ATTACHMENT 5 – Water Management Strategy (Draft)

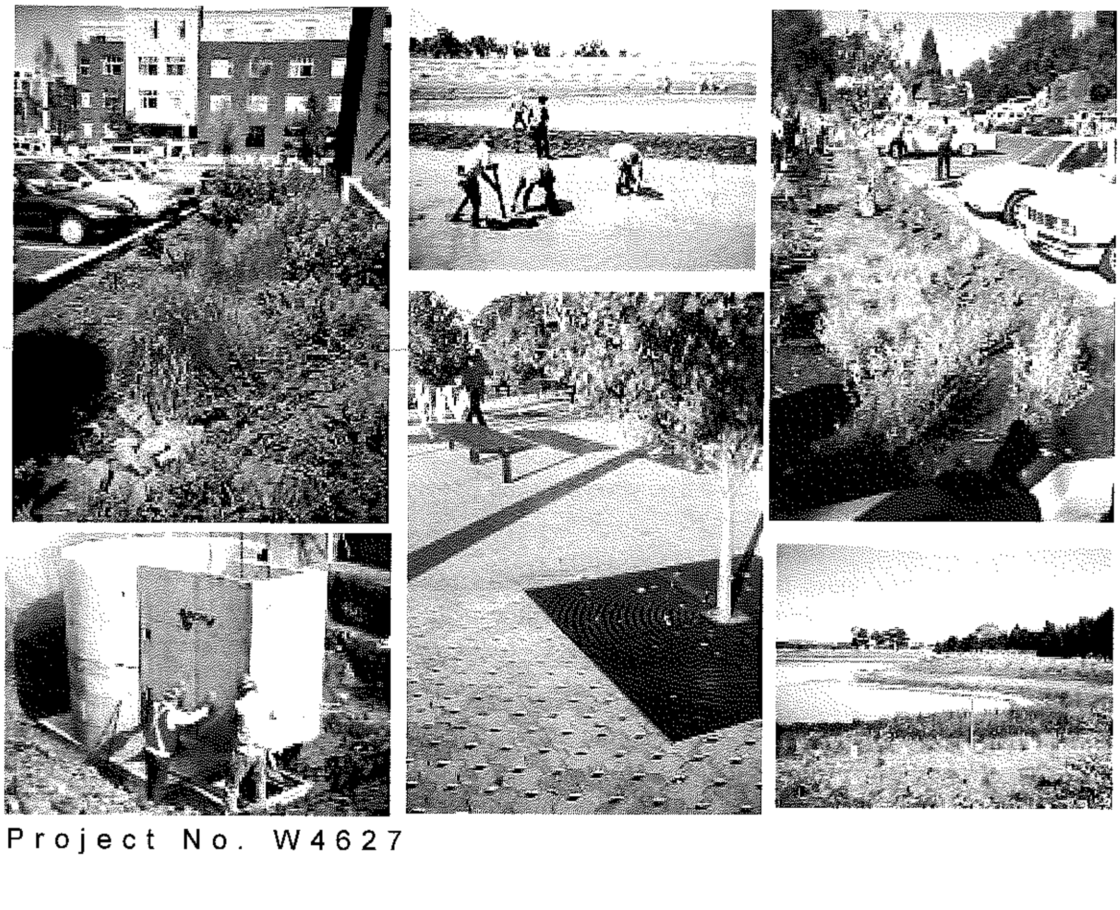
Cardno Willing

Engineering the Future

De Groot & Benson Pty Ltd

WATER SENSITIVE URBAN DESIGN CONCEPTS FOR MINARKA BRINNY GARDENS, MACKSVILLE

DRAFT REPORT
December 2004



Project No. W4627

DE GROOT & BENSON PTY LTD

Water Sensitive Urban Design Concepts for Minarka Brinny Gardens, Macksville

Draft Report

December 2004

Client	De Grrot & Benson Pty Ltd			
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As of 29 June 2001 Willing & Partners (NSW) Pty Ltd merged with the Cardno group and was re-named Cardno Willing (NSW) Pty Ltd. Any reference to Willing & Partners is to be read as a reference to Cardno Willing.

Cover Photographs
Views of water sensitive design techniques including (clockwise from top left) carpark with swale, planting macrophytes, Pervious paved car park draining to bio-swale, constructed wetland, pervious pavement and a gross pollutant trap.

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1 INTRODUCTION

Macksville Investments is the owner of the existing Lots 188 and 155 at Macksville in the Nambucca Local Government Area in NSW (referred to as the Site). The existing land is vacant with a mixture of open grassland and surrounded by bushland and wetland vegetation to the north and west and similar grassland to the south and east. It is proposed to redevelop the land for aged residential use comprising:

- Residential dwellings (around 220 units plus other community buildings);
- Additional Roads;
- Community Spaces (nominal);
- Wetland/Detention Basin Zone(s);
- Grasslands; and the
- Existing SEPP 14 Wetland.

A concept Site Based Stormwater Management Plan (SBSMP) has been prepared for the site. This Plan describes how stormwater runoff from the site could be managed in order to ensure drainage, flooding and stormwater quality objectives as defined by Nambucca Shire Council are met and minimising potential impacts upon the existing SEPP 14 wetlands to the north.

The concept SBSMP has been prepared to address the necessary requirements of the ***Nambucca Shire Council Local Environmental Plan 1995*** and the following guidelines:

- *State Environmental Planning Policy* (SEPP) 14 Coastal Wetlands;
- *State Environmental Planning Policy* (SEPP) 71 Coastal Protection; and
- *Australian Water Quality Guidelines for Fresh and Marine Waters*, Australian and New Zealand Environment and Conservation Council (ANZECC), 2000.

This SBSMP outlines the hydrological and water quality assessments that have been undertaken and describes a number of options for stormwater management for the proposed development.

2 SITE CHARACTERISTICS

The Site is accessed from Coronation Road at Macksville, South of Nambucca Heads (refer Figure 1). The 57.3 ha site is known as part lot DP 755537, Lots 188 and 155, Parish of Bowra, County of Raleigh.

The site is bounded by Lots 151 and 154 to the south, with SEPP 14 Coastal Wetlands (No 384) consisting part of Lot 155 to the north. The existing site is relatively steep consisting of several ridgelines. Levels vary from about 2 m AHD to 30 m AHD. There are distinctive flow paths across the site with drainage flowing north toward the wetlands. There is bushland vegetation located to the west of the site and a dam and buildings to the east bounded by Taylors Arm a tributary of the Nambucca River. The existing vegetation, terrain and soils are indicated in **Plates 1,2,3,4** and **5** and **Figure 2**.

The site is located on sandy clay soils.

2.1 SEPP 14 Coastal Wetlands

The SEPP 14 Coastal Wetlands Policy has been made under the *Environmental Planning and Assessment Act 1979* to ensure that wetlands are preserved and protected in the environmental and economic interest of the State. The wetlands to the north are protected and listed as SEPP 14 Wetlands. . The proposed development has the potential to impact on these wetlands by increasing the rate and magnitude of runoff and to increase the export of pollutants to the wetland.

Wetlands are ecologically, economically and socially important, often being cited as amongst the most productive ecosystems on Earth. These wetlands exist as multiple value systems providing many and varied services and function. A transitional zone between terrestrial and aquatic environments becoming a refuge in times of drought, able to support plants and animals not found elsewhere. Approximately 800 species of flora and fauna exist in wetlands of NSW. Important breeding and nursery areas are provided by wetlands; buffer zones for runoff, including sediment, nutrients, contaminants and drainage impacts. Wetlands detain floodwaters, reducing downstream flood peaks that have the potential to cause erosion and flood damage. This also improves water quality downstream.

Wetlands also provide great locations for educational and scientific research of such subjects as biology, ecology and past ecosystems and climate sequences.

2.2 SEPP 71 Coastal Protection

SEPP 71 Coastal Protection Policy has been made under the *Environmental Planning and Assessment Act 1979* to ensure that development in the NSW coastal zone is appropriate and suitably located. This Policy also provides a clear development assessment framework and a consistent strategic approach to coastal planning and management.

The 1997 Coastal Policy sets out the direction for management, planning and conservation of the coastal zone in NSW. SEPP 71 supports this policy. It is required under SEPP 71 that consent not be granted for specific types of subdivision development in the coastal zone unless there is an adopted master plan or the Minister for Planning has waived the need for a master plan.

A consent authority must not determine a development application (DA) on land to which SEPP 71 applies unless it has taken into account the provision of an adopted master plan, in accordance with this SEPP (clause 17).

3 DEVELOPMENT PROPOSAL

The proposal provides a conventional internal road system to service the 220 units, other community buildings, community parks and sporting facilities. The indicative layout of the proposed development is given in **Figure 3**.

The proposed residential buildings, internal road system public reserve and upstream catchment either drain directly into the existing wetland (Subcatchments 1, 2 and 3) or drain indirectly into the existing wetland (Subcatchment 4). Future planning requirements with respect to water quantity management that will come into force by July 2005 will require a significant saving of potable water in new dwellings through the installation of water efficient appliances, re-use of rainwater and/or the re-use of greywater.

It is anticipated that the future planning requirement (BASIX) will be met by installing water efficient appliances and a rainwater tank (say 3 kL) for each dwelling.

The proposed dwellings and internal access roads, in association with increased hardstand areas around the periphery of the dwellings will serve to increase the impervious area of the site and as such increase stormwater runoff volumes and peak discharge levels. This resultant effect is proposed to be managed by implementing an integrated stormwater management scheme comprising flood retardation in combination with measures to improve stormwater quality.

4 WATER MANAGEMENT STRATEGY

Hydrological and water quality assessments were undertaken to guide the formulation of a concept water management strategy for the Minarka Brinny Gardens based on the principles of water sensitive urban design. These assessments were undertaken on a subcatchment by subcatchment basis. The measures that have been assessed to manage stormwater quantity and quality and for water reuse are discussed below.

4.1 Water Management Objectives

Drainage and Flooding

The objectives for drainage and flooding include:

- All building development is to be at least 0.5 m above the 100 Yr ARI flood level of 3.8 m AHD to minimise any potential flood impacts of the development;
- Nuisance flooding of roads and dwellings is to be avoided,
- Depths and velocities of overland flows are to be kept to safe levels below accepted industry safety criteria; and
- Peak flows rates in events up to the 100 yr ARI flood after development are to be no greater than peak flows under existing conditions in order to protect the downstream ecosystem.

Water Quality

The objective for stormwater quality is to:

- Reduce post-development pollutant exports to levels no greater than existing conditions.

Water Re-use

The objective for water re-use is to:

- Achieve significant savings of potable water in accordance with the requirements of BASIX that will come into operation on 1 July 2005

4.1 Water Management Measures

Drainage and Flooding

In view of the existing slopes and the proposed road layout the concept for local drainage is to collect convey stormwater on the uphill side of each road and to convey it to major drainage corridors that are generally located in the valley of each subcatchment. Stormwater could be collected and conveyed to these drainage corridors by:

- Traditional kerb, gutter, pits and pipes;
- Swales; or
- Bio-swales

A decision on the preferred method to collect and convey stormwater to the major drainage corridors will be guided by the volume of cut and fill that would be required to construct each option and the slopes of these drainage lines.

The aim of the major drainage corridors is to convey up to 100 yr ARI runoff to the subcatchment outlets. Stormwater could be collected and conveyed to the subcatchment outlets by:

- Constructed watercourse;
- Swales; or
- Bio-swales

Calculations reveal, however, that the steep fall of the land at the low point of the catchment can result in unacceptably high velocities in a constructed watercourse. In order to maintain the depth and velocity of flows in a constructed watercourse within acceptable limits, a series of cascade drop structure would need to be constructed. A sketch of a typical cascade structure is given in **Figure 5**. The cascade structure allows lower grades to be specified for the constructed watercourse and acts to dissipate energy of the runoff. These structures have the added benefit that they entrain air through the water as it cascades down the structure. This increases the Dissolved Oxygen in the water column resulting in water quality improvements.

The available measures to ensure that peak flows rates in events up to the 100 yr ARI flood after development are no greater than peak flows under existing conditions include:

- On-Site Detention (OSD); and/or;
- Detention basins

An increasing number of Councils are adopting on-site retention (OSR) or detention (OSD) policies to stop current flooding and drainage problems from growing. Detention policies require that any extra runoff generated by new developments or redevelopments be temporarily stored within the site and released at a controlled rate. The allowable rate of discharge is set so that there is no increase in flood flows in all storms up to and including the 100 Yr ARI flood at all downstream locations.

While OSD is one way that the increases in the peak rate of surface runoff due to increased impervious surfaces could be addressed, the topography of the site would pose a significant challenge for the capture of all site runoff in an OSD device.

Detention basins temporarily store stormwater runoff and release it into the downstream drainage system at a controlled rate to reduce the peak flow in the downstream system. The site conditions are suited to the construction of detention basins on the flatter land at the subcatchment outlets.

Water Quality

The available measures to reduce post-development pollutant exports to levels no greater than existing conditions include:

- Gross pollutant traps;
- Bio-swales; and/or;
- Wetlands
- Ponds

A wide range of structural measures are now available to capture gross pollutants including:

• Enviropod®	Pit inserts that trap sediment and gross pollutants with provision for overflow into the piped drainage system.
• Baramy® Trap	A trap with an inclined screen that filters stormwater - it requires a vertical drop in height for best results. A Baramy Trap has been installed at Avenue Rd, Mosman.
• Fishnet® (Net-tech) Trap	Device comprises a mesh bag that is fitted over the end of a pipe - when the bag is full it detaches from the pipe and is sealed ready to be picked up and emptied. A Net-tech trap can also be viewed at Avenue Rd, Mosman.
• CDS® Trap	Consists of a stainless steel perforated separation plate that is installed in a hydraulically balanced chamber. Solid pollutants are trapped by a mild vortex action and are retained in a central sump for later removal. Examples can be seen at Cowles Rd Mosman.
• Ecosol® Traps	Include a range of devices ranging from in-pit baskets to units that can capture gross pollutants, sediment and oil and grease eg. an RSF 4000 trap.
• Humeceptor® Trap	An in-line device that deflects low flows into a baffled sump that captures oil and sediment.

- Humeguard® Trap — An on-line trap that comprises a specially shaped (floating) boom which deflects floating material into an adjacent holding chamber. An example of this trap can be seen at Roselands Shopping Centre car park, Roselands.
- Cleansall® Trap — Consists of one or more stainless steel perforated baskets placed in a hydraulically balanced chamber. Stormwater is deflected into the chamber and is filtered through the baskets.
- Downstream Defender® Trap — Is a vortex-type treatment device designed to capture settleable solids, floatables, oils and grease from stormwater runoff.

The strategy for trapping of gross pollutants will be guided by the strategy adopted to treat stormwater runoff. If bio-swales are constructed to collect and convey stormwater to the major drainage corridors then these swales would need to include provision for a grass filter to capture coarse sediment. If bio-swales are only constructed within the major drainage corridors and kerb, gutter, pits and pipes are constructed to convey local runoff to the major drainage line then either Enviropods could be installed in all pits or small GPTs installed at each pipe outlet. If wetlands are constructed near the subcatchment outlets then a single larger GPT could be constructed upstream of the wetland.

Bio-swales can provide efficient treatment of stormwater through fine filtration, extended detention and some biological uptake. They appear to be very efficient at removing nitrogen. Bio-swales are not infiltration systems rather they slowly convey stormwater to downstream systems without losing water to surrounding soils.

Wetlands are shallow water bodies that improve stormwater quality by filtering stormwater through aquatic vegetation and through the settling of solids.

Ponds are deeper water bodies with open water zones that improve stormwater through the settling of solids and filtering stormwater through fringing aquatic vegetation. Ponds are less suited to this site than shallow wetlands because of the likelihood that any significant excavation in the lower lying land near the subcatchment outlets would encounter acid sulphate soils. Consequently the water quality assessments only considered bio-swales and constructed wetlands.

Water Re-use

The available measures to achieve significant savings of potable water include:

- water efficient appliances;
- rainwater tanks; and
- greywater re-use

It is proposed that the domestic (black) waste water will be connected to Council's sewer reticulation system while domestic grey water (bathroom and laundry) may be available for re-use. It is anticipated that the BASIX requirements that will come into operation on 1 July 2005 can be met by installing water efficient appliances and a rainwater tank (say 3 kL) for each dwelling and that grey water re-use will not need to be implemented.

4.3 Subcatchment 1

Site Constraints

The constraints on the water management options include the:

- topography of the subcatchment which does not offer any opportunities to construct a detention basin in its lower reaches

Drainage and Flooding

The planned development is orientated with the ridgeline between Subcatchment 1 and 2. It is anticipated that the major drainage line would be constructed parallel to the western edge of the development in the form of an open swale or a bio-swale. Local runoff could be conveyed to the major drain by either local swales or piped drainage.

In view of the topographic constraints it is anticipated that it would be necessary to construct a diversion drain at the northern end of Subcatchment 1 to divert flood flows from Subcatchment 1 into the planned detention basin in Subcatchment 2.

Water Quality

The strategy for trapping of gross pollutants will be guided by the strategy adopted to treat stormwater runoff. If swales are constructed to collect and convey stormwater to the major drainage line then these swales would need to include provision to capture coarse sediment. If a bio-swale is constructed within the major drainage line and kerb, gutter, pits and pipes are constructed to convey local runoff to the major drainage line then either Enviropods could be installed in all pits or small GPTs installed at each pipe outlet.

The required size of a bio-swale (Option 1A) to treat runoff has been assessed (refer **Appendix B**) and is summarised in **Table 2.** This bio-swale would range in width from 3.0 m to 7.0 m at the downstream subcatchment outlet (refer **Figures 3** and **4**). The topography of Subcatchment 1 could pose a challenge for constructing a bio-swale up to 7.0 m wide.

The other alternative is to divert all runoff from Subcatchment 1 via a diversion drain into an enlarged wetland at the outlet of Subcatchment 2 (Option 2C).

Water Re-use

It is anticipated that the future planning requirement (BASIX) will be met by installing water efficient appliances and a rainwater tank (say 3 kL) for each dwelling.

4.4 Subcatchment 2

Site Constraints

The constraints on the water management options include the:

- topography of the subcatchment; and
- the likely occurrence of acid sulphate soils in the flatter land adjoining the SEPP 14 wetland.

Drainage and Flooding

In view of the existing slopes and the proposed road layout the concept for local drainage is to collect convey stormwater on the uphill side of each road and to convey it to major drainage corridors that are generally located in the valley of each subcatchment. Stormwater could be collected and conveyed to these drainage corridors by:

- Kerb, gutter, pits and pipes;
- Swales; or
- Bio-swales

A decision on the preferred method to collect and convey stormwater to the major drainage corridors will be guided by the volume of cut and fill that would be required to construct each option and the slopes of these drainage lines.

It is anticipated that the major drainage line would be constructed broadly along the existing drainage line in the form of a bio-swale or an open constructed watercourse. The alignment of this drainage corridor is shown in **Figure 3**. The indicative width of the corridor varies from approximately 9.0m at the downstream discharge point to 6.0 m at the southern edge of development (refer **Figure 4**). In order to maintain the depth and velocity of flows in a constructed watercourse within acceptable limits, a series of cascade drop structure would need to be constructed. A sketch of a typical cascade structure is given in **Figure 5**. The cascade structure allows lower grades to be specified for the constructed watercourse and acts to dissipate energy of the runoff.

The required size of a detention basin that would retard runoff from Subcatchments 1 and 2 has been assessed (refer **Appendix A**) and is summarised in **Table 1**.

Water Quality

The strategy for trapping of gross pollutants will be guided by the strategy adopted to treat stormwater runoff. If bio-swales are constructed to collect and convey stormwater to the major drainage line then these swales would need to include provision for a grass filter to capture coarse sediment. If bio-swales are only constructed within the major drainage line and kerb, gutter, pits and pipes are constructed to convey local runoff to the major drainage line then either Enviropods could be installed in all pits or small GPTs installed at each pipe outlet. If a wetland is constructed near the subcatchment outlets then a single larger GPT could be constructed upstream of the wetland.

The required size of a bio-swale (Option 2A) to treat runoff has been assessed (refer **Appendix B**) and is summarised in **Table 2** (refer also **Figures 3** and **4**). The topography of Subcatchment 2 could pose a challenge for constructing a bio-swale within the major drainage corridor.

The required sizes of a wetland (Option 2B) to treat runoff from Subcatchment 2 alone or a wetland to treat runoff from Subcatchments 1 and 2 have been assessed (refer **Appendix B**) and are summarised in **Table 2** (refer also **Figure 3**).

In view of the potential difficulties with constructing a bio-swale within the major drainage corridor the preferred approach would be to construct a wetland within the proposed detention basin. If bio-swales are constructed to collect and convey stormwater to the major drainage line then the size of the wetland could be reduced.

Water Re-use

It is anticipated that the future planning requirement (BASIX) will be met by installing water efficient appliances and a rainwater tank (say 3 kL) for each dwelling.

4.5 Subcatchment 3

Site Constraints

The constraints on the water management options include the:

- topography of the subcatchment; and
- the likely occurrence of acid sulphate soils in the flatter land adjoining the SEPP 14 wetland.

Drainage and Flooding

In view of the existing slopes and the proposed road layout the concept for local drainage is to collect convey stormwater on the uphill side of each road and to convey it to major drainage corridors that are generally located in the valley of each subcatchment. Stormwater could be collected and conveyed to these drainage corridors by:

- Kerb, gutter, pits and pipes;
- Swales; or
- Bio-swales

A decision on the preferred method to collect and convey stormwater to the major drainage corridors will be guided by the volume of cut and fill that would be required to construct each option and the slopes of these drainage lines.

It is anticipated that the major drainage line would be constructed broadly along the existing drainage line in the form of a bio-swale or an open constructed watercourse. The alignment of this drainage corridor is shown in **Figure 3**.

The indicative width of the corridor varies from approximately 7.0m at the downstream discharge point to 5.0 m at the southern edge of development (refer **Figure 4**). In order to maintain the depth and velocity of flows in a constructed watercourse within acceptable limits, a series of cascade drop structure would need to be constructed. A sketch of a typical cascade structure is given in **Figure 5**. The cascade structure allows lower grades to be specified for the constructed watercourse and acts to dissipate energy of the runoff.

The required size of a detention basin that would retard runoff from Subcatchment 3 has been assessed (refer **Appendix A**) and is summarised in **Table 1**.

Water Quality

The strategy for trapping of gross pollutants will be guided by the strategy adopted to treat stormwater runoff. If bio-swales are constructed to collect and convey stormwater to the major drainage line then these swales would need to include provision for a grass filter to capture coarse sediment. If bio-swales are only constructed within the major drainage line and kerb, gutter, pits and pipes are constructed to convey local runoff to the major drainage line then either Enviropods could be installed in all pits or small GPTs installed at each pipe outlet. If a wetland is constructed near the subcatchment outle, then a single larger GPT could be constructed upstream of the wetland.

The required size of a bio-swale (Option 3A) to treat runoff has been assessed (refer **Appendix B**) and is summarised in **Table 2** (refer also **Figures 3** and **4**). The topography of Subcatchment 3 could pose a challenge for constructing a bio-swale within the major drainage corridor.

The required size of a wetland (Option 3B) to treat runoff from Subcatchment 3 has been assessed (refer **Appendix B**) and are summarised in **Table 2** (refer also **Figure 3**).

In view of the potential difficulties with constructing a bio-swale within the major drainage corridor the preferred approach would be to construct a wetland within the proposed detention basin. If bio-swales are constructed to collect and convey stormwater to the major drainage line then the size of the wetland could be reduced.

Water Re-use

It is anticipated that the future planning requirement (BASIX) will be met by installing water efficient appliances and a rainwater tank (say 3 kL) for each dwelling.

4.6 Subcatchment 4

Site Constraints

The constraints on the water management options include the:

- topography of the subcatchment; and the
- existing pond/wetland located in the eastern edge of the subcatchment.

Drainage and Flooding

The planned development is orientated parallel to the ridgeline between Subcatchments 3 and 4. It is anticipated that the major drainage line would be constructed parallel to the northern and southern edges of the development in the form of bio-swales. Local runoff could be conveyed to the major drain by either local swales or piped drainage.

In order to maintain the depth and velocity of flows in the main drain within acceptable limits, it is likely a series of cascade drop structure would need to be constructed. A sketch of a typical cascade structure is given in **Figure 5**. The cascade structure allows lower grades to be specified for the major drain and acts to dissipate energy of the runoff.

The existing wetland area offers an opportunity to construct a low (0.8 m) high embankment to create detention storage as well. The required size of a detention basin that would retard runoff from Subcatchment 4 has been assessed (refer **Appendix A**) and is summarised in **Table 1**.

Water Quality

The strategy for trapping of gross pollutants will be guided by the strategy adopted to treat stormwater runoff. If swales are constructed to collect and convey stormwater to the major drainage line then these swales would need to include provision to capture coarse sediment. If kerb, gutter, pits and pipes are constructed to convey local runoff to the major drainage line(s) then either Enviropods could be installed in all pits or small GPTs installed at each pipe outlet.

The required size of a bio-swale (Option 4A) to treat runoff has been assessed (refer **Appendix B**) and is summarised in **Table 2.** This bio-swale would range in width from 3.0 m to 5.0 m at the downstream subcatchment outlet (refer **Figures 3** and **4**).

It is not intended to use the existing wetland to treat local runoff rather it is proposed to treat runoff prior to its discharge into the existing wetland.

Water Re-use

It is anticipated that the future planning requirement (BASIX) will be met by installing water efficient appliances and one or more larger rainwater tanks with are equivalent to say 3 kL of storage for each equivalent dwelling.

4.7 Erosion and Sediment Control

During the construction phase, the potential exists for significant increases in the amount of pollutants, particularly sediment, exported from the site. During this period, an Erosion and Sediment Control Plan would be required as part of the overall Environmental Management Plan prepared for the construction phase.

The erosion and sediment control plan for the site would be completed in accordance with the NSW Department of Housing *'Managing Urban Stormwater'* 4th ed (2004) manual, NSW EPA *'Managing Urban Stormwater: Treatment Techniques'* (1998) and NSW EPA's guidelines on *'Bunding and Spill Management'*.

4.8 Indicative Cost Estimates

Indicative cost estimates for the various stormwater management measures are summarised in **Appendix C**. These estimate of costs were prepared on an indicative basis only and for comparison purposes and no liability for the accuracy of the estimates is accepted. If de Grrot & Benson intends to rely on these estimates for budgeting purposes then it is recommended more detailed analysis and sizing of the measures be undertaken and that cost estimates be prepared independently by a qualified Quantity Surveyor. (It should be noted that Cardno Willing is not covered by its insurers for the provision of cost estimates).

5 CONCLUSIONS

A range of options for a water management strategy for the proposed development have been assessed and sized with a view to achieving a range of objectives for water quantity, water quality and water re-use.

The implementation of a strategy based on the various measures that have been considered will protect the adjoining SEPP 14 wetlands from the potential impacts of the development as well as complying with requirements of SEPP 71, having addressed particular issues in Clause 20(2) in relation to the conservation of water quality.

It therefore concluded that the proposed development when undertaken in conjunction with the identified stormwater management measures would have minimal impact on SEPP 14 wetland and the external environment.

6 REFERENCES

Australian and New Zealand Environment and Conservation Council (1992) *Australian Water Quality Guidelines for Fresh and Marine Waters.*

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Nambucca Shire Council (1995) *Nambucca Shire Council Local Environmental Plan.*

A HYDROLOGY

A.1 Aims

The aims of the hydrological analyses were to estimate the:

- 1 yr ARI, 10 yr ARI and 100 yr ARI flood hydrographs at the outlets to each subcatchment under existing conditions and future conditions (without controls);
- concept size and outlet configuration for retarding basins to limit peak flows after development to no greater than peak flows under existing conditions.

A.2 Rainfall/Runoff Modelling

Estimates of runoff from the East Bandiana catchments during design storms were obtained using the XP-RAFTS rainfall/runoff model.

The XP-RAFTS Model

The features offered by XP-RAFTS which were particularly suited to the study include:

(i) a link-node approach based on subcatchments (each comprising 10 sub-areas) joined by flood routing "links";
(ii) the option to calibrate each subcatchment separately within a watershed if required;
(ii) global or catchment dependent input of rainfall;
(iii) specific features for the modelling of urbanising and urban catchments including:
  - direct inclusion of the "degree of urbanisation", U, in the storage-delay equation for subcatchment flow routing,
  - optional separate routing of runoff from pervious and impervious surfaces for improved modelling of runoff from urban catchments,
  - optional modification of the storage-delay equation to represent additional subcatchment storage in older urban areas with limited provision for overland flows
(iv) subcatchment roughness factor to characterise the full range of catchment conditions including forested catchments;
(v) a range of rainfall loss models including:
  - initial and continuing rainfall losses,
  - proportional rainfall losses,
  - full ARBM soil water balance model.
(vi) separate routing of flows using either a time lag or routing of flows using a Muskingum-Cunge flood routing procedure with cross sectional data;
(viii) direct export of hydrographs to the XP-SWMM flood routing model; and
(ix) a graphical user interface with an embedded decision support system.

The use of the XP-RAFTS model for developed catchments is widespread and was further validated in the study entitled "Drainage Design Practice for Land Development in the ACT - Part II: Flood Estimation Procedures" undertaken for the Department of Urban Services in the ACT.

Model Description and Parameters

Based upon the existing stormwater drainage network and the natural topography, a simple XP-RAFTS network was established for each subcatchment ie. Subcatchments 1 to 4 (refer **Figure 3**).

The approach which was adopted to the estimation of rainfall excess and its runoff was to subdivide each subcatchment into estimated pervious and impervious areas and to estimate the rainfall excess for both surfaces and to separately route the runoff from each surface to the subcatchment outlet ie. a "split" subcatchment modelling approach.

Imperviousness

The area of impervious surfaces within each subcatchment was based on the surface types present in each subcatchment.

Vector Average Slope

The vector average slope for each subcatchment was estimated from the available information. The slopes varied from around 3% to 10%.

Surface Roughness

For each subcatchment, a surface roughness was entered for each surface type. The adopted surface roughness values were 0.025 for impervious surfaces and 0.06 for pervious surfaces.

A.3 Design Flood Estimates

1 yr ARI, 10 yr ARI and 100 yr ARI flood hydrographs at the outlets to each subcatchment under existing conditions and future conditions (without controls). The design flood modelling approach is outlined as follows.

Rainfall

Rainfall intensities and temporal patterns for the synthetic design storms were derived from "Australian Rainfall and Runoff" (IEAust., 1998). Rainfall - Intensity - Duration (IFD) tables were generated for a representative location in the catchment. This table is presented in **Table A.1**. The input parameters were:

Table A.1
Rainfall Intensities (mm/hr) for Macksville, NSW

Duration		Average Storm Recurrence Interval (years)						
		1	2	5	10	20	50	100
5	Mins	107	137	172	192	219	254	281
6		101	129	162	181	206	239	265
7		95	121	153	171	195	227	251
8		90	115	145	163	186	216	240
9		86	110	139	156	178	207	229
10		82	105	133	149	171	199	220
11		79	101	128	144	164	192	212
12		76	98	123	138	159	185	205
13		73	94	119	134	153	179	199
14		71	91	116	130	149	174	193
15		69	88	112	126	144	169	187
16		67	86	109	122	140	164	182
17		65	83	106	119	137	160	177
18		63	81	103	116	133	156	173
20		60	77	98	110	127	148	165
25		54	69	88	99	114	134	149
30		48.7	63	80	91	104	123	136
40		41.7	54	69	78	90	106	118
45		39.1	50	65	74	85	100	111
50		36.8	47.5	61	70	80	95	106
55		34.9	45	58	66	76	90	100
60		33.2	42.9	55	63	73	86	96
75		29	37.5	48.7	55	64	76	85
90		25.9	33.6	43.7	49.8	58	68	76
2	Hours	21.7	28.2	36.8	42	48.8	58	65
3		16.9	21.9	28.8	32.9	38.4	45.6	51
4.5		13.1	17	22.5	25.8	30.1	35.9	40.4
6		10.9	14.2	18.9	21.7	25.4	30.3	34.2
9		8.47	11.1	14.8	17	20	23.9	27
12		7.08	9.27	12.4	14.4	16.9	20.2	22.9
18		5.59	7.34	9.9	11.5	13.5	16.3	18.4
24		4.72	6.2	8.41	9.78	11.5	13.9	15.8
36		3.69	4.86	6.64	7.75	9.18	11.1	12.6
48		3.07	4.06	5.57	6.52	7.74	9.4	10.7
60		2.65	3.5	4.83	5.66	6.74	8.2	9.35
72		2.33	3.09	4.27	5.02	5.98	7.29	8.33

${}^{1}I_{2}$	=	43.0	mm/h	${}^{1}I_{50}$	=	85.0	mm/h
${}^{12}I_{2}$	=	9.3	mm/h	${}^{12}I_{50}$	=	20.0	mm/h
${}^{72}I_{2}$	=	3.1	mm/h	${}^{72}I_{50}$	=	7.2	mm/h
F_{2}	=	4.37		F_{50}	=	16.50	

Skewness = 0.05

Rainfall Losses

Rainfall losses were determined using an initial loss/continuing loss model. The adopted rainfall loss rates are summarised in **Table A.2**.

Table A.2
Adopted Rainfall Losses for Design Floods

Surface Type	Initial Loss (mm)	Continuing Loss (mm/hr)
Impervious	1.0	0.0
Pervious	20	2.5

Retarding Basins

Concept retarding basins were sized for Subcatchments1 & 2, 3 and 4. In the case of Subcatchment 1 it was concluded that it would not be feasible to construct a retarding basin to mitigate the impacts on flood flows. Instead it was assessed that it would be preferable to construct a diversion drain at the northern end of Subcatchment 1 to convey runoff from subcatchment 1 into a concept basin located at the outlet of Subcatchment 2.

A concept basin was also located at the outlet to Subcatchment 3.

In the case of Subcatchment 4 it was assessed that it would be feasible to construct a low embankment around the existing wetland to allow it to also serve as a retarding basin.

Results

Analyses were undertaken for design flood events with rainfall durations ranging from 30 minutes to 18 hours. The estimated peak design flows for the 1 yr ARI, 10 yr ARI and 100 yr ARI design floods are summarised in **Table A.3**. The concept sizes of the three retarding basins are also identified.

Table A.3
Estimated Peak Flows (m3/s) for 1 yr ARI, 10 yr ARI and 100 yr ARI Design Floods

	1 yr ARI			
Subcatchment	Existing Peak flow (m^3/s)	Basin Peak inflow (m^3/s)	Basin Peak outflow (m^3/s)	Peak WL (m)
2	1.08 (12hr)	2.44 (1.5hr)	0.88 (9hr)	0.81 (9hr)
3	0.35 (12hr)	0.75 (1.5hr)	0.29 (9hr)	0.68 (9hr)
4	0.44 (12hr)	0.91 (1.5hr)	0.20 (9hr)	0.59 (9hr)

	10 yr ARI			
Subcatchment	Existing Peak inflow (m^3/s)	Basin Peak inflow (m^3/s)	Basin Peak outflow (m^3/s)	Peak WL (m)
2	3.03 (2hr)	5.80 (1.5hr)	2.41 (12hr)	1.30 (12hr)
3	1.10 (2hr)	1.85 (1.5hr)	0.68 (4.5hr)	1.13 (4.5hr)
4	1.45 (2hr)	2.33 (1.5hr)	1.00 (12hr)	0.70 (12hr)

	100 yr ARI			
Subcatchment	Existing Peak inflow (m^3/s)	Basin Peak inflow (m^3/s)	Basin Peak outflow (m^3/s)	Peak WL (m)
2	5.84 (2hr)	9.31 (1.5hr)	5.59 (2hr)	1.48 (2hr)
3	2.11 (2hr)	3.02 (1.5hr)	2.03 (2hr)	1.37 (2hr)
4	2.72 (2hr)	3.78 (1.5hr)	2.17 (2hr)	0.78 (2hr)

Summary of Concept Retarding Basin Properties

		Embankment		Outlets		
Subcatchment	Base Area (ha)	Side Slope	Height (m)	Primary Outlet RCP(s)	Secondary Spillway RL (m)	Secondary Spillway Width (m)
2	0.42	1 (V): 3 (H)	1.5	2 x 600 mm	1.2	12
3	0.13	1 (V): 3 (H)	1.5	1 x 600 mm	1.2	12
4	0.35	1 (V): 3 (H)	0.8	1 x 450 mm	0.6	15

B WATER QUALITY

B.1 Aims

The aims of the catchment based water quality modelling were to assess the:

- impacts of the proposed development on stormwater quality and pollutant exports to the SEPOP 14 wetland ; and to
- estimate the size of water quality treatment measures to reduce post-development pollutant exports to levels no greater than existing conditions.

B.2 The Modelling Approach

The modelling approach was to assemble a series of MUSIC models comprising a sub-daily rainfall-runoff model in conjunction with representative baseflow and stormflow event mean concentrations (EMCs).

The creation of the water quality model was undertaken in sequential steps as follows:

- pluviograph rainfall data was obtained for the Bellbrook rainfall station;
- the catchment was divided into subcatchments;
- areas of each subcatchment land use were determined;
- representative baseflow and stormflow event mean concentrations (EMCs) were reviewed and adopted;
- the rainfall/runoff models were run and the model parameters were adjusted to give representative runoff rates;
- various catchment models were assembled;
- the models were run to estimate pollutant exports under existing and future conditions (without any controls) and pollutant capture in the various measures that were considered.

Classification of Surface Types

The two land use categories that were modelled were Grazing and Urban.

Rainfall / Runoff Modelling

Rainfall

Rainfall data was obtained from the Bureau of Meteorology Office. Six (6) minute rainfall for the period 1956 to 2004 was obtained from the Bellbrook rainfall gauge (Station No 59000) located approximately 40 km from the site.

Daily rainfall was also obtained for Bellbrook and Macksville (Station No. 59018) to allow a comparison of annual rainfalls.

Evaporation

Monthly pan evaporation rates recorded at Station 059040 at Coffs Harbour were adopted, and are summarised in **Table B.1.**

Table B.1
Adopted Average Daily Average Pan Evaporation at Coffs Harbour (mm)

Month	Evaporation (mm)	Month	Evaporation (mm)
January	201.5	July	83.7
February	165.0	August	111.6
March	161.2	September	144.0
April	123.0	October	173.6
May	89.9	November	186.0
June	75.0	December	201.5

Rainfall/runoff model

In the absence of direct calibration of the rainfall/runoff model against gauged runoff from the catchment, the rainfall/runoff model parameters were "calibrated" against representative annual volumetric runoff coefficients for each land use.

MUSIC parameters are summarised in **Table B.3.**

Non-Point Source Pollutant Modelling

Pollutant Exports

Non-point source pollutant loads were statistically generated from representative baseflow and stormflow event mean concentrations (EMCs). The adopted EMSs are given in **Table B.2**.

Table B.2
Adopted Average Daily Average Pan Evaporation at Coffs Harbour (mm)

Pollutant	Grazing		Urban	
	Baseflow	Stormflow	Baseflow	Stormflow
SS	25	200	12.6	158
TP	0.132	0.537	.151	.355
TN	1.19	3.89	2.09	2.63

Stormwater Treatment Measures

The stormwater treatment measures that were assessed using MUSIC included bio-swales and constructed wetlands. An existing pond/wetland in Subcatchment 4 was also modelled.

The adopted MUSIC parameters are given in **Table B.4**.

B.3 Results

The MUSIC models were run for the period January 1999 to December 2002 at 12 minute intervals to calculate to subcatchment runoff, pollutant exports and pollutant capture in the concept stormwater treatment measures. The period analysed was chosen on the basis that it included a range of rainfall years with an average for the three years that is similar to the long term average rainfall for Macksville.

The pollutants analysed were suspended solids, total nitrogen and total phosphorous.

The average annual runoff, pollutant loads and pollutant capture are summarised in **Table B.5**. The concept sizes of each of the stormwater treatment measures that were assessed are given in **Table B.6**.

The following conclusions were drawn from the results of the water quality modelling:

(i) Post-development pollutant exports can be reduced to levels no greater than existing conditions through a scheme comprising:
- Bio-swales only; or a
- Combination of bio-swales and constructed wetlands; and

(ii) Subject to any planned recreation facilities in the northern area of Subcatchment 2 the preferred approach would be to divert runoff from Subcatchment 1 into Subcatchment 2 and to treat the combined flows in a constructed wetland.

Table B.3 Adopted MUSIC Parameters

	Mixed Urban	Exist Grazing
Rainfall/Runoff Model Parameters		
Field Capacity (mm)	170	170
Pervious Area Infiltration Capacity coefficient - a	200	200
Pervious Area Infiltration Capacity exponent - b	1	1
Impervious Area Rainfall Threshold (mm/day)	1	1
Pervious Area Soil Storage Capacity (mm)	200	200
Pervious Area Soil Initial Storage (% of Capacity)	30	30
Groundwater Initial Depth (mm)	10	10
Groundwater Daily Recharge Rate (%)	25	25
Groundwater Daily Baseflow Rate (%)	5	5
Groundwater Daily Deep Seepage Rate (%)	0	0
Stormwater Pollutant Parameters		
Stormflow Total Suspended Solids Mean (log mg/L)	2.2	2.3
Stormflow Total Suspended Solids Standard Deviation (log mg/L)	0.32	0.31
Stormflow Total Suspended Solids Mean (mg/L)	158.5	199.5
Stormflow Total Suspended Solids Standard Deviation (mg/L)	2.09	2.04
Stormflow Total Suspended Solids Estimation Method	Stochastic	Stochastic
Stormflow Total Phosphorus Mean (log mg/L)	-0.45	-0.27
Stormflow Total Phosphorus Standard Deviation (log mg/L)	0.25	0.3
Stormflow Total Phosphorus Mean (mg/L)	0.35	0.54
Stormflow Total Phosphorus Standard Deviation (mg/L)	1.78	2.00
Stormflow Total Phosphorus Estimation Method	Stochastic	Stochastic
Stormflow Total Nitrogen Mean (log mg/L)	0.42	0.59
Stormflow Total Nitrogen Standard Deviation (log mg/L)	0.19	0.26
Stormflow Total Nitrogen Mean (mg/L)	2.630	3.890
Stormflow Total Nitrogen Standard Deviation (mg/L)	1.549	1.820
Stormflow Total Nitrogen Estimation Method	Stochastic	Stochastic
Baseflow Total Suspended Solids Mean (log mg/L)	1.1	1.4
Baseflow Total Suspended Solids Standard Deviation (log mg/L)	0.17	0.13
Baseflow Total Suspended Solids Mean (mg/L)	12.589	25.119
Baseflow Total Suspended Solids Standard Deviation (mg/L)	1.479	1.349
Baseflow Total Suspended Solids Estimation Method	Stochastic	Stochastic
Baseflow Total Phosphorus Mean (log mg/L)	-0.82	-0.88
Baseflow Total Phosphorus Standard Deviation (log mg/L)	0.19	0.13
Baseflow Total Phosphorus Mean (mg/L)	0.151	0.132
Baseflow Total Phosphorus Standard Deviation (mg/L)	1.549	1.349
Baseflow Total Phosphorus Estimation Method	Stochastic	Stochastic
Baseflow Total Nitrogen Mean (log mg/L)	0.32	0.074
Baseflow Total Nitrogen Standard Deviation (log mg/L)	0.12	0.13
Baseflow Total Nitrogen Mean (mg/L)	2.089	1.186
Baseflow Total Nitrogen Standard Deviation (mg/L)	1.318	1.349
Baseflow Total Nitrogen Estimation Method	Stochastic	Stochastic

Table B.4 Adopted MUSIC Parameters for Treatment Measures

USTM Treatment Types	Wetland	Bio-Swale	Pond
Number of CSTR cells	5	3	2
Total Suspended Solids k (m/yr)	5000	1000	1000
Total Suspended Solids C* (mg/L)	9	12	12
Total Suspended Solids C** (mg/L)	6		12
Total Phosphorus k (m/yr)	2800	500	500
Total Phosphorus C* (mg/L)	0.03	0.13	0.063
Total Phosphorus C** (mg/L)	0.09		0.13
Total Nitrogen k (m/yr)	500	50	50
Total Nitrogen C* (mg/L)	0.2	1.3	0.676
Total Nitrogen C** (mg/L)	1.3		1.3
Threshold hydraulic loading for C** (m/yr)	3500		3500
Extraction for Re-use	Off	Off	Off

Table B.5 Results of Water Quality Assessment

Parameter	Subcatchment 1		
	Existing	Post Development	
		Option 1A	
Flow (ML/yr)	8.60	29.50	
Total Suspended Solids (kg/yr)	2050	1340	
Total Phosphorus (kg/yr)	5.38	3.48	
Total Nitrogen (kg/yr)	34.6	30.3	
Gross Pollutants (kg/yr)	108.0	0.0	

Parameter	Subcatchment 2		
	Existing	Post Development	
		Option 2A	Option 2B
Flow (ML/yr)	19.60	73.10	69.00
Total Suspended Solids (kg/yr)	5190	3380	2300
Total Phosphorus (kg/yr)	13.2	9.0	6.0
Total Nitrogen (kg/yr)	80.5	77.1	73.4
Gross Pollutants (kg/yr)	247.0	0.0	105.0

Parameter	Subcatchment 1 and 2		
	Existing	Post Development	
		Option 2C	
Flow (ML/yr)	28.20	96.60	
Total Suspended Solids (kg/yr)	7240	3420	
Total Phosphorus (kg/yr)	18.6	9.0	
Total Nitrogen (kg/yr)	115.1	105.0	
Gross Pollutants (kg/yr)	355.0	158.0	

Parameter	Subcatchment 3		
	Existing	Post Development	
		Option 3A	Option 3B
Flow (ML/yr)	8.60	29.50	30.50
Total Suspended Solids (kg/yr)	1880	1230	862
Total Phosphorus (kg/yr)	5.45	3.45	2.59
Total Nitrogen (kg/yr)	38.00	28.80	32.70
Gross Pollutants (kg/yr)	108.0	0.0	9.4

Parameter	Subcatchment 4		
	Existing	Post Development	
		Option 4A	
Flow (ML/yr)	10.40	38.60	
Total Suspended Solids (kg/yr)	2290	1900	
Total Phosphorus (kg/yr)	6.19	5.00	
Total Nitrogen (kg/yr)	45.5	41.6	
Gross Pollutants (kg/yr)	131.0	0.0	

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Figure B.6 Concept Sizes of Stormwater Treatment Measures

	Option 1A	Option 2A	Option 2B	Option 2C			
	Bio-swale	Bio-swale	Wetland	Wetland	+		Swale
Surface Area (m^2)	700	1500	2400	3500*		Length (m)	100
Filter Area (m^2)	350	750	n/a	n/a		Bed slope (%)	1
Extended Detention Depth (m)	0.5	0.5	1.0	1.0		Bed width (m)	1
Filter Depth (m)	1	1	n/a	n/a		Top width (m)	4
Permanent Storage Volume (m^3)	n/a	n/a	2200	3200		Depth (m)	0.5
Equivalent Pipe Dia (mm)	n/a	n/a	300	300		Veg Height (m)	0.25
Overflow weir width (m)	4.0	4.0	10.0	10.0		Seepage loss	0.0

	Option 3A	Option 3B	Option 4A
	Bio-swale	Wetland	Bio-swale
Surface Area (m^2)	700	900	800
Filter Area (m^2)	350	n/a	400
Extended Detention Depth (m)	0.5	1.0	0.5
Filter Depth (m)	1	n/a	1
Permanent Storage Volume (m^3)	n/a	800	n/a
Equivalent Pipe Dia (mm)	n/a	300	n/a
Overflow weir width (m)	4.0	10.0	4.0

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C INDICATIVE COST ESTIMATES

Catchment 1

Item	Quantity	Unit	Rate	Amount
Water Quantity				
Minor system stormwater (pipes)	450	m	250	$112,500
Minor system stormwater (pits)	25	e.a	2600	$65,000
Major stormwater system (open channel)	600	sqm	30	$18,000
			Subtotal	**$195,500**
Water Quality				
Option 1A- Bioswale and pit inserts				
Bioswale	700	sq.m	130	$91,000
Pit inserts	25	e.a	600	$15,000
			Subtotal	**$106,000**
Option 1B- Divert to Catchment No.2				
Open channel	2600	sq.m	30	$78,000
			Subtotal	**$78,000**
Water Resuse				
3000l rainwater tanks to each house	53	e.a	3500	$185,500
			Subtotal	**$185,500**

Catchment 2

Item	Quantity	Unit	Rate	Amount
Water Quantity				
Minor system stormwater (pipes)	2200	m	250	$550,000
Minor system stormwater (pits)	110	e.a	2600	$286,000
Major stormwater system	180	m	1200	$216,000
			Subtotal	**$1,052,000**
Water Quality				
Option 2A- Bioswale and pit inserts				
Bioswale	1500	m	130	$195,000
Pit inserts	110	e.a	600	$66,000
			Subtotal	**$261,000**
Option 2B- Wetland and GPT				
Construct artificial wetland for Cat.	1	e.a	430000	$430,000
GPT	1	e.a	40000	$40,000
			Subtotal	**$470,000**
Option 2C- Wetland and GPT for Cat. 1&2				
Construct artificial wetland Cat 1&	1	e.a	620000	$620,000
GPT	1	e.a	50000	$50,000
			Subtotal	**$670,000**
Water Resuse				
Provide 3000l rainwater tanks	140	e.a	3500	$490,000
			Subtotal	**$490,000**

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Catchment 3

Item	Quantity	Unit	Rate	Amount
Water Quantity				
Minor system stormwater (pipes)	960	m	250	$240,000
Minor system stormwater (pits)	48	e.a	2600	$124,800
Major stormwater System	100	m	1100	$110,000
			Subtotal	**$474,800**
Water Quality				
Option 3A- Bioswale and pit inserts				
Bioswale	700	sq.m	130	$91,000
Pit inserts	48	e.a	600	$28,800
			Subtotal	**$119,800**
Option 3B- Wetland				
Construct artificial wetland for Cat	1	e.a	250000	$250,000
GPT	1	e.a	30000	$30,000
			Subtotal	**$280,000**
Water Resuse				
Provide 3000l rainwater tanks	50	e.a	3500	$175,000
			Subtotal	**$175,000**

Catchment 4

Item	Quantity	Unit	Rate	Amount
Water Quantity				
Minor system stormwater (pipes)	350	m	250	$87,500
Minor system stormwater (pits)	20	e.a	2600	$52,000
			Subtotal	**$139,500**
Water Quality				
Option 4A- Bioswale and pit insert				
Bioswale	800	sq.m	130	$104,000
Pit inserts	20	e.a	600	$12,000
			Subtotal	**$116,000**
Water Resuse				
Provide large rainwater tank/s	1	item	115000	$115,000
			Subtotal	**$115,000**

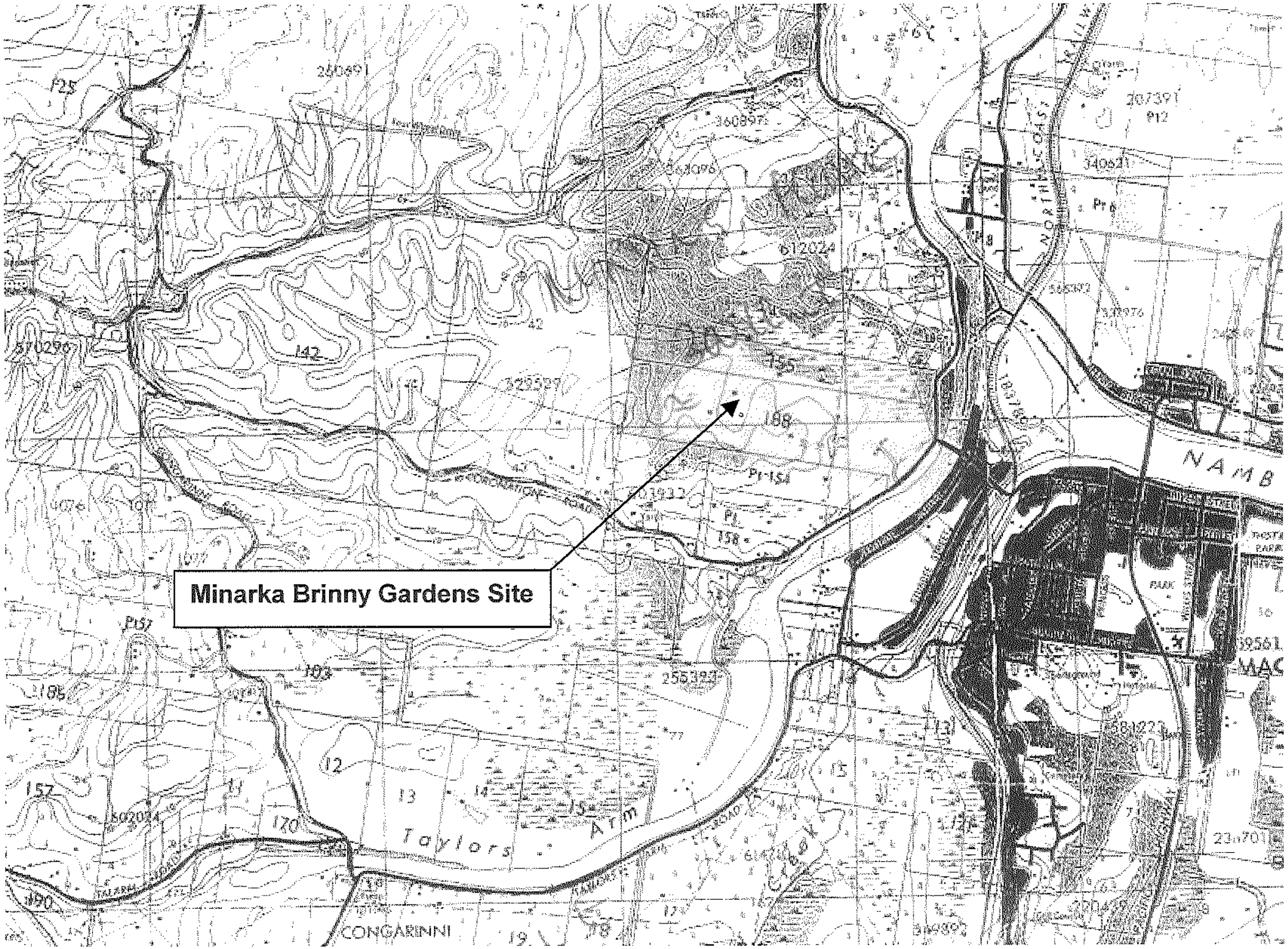


Figure 1 Site Locality Plan

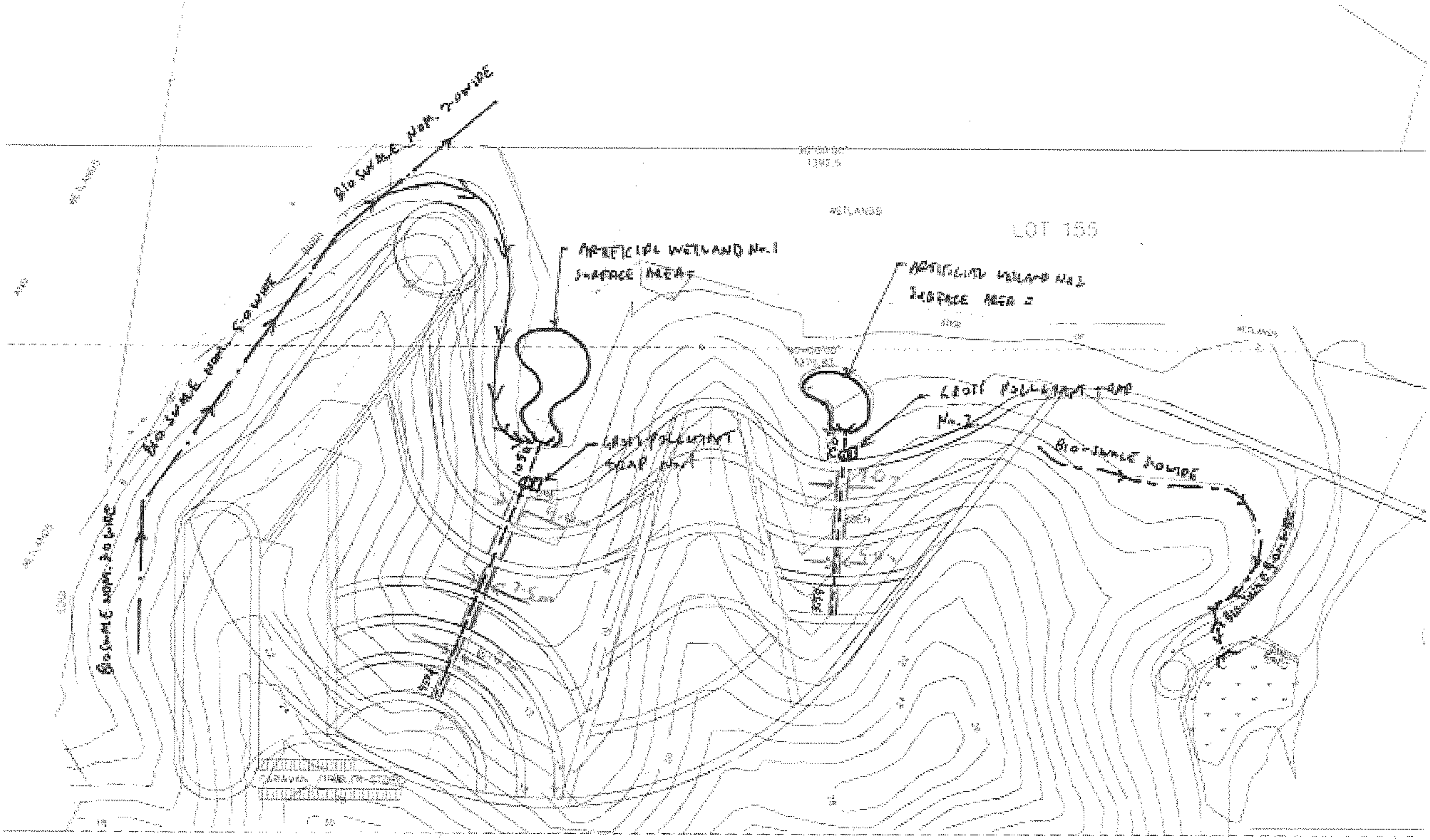


Figure 4 Concept Dimensions of Drainage Corridors

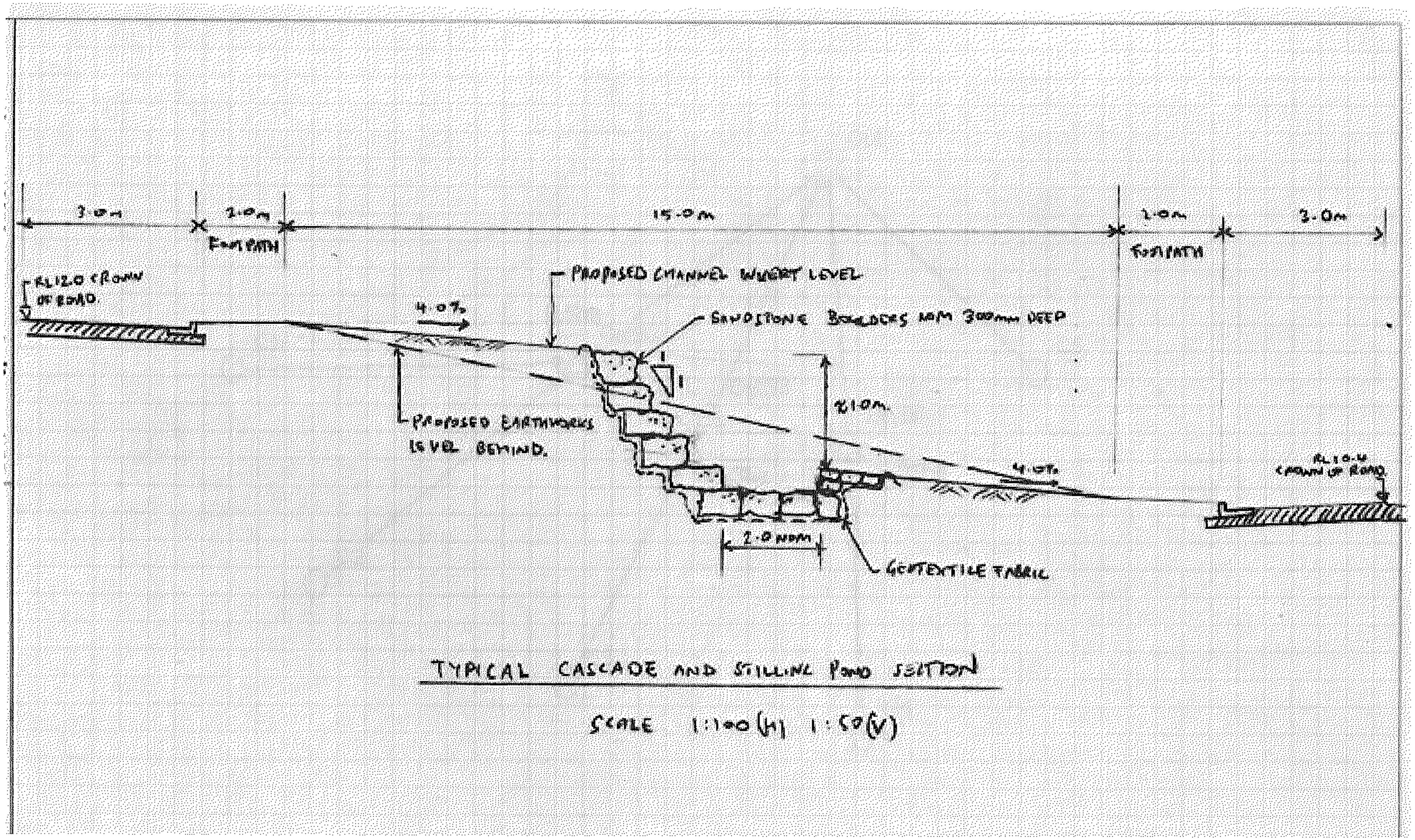


Figure 5 Concept Cascade for Drainage Corridors

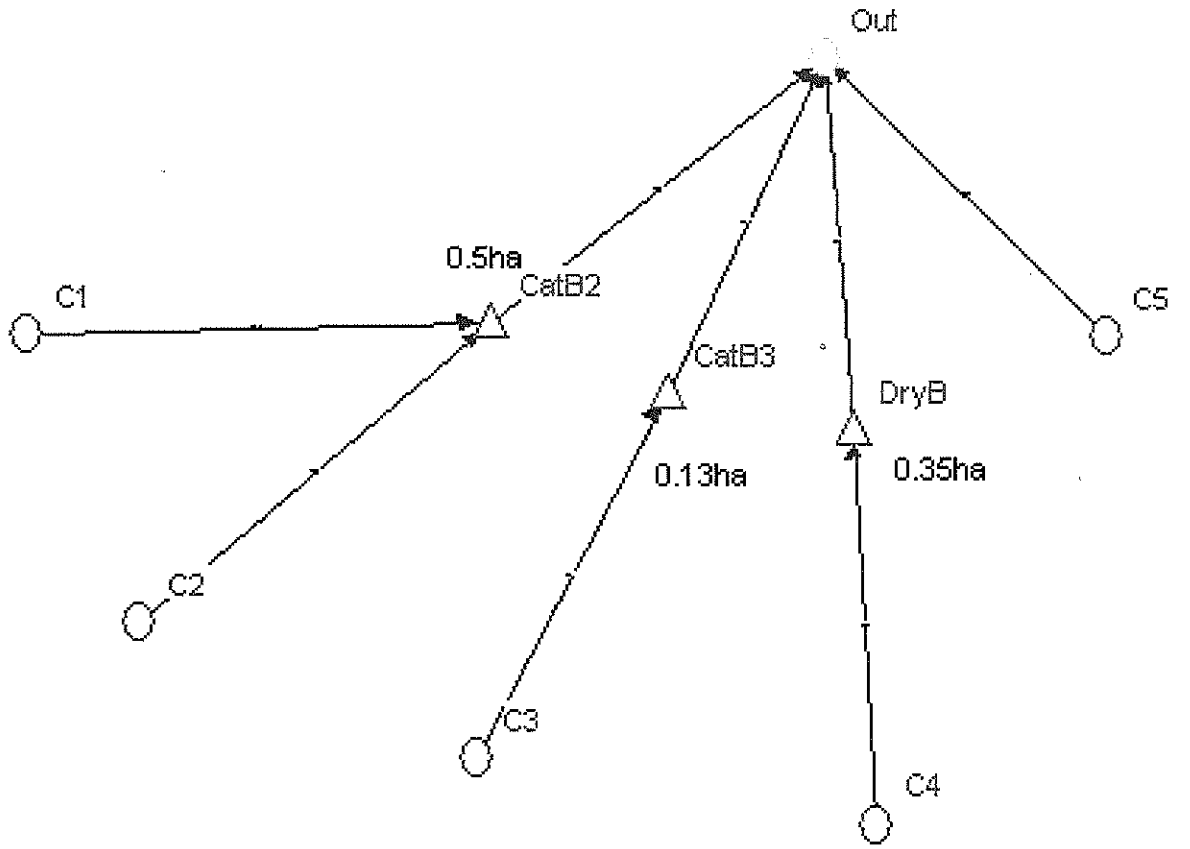


Figure A.1
Representative XP-RAFTS Link - Node Diagram

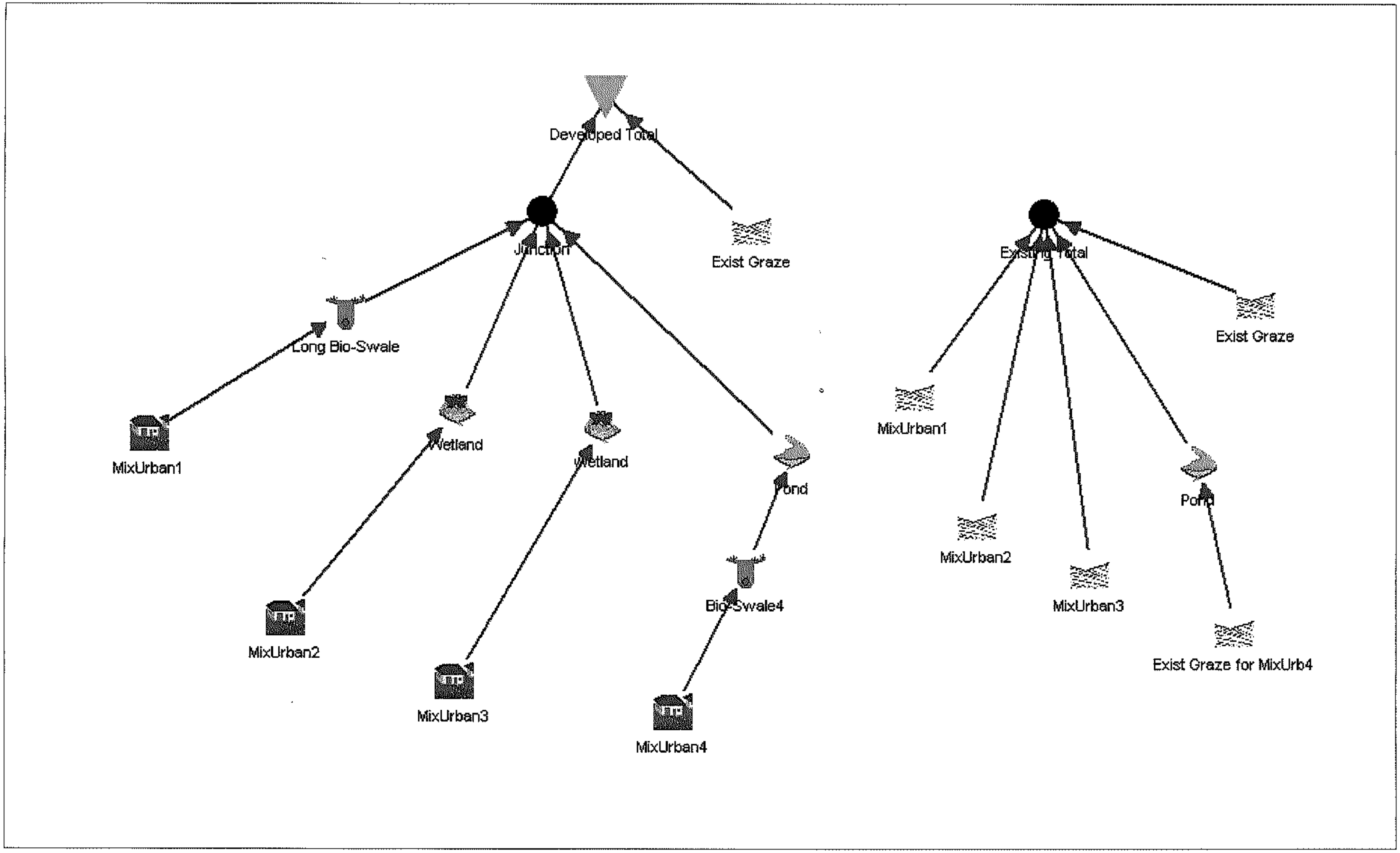


Figure B.1
Existing Conditions and Mixed Bio-swale & Wetland Options

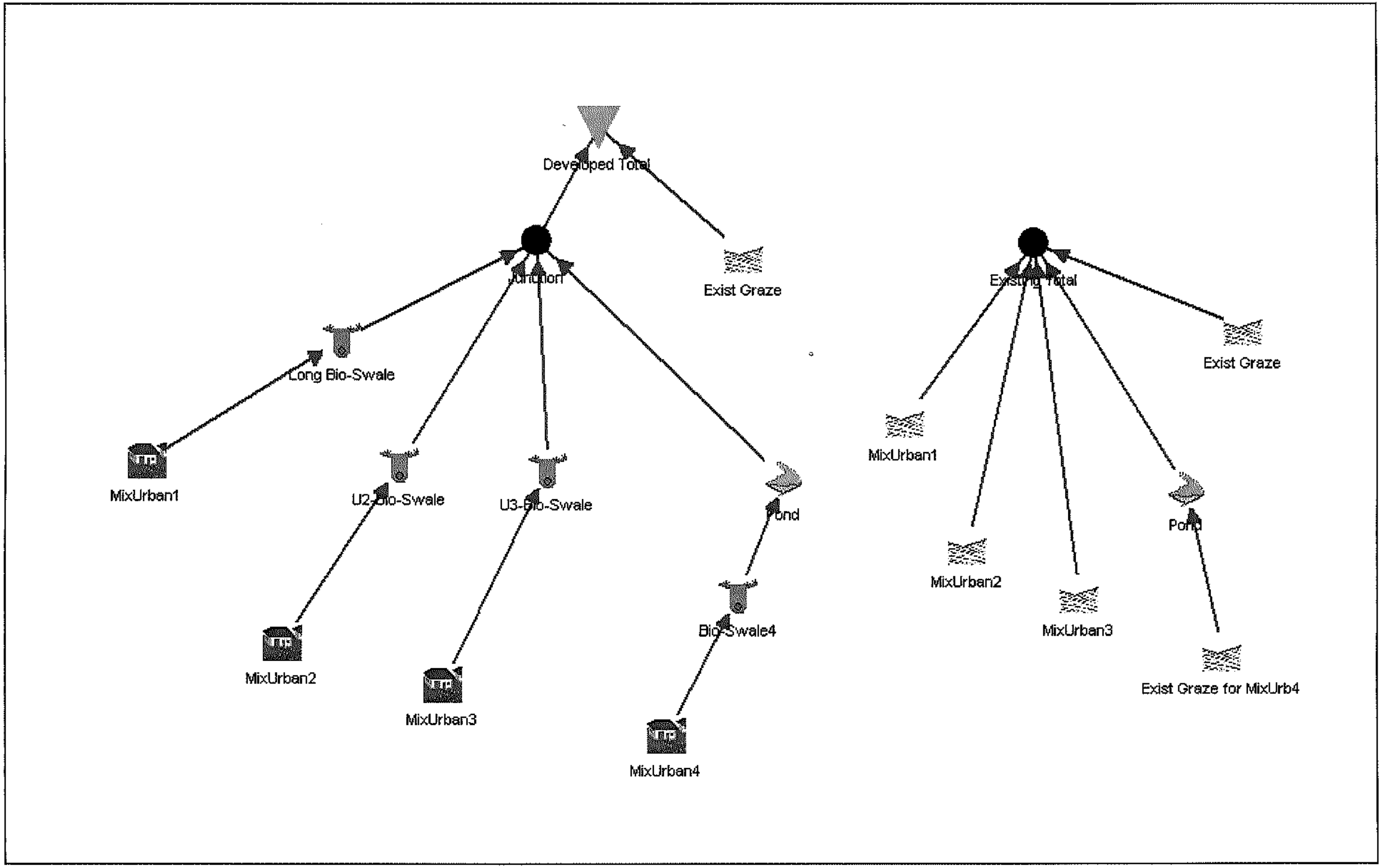


Figure B.2
Existing Conditions and All Bio-swale Options

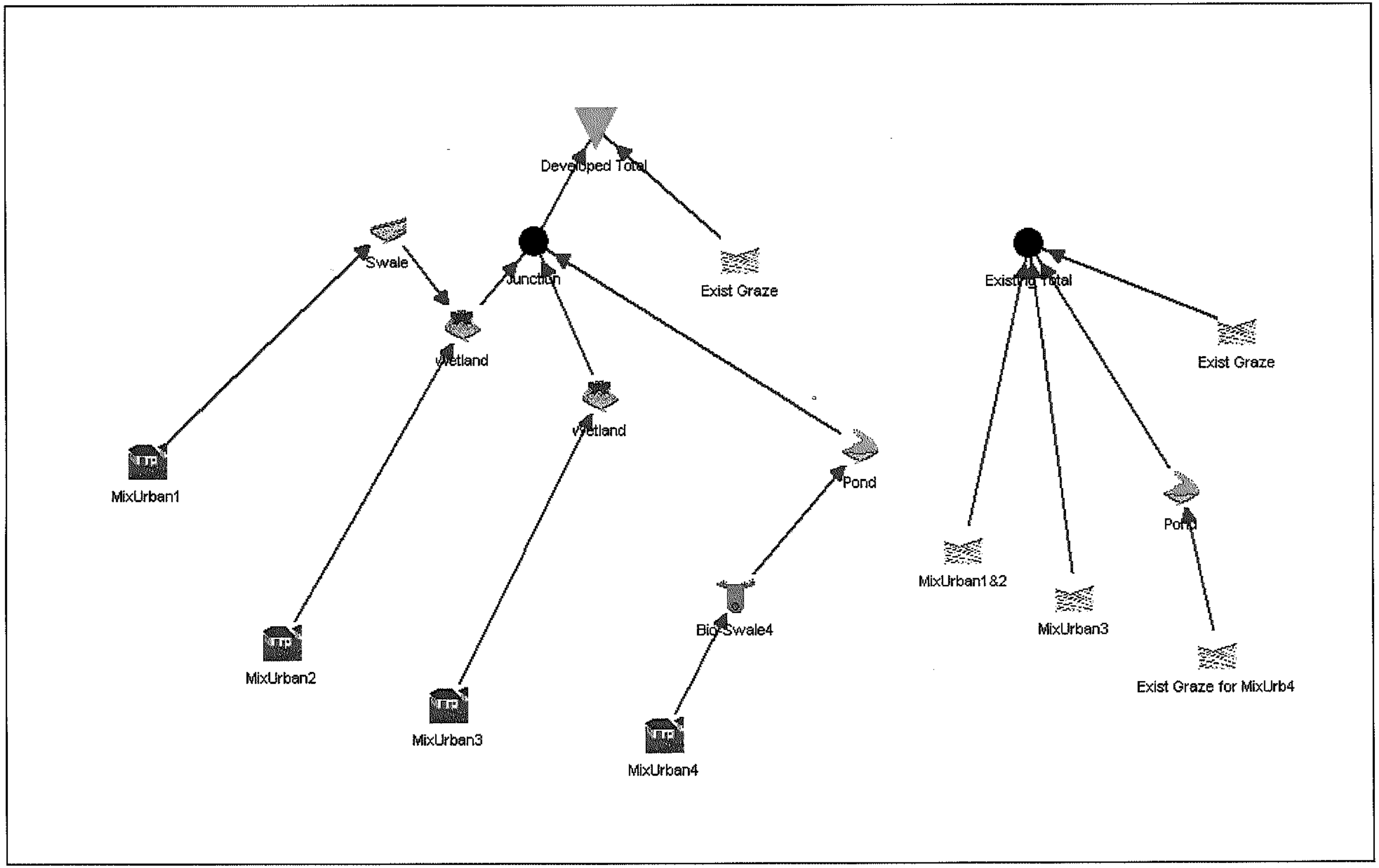


Figure B.3
Mixed Bio-swale & Wetland Options with Diversion of Subcatchment 1 into Subcatchment 2

Plate 1 Panoramic View towards Taylors Arm

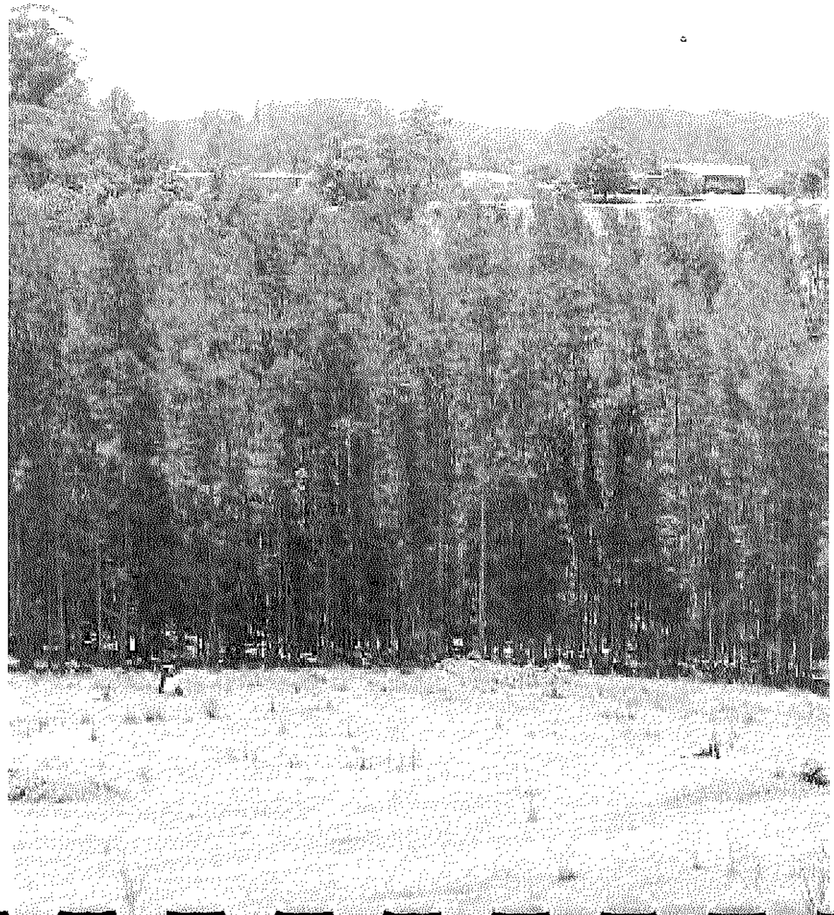
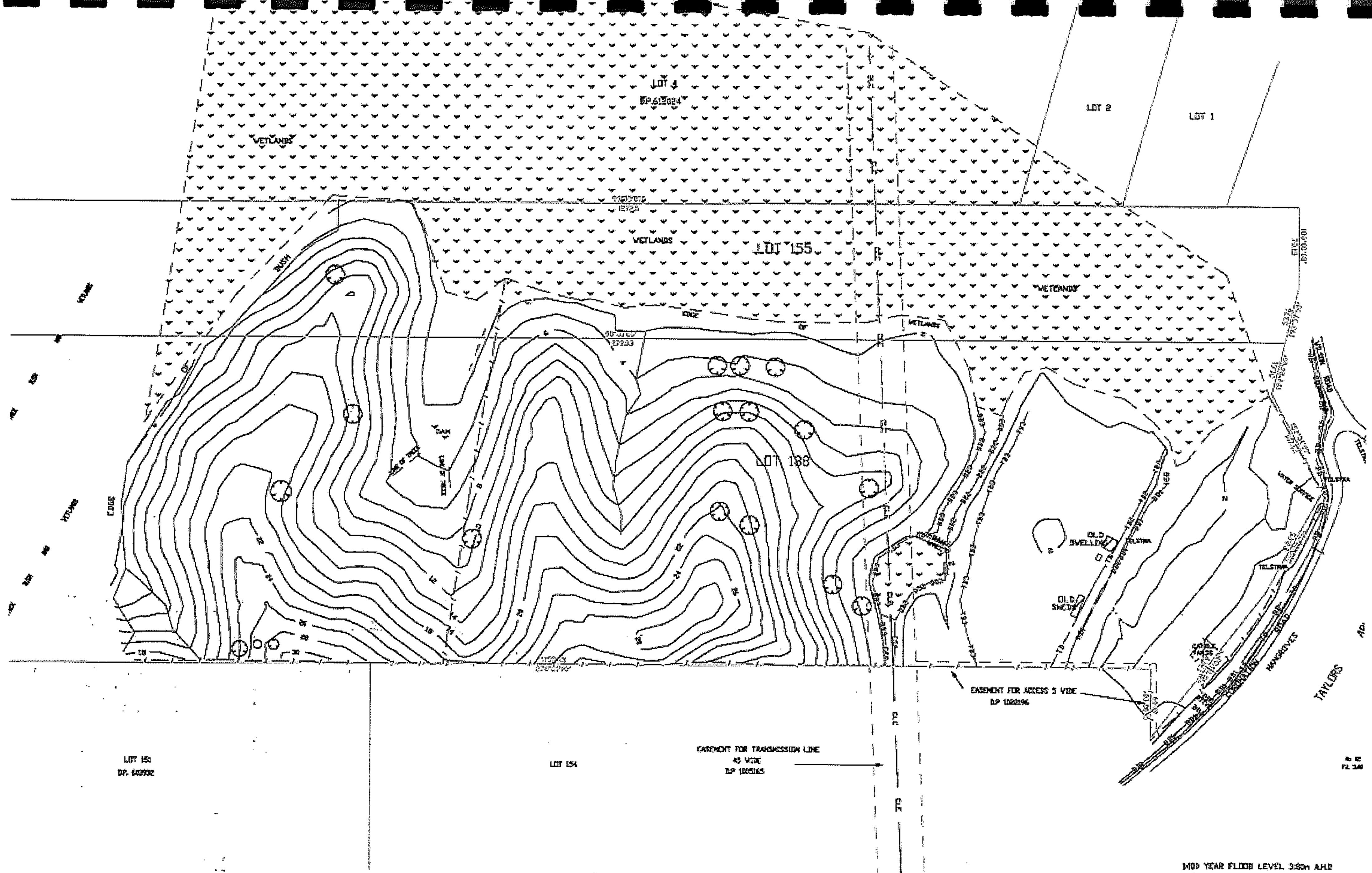


Plate 5   Panoramic View West to Proposed Area of Development

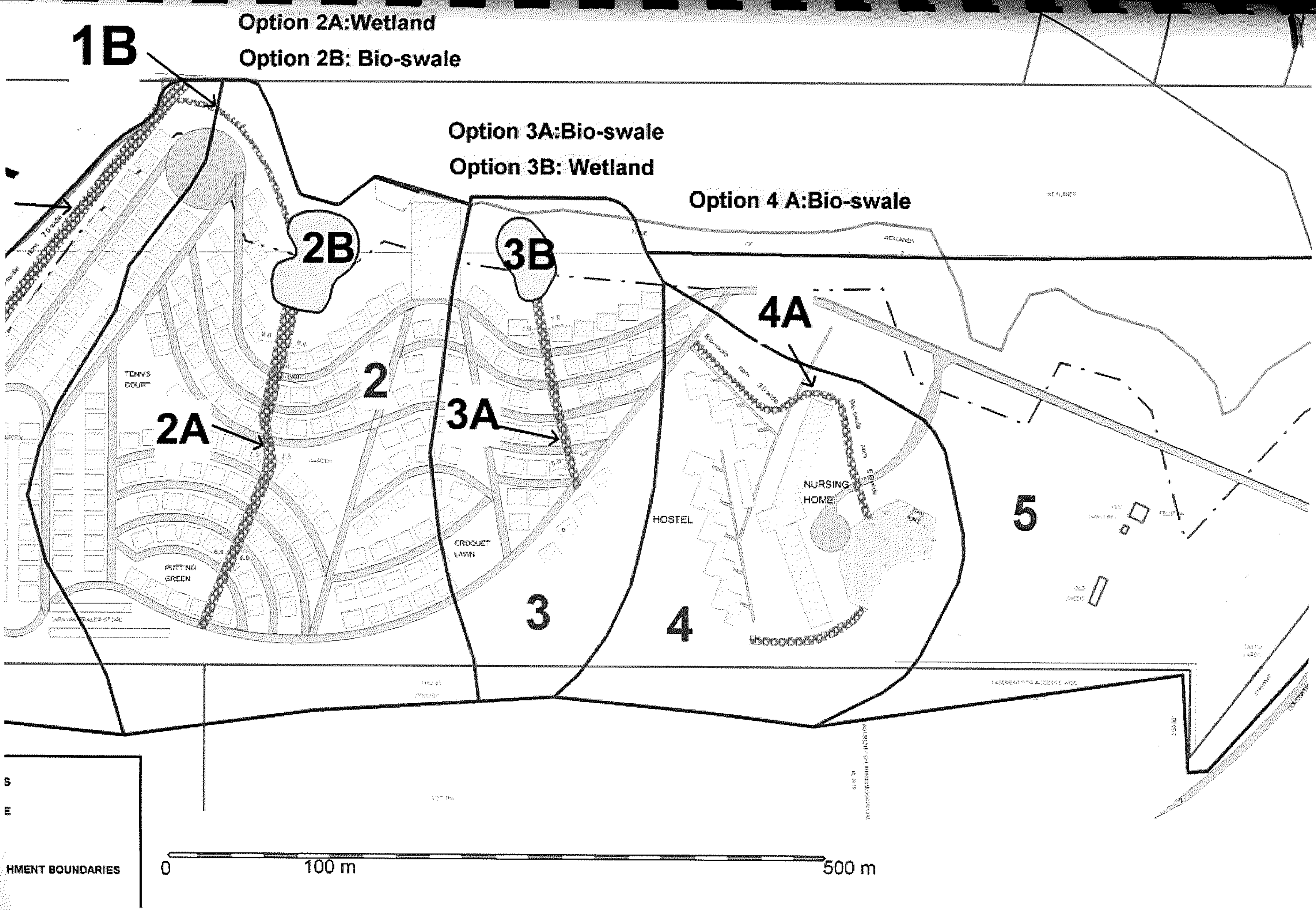


1:100 YEAR FLOOD LEVEL 3.80m A.H.D
1:50 YEAR FLOOD LEVEL 3.60m A.H.D

AMOS & McDONALD
SURVEYORS

CONTOUR & DETAIL PLAN

P.O.
PH
EMA
L.G.A


Option 2A:Wetland
Option 2B: Bio-swale
Option 3A:Bio-swale
Option 3B: Wetland
Option 4 A:Bio-swale
1B
2A
2B
3A
3B
4A
2
3
4
5
TENNIS COURT
PUTTING GREEN
CROQUET LAWN
HOSTEL
NURSING HOME
HMENT BOUNDARIES
0
100 m
500 m

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