0	– large open pipe joint	H	clean pipe joint and seal with epoxy cement
				17.0	– leaking pipe lifting holes	L	clean pipe lifting holes and seal with epoxy cement
D01	D01A	1200	20	7.3 – 20.3	– leaking pipe lifting holes	L	clean pipe lifting holes and seal with epoxy cement
D01A	A03	825	1200		– no major problems, so OK	–	

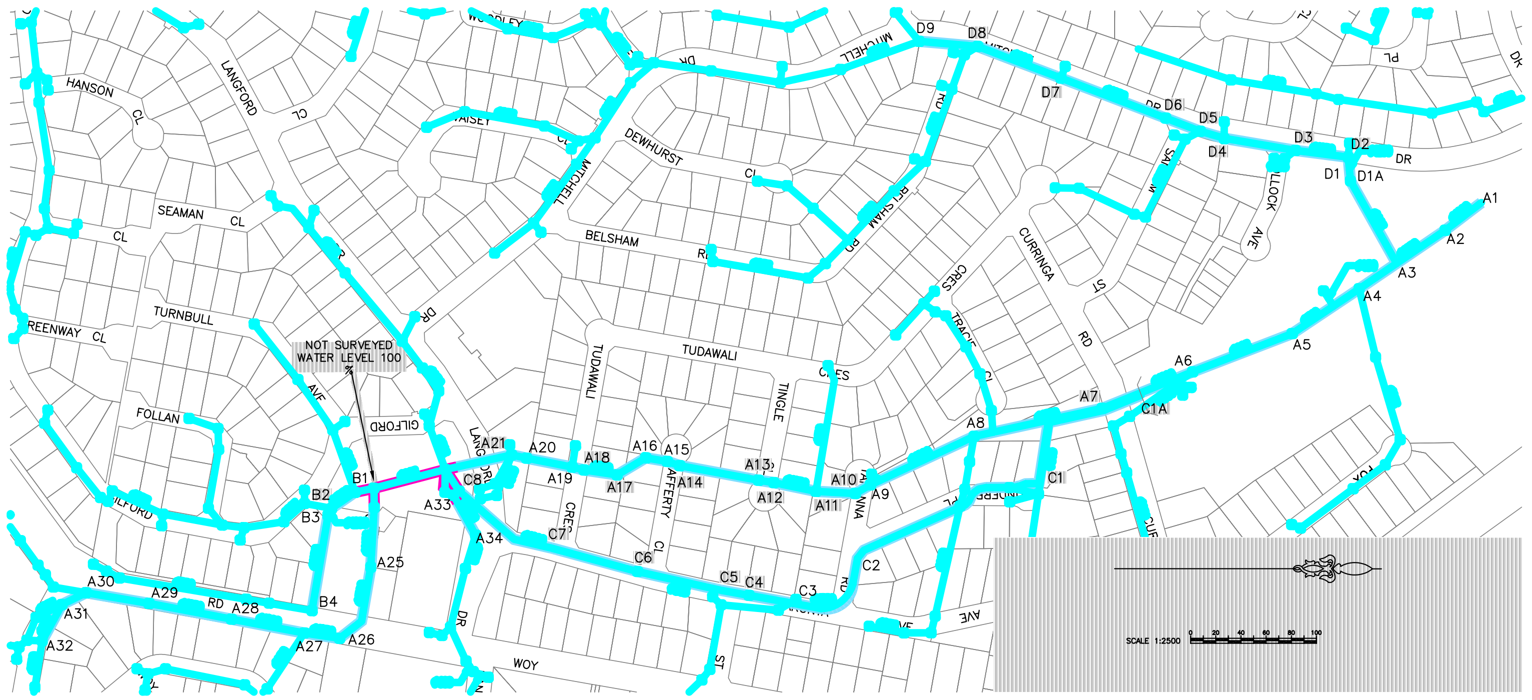

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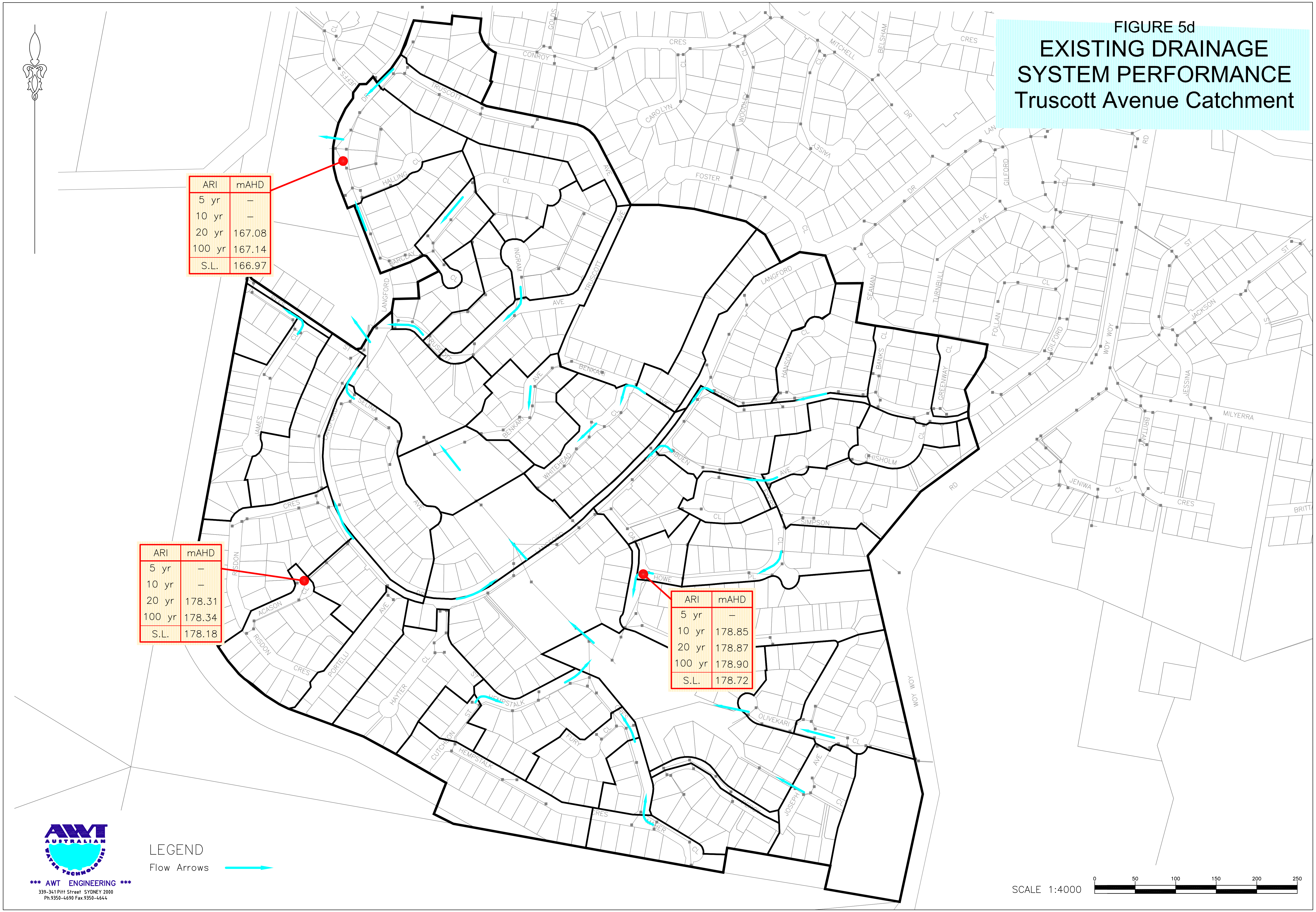
FIGURE 5d
EXISTING DRAINAGE SYSTEM PERFORMANCE
Truscott Avenue Catchment



ARI	mAHD
5 yr	–
10 yr	–
20 yr	167.08
100 yr	167.14
S.L.	166.97

ARI	mAHD
5 yr	–
10 yr	–
20 yr	178.31
100 yr	178.34
S.L.	178.18

ARI	mAHD
5 yr	–
10 yr	178.85
20 yr	178.87
100 yr	178.90
S.L.	178.72

LEGEND

Flow Arrows

SCALE 1:4000

0 50 100 150 200 250

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FIGURE 5c

EXISTING DRAINAGE SYSTEM PERFORMANCE

Casey Crescent Catchment

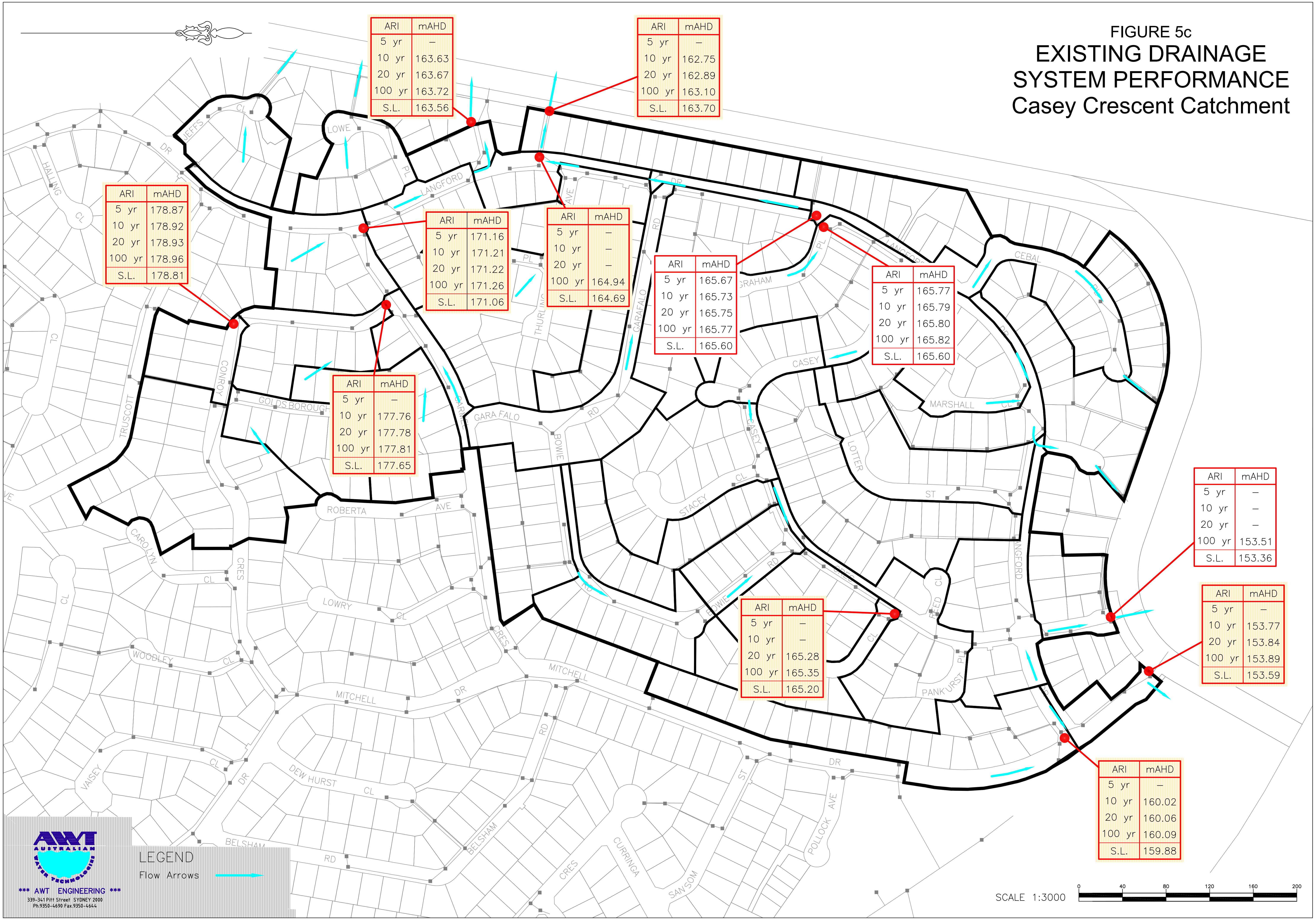


FIGURE 5b

EXISTING DRAINAGE SYSTEM PERFORMANCE
Belsham Road Catchment

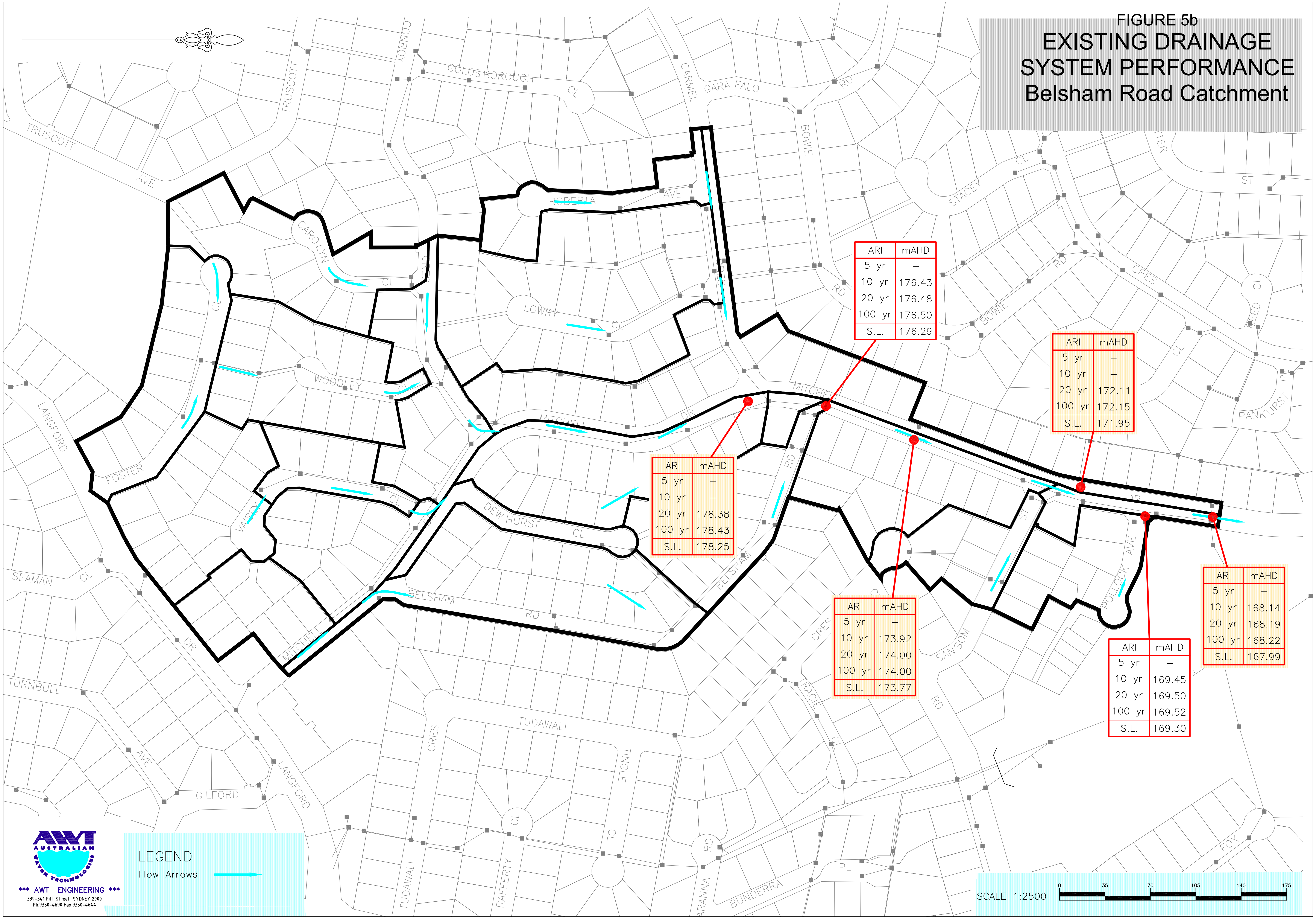


FIGURE 5a
EXISTING DRAINAGE SYSTEM PERFORMANCE
Arunta Avenue Catchment

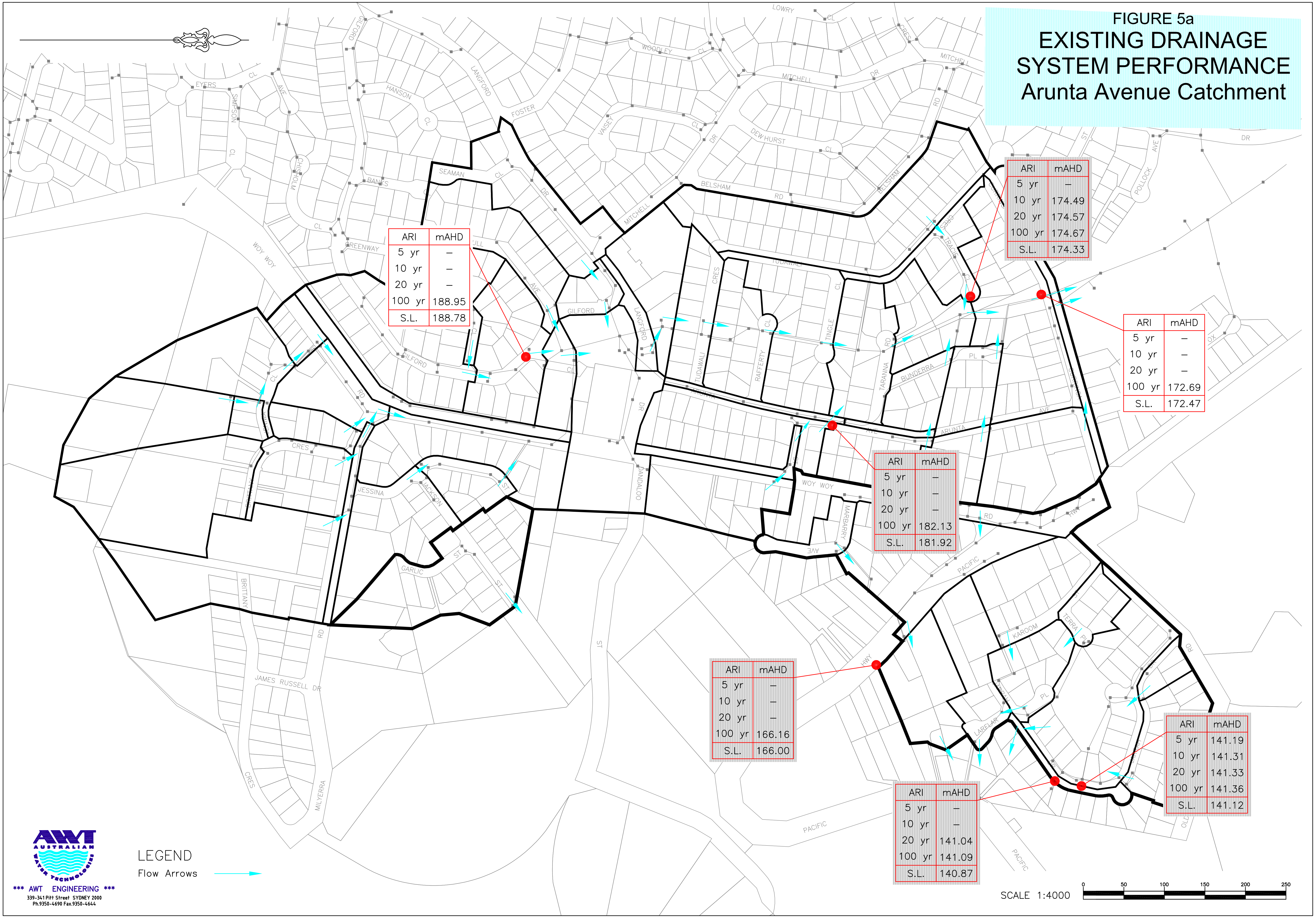


FIGURE 4d

DRAINS MODEL LAYOUT

Truscott Avenue Catchment

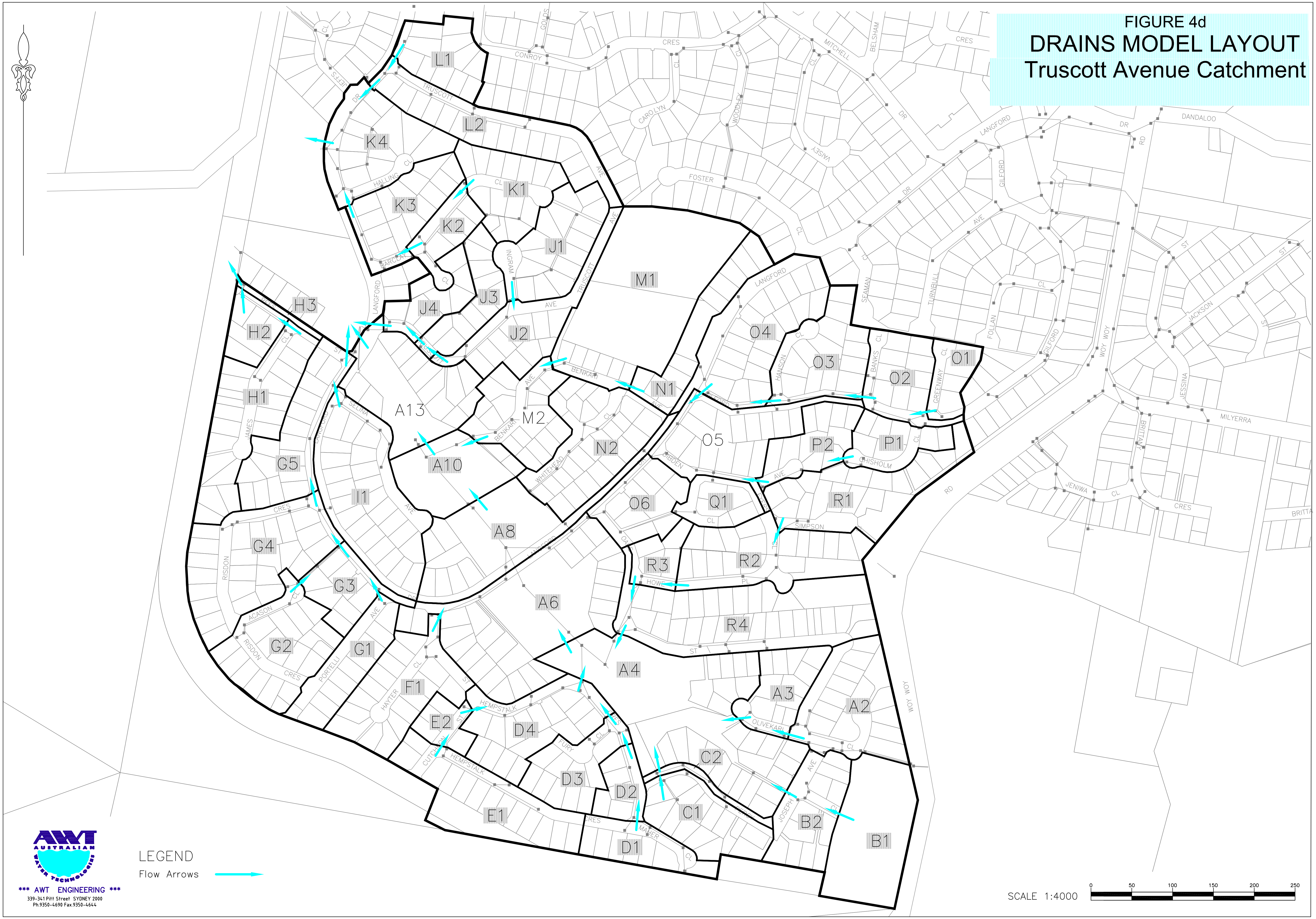
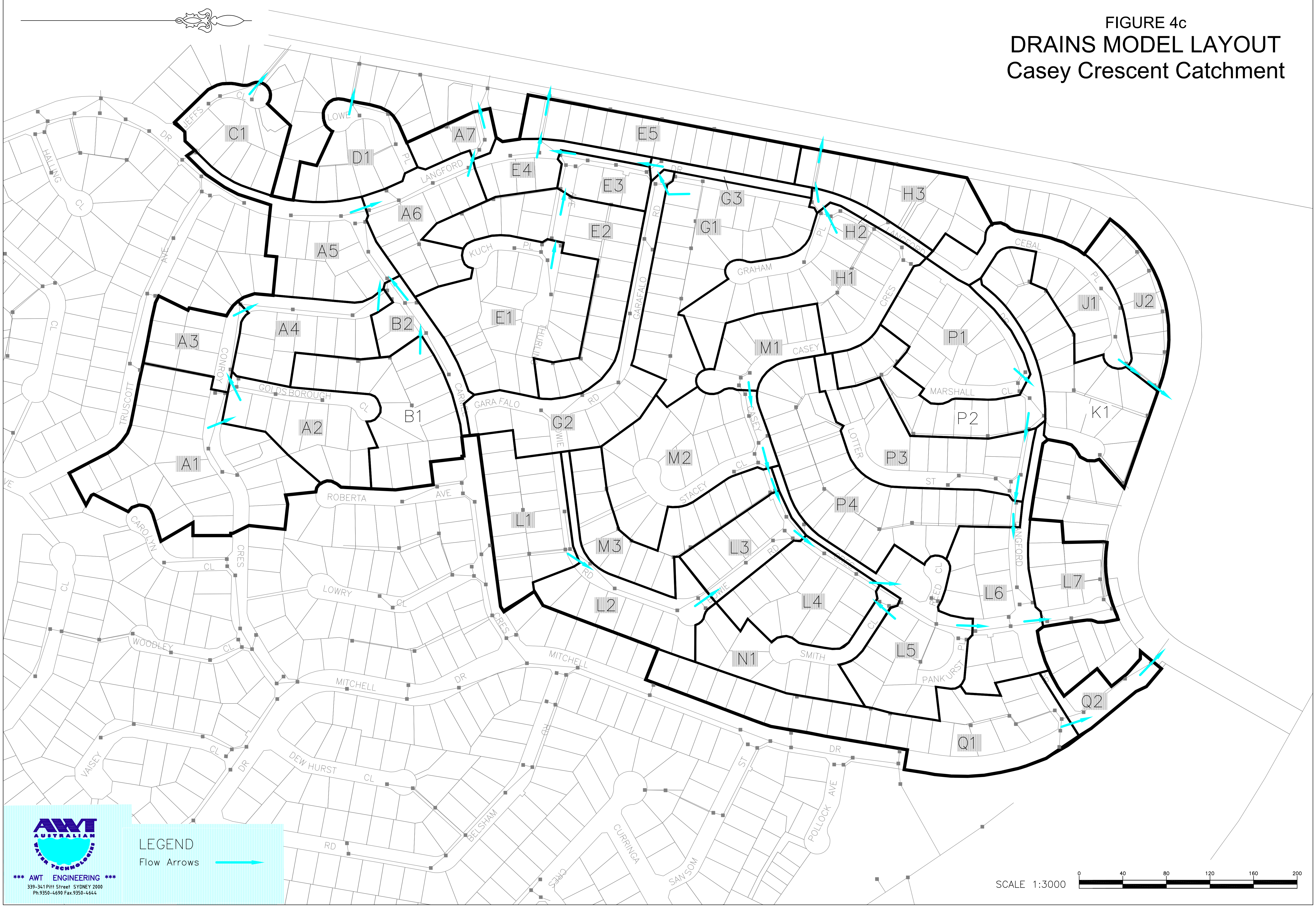


FIGURE 4c

DRAINS MODEL LAYOUT

Casey Crescent Catchment



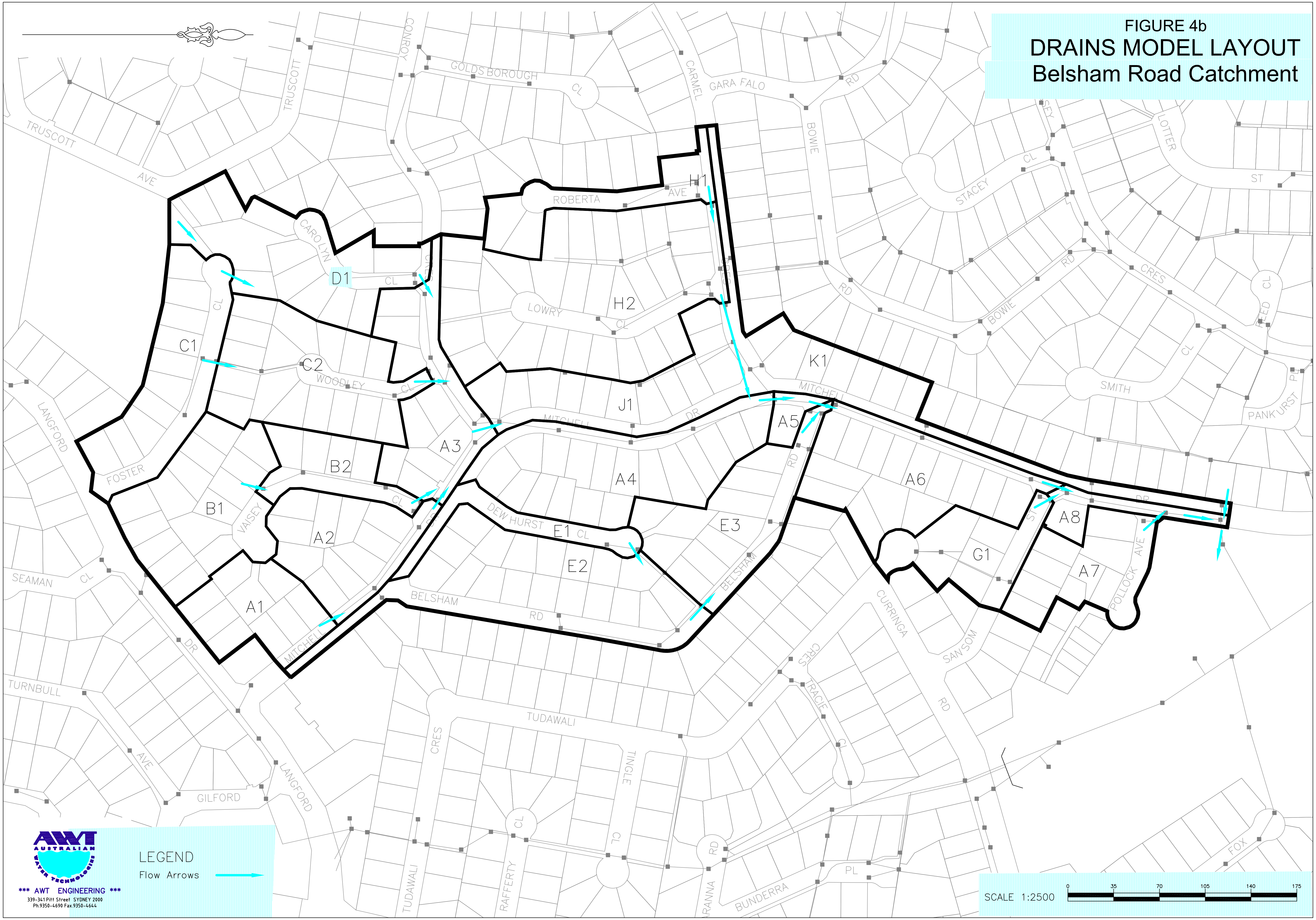


FIGURE 4b
DRAINS MODEL LAYOUT
Belsham Road Catchment
LEGEND
Flow Arrows
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SCALE 1:2500
0 35 70 105 140 175
A1
A2
A3
A4
A5
A6
A7
A8
B1
B2
C1
C2
D1
E1
E2
E3
G1
H1
H2
J1
K1
BELSHAM RD
MITCHELL DR
DEW HURST CL
VAISEY CL
FOSTER CL
WOODLEY CL
CAROLYN CL
ROBERTA AVE
LOWRY CL
TRUSCOTT AVE
CONROY
GOLDSBOROUGH CL
CARMEL
GARA FALO RD
BOWIE RD
STACEY CL
LOTTER ST
SMITH CL
PANKURST PL
FEED CL
CURRINGA RD
SANSOM ST
POLLOCK AVE
TRACIE CL
CRES
TUDAWALI CRES
TINGLE CL
RAFFERTY CL
LANGFORD DR
SEAMAN CL
TURNBULL AVE
GILFORD
ARANNA RD
BUNDERRA PL
FOX

FIGURE 4a

DRAINS MODEL LAYOUT

Arunta Avenue Catchment

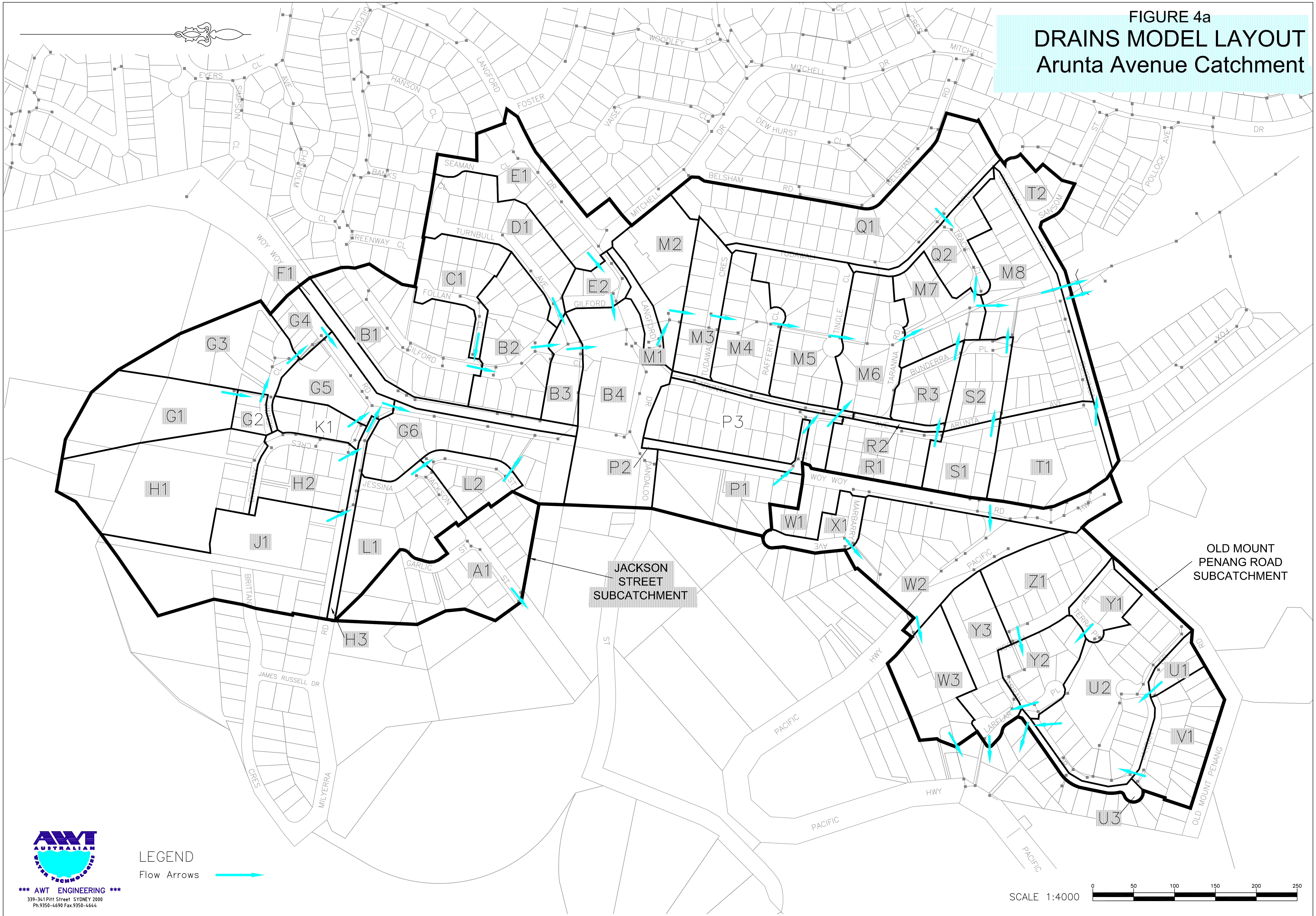

FIGURE 3d
EXISTING DRAINAGE
Truscott Avenue Catchment

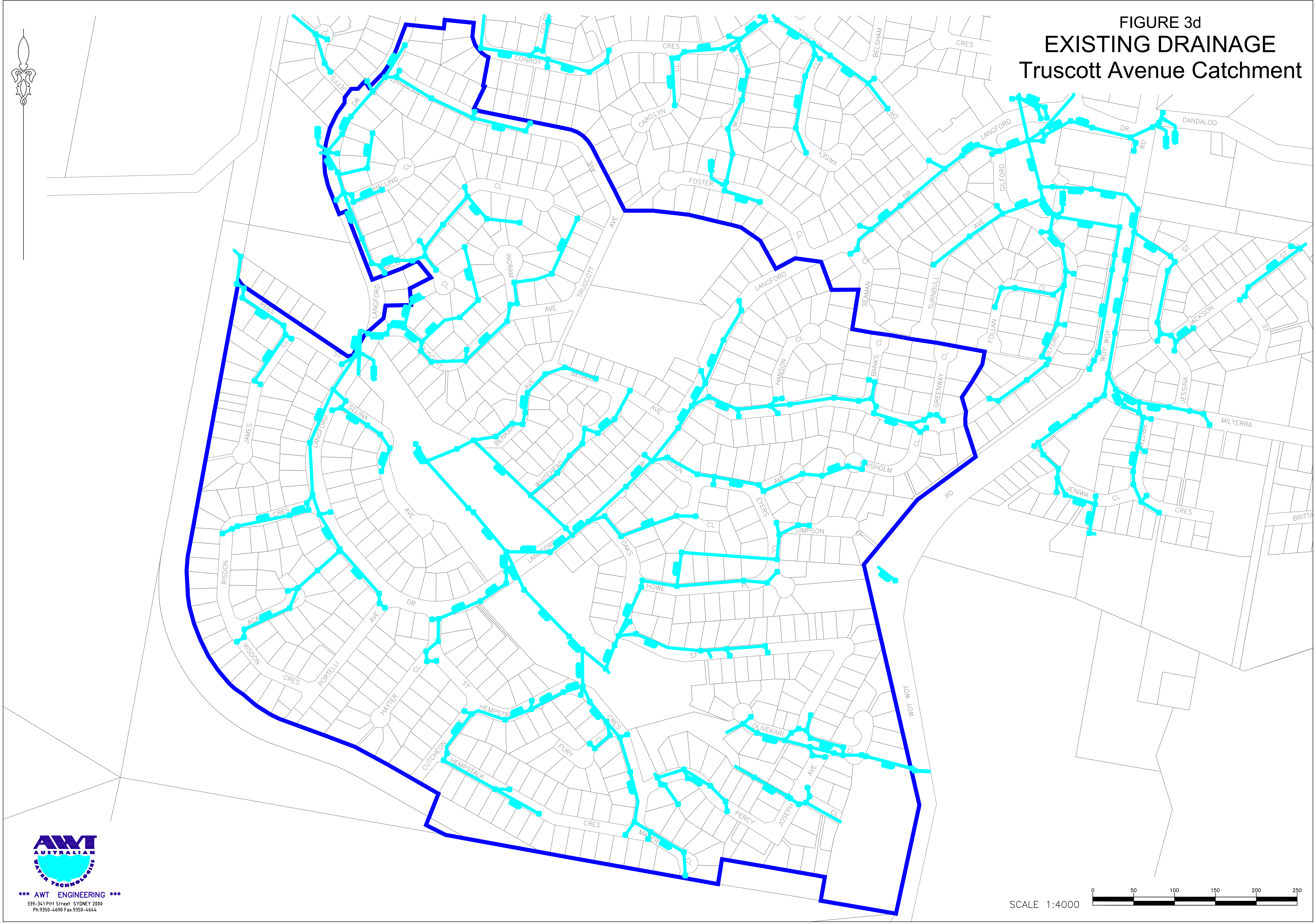

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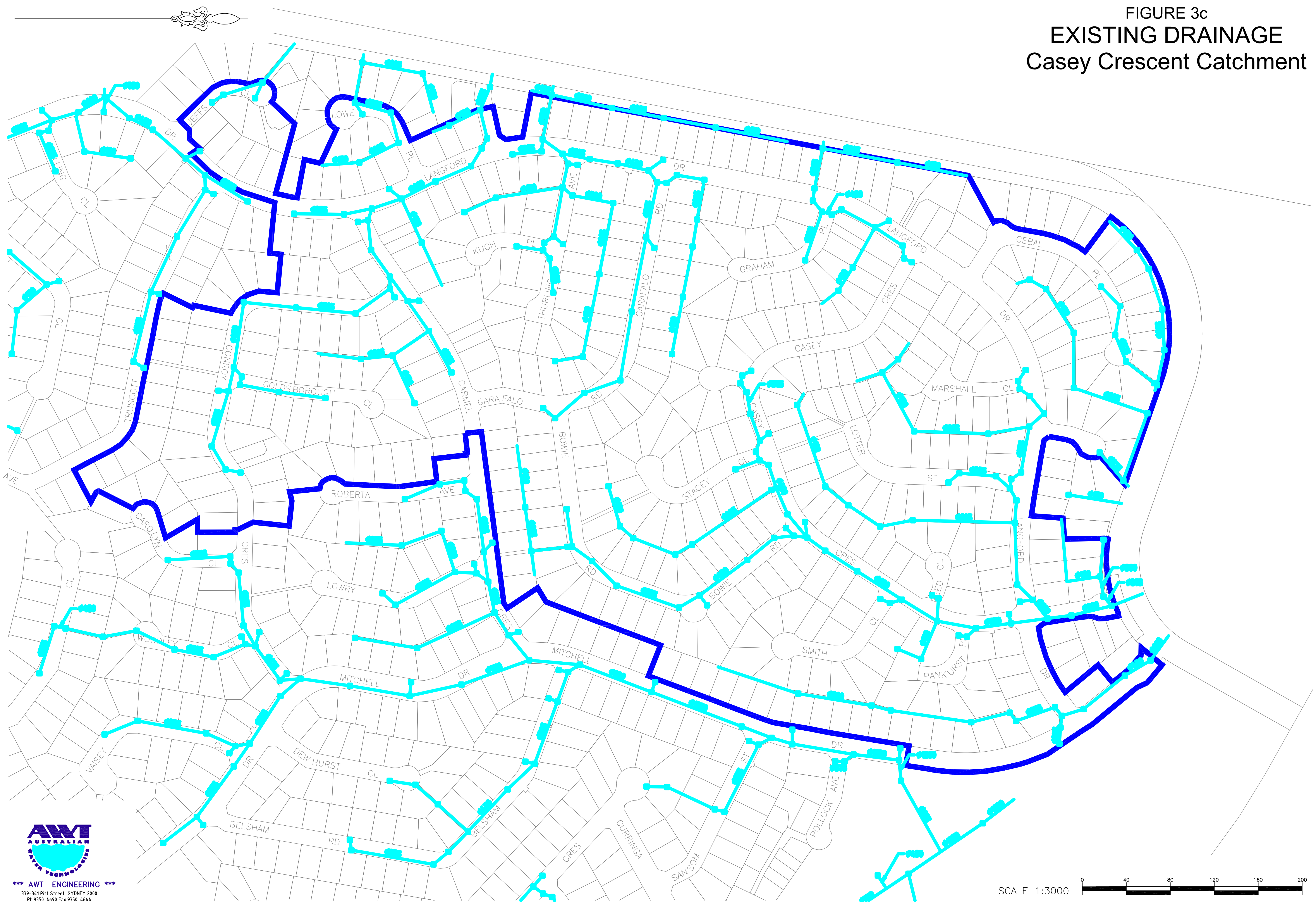
FIGURE 3c
EXISTING DRAINAGE
Casey Crescent Catchment



SCALE 1:3000

0 40 80 120 160 200

FIGURE 3b
EXISTING DRAINAGE
Belsham Road Catchment

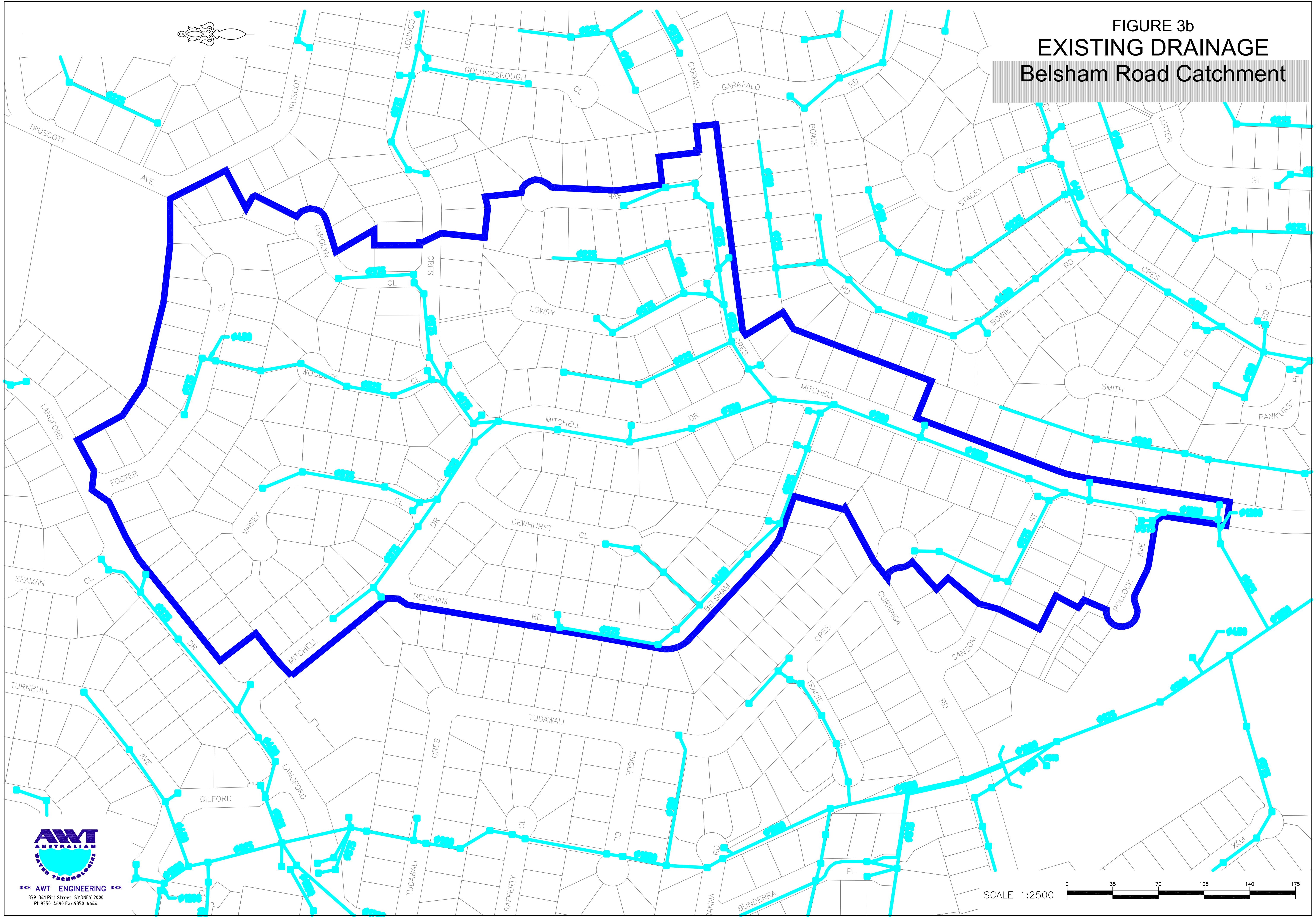


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FIGURE 3a
EXISTING DRAINAGE
Arunta Avenue Catchment

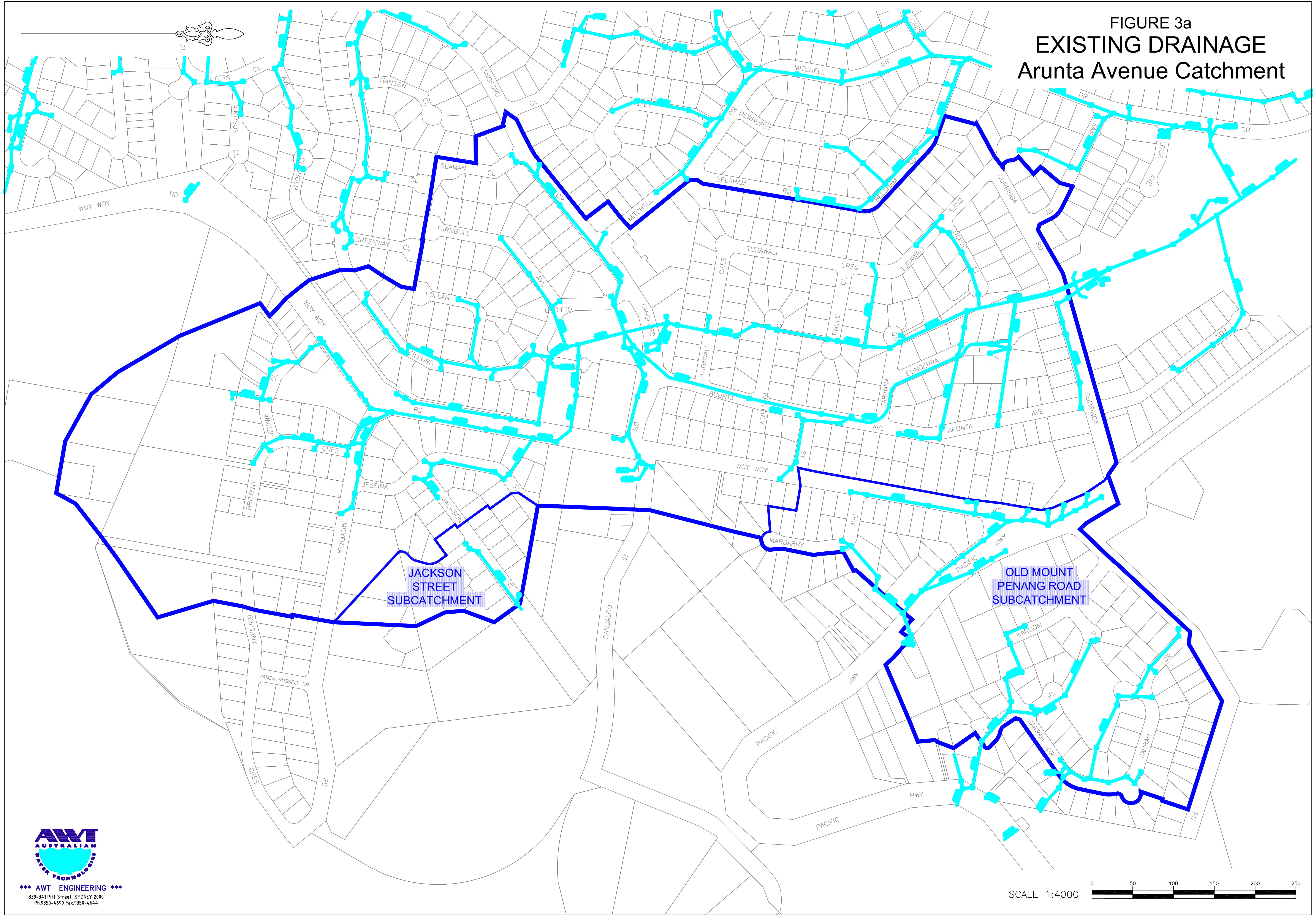

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FIGURE 9
SECTION 94 PLAN

ITEM	PROPOSED WORKS	PRIORITY	COST
1	Construct a retarding basin in Jarrah Park and acquire a drainage easement over the existing 525 mm pipe between Jarrah Drive and Pacific Highway.	HIGH	$50,000
2	Fix leaking pipe joints between Langford Drive and Taranna Road	HIGH	$140,000
3	Provide and maintain a Gross Pollutant Trap in the Recreational Reserve adjacent to Mitchell Drive.	MEDIUM	$352,000
4	Provide additional drainage in Foster Close.	HIGH	$25,000
5	Upgrade existing cut off drain and levee at rear of properties fronting Maher Close.	HIGH	$8,000
6	Replace existing 375 mm and 450 mm pipes across Woy Woy Road with a 900 mm pipe. Reconstruct pit on the western side of Old Woy Woy Road.	HIGH	$25,000
General Works			
*	Seal leaky pipe joints and bung holes (pipe lifting holes).	HIGH	$100,000
*	Trim all small diameter uPVC pipes intruding into the trunk drainage pipes. Remove rust from exposed reinforcement and paint with coal tar epoxy. Repair spalled concrete around reinforcement.	HIGH	$50,000
*	Repair cracked pipes with epoxy cement.	HIGH	$50,000
Investigation			$70,000
	TOTAL		$870,000

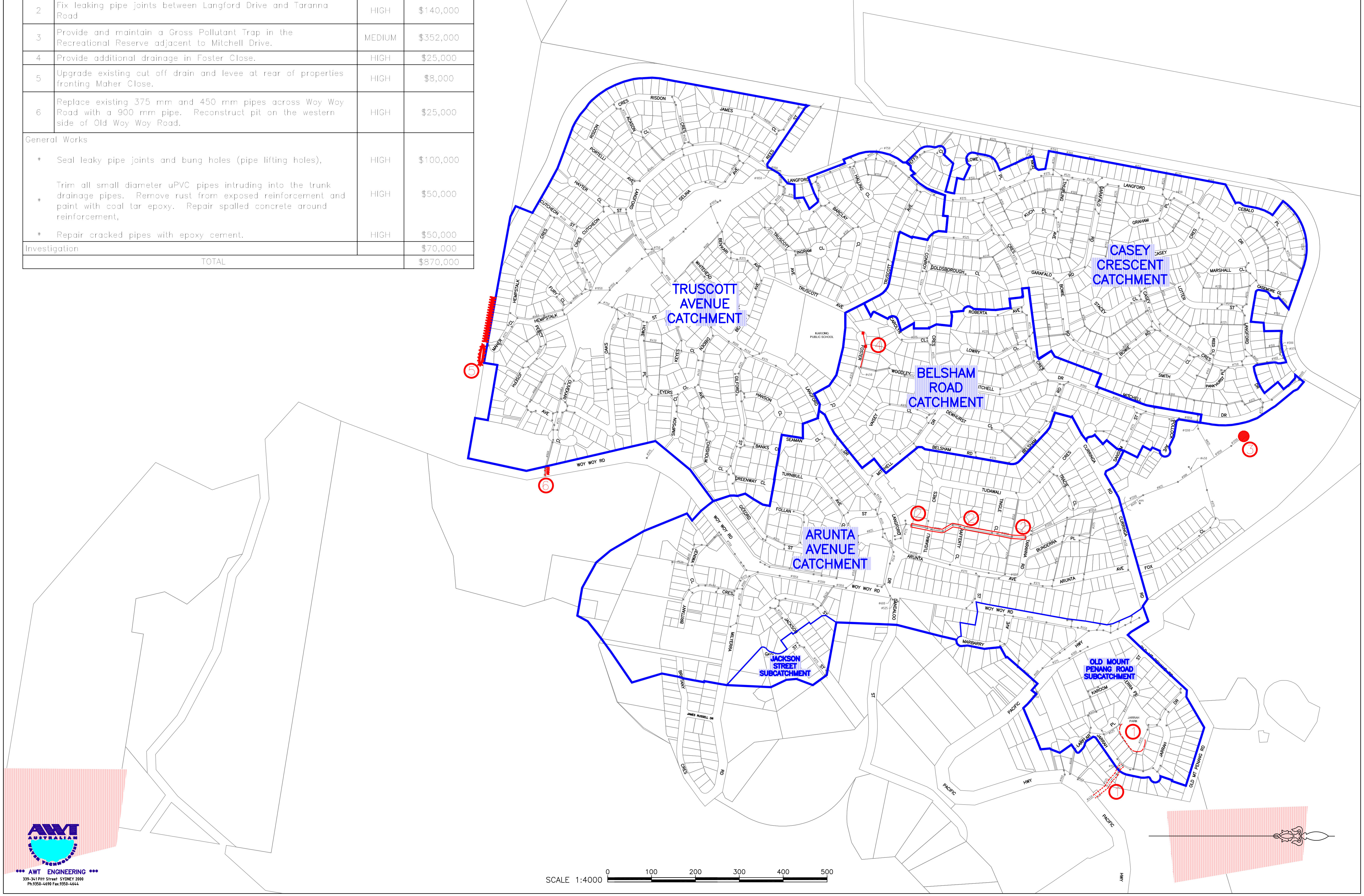
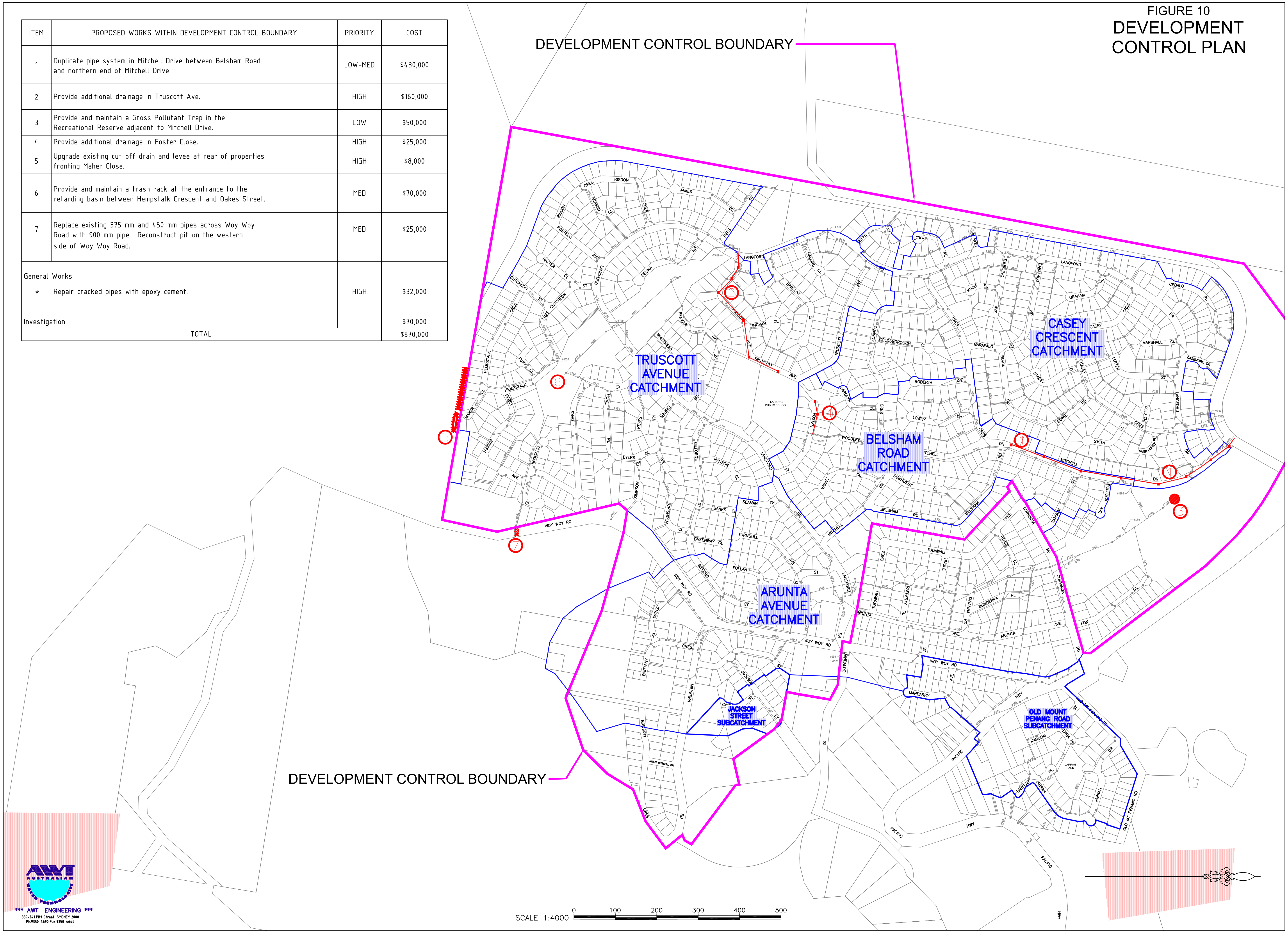


FIGURE 10
DEVELOPMENT CONTROL PLAN

ITEM	PROPOSED WORKS WITHIN DEVELOPMENT CONTROL BOUNDARY	PRIORITY	COST
1	Duplicate pipe system in Mitchell Drive between Belsham Road and northern end of Mitchell Drive.	LOW-MED	$430,000
2	Provide additional drainage in Truscott Ave.	HIGH	$160,000
3	Provide and maintain a Gross Pollutant Trap in the Recreational Reserve adjacent to Mitchell Drive.	LOW	$50,000
4	Provide additional drainage in Foster Close.	HIGH	$25,000
5	Upgrade existing cut off drain and levee at rear of properties fronting Maher Close.	HIGH	$8,000
6	Provide and maintain a trash rack at the entrance to the retarding basin between Hempstalk Crescent and Oakes Street.	MED	$70,000
7	Replace existing 375 mm and 450 mm pipes across Woy Woy Road with 900 mm pipe. Reconstruct pit on the western side of Woy Woy Road.	MED	$25,000
General Works * Repair cracked pipes with epoxy cement.		HIGH	$32,000
Investigation			$70,000
TOTAL			$870,000



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