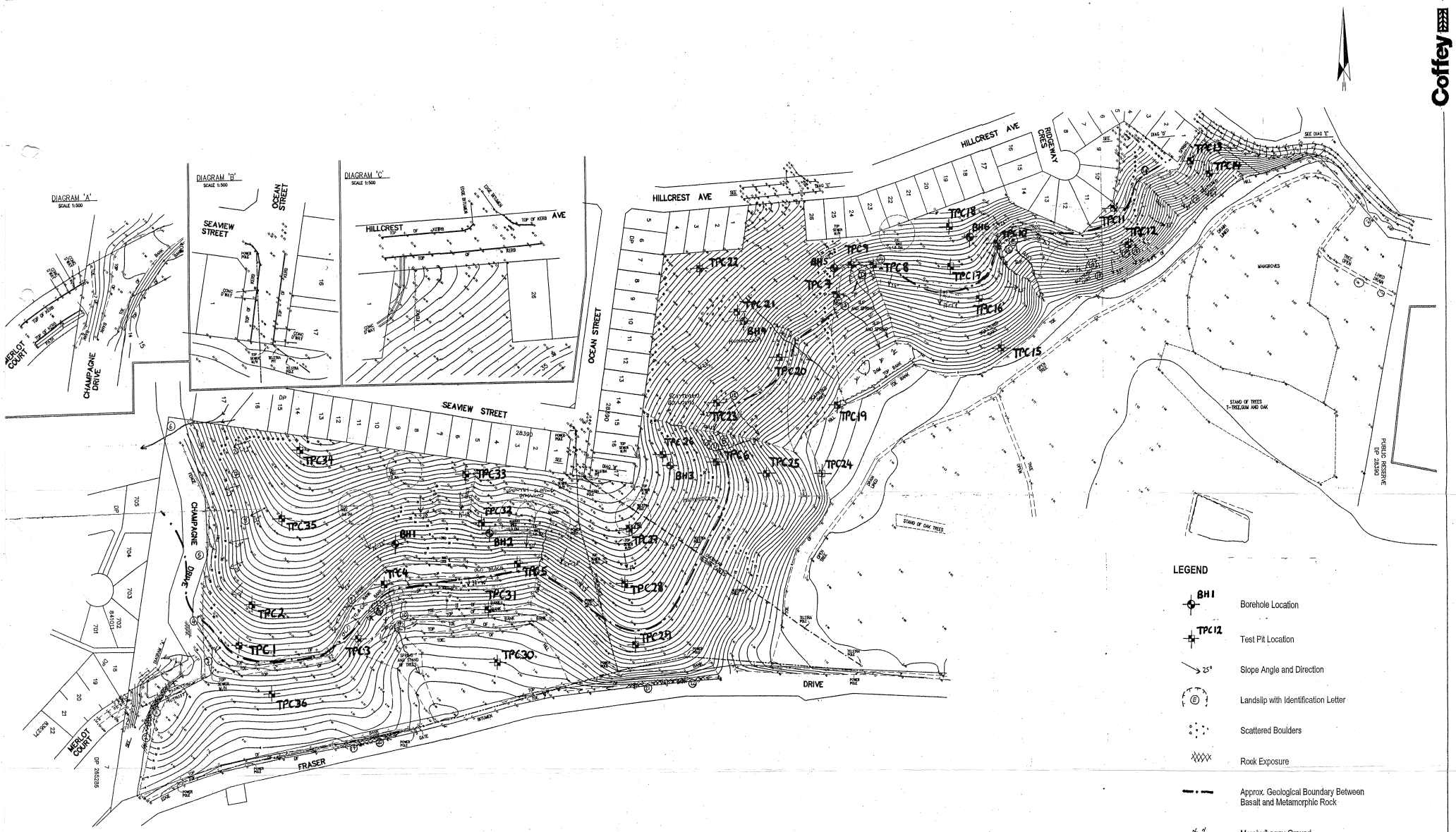

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Drawn	SPP
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MARTIN FINDLATER AND ASSOCIATES PTY LTD
GREENVIEW DEVELOPMENTS PTY LTD
RESIDENTIAL DEVELOPMENT FRASER DRIVE
TWEED HEADS SOUTH
SITE CONTOUR PLAN

Drawing No: DRAWING 1

Job no: B17439/1 - F

Appendix 09

Groundwater Assessment

Cardno
Shaping the Future

FRASER DRIVE, TWEED HEADS SOUTH

Groundwater Assessment

19 January 2007
Job No. 7214/29

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Document Title: **Groundwater Assessment**
Job No: **7214/29**

Document Control

Version	Date	Author		Reviewer	
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2	19 January 2007	Doug Boys		Karina Berry	
1	17 January 2007	Doug Boys	JDB		

FRASER DRIVE, TWEED HEADS SOUTH
GROUNDWATER ASSESSMENT

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EXECUTIVE SUMMARY

A qualitative assessment of groundwater systems within the proposed development site has been carried out which:

- Describes the groundwater systems of the site and the characteristics of groundwater responses to climate inputs.
- Provides quantitative estimates annual flow volumes in the groundwater systems.
- Evaluates the impacts on groundwater water levels and flows of the proposed residential development.
- Provides a Groundwater Management Plan to for the construction phase of the development to avoid adverse impacts on groundwater systems.

The assessment demonstrates that the development does not significantly affect the groundwater regime of the floodplain aquifer which extends over the northern parts of the site.

The assessment also demonstrates that the SEPP14 wetlands are not adversely affected by changes in the groundwater regime resulting from the proposed development.

1. INTRODUCTION

1.1 Site Location

The site comprises Lot 9 DP 1039569 located on Fraser Drive, Tweed Heads South (see Figure 1).

1.2 Scope

The groundwater assessment is intended to:

- Describe the existing groundwater systems using available historical monitoring data from bores on the site.
- Evaluate the potential long-term future impacts on the groundwater systems of the residential development proposed for the site including effects on:
    - Groundwater levels, volumes and water quality
    - Nearby groundwater users and future potential users
    - The SEPP14 wetlands lying north of the site
- Evaluate the potential impacts of proposed construction phase activities
- Provide a Groundwater Management Plan for the construction and operational phases which incorporates procedures designed to avoid detrimental environmental impacts.

This initial Version 1 of the assessment provides a qualitative assessment of groundwater impacts. The investigations will be revised in future to include quantitative modelling of the groundwater systems in accordance with requirements to be negotiated with development application assessment agencies.

2. EXISTING SITE CONDITIONS

2.1 Terrain

The terrain at the site is described in the Environmental Assessment Report (PMM 2006).

The northern half of the site forms part of the floodplain of Terranora Creek which rises steeply towards the western and southern boundaries to a well-defined north-south aligned ridgeline created by outcropping igneous bedrock bordering Terranora Broadwater.

The site thus consists of two distinct terrain zones, namely a northern low-lying floodplain zone with the remainder consisting of steep hill slopes extending over the western parts of the site and the entire southern half of the site to elevations up to RL 55 mAHD.

The northern floodplain zone has been cleared in the past and filled in places in recent years to about RL 2.65 mAHD. There are some areas of trees. The northern floodplain zone has been drained in the past by means of excavated drains which discharge into heavily vegetated wetlands extending over the northern limits of the site and into adjoining land to the north. The wetlands are included under SEPP 14 legislative controls.

The hill slope zones drain in eastern and northern directions via natural gullies into the floodplain zone. The northern hill slopes drain to the northern floodplain zone of the site. This catchment is marked on Figure 1 as “North Catchment”. The southern hill slopes drain to a separate part of the Terranora floodplain east of Fraser Drive separated from the Northern Catchment by a steep bedrock ridge which extends across Fraser Drive towards the north-east and divides the Terranora floodplain into two distinct parts which can be distinguished in Figure 1. The southern catchments within the site are marked in Figure 1 as “East” and “South” Catchments respectively.

The hill slopes of the site are sparsely forested and subject to land slippage.

2.2 Tide Levels

The tidal plane levels in the Terranora Broadwater (at the “entrance”) from levels recorded between 2000 to 2006 are as follows:

Table 1 Tidal Levels

Plane	mAHD
MHWS	0.43
MSL	0.10
MLWS	-0.23

2.3 Wetlands Outlet

The water level in the wetlands north of the development site is governed by a pair of tidal flap gates which connect with the Terranora Broadwater via a constructed tidal channel alongside James Road. These gates allow water to flow out of the wetlands when the level in the wetlands is higher than the tide but prevent tidal inflow when the tide is higher than the water level in the wetlands.

As a result, the average level in the wetlands is likely to be relatively constant at MSL of RL 0.10 mAHD or lower except during periods of heavy rainfall.

This constant water level will persist upstream to the limit of the excavated drains which lead to the gated outlet and the wetlands. This uniform water level appears to persist throughout the flatter northern parts of the site almost to Fraser Drive.

2.4 Geology and Soil Conditions

The geology and soil conditions at the site are described in an earlier study (LNW 2002) which also established a series of groundwater monitoring wells. The geology was inferred from regional geology maps (DNR 2006) and the bore logs of eleven bores drilled at this time in the North catchment floodplain to a depth of five metres.

The location of the boreholes is shown in Figure 2.

The soils of the floodplain areas consist of sandy alluvial material with some clay generally at least five metres deep overlying relatively impervious clayey weathered bedrock.

Bedrock outcrops over the western and southern parts of the site in the form of steep ridges consisting of weathered clayey basalts underlain by weathered metamorphic rock. These bedrock outcrops also extend from near the centre of the site to the north-east across Fraser Drive in the form a distinct ridge extending to the Pacific Highway. The bedrock is probably continuous beneath the floodplain alluvia although exploratory bores at the site are not deep enough to establish the full depth of the alluvial material.

2.5 Stratigraphy and Aquifer Configuration

The available geological information indicates that the site lies along the western edge of extensive alluvial deposits of the Terranora floodplain. Within the northern parts of the site these deposits appear to form a relatively uniform and well-connected surface aquifer though they are probably the result of a number of successive incidents of riverine deposition events and marine inflows and reworking.

The alluvial deposits of the northern floodplain area are probably appreciably deeper than five metres (the limit of the exploratory boreholes) particularly at the northern site boundary beneath the wetlands area furtherest from the hill slopes. These deposits appear to be a significant fresh groundwater resource.

The hill slopes of the western and southern parts of the site consist of a low-permeability clayey weathered soil layer some six metres in depth over bedrock (PMM 2006). The boundary between the deep upper soil layer and the basalt bedrock is marked by a residual soil layer which outcrops at about RL 20 marked by slips and springs (see Figure 1 and Figure 2).

The hill slope areas are not likely to contain significant groundwater reserves because of their low permeability.

The effective boundary of the floodplain alluvial aquifer probably coincides with the change of surface slope at the base of the steep slopes marking the emergence of the outcropping bedrock. This boundary has been outlined in Figure 1 as a dashed line.

2.6 Existing Groundwater Regime

The flat low-lying terrain at or below RL 3.0 extending over the north-east portion of the site forms part of the floodplain of Terranora Creek. The soils of this area consist of sandy alluvial material which may be more than five metres deep overlying relatively impervious clayey weathered bedrock. This surficial alluvial layer contains fresh groundwater which is accessed in places for domestic use. Groundwater reserves in the alluvial surface layer

are maintained by rainfall infiltration and by infiltration from surface dams and drainage channels retaining surface runoff.

The surficial alluvial floodplain aquifer is probably recharged by local rainfall infiltration from the surface. It is expected that there will be net horizontal groundwater flows within the aquifer towards the nearest constant water level boundary defined by the excavated drains. The high permeability of the floodplain alluvia indicate that groundwater levels within the northern areas probably varies seasonally from close to ground level in wet summer periods falling to close to the mean wetlands water level of RL 0.1 mAHD during dryer winter periods.

Groundwater seepage is also evident within the higher steep slopes of the west and south-west areas of the site particularly at about RL 20 which appears to correspond to a discontinuity between an upper weathered basalt soil layer and underlying basalt rock layer from which the hills and ridges of this part of the site are formed. This groundwater seepage is evident as springs and saturated ground at this elevation (see Figure 1 and Figure 2). These springs contribute only minor flows to the surface drainage of the floodplain. The groundwater reserves in these upper weathered rock areas are "perched" and effectively isolated from the lower alluvial floodplain aquifer by the impermeable nature of the weathered rock soils of the hill areas.

The southern part of the site consists almost entirely of clayey weathered basaltic hill slope soils. Groundwater volumes and flows are not likely to be significant in this area. These areas will contribute minor flows mainly via surface seepage to the Terranora floodplain external to the site east of Fraser Drive.

2.7 Recorded Groundwater Levels

Groundwater levels measured on 22 Oct 2002 (LNW 2002) and in some bores through to June 2003 (Blueland 2006) were as follows:

Table 2 Recorded Groundwater Levels in mAHD

Bore #	22/10/2002	7/4/2003	5/5/2003	27/6/2003	25/7/2003
1	0.27	0.7	0.97	0.95	0.85
2	0.23	0.5	0.8	0.8	
2A	0.18	0.48	0.83		
3	0.16				
4	0.24	0.41			
5	0.23				
5A	0.23				
6	0.58				
6A	0.34				
7	0.32	0.29	0.29		
8	0.41				

Monitoring data from these wells since July 2003 are not consistent with the data in the table and appear to have been corrupted by changes in the ground surface levels resulting from filling of the flood plain which were not recorded

The levels recorded on 22/10/2002 are plotted in Figure 2. These levels are consistent with the conclusions in Section 2.6. They indicate that levels in the floodplain alluvial aquifer

vary in the range RL 0.2 to about RL 0.9 mAHD probably in response to seasonal and annual variations in rainfall.

The areal pattern of levels in Figure 2 confirm that groundwater hydraulic gradients slope towards the controlling constant water level in the surface drains.

Gradients in the direction of the surface drains are flat indicating that groundwater flows in the aquifer directly into the SEPP14 wetlands are likely to be small. The wetlands are probably replenished mainly by surface runoff in the drains.

2.8 Recorded Groundwater Quality

Monitoring data on water quality in Bores #1 to #8 and surface water within the floodplain aquifer for the period 22/10/2002 to 07/01/2005 (Blueland 2006) indicate that:

- Water in the surface drains is slightly brackish (1400 µS/cm) indicating that there may be some occasional sea water intrusion at the outlet gates.

- Groundwater is generally consistently fresh (conductivities less than 1000 µS/cm) except for readings up to 3020 µS/cm in Bore 2 and 2140 µS/cm in Bore 2a. The reason for these higher levels is not clear. They may be the result of some isolated salt content in the original alluvia at this location or some previous sea water intrusion from the surface drains. The salinity variations do not appear to be associated with the filling of the floodplain which has taken place.

- The freshness of the groundwater relative to the water in the surface drains indicates that there is a persistent groundwater seepage from the aquifer into the drains. This is consistent with groundwater being recharged by rainfall infiltration.

- Nutrient and heavy metal concentrations are consistently low.

- pH levels are consistently neutral to alkaline (in a range of 6.0 to 8.5) indicating that aquifer soils do not contain acid sulfate material. The exception is at Bore #8 where the pH showed decrease from about 6.0 to about 4.0 over the period mid-2004 to the end of 2005. This decrease is probably due to some acid discharge from fill material at this location.

3. DEVELOPMENT CONDITIONS

3.1 Proposed Development

The proposed development consists of urban residential development over parts of the north catchment floodplain and low density residential development over much of the hill slope areas within the site. The extent of the residential areas is shown in Figure 1. Fill has already been placed on some parts of the floodplain in the proposed residential areas under a separate development application. This filling will be completed as part of the proposal including infilling the existing surface drain channels in this area.

Runoff from the residential areas will drain to an arrangement of constructed detention basins located between the residential zone and the existing SEPP14 wetlands (see Figure 1). These basins will overflow into the remaining existing surface drain and flow into the SEPP14 wetlands. Runoff from east of Fraser Drive will be diverted around the residential development to discharge into the remaining existing surface drain and thence into the SEPP14 wetlands.

3.2 Potential Development Impacts

The location of the proposed residential areas, the proximity of the SEPP14 wetlands and the characteristics of urban residential development (with up to 50% impervious areas of roofing and road pavement) indicate that the following impacts may be important within the North Catchment:

- Reduction in the infiltration of rainfall into the groundwater systems of the floodplain and the hill slopes with subsequent decrease in groundwater levels and available groundwater volumes;
- Changes in the water level and flows through the SEPP14 wetlands from both surface flows and groundwater seepage.
- Increases in the concentrations of nutrients and pollutants in groundwater systems which may also increase dispersion of pollutants into the SEPP14 wetlands.
- Localised effects on the alluvial aquifer as result of construction activities in the floodplain area.

There are unlikely to be any significant groundwater impacts from development within the East Catchment or the South Catchment because there are no areas of floodplain aquifer in these catchments and the catchments contribute only minor inflows to the aquifer external to the site.

There are no significant impacts on groundwater systems during the construction phase because there are no deep excavations proposed and there will only be minor localised dewatering of limited duration to construct sewer pipelines in trench.

3.3 Catchment Inflows – Typical Yield Rates

In order to investigate these potential impacts, typical rainfall water yield rates for the site catchments were calculated using the MEDLI irrigation modelling system. This system analyses water flows from rainfall based on historical recorded daily climate data. Surface runoff and infiltration to groundwater systems are calculated when simulating rainfall behaviour on an irrigated plot of typical soil types from the catchment.

In this instance, irrigation rates are set to zero so as to simulate only existing natural rainfall conditions. The "irrigated" area was assumed to be vegetated with melaleuca shrubs. Climate data was obtained for the period 1914 to 2004 from the SILO synthetic data base.

A range of standard MEDLI soil profiles were calculated corresponding to the two aquifer types from the site, namely:

- sandy floodplain alluvium
- clayey weathered basalt hill slope soil.

Appropriate average yield rates for these two aquifer types were then adopted based on the results for the standard MEDLI soil types. The results are shown in Table 3. This table also shows yield rates for water bodies which directly capture 100% of rainfall as runoff with no infiltration. Evaporation from water bodies has been ignored because the storages are small and most runoff overflows.

Table 3 Typical Catchment Water Yield Rates

Scenario	Soil Type / Catchment Type	Average annual depths (mm)		
		Rainfall	Runoff	Recharge (Infiltration)
MEDLI analysis	Sand	1710	63	976
	Red earths	1710	193	716
	High permeability soils	1710	302	542
	Medium permeability soils	1710	465	427
	Grey clay	1710	570	234
Adopted for this assessment	Floodplain (permeable sand)	1710	170	855
	Hill slopes (low permeability)	1710	570	257
	Water bodies	1710	1710	0

The rates in the table are estimated values appropriate to a qualitative assessment. More accurate rates could be established by calibration of a groundwater model based on recorded groundwater levels.

3.4 Catchment Inflows – Changes with Development

The changes in catchment yield rates for developed residential areas were then estimated assuming that 50% of the developed areas are impervious with 100% runoff and no infiltration with the remaining 50% of the area having yield rates as shown in Table 3.

The resulting yield rates for developed areas are shown in Table 4

Table 4 Catchment Water Yield Rates for Developed Areas

	Average annual depths (mm)		
	Rainfall	Runoff	Infiltration
Developed Floodplain	1710	941	428
Developed Hill Slopes	1710	1140	129

In each case the average runoff has increased and the infiltration to groundwater has decreased because of the development.

3.5 North Catchment – Effects of Development Changes

The impact of these changes on overall runoff and infiltration to the groundwater systems in the North Catchment was then calculated allowing for the existing and future proposed areas of residential development.

The results are shown in Table 5 to Table 8. Table 5 and Table 6 show changes to runoff volumes. Table 7 and Table 8 show changes to infiltration volumes entering the aquifers.

Table 5 Average Annual RUNOFF Volumes – Existing Conditions

	Area (ha)	Annual RUNOFF Depth (mm)	Annual RUNOFF Volume (ML)
Floodplain	18.69	170	31.79
Developed Floodplain	16.46	941	154.89
Hill Slopes	14.94	570	85.16
Developed Hill Slopes	2.93	1140	33.40
Water Bodies	4.46	1710	76.27
Total Volume (ML)			**381.5**

Table 6 Average Annual RUNOFF Volumes – Development Conditions

	Area (ha)	Annual RUNOFF Depth (mm)	Annual RUNOFF Volume (ML)
Floodplain	10.73	170	18.24
Developed Floodplain	23.47	941	220.85
Hill Slopes	10.6	570	60.42
Developed Hill Slopes	7.27	1140	82.88
Water Bodies	5.41	1710	92.51
Total Volume (ML)			**474.9**

Table 7 Average Annual INFILTRATION Volumes – Existing Conditions

	Area (ha)	Annual INFILTRATION Depth (mm)	Annual INFILTRATION Volume (ML)
Floodplain	18.69	855	159.80
Developed Floodplain	16.46	428	70.45
Hill Slopes	14.94	257	38.40
Developed Hill Slopes	2.93	129	3.78
Water Bodies	4.46	0	0
Total Volume (ML)			**272.4**

Table 8 Average Annual INFILTRATION Volumes – Development Conditions

	Area (ha)	Annual INFILTRATION Depth (mm)	Annual INFILTRATION Volume (ML)
Floodplain	10.73	855	91.74
Developed Floodplain	23.47	428	100.45
Hill Slopes	10.6	257	27.24
Developed Hill Slopes	7.27	129	9.38
Water Bodies	5.41	0	0
Total Volume (ML)			**228.8**

3.5.1 Effects on Groundwater Regime of the North Catchment

There is a 24.5% increase in surface runoff in the North Catchment and a 16% decrease in infiltration within the North Catchment.

The change in runoff is not considered significant because the bulk of the surface runoff is probably discharged rapidly from the system by overflow into Terranora Broadwater since surface storage volumes in wetlands and drains is relatively small. There may be a small increase in surface drain velocities but these are not expected to result in any increased erosion.

The decrease in infiltration is not large overall and is likely to cause only a small decrease in groundwater levels since groundwater hydraulic gradients are flat. Available groundwater volumes for domestic users will not be significantly decreased because the annual groundwater flux of some 230 ML is large compared with domestic requirements which are of the order of 0.2 ML/annum/household.

3.5.2 Effects on SEPP14 Wetlands

Environmental flows through the SEPP14 wetlands are maintained because the runoff increases with development. The small decrease in groundwater levels is not expected to affect the SEPP14 wetlands because direct seepage flows from the aquifer into the wetlands are probably small compared with surface runoff replenishment.

The development does not change the pattern of seasonal or annual variation in the volumes of surface runoff discharging into the SEPP14 wetlands.

3.5.3 Detention Basins

The proposed detention basins have a bed level of RL 0.5 mAHD and a standing water level of RL 1.0 mAHD.

The basin water level will be higher than the average surrounding groundwater level which varies between RL 0.2 and RL 0.9 and is likely to remain in that range. The difference is small and is not expected to result in significant leakage from the basins since compaction of the basin bunds and bed will result in low permeability.

3.6 Other Catchments

The other two catchments within the southern parts of the site, namely the East and South Catchments (see Figure 1) consist almost entirely of weathered clayey hill slope soils of low permeability. There will be some decrease in infiltration to the surface soils in these areas but this is not significant since these areas are not important as a groundwater resource. There will be some increase in runoff from these areas after development which will result in a very small but insignificant increase in surface seepage into the floodplain aquifer to the east of Fraser Drive.

3.7 Construction Activities

There will be no significant impacts on groundwater systems during the construction phase because there are no deep excavations proposed and there will only be minor localised dewatering of limited duration to construct detention basins and sewer pipelines in trenches.

3.8 Groundwater Management Plan

The Site Management Plan should include the following provisions in order to protect the groundwater system and the SEPP14 wetlands from adverse impacts:

- There shall be no extraction of groundwater from the site during construction activities except with permission in accordance with regulations.
- Saline or brackish water shall not be pumped onto the site for purposes of placing fill material.
- All fill imported to the site must be fully treated for acid sulfate soil conditions in accordance with regulations.
- Dewatering of excavations for construction purposes is to be limited in extent and duration to the minimum required for the actual construction underway at any time.
- Groundwater conditions shall be monitored at the existing monitoring bores in accordance with the agreed sampling schedule during the construction period. Any significant variations in water quality not consistent with conditions prior to construction shall be investigated promptly and corrective action taken.

3.9 Summary of Development Impacts

A qualitative assessment of groundwater systems within the proposed development site has been carried out which:

- Describes the groundwater systems of the site and the characteristics of groundwater responses to climate inputs.
- Provides quantitative estimates of annual flow volumes in the groundwater systems.
- Evaluates the impacts on groundwater water levels and flows of the proposed residential development.

The assessment demonstrates that the development does not significantly affect the groundwater regime of the floodplain aquifer which extends over the northern parts of the site.

The assessment also demonstrates that the SEPP14 wetlands are not adversely affected by changes in the groundwater regime resulting from the proposed development.

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FIGURES

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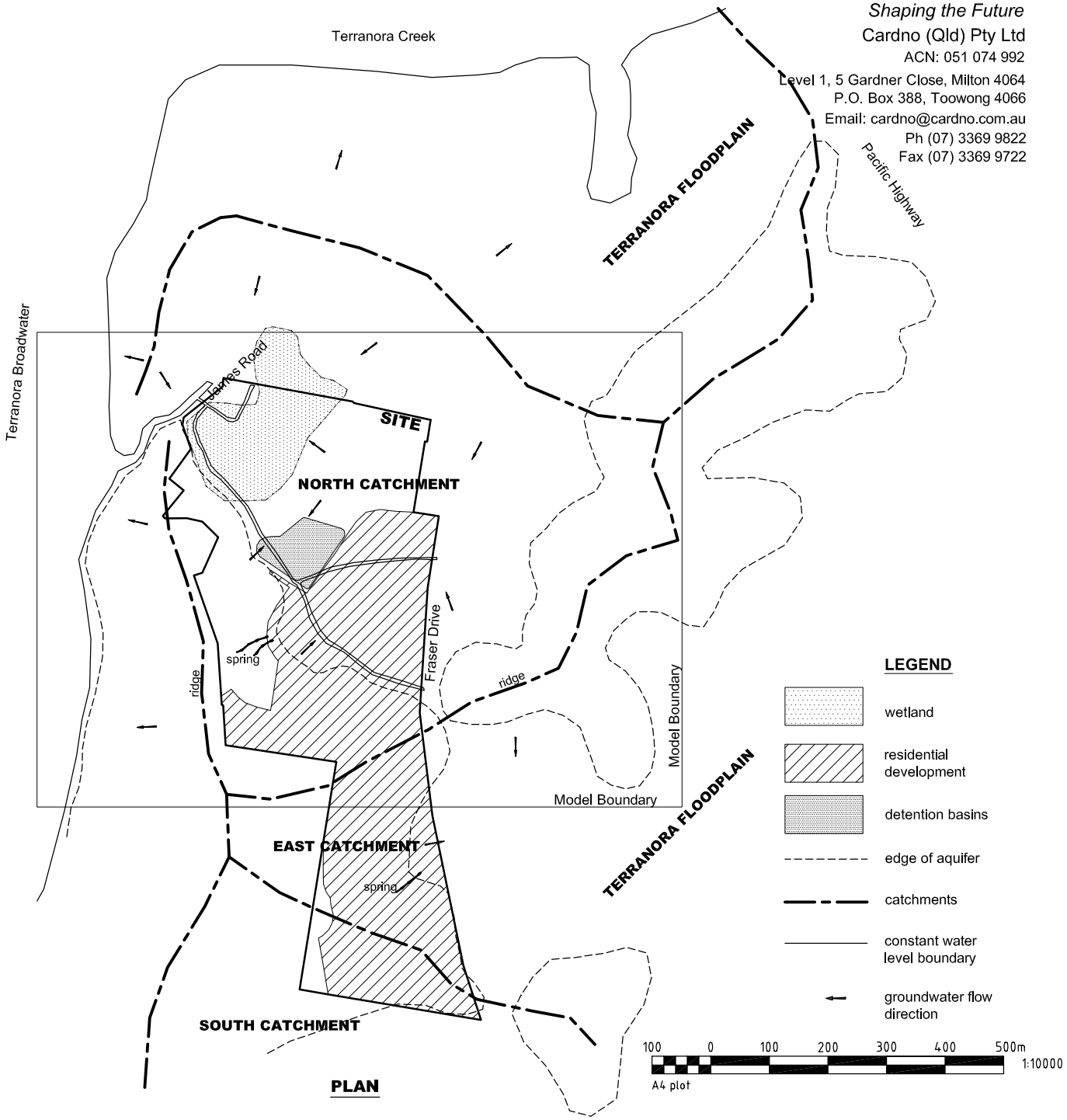

PLAN

Ver.	Date	Drwn	Appr.	Description	Job No.	7214/29/01
2	19/01/2007	JDB				
1	17/01/2007	JDB				

VILLA WORLD
FRASER DRIVE, TWEED SOUTH
GROUNDWATER IMPACTS ASSESSMENT

GROUNDWATER FEATURES
FIGURE 1