Box Hill Water

Appendix 4.2.1(a) Process Flow Diagram (Sewerage and Recycled Water)

Quality Control Points (QCP) for Water Quality

Bioreactor
- pH
- Dissolved oxygen
- Temperature
- Flow

Chlorine Residual
- Chlorine residual

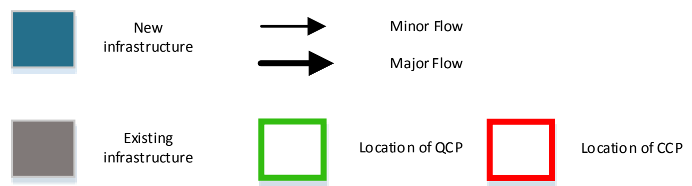
Critical Control Points (CCP) for Water Quality

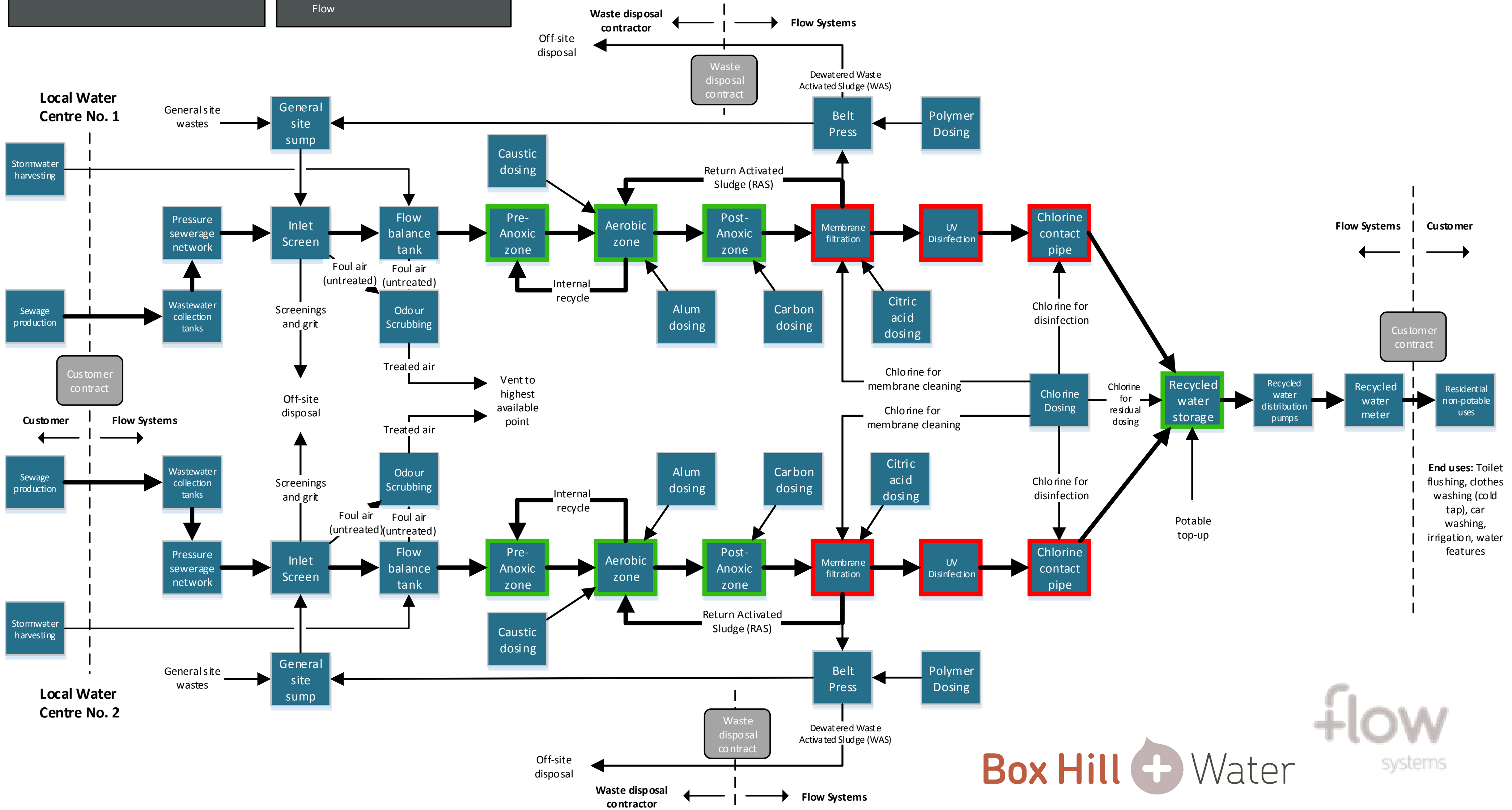
Membranes
- Permeate turbidity

UV
- UV transmissivity
- UV Intensity
- Flow

Chlorine Contact
- Chlorine residual
- Flow

Unit Operation	Log Removal Virus	Log Removal Protozoa	Log Removal Bacteria
MBR	≥2.5	≥4.0	≥4.0
UV	≥1.0	≥1.5	≥3.0
Chlorine	≥3.0	-	≥4.0
Design	**≥6.5**	**≥5.5**	**≥11.0**
Required	**≥6.5**	**≥5.0**	**≥5.0**
	✓	✓	✓

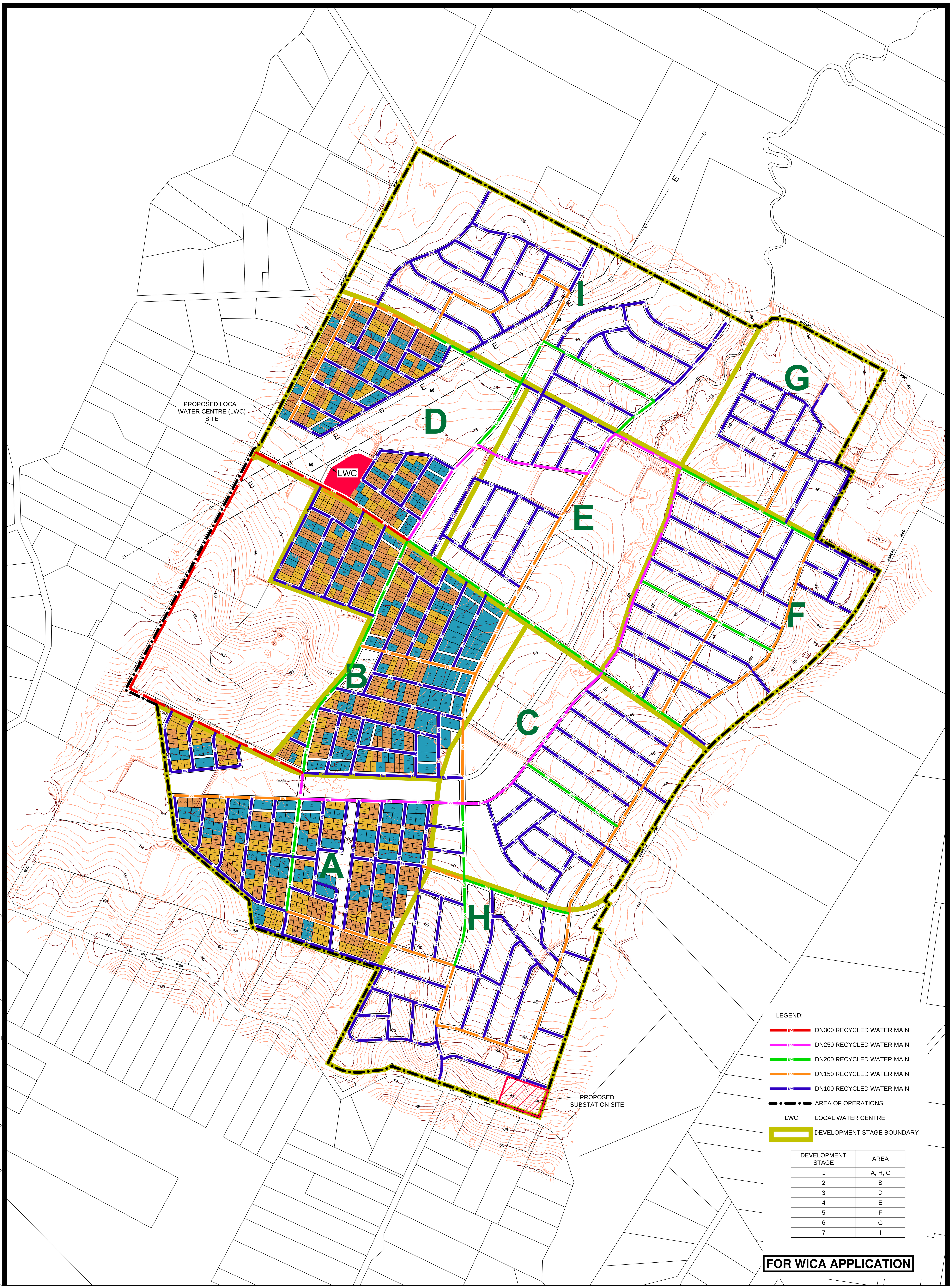




Date: 17/12/2014	Sewerage and Recycled Water Process Flow Diagram	Revision D

Box Hill Water

Appendix 4.2.1(b) Recycled Water Reticulation Masterplan



DEVELOPMENT STAGE	AREA
1	A, H, C
2	B
3	D
4	E
5	F
6	G
7	I

Date: 18/12/2014

Rev: C

Drawing No: SK301

Scale: 0 50 100 150 200m SCALE 1:4000 AT A0

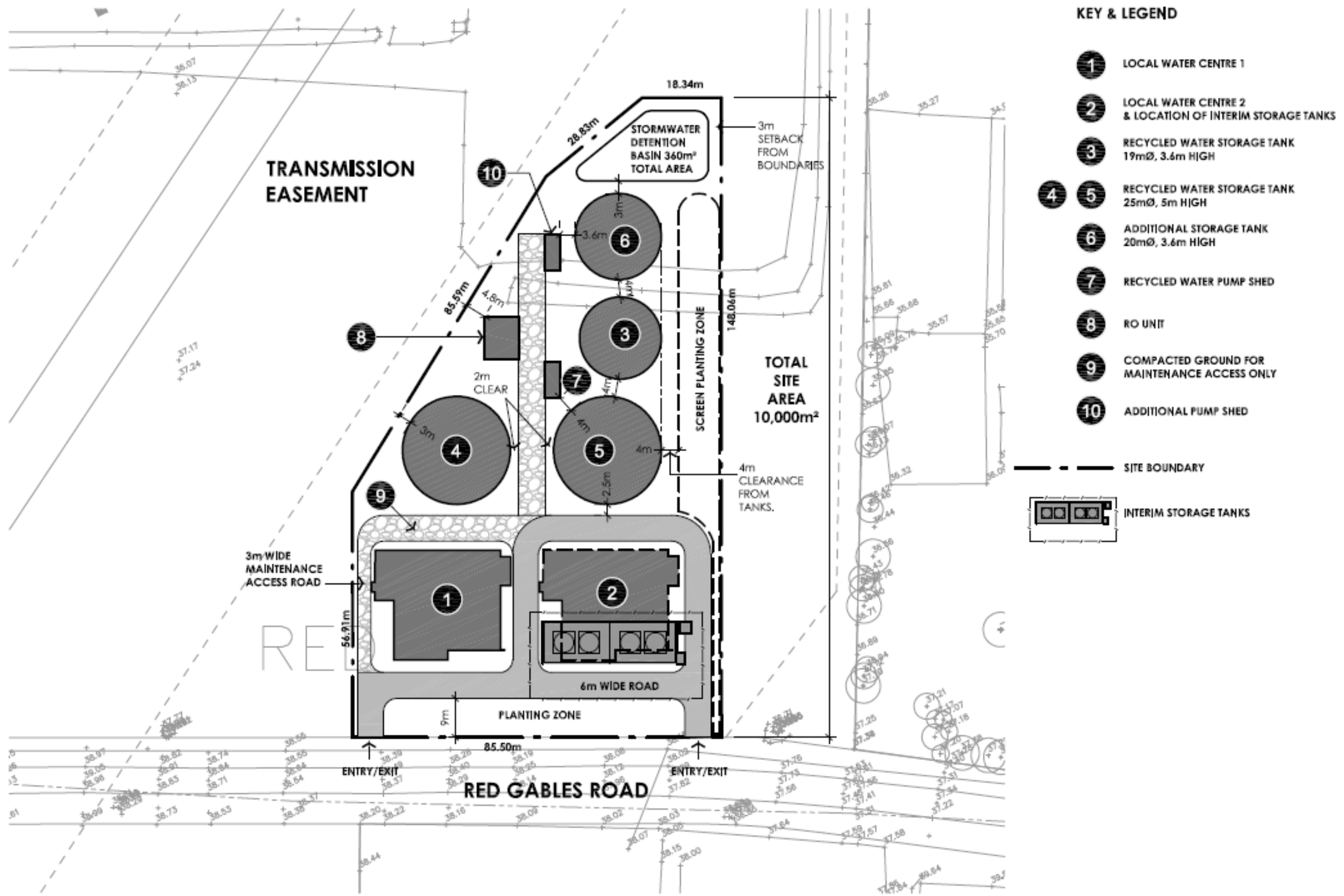
BOX HILL NORTH
RECYCLED WATER
MASTERPLAN - WICA APPLICATION

flow systems
Pressure System Solutions Pty Ltd
PLANNING, DESIGN & IMPLEMENTATION OF WATER & WASTEWATER SYSTEMS
Our Understanding and Experience Provides Certainty
PS Solutions
PO Box 630 Jannali NSW 2226
www.pssolutions.net.au
T: +61 2 9584 1177
F: +61 2 9584 1477

Saved: 18.12.2014, By: kgao
J:\700-Projects\702-Current projects\141010 Box Hill North\720-Design\721-Drawings\730-Street mains\Box Hill_SK301 Recycled Water Masterplan.dwg

Box Hill + Water

Appendix 4.2.1(c) LWC Concept Layout



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1:1 SHEET PRINT SCALE 5 10 20 50

NOT FOR CONSTRUCTION

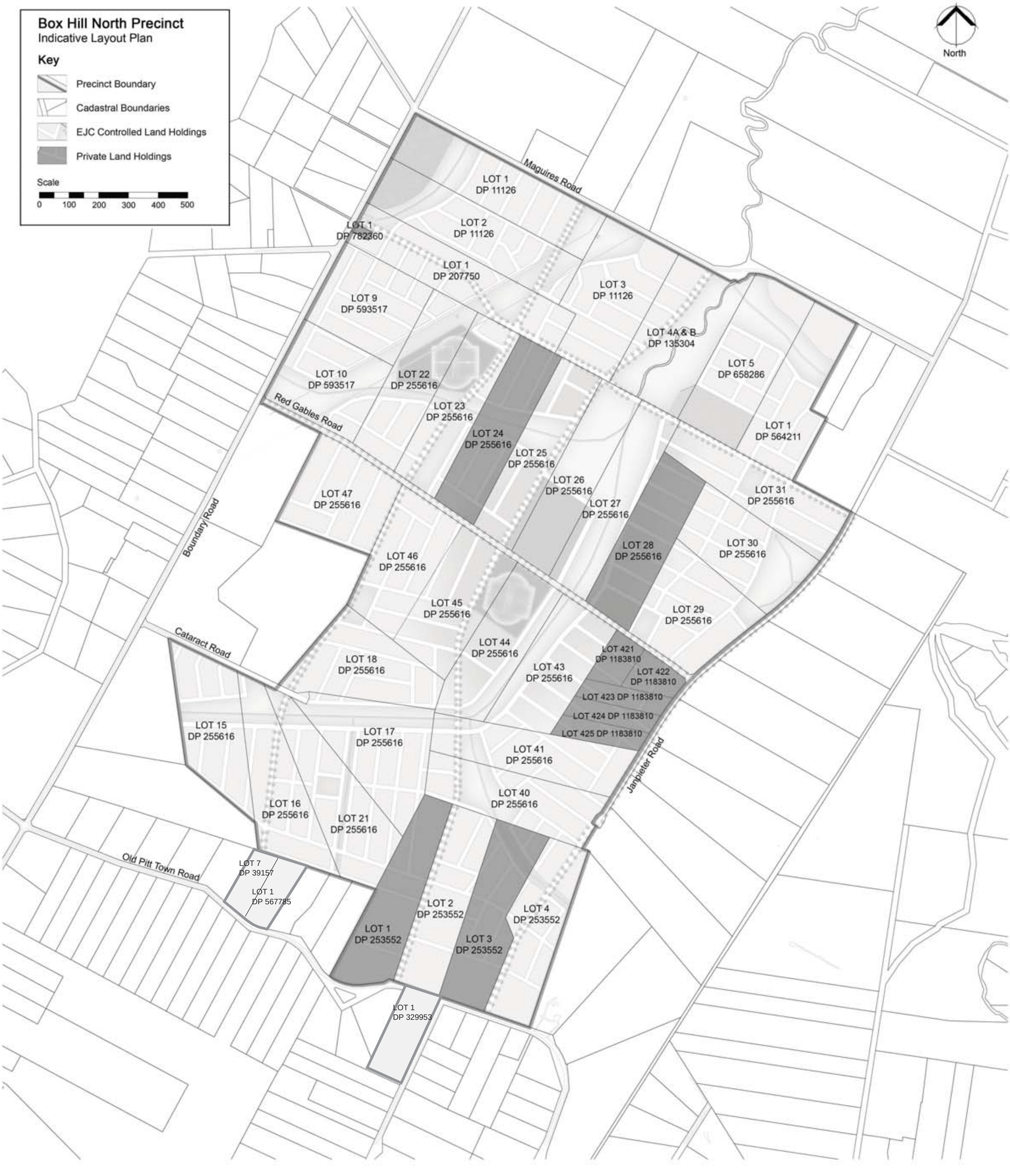
NO.	DATE	DRAFTER	DESIGN	MGMT	DESCRIPTION
6	17.03.15	VC	AC	"	ISSUED FOR COMMENT
5	16.03.15	VC	AC	"	ISSUED FOR COMMENT
4	19.12.14	VC	AC	"	ISSUED FOR COMMENT

CLIENT: flow systems

NAME:	BOX HILL NORTH		
PROJECT:	LOCAL WATER CENTRE		
Design	Date	Drafting	Date
AJC	17-Mar-15	MDP	17-Mar-15

TITLE:	SITE PLAN	
SCALE	PERMEATE PROJECT # C14121	PERMEATE DRAWING # C14121-100
SHEET A3	CLIENT PROJECT # TBA	CLIENT DRAWING # TBA

Appendix 4.2.3(a) Scheme Lot and DP References


Box Hill North Precinct
Indicative Layout Plan
Key
Precinct Boundary
Cadastral Boundaries
EJC Controlled Land Holdings
Private Land Holdings
Scale
0 100 200 300 400 500
North
Maguires Road
Red Gables Road
Boundary Road
Cataract Road
Old Pitt Town Road
Janpieter Road
LOT 1 DP 11126
LOT 2 DP 11126
LOT 1 DP 782360
LOT 1 DP 207750
LOT 3 DP 11126
LOT 9 DP 593517
LOT 4A & B DP 135304
LOT 5 DP 658286
LOT 10 DP 593517
LOT 22 DP 255616
LOT 23 DP 255616
LOT 24 DP 255616
LOT 1 DP 564211
LOT 25 DP 255616
LOT 26 DP 255616
LOT 47 DP 255616
LOT 27 DP 255616
LOT 31 DP 255616
LOT 28 DP 255616
LOT 30 DP 255616
LOT 46 DP 255616
LOT 45 DP 255616
LOT 29 DP 255616
LOT 44 DP 255616
LOT 421 DP 1183810
LOT 18 DP 255616
LOT 43 DP 255616
LOT 422 DP 1183810
LOT 423 DP 1183810
LOT 424 DP 1183810
LOT 15 DP 255616
LOT 425 DP 1183810
LOT 17 DP 255616
LOT 41 DP 255616
LOT 40 DP 255616
LOT 16 DP 255616
LOT 21 DP 255616
LOT 7 DP 39157
LOT 1 DP 567785
LOT 2 DP 253552
LOT 4 DP 253552
LOT 1 DP 253552
LOT 3 DP 253552
LOT 1 DP 329953

Box Hill Water

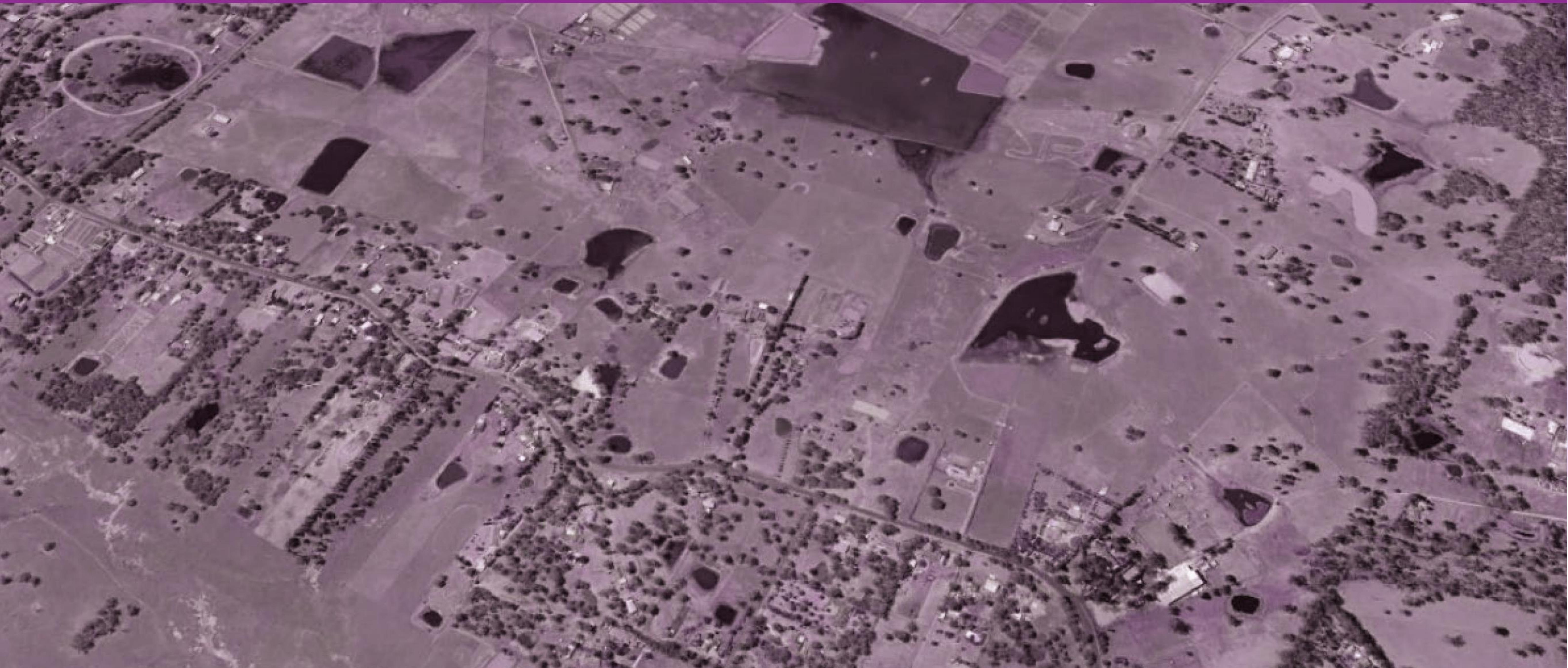
Appendix 4.2.6(a) Box Hill Water Balance Summary Report

BOX HILL WATER

WATER BALANCE SUMMARY

PREPARED BY KINESIS FOR FLOW SYSTEMS

1 MAY 2015



Prepared by Kinesis
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NSW 1230
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Document Version
Final

Authors
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Tom Watson, Sustainability Analyst
Tu Tu, Senior Analyst

Cover Image Credits
Google Earth, 2015

Note: This report is provided subject to some important assumptions and qualifications:

The results presented in this report are modelled estimates using mathematical calculations. The data, information and scenarios presented in this report have not been separately confirmed or verified. Accordingly, the results should be considered to be preliminary in nature and subject to such confirmation and verification.

Energy, water and greenhouse consumption estimates are based on local climate and utility data available to the consultant at the time of the report. These consumption demands are, where necessary, quantified in terms of primary energy and water consumptions using manufacturer's data and scientific principles.

Generic precinct-level cost estimates provided in this report are indicative only based on Kinesis's project experience and available data from published economic assessments. These have not been informed by specific building design or construction plans and should not be used for design and construct cost estimates.

The Kinesis software tool and results generated by it are not intended to be used as the sole or primary basis for making investment or financial decisions (including carbon credit trading decisions). Accordingly, the results set out in this report should not be relied on as the sole or primary source of information applicable to such decisions.

CONTENTS

EXECUTIVE SUMMARY

Box Hill North is a proposed residential development near Rouse Hill. Construction will be completed in 2032 which will consist of approximately **4,114** dwellings and a **5.5 ha** town centre and **2.2 ha** school site.

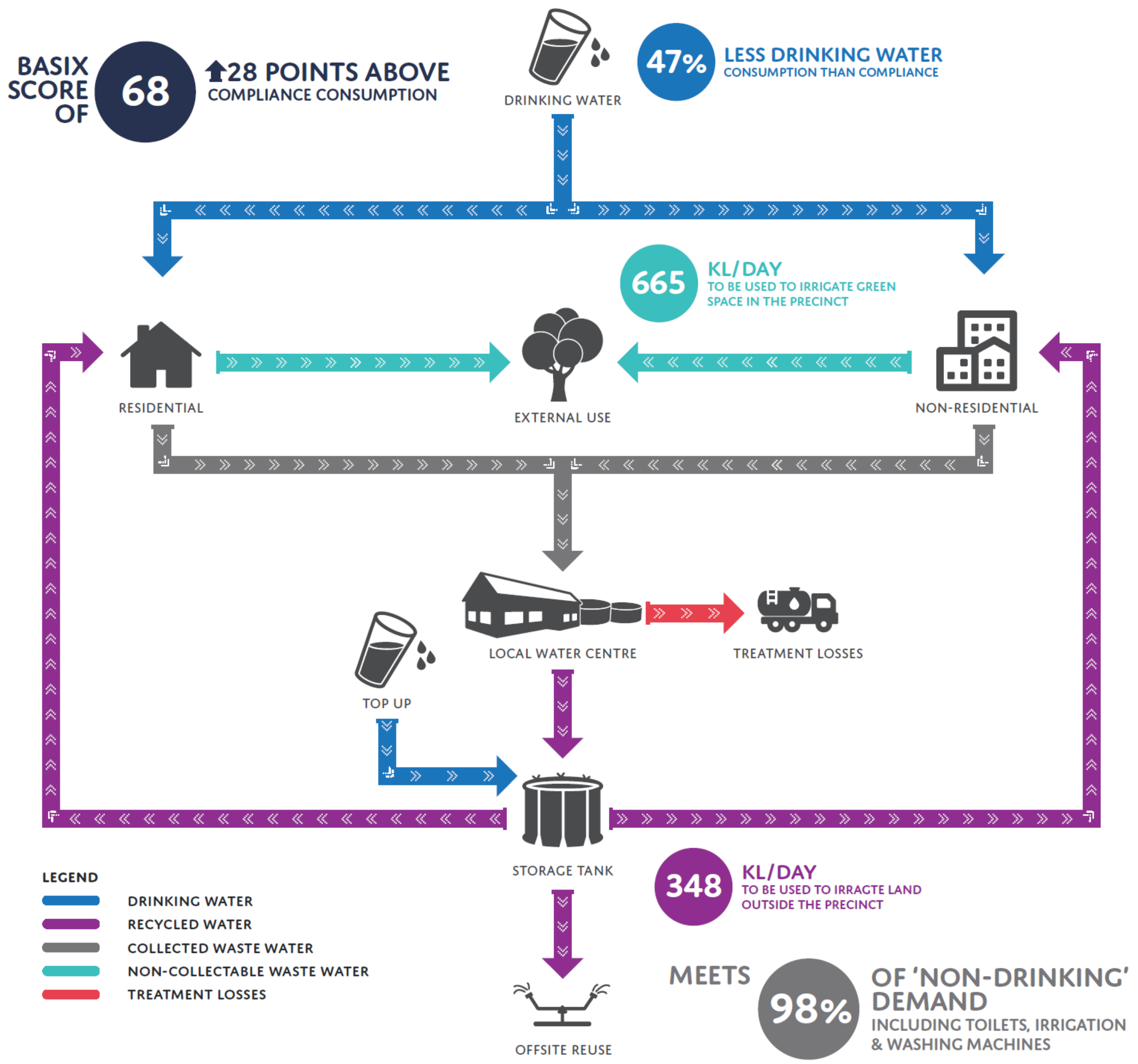
Box Hill Water is a recycled water scheme that incorporates a combined membrane bioreactor and ultrafiltration system with two **2.5 ML** storage tanks for a total of **5.0 ML** of storage. The system will take inflows from all grey and black waste water from both the residential and non-residential buildings and provide recycled water for:

- Residential use in
  - Toilets
  - Washing Machines (cold only)
  - Car washing
  - External irrigation
- Non-residential use in
  - Toilets
  - Irrigation
  - Washdown, and
  - Water features.

In the event that the storage tanks are empty and the recycled water system is unable to service recycled water demand then drinking water will be used for these end-uses. It is expected, however, that during an average year recycled water will meet **98% of the water demands** of the above end-uses. In addition, stormwater has been identified as a secondary source for recycled water drawn from stormwater flows across the site.

With the recycled water scheme, dwellings in the precinct are expected to achieve, on average, a **BASIX Water score of 68**. Furthermore, to achieve BASIX Water targets without the recycled water scheme, dwellings at Box Hill North would be required to install individual rainwater tanks connected to both toilet flushing and external use.

BOX HILL WATER SYSTEM



PROJECT DETAILS

This report documents the water balance analysis for Box Hill Water in order to inform the delivery of a proposed recycled water scheme for Box Hill North.

The Box Hill North development is a proposed residential development near Rouse Hill in the local government area of Baulkham Hills. Ultimately it will comprise approximately 4,114 residential lots, a 5.5 ha new town centre area and a 2.2 ha new school site. Analysis in this report outlines the results and performance outcomes for Box Hill North.

This analysis is undertaken based on figures provided by Flow Systems (see Figure 1 and Table 1) using Kinesis's CCAP Precinct modelling tool. CCAP Precinct is a strategic sustainability and infrastructure design tool that models key environmental, economic, social and infrastructure implications and requirements for precinct-scale development projects.

The report is structured as follows:

- Water Demands
- Source Water Production
- Recycled Water System Performance

Land Use	Area
Total Development Area	**380 ha**
Public Space	
Road area	120 ha
Playing fields	9.2 ha
Native Parklands/Reserves	57.5 ha
Total public space	**186.7 ha**
Non-Residential Land Use	
Retail	7,900 m^2
Entertainment	1,150 m^2
Commercial	500 m^2
Primary Secondary Education	4,400 m^2
Day Clinic	450 m^2
Total non-residential	**14,400 m^2**
Residential Dwellings	
Detached dwellings	3,719
Attached dwellings	95
Apartments	200
Total dwellings	**4,114**

Table 1: Dwelling yield and floor space for the Box Hill North Precinct.

BOX HILL NORTH MASTER PLAN

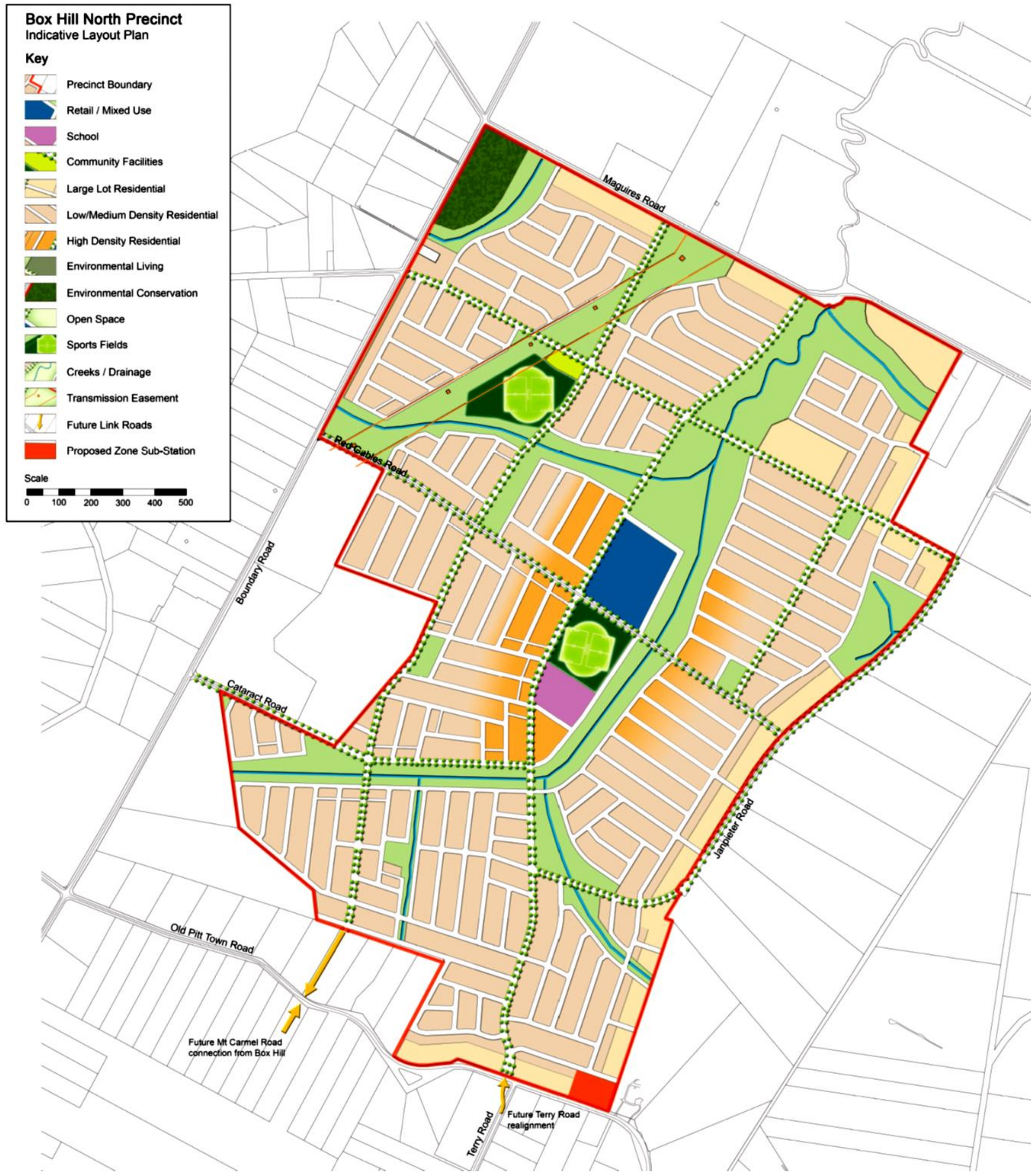


Figure 1: Box Hill North Master Plan

WATER DEMANDS

2.1 RESIDENTIAL WATER DEMANDS

Residential water demands were calculated based on the specific residential building types proposed for the Box Hill North development. The estimated water balance for an average household is shown in Figure 2. The details of the dwelling type configuration are outlined in Tables 2 and 3. Monthly total and daily average residential water demands by end use are outlined in Figures 3 and 4.

Month to month variation is evident due to changes to irrigation water demands based on rainfall and evaporation profiles (see climate data in Figure 5). Monthly internal total demands vary slightly due to differences in the number of days per month.

HOUSEHOLD DAILY WATER BALANCE

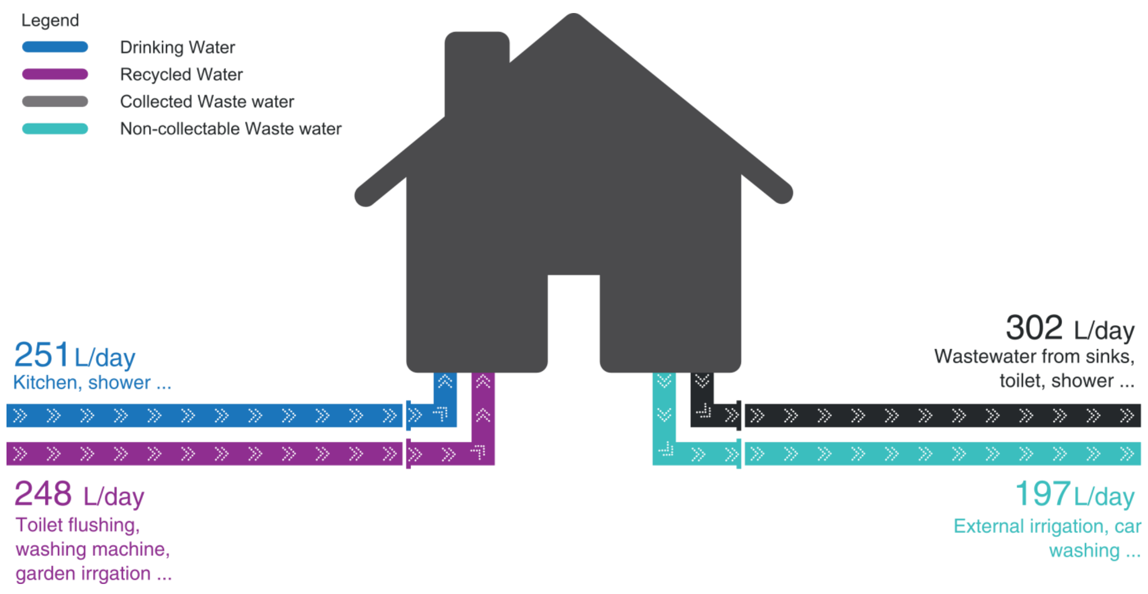


Figure 2: Schematic showing a household's expected daily drinking and recycled water consumption, sewage production and non-collectable water use.

NOTE: Wastewater is discussed further in Section 3 - Source Water Production.

RESIDENTIAL DWELLING SPECIFICATIONS

Dwelling type	Number	Lot area	Bedrooms	Occupancy	Irrigated area	EP
Detached dwellings	1,249	550 - 2,000 m2	4 to 5	3.44 - 4.04	100 - 462 m2	4,695
Detached dwellings	2,470	300 - 500 m2	3 to 4	2.73 - 3.44	30 - 130 m2	7,810
Attached dwellings	195	200 - 250 m2	2 to 3	1.86 - 2.6	85 - 95 m2	437
Apartments						
3-bedroom	50		3	2.57	-	128
2-bedroom	100		2	1.99	-	199
1-bedroom	50		1	1.32	-	66
TOTAL	**4,114**	**-**	**-**	**-**	**-**	**13,335**
AVE. DWELLING		**561 m2**	**3.8**	**3.2**	**111 m2**	

Table 2: Residential dwelling specifications used in the analysis

RESIDENTIAL END USE SPECIFICATIONS AND AVERAGE DEMANDS

Water End Use	Technology	Per Person Demand L/day			Development Demand kL/day		
		DW	RW	Total	DW	RW	Total
Shower	3+ star WELS	28.4	-	28.4	378.7	-	378.7
Kitchen Sink	5 Star WELS	7	-	7	93.4	-	93.4
Bathroom Basin	5 Star WELS	1.4	-	1.4		-	
Dishwasher	4 Star WELS	2.1	-	2.1	28.0	-	28.0
Laundry trough	-	5.0	-	5.0	66.7	-	66.7
Bath	-	8.7	-	8.7	116.0	-	116.0
Leaks	-	10	-	10	133.4	-	133.4
Pools/Spa	-	10.5	-	10.5	140.0	-	140.0
Toilet	4 star WELS	-	17.5	17.5	-	233.4	233.4
Washing Machine	4.5 star WELS	3.5	19.6	23.1	46.7	261.4	308.1
Garden Irrigation	-	-	27.5	27.5	-	366.3	366.3
Car Washing	-	-	6.4	6.4	-	85.34	85.34
TOTAL	**-**	**78.4**	**77.5**	**155.9**	**1,045.5**	**1,033.5**	**2,078.9**
AVE. DWELLING		**251**	**248**	**499**			

Table 3: Residential dwelling end use specifications and average per person daily demands used in the analysis (DW = Drinking water demand, RW = Recycled water demand)

TOTAL RESIDENTIAL WATER DEMANDS

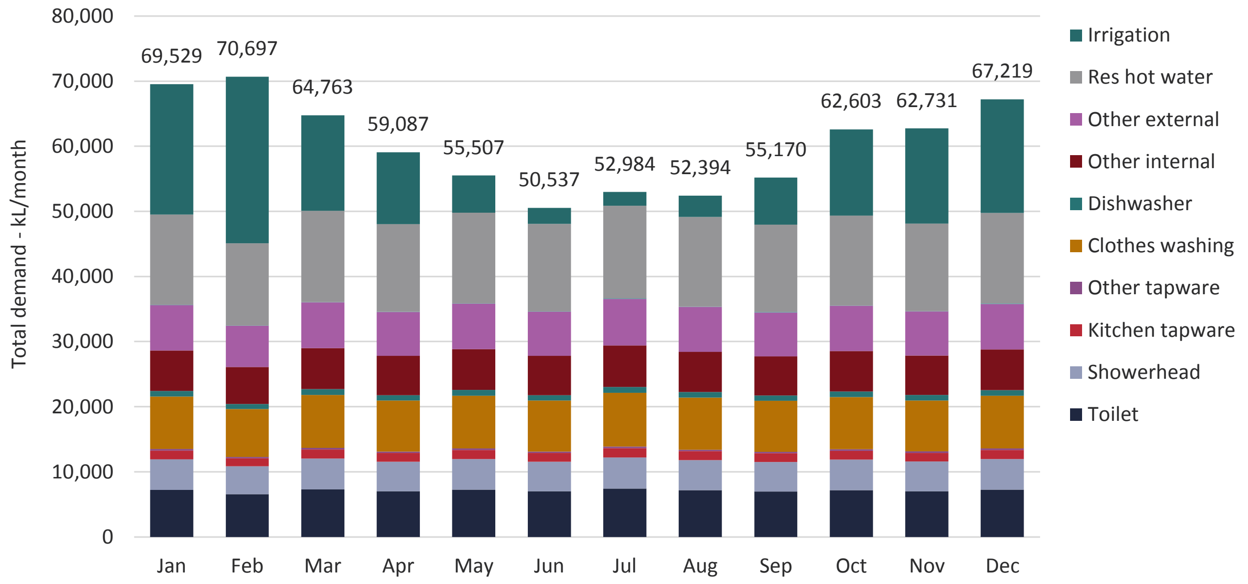


Figure 3: Total residential total water demands by end use, by month

TEMPERATURE, RAINFALL AND EVAPORATION AT BOX HILL

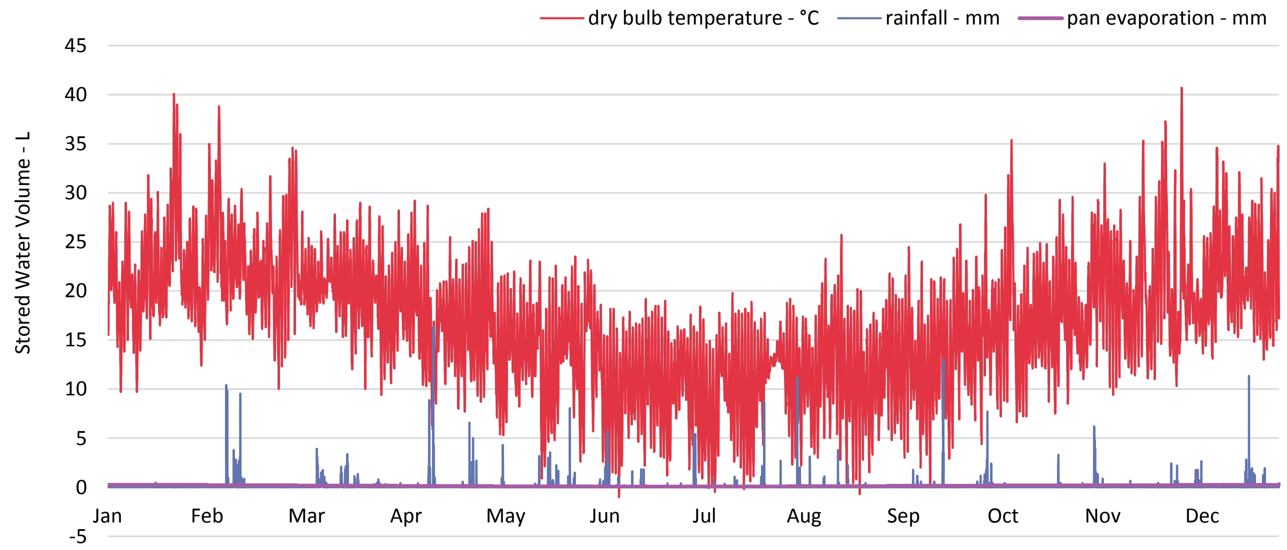


Figure 5: Dry bulb temperature, historic average rainfall and pan evaporation for local climate zone.

AVERAGE DAILY RESIDENTIAL WATER DEMANDS

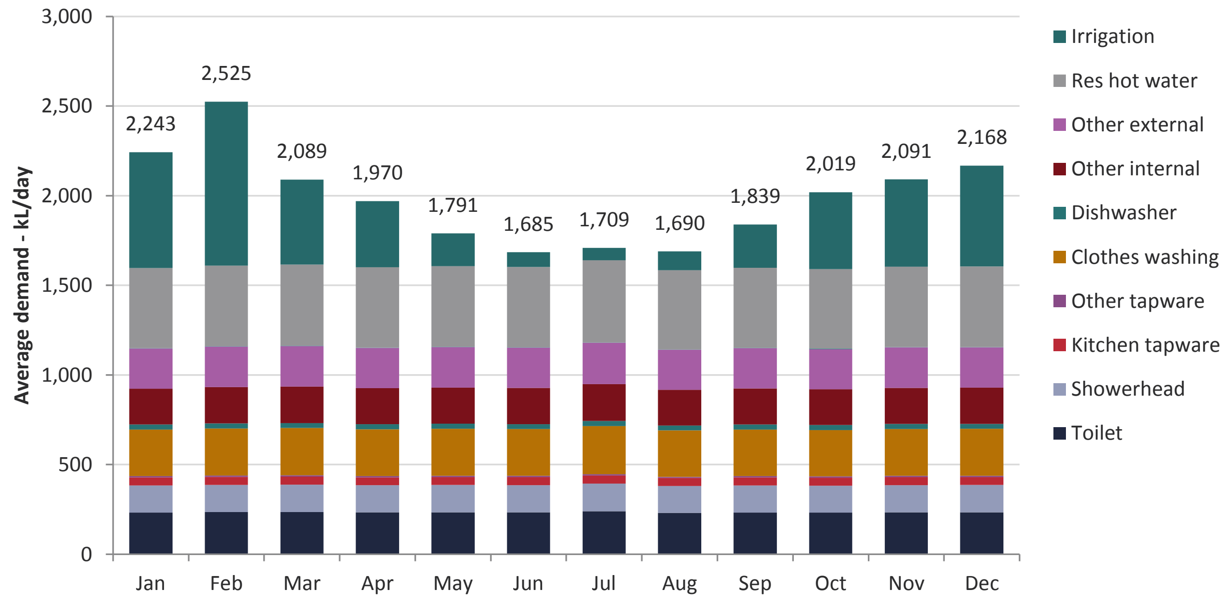


Figure 4: Average daily residential water demands by end use, by month

2.2 NON-RESIDENTIAL WATER DEMANDS

Non-Residential water demand was calculated based on the specific commercial, retail, education, community and open space proposed for the Box Hill North development.

Details of the building type configuration are outlined in Table 4. Median Practice is assumed to be current average practice and is derived from various sources, including Sydney Water Best Practice Guidelines for water conservation in commercial office buildings and shopping centres (see Key Data Sources – Appendix A).

Monthly total and daily average non-residential water demands by end use are outlined in Figures 6 and 7. Monthly internal total demands vary due to differences in the number of days per month. Month to month variation is only evident in changes to irrigation water demand based on rainfall and evaporation profiles.

NON-RESIDENTIAL SPECIFICATIONS - TOTAL

Demand Hierarchy	Water End Use	Area	Per m2 demand L/day			Development Demand kL/day		
			DW	RW	Total	DW	RW	Total
1	Retail	7,900 m^2	1.4	0.4	1.8	11.1	3.2	14.2
1	Commercial	500 m^2	0.5	1.2	1.8	0.3	0.6	0.9
	Entertainment	1,150 m^2	1.3	0.23	1.5	1.5	0.3	1.7
	Commercial Total	**8,400 m^2**				**12.9**	**4.1**	**16.8**
1	Education	4,500 m^2	0.2	1.2	1.4	0.9	5.3	6.2
1	Day Clinic	4500 m^2	9.6	0.6	10.2	4.3	0.3	4.6
	Community Total	**4,950 m^2**				**5.2**	**5.6**	**10.8**
3	Playing field irrigated	92,000 m^2	0	0.6	0.6	0.0	55.2	55.2
	Irrigation Total	92,000 m^2				**0.0**	**55.2**	**55.2**
n/a	Native Parklands	575,100 m^2	0	0	0	0.0	0.0	0.0
				TOTAL		**16.5**	**64.5**	**81.0**

Table 4: Non-Residential specifications and average annual demands used in the analysis

DW = Drinking water demand, RW = Recycled water demand

TOTAL NON-RESIDENTIAL WATER DEMANDS

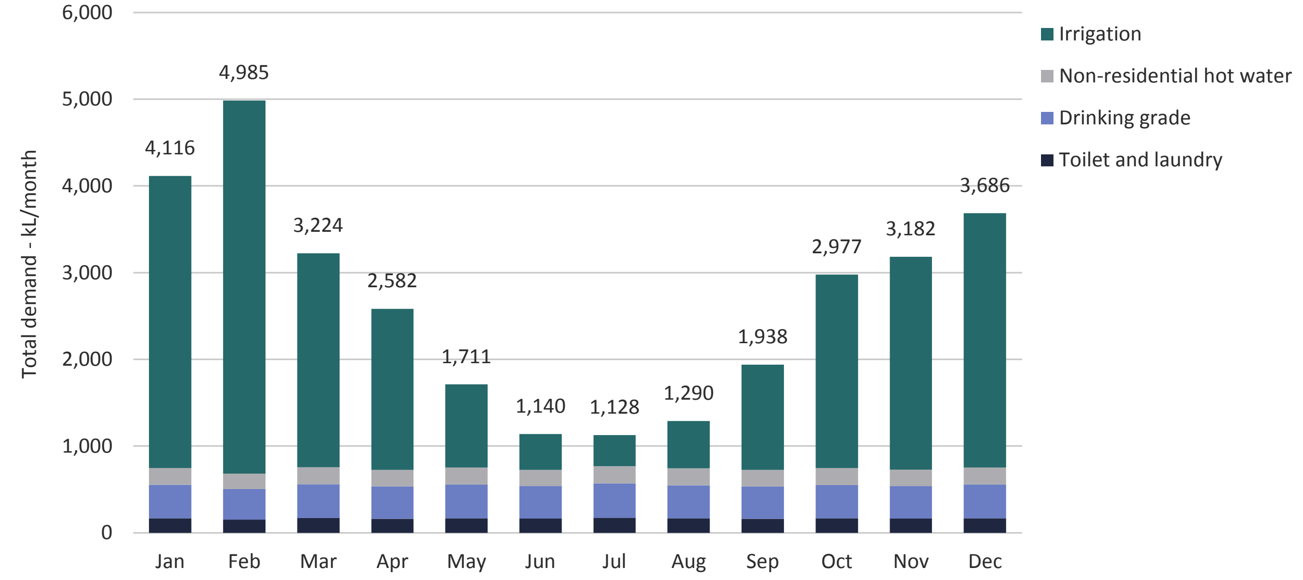


Figure 6: Non-Residential total water demands by end use, by month

AVERAGE DAILY NON-RESIDENTIAL WATER DEMANDS

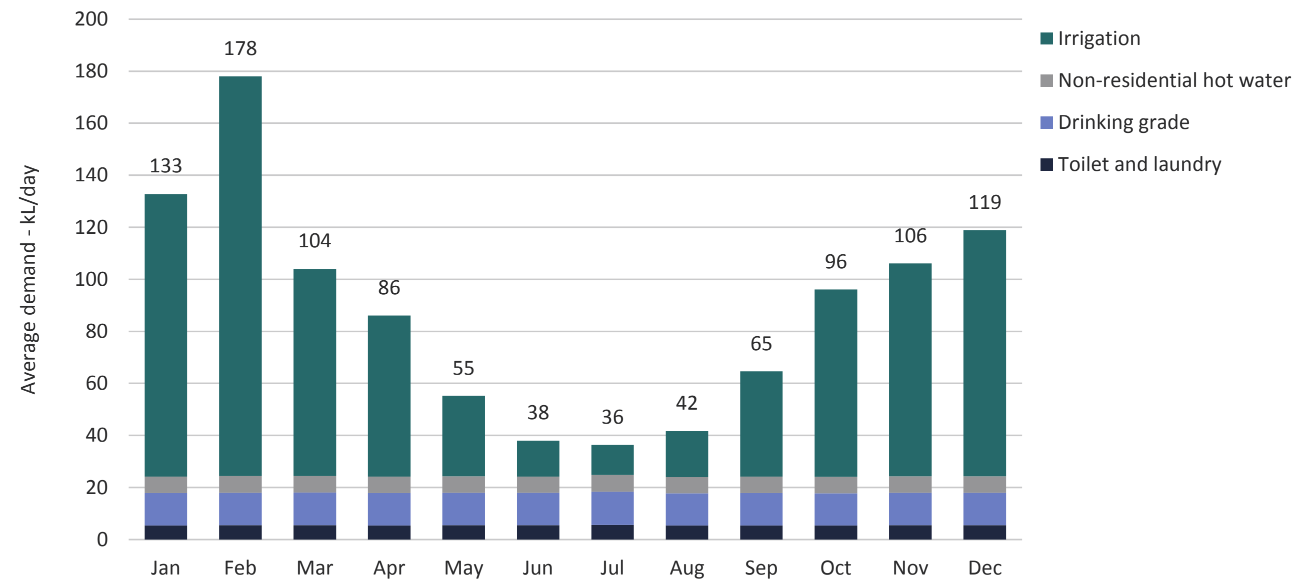


Figure 7: Average daily Non-Residential water demands by end use, by month

2.3 TOTAL AND PEAK WATER DEMANDS

Total water consumption, drinking water demand and recycled water demands are outlined in Tables 5 to 7, showing both total and peak demands for each use.

Total water demands are outlined in Figures 8 to 10 (monthly totals) and Figures 11 to 13 (daily average), summarising the results of the residential and non-residential demands for both drinking and recycled water demands.

As with the individual residential and non-residential demands, month to month variation is predominantly due to changes in irrigation demands. The irrigation demand analysis takes into account hourly rainfall data and cumulative period since the last rain event and irrigation, to predict the time and water use of the next irrigation event. Predictions are also calibrated against real irrigation data for better alignment and accuracy (See Key Data Sources in Appendix A).

Peak water demand (kilolitres per hour) for each month is provided in Figure 14. Peak demands for drinking and recycled water are also shown separately in Figures 15 and 16. The peak demand was determined based on the hourly maximum demand for each month, calculated based on the following variables:

- Hourly internal water demands based on a standard hourly internal water demand profile for each end use and building type.
- Hourly irrigation demands based on the irrigation area and local hourly rainfall and evaporation rates (see Key Data Sources in Appendix A).
- Analysis was undertaken for a historic average year of rainfall and evaporation representative of the local climate zone.

Due to the fact that internal water demand is relatively consistent over time, in all cases, outdoor irrigation demand is the key contributor towards peak water demands. It should also be noted that peak demands for drinking water and recycled water (Figures 15 and 16) do not necessarily add up to the total peak demand (Figure 14) as the individual peak demands may occur at different times.

TOTAL WATER DEMAND PROFILE

FACTOR	RESIDENTIAL	NON-RESIDENTIAL	TOTAL
Average Daily Demand - kL/d	1,980	87	2,069
Peak day - kL/d	3,980	365	4,344
Peak hour – kL/hr	361	31	390

Table 5: Demand profile for the Box Hill North development

DRINKING WATER DEMAND PROFILE

FACTOR	RESIDENTIAL	NON-RESIDENTIAL	TOTAL
Average Daily Demand - kL/d	1,109	19	1,128
Peak day - kL/d	1,600	27	1,627
Peak hour – kL/hr	168	3	171

Table 6: Demand profile for the Box Hill North development

RECYCLED WATER DEMAND PROFILE

FACTOR	RESIDENTIAL	NON-RESIDENTIAL	TOTAL
Average Daily Demand - kL/d	872	69	941
Peak day - kL/d	2,605	341	2,946
Peak hour – kL/hr	223	29	252

Table 7: Demand profile for the Box Hill North development

TOTAL WATER DEMAND

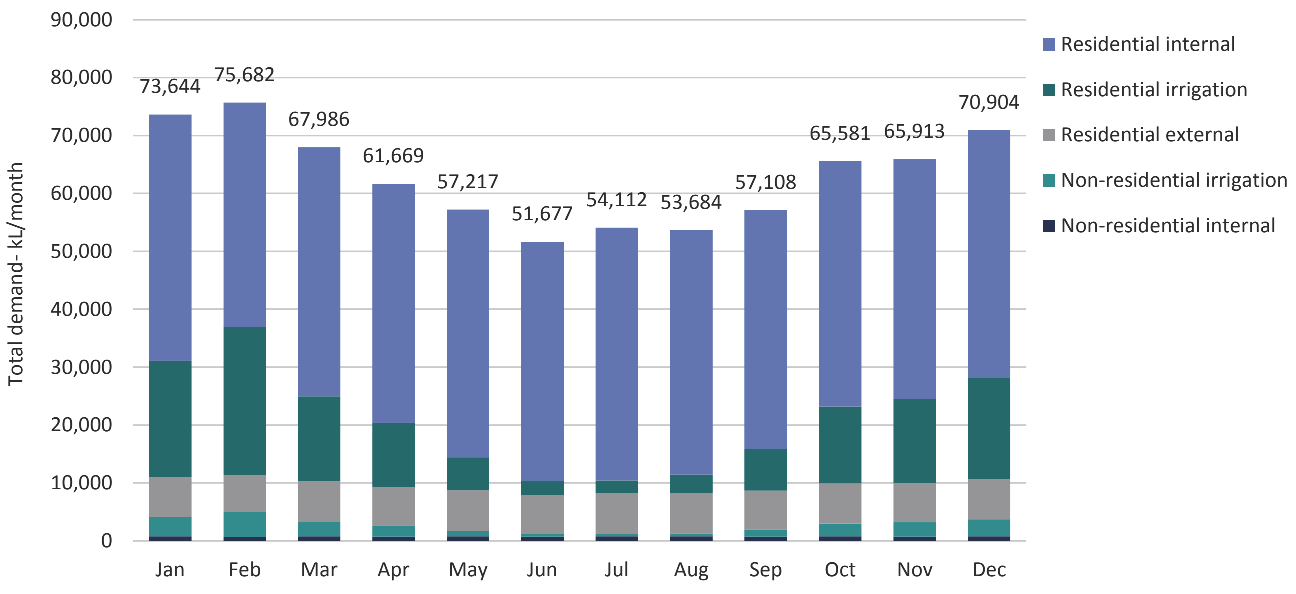


Figure 8: Total water demand by month

TOTAL DRINKING WATER DEMAND

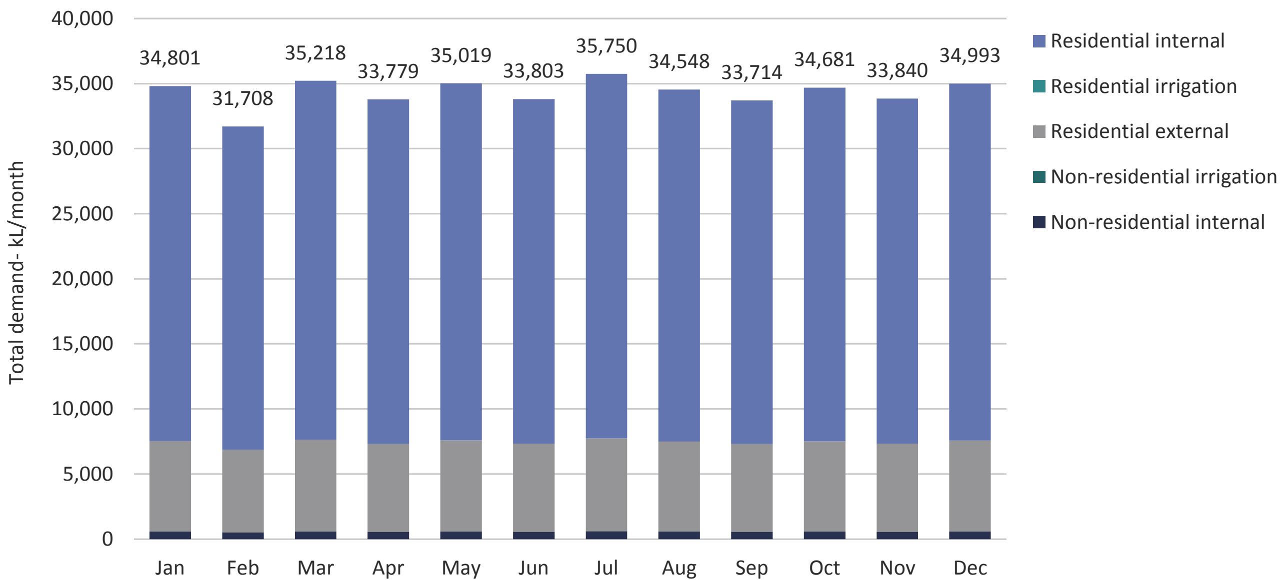


Figure 9: Total drinking water demand by month

DAILY AVERAGE WATER DEMAND

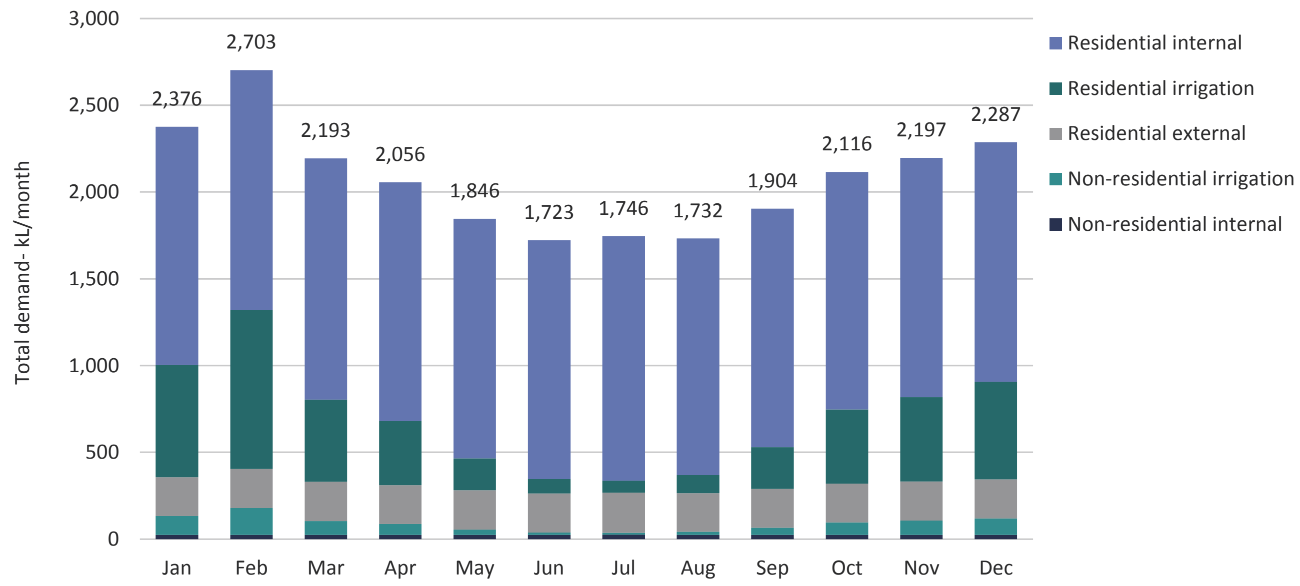


Figure 11: Daily average total water demands by month

TOTAL RECYCLED WATER DEMAND

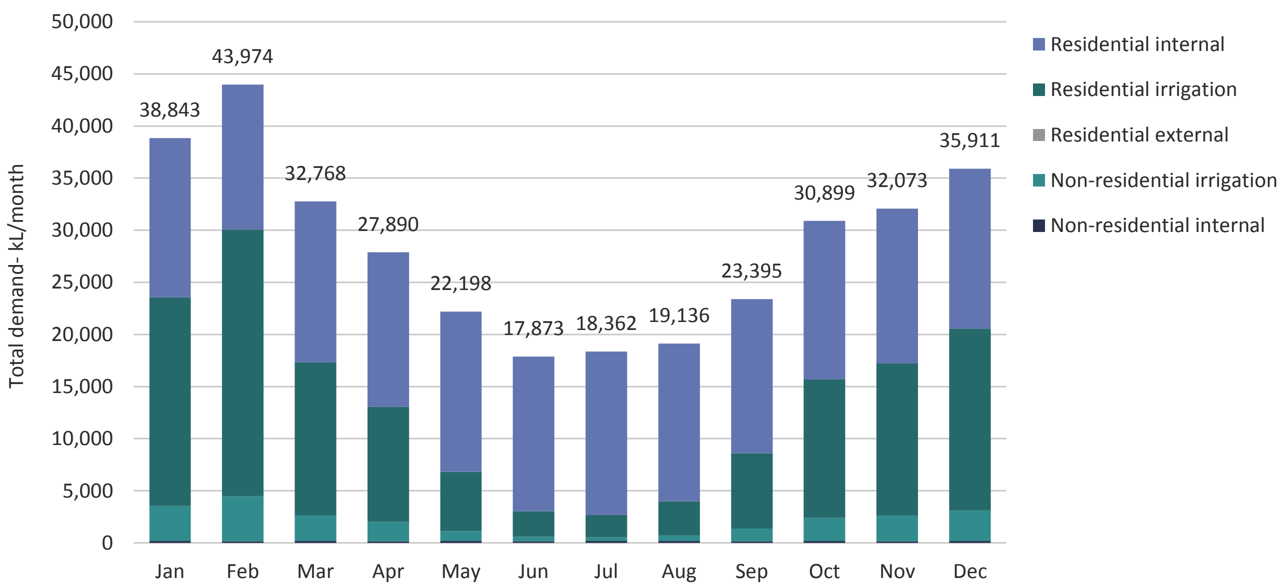


Figure 10: Total recycled water demands by month

DAILY AVERAGE DRINKING WATER DEMAND

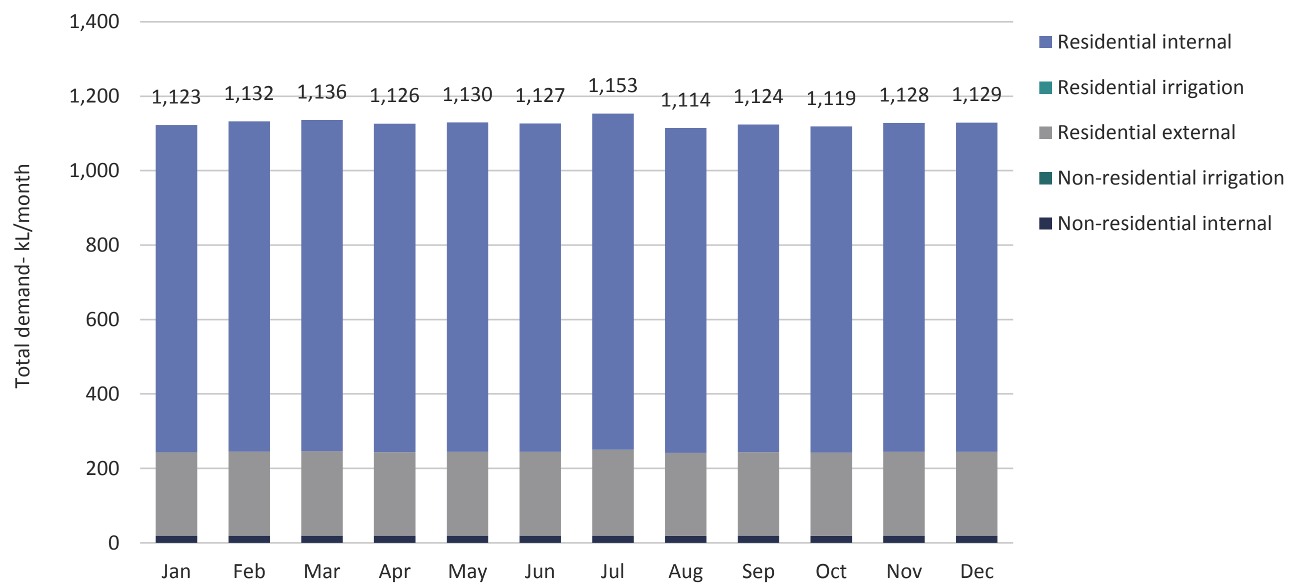


Figure 12: Daily average drinking water demand by month

DAILY AVERAGE RECYCLED WATER DEMANDS

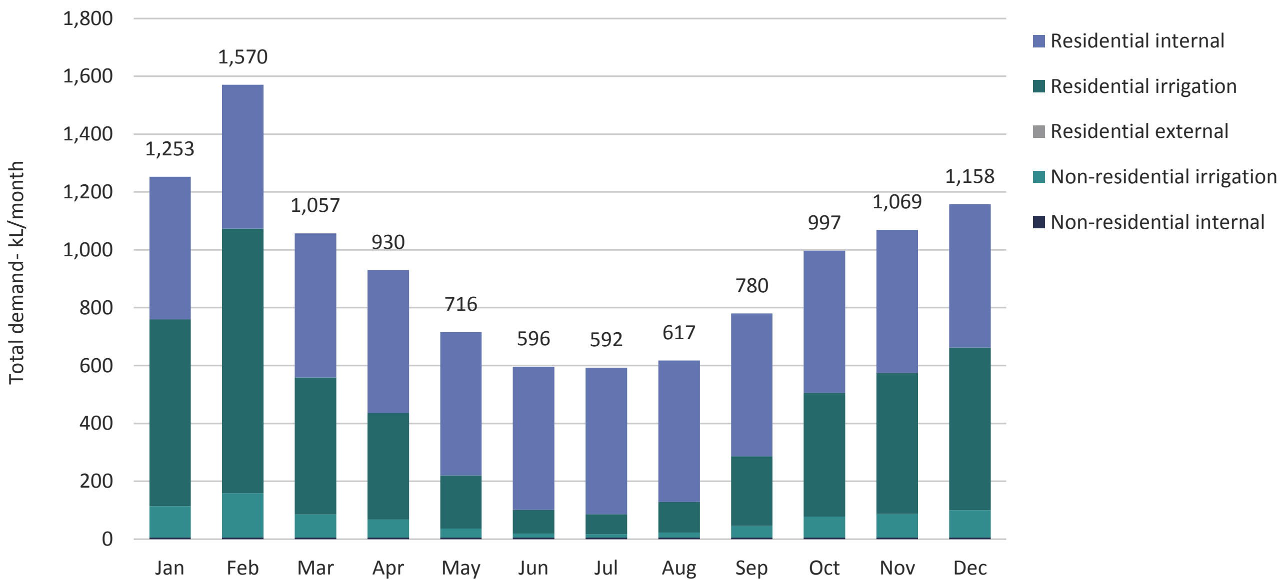


Figure 13: Daily average recycled water demand by month

PEAK RECYCLED WATER DEMANDS

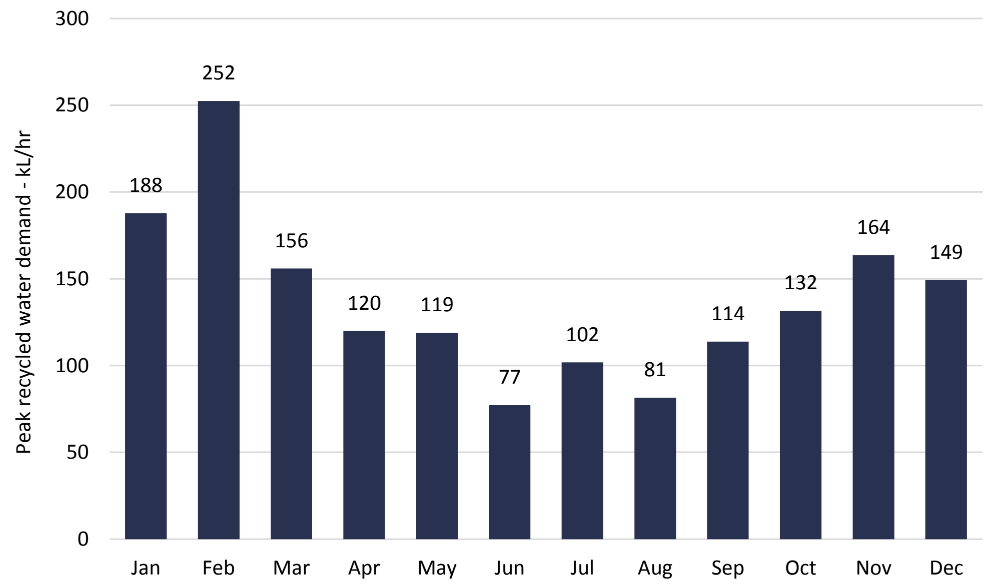


Figure 15: Peak recycled water demands by month

PEAK TOTAL WATER DEMANDS

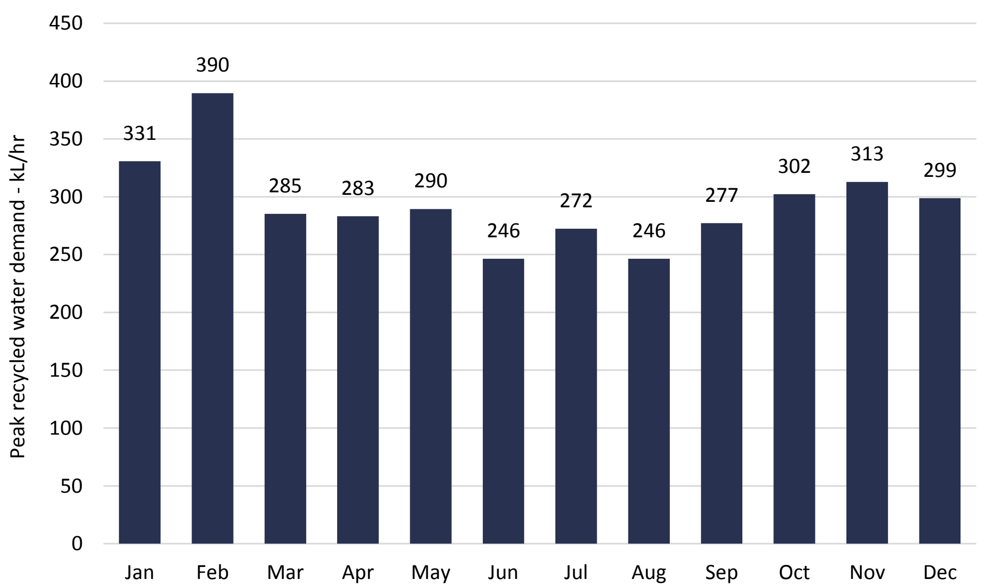


Figure 14: Peak total water demand by month

PEAK DRINKING WATER DEMANDS

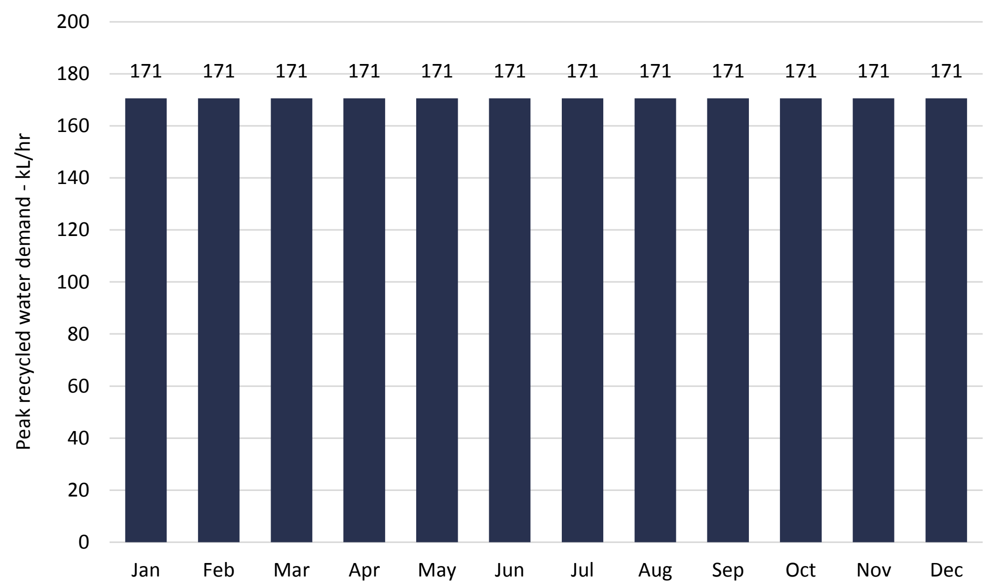


Figure 16: Peak drinking water demand by month

NOTE: Peak demands for drinking water and recycled water (Figures 15 and 16) do not necessarily add up to the total peak demand (Figure 14) as the individual peak demands may occur at different times.

3.1 SOURCE WATER PRODUCTION

Source water for the recycled water scheme is primarily sourced from sewage production. Residential and non-residential sewage production is calculated based on the specific building types proposed for the Box Hill North development (as shown previously in Tables 3 and 4).

Table 9 outlines the average daily and peak sewer production for the residential and non-residential components of the development. Source water production from the residential and non-residential buildings is broken down further in Tables 8 and 10.

It should be noted that **stormwater** has been identified as a secondary source for recycled water drawn from stormwater flows across the site. It is assumed that the stormwater volume available for top-up will be provided from both stormwater captured from the development as well as flows originating from areas outside the Stage 1 development. In addition, stormwater use will be managed for environmental reasons. As a result, specific stormwater top-up volumes were not available at the time of this report.

PRODUCTION PROFILE

FACTOR	RESIDENTIAL	NON-RESIDENTIAL	TOTAL
Average Daily Production - kL/d	1,243	24	1,267
Peak day - kL/d	1,794	35	1,829
Peak hour – kL/h	188	4	192

Table 9: Source water production profile for the Box Hill North development

RESIDENTIAL SEWAGE PRODUCTION

Water End Use	Per Person Sewage Production L/day	Development Sewage Production kL/day
Shower	28.5	379.4
Kitchen Sink	7.0	93.7
Bathroom Basin	1.4	18.5
Dishwasher	2.1	28.0
Laundry trough	5.0	66.7
Bath	8.7	116.0
Leaks	0.0	0.0
Pools/Spa	0.0	0.0
Toilet	17.5	233.8
Washing Machine	23.1	307.4
Garden Irrigation	-	-
Cooling Tower	-	-
Fire Test	-	-
Car Washing	-	-
TOTAL	93.3	1243.4
AVE. DWELLING	302.2 L/dwelling/day	

Table 8: Residential dwelling end use specifications and per person daily demands used in the analysis

NON-RESIDENTIAL SEWAGE PRODUCTION

Building Type	Per m2 Sewage Production L/day	Development Sewage Production kL/day
Retail	1.8	13.9
Commercial	1.8	0.9
Entertainment	1.5	1.7
Commercial Total		**14.7**
Education	0.8	3.7
Day Clinic	10.1	4.6
Community Total		**8.3**
Public Plaza irrigated	0	0
Playing field irrigated	0	0
Irrigation Total		**0**
Native Parklands	0	0
	TOTAL	23.0

Table 10: Non-Residential specifications and average annual demands used in the analysis

4.1 RECYCLED WATER SYSTEM CONFIGURATION

The recycled water system for Box Hill North was configured as follows:

- Connection to all dwellings for irrigation, toilet, washing machine (cold tap)
- Connection to all non-residential buildings for irrigation, toilet flushing and washdown
- Connection to all open space for irrigation
- Storage tank is sized at 5.0 ML (2 x 2.5 ML tanks)
- Accepted inflow volume is calculated as the sum of end-use demand and missing storage volume, analysed on an hourly basis.
- A 2% volume loss is also considered for the UF treatment process.

4.2 WATER BALANCE

The average daily flows of the recycled water system at full build out of Box Hill North are in Figure 17 and the key water results are shown in Figure 18 and Table 11.

Water Source	ML per year
Sewage Production	463
Recycled Water Demand	343
Recycled Water Demand Met	336
Water Import for Recycled Water Use	7
Drinking Water Demand	412
New lot establishment irrigation or offsite use	127

Table 11: Estimated development average water balance with recycled water system at full build out

Water Import for Recycled Water Use

The model shows that at full build out, a small amount of mains water top-up (water import) will be required when daily sewage production is less than daily recycled water demand. As per section 3.1 stormwater will be sourced as a secondary source of recycled water to provide both top up water as required during the staging of the development and to maintain full storage as a contingency measure.

New lot establishment irrigation or off-site use

New lot establishment irrigation or off-site use of recycled water only occurs when the treated volume is greater than the demand. The daily average volume available for this end use at full build out varies from 0 kL/day in February to 704 kL/day in July. The peak day volume in July equates to 1,110 kL, assuming a sustainable irrigation application rate of 2 mm per day (according to the land capability assessment), this equates to approximately 56 ha of irrigated land. Figure 19 shows, however, that the daily average of the peak month, 35 ha, is sufficient for 87% of days and only 2.5 ha of irrigated land is required for much of the year.

ANNUAL AVERAGE DAILY FLOWS IN KL/DAY

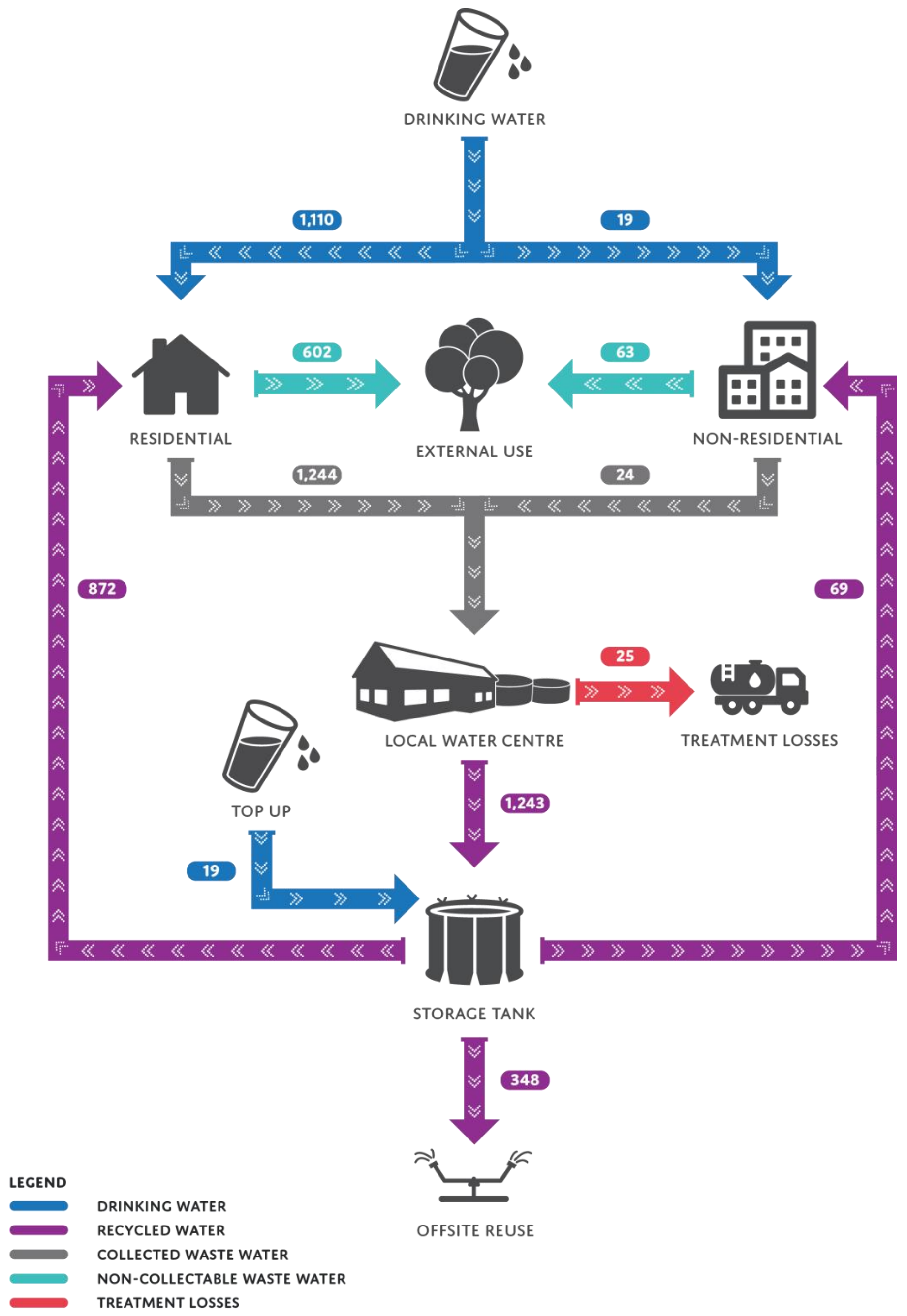


Figure 17: Schematic of the recycled water system showing annual average daily flows in kL/day.

Note - The sum of monthly recycled water use and new lot establishment irrigation does not always equal the total sewage production, due to the hourly analysis run by CCAP Precinct and the storage tank actively accepting and supplying water in order to minimize top-up and off-site use, e.g. sewage production excessive of the recycled water demand is kept in the recycled water storage tank, for periods where sewage production cannot meet the recycled water demand.

RECYCLED WATER SYSTEM PERFORMANCE AT FULL BUILD OUT

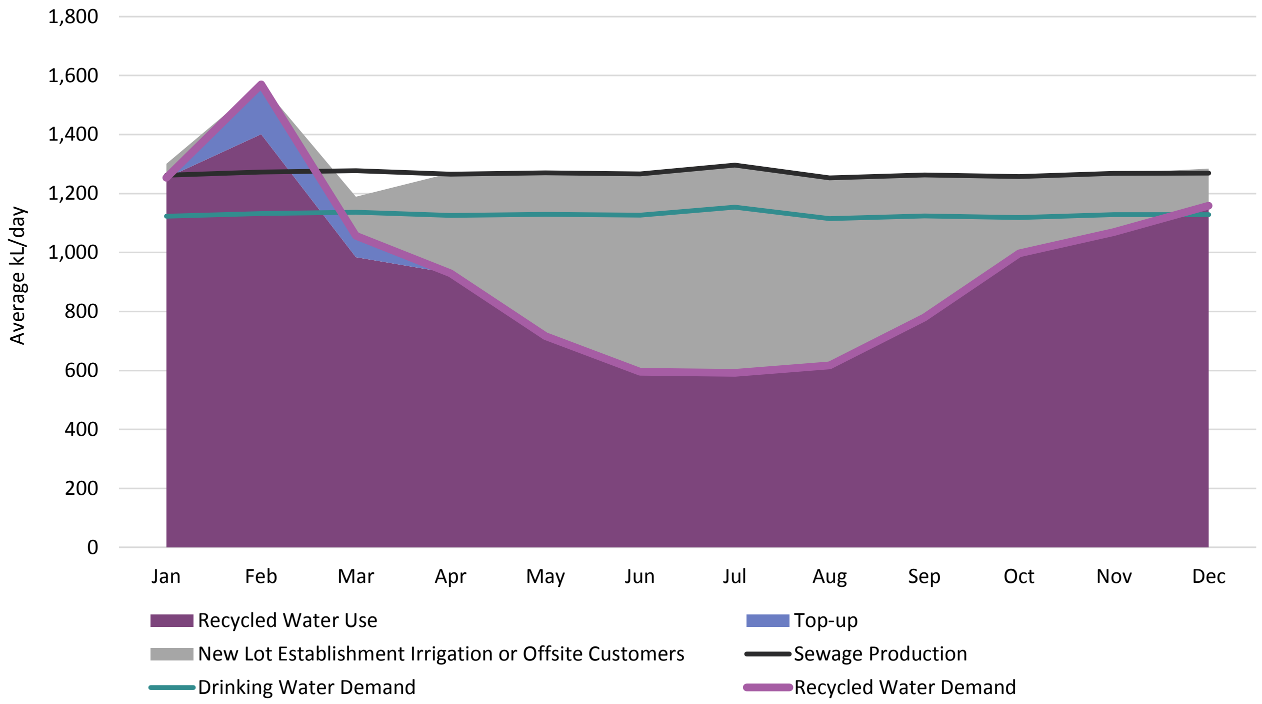


Figure 18: Recycled water system performance showing monthly recycled water use, demand and off-site use

DISTRIBUTION OF NEW-LOT ESTABLISHMENT IRRIGATION AT 2033

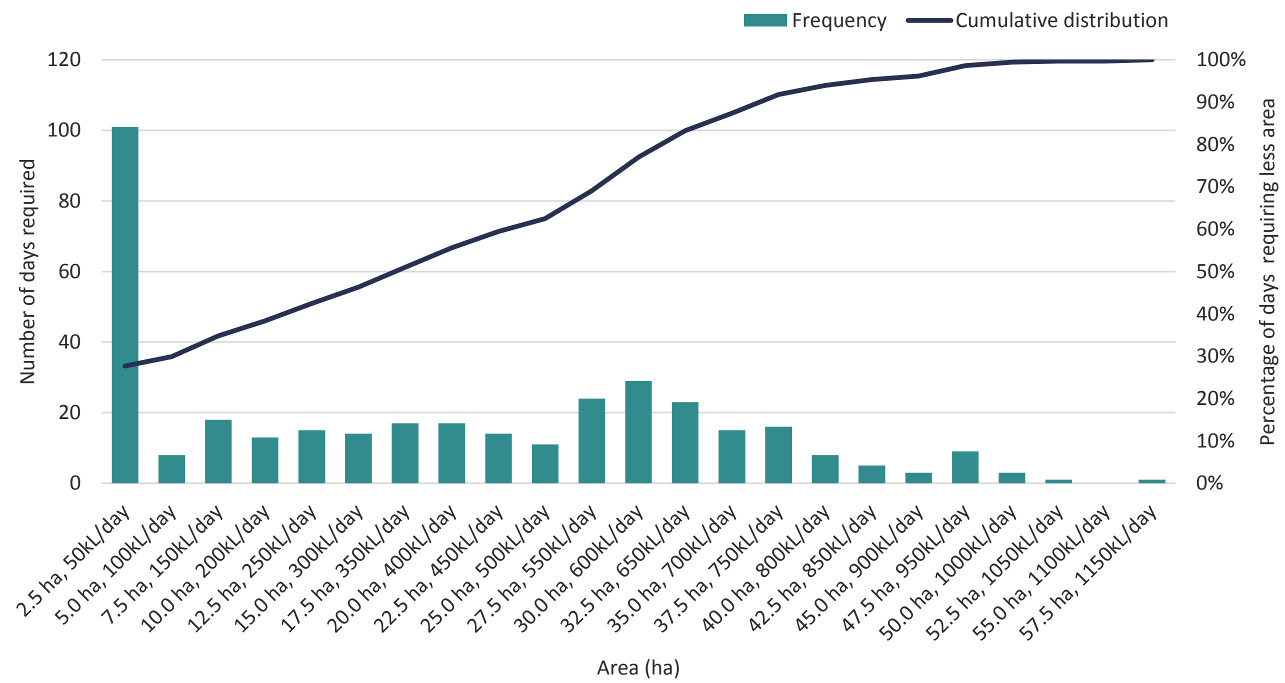


Figure 19: Frequency histogram and cumulative distribution of area required for new-lot irrigation

Recycled Water System Stored Volume

Figure 20 outlines the hourly recycled water storage volume over the year, highlighting the significant recycled water consumption for irrigation during summer and lower recycled water demands over the winter months. On average, the daily stored volume in the recycled water system tanks is 4,425 kL.

RECYCLED WATER STORED VOLUME

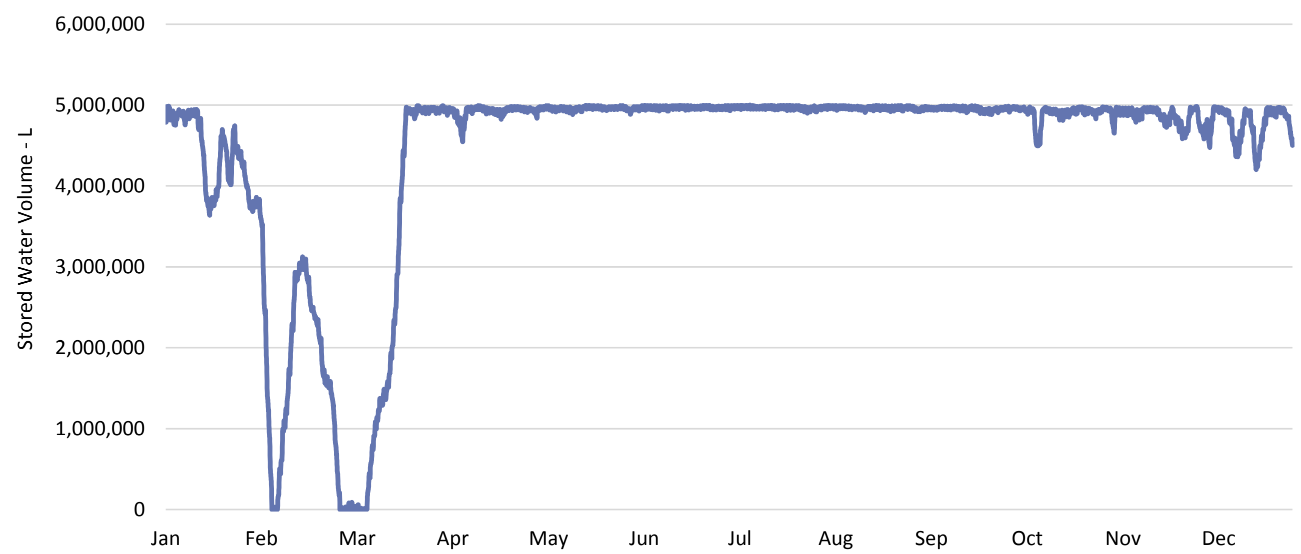


Figure 20: Hourly recycled water stored volume for the recycled water system

4.3 BASIX COMPLIANCE

With connection to the recycled water system, residential dwellings at Box Hill North are estimated to achieve an average **BASIX water score of approximately 68**.

Without connection to the recycled water system, dwellings at Box Hill North would be required to install rainwater tanks in all dwellings connected to both irrigation and toilet flushing. Rainwater tanks would need to be sized as follows:

- Detached dwellings - 3,500 L per dwelling
- Attached dwellings - 2,500 L per dwelling
- Apartments - 500 L per dwelling

This scenario would achieve an average BASIX water score of approximately 50 (modelled to reflect the NSW Department of Planning's proposed new BASIX Water Targets for residential dwellings).

APPENDIX

KEY DATA SOURCES

- ACADS-BSG Australian Climatic Data (Reference Meteorological Year, RMY) for hourly temperature, insulation and humidity.

- Bureau of Meteorology local rainfall and evaporation data (station 67021 – Richmond – UWS Hawkesbury, 140 km from development, synthesized RMY)

  - Data is from the representative weather station for the local climate zone (NatHERS zone 28)
  - The RMY (Representative Meteorological Year) is synthesized from a composite of 12 typical meteorological months that best represent the historic average of the specified location using post-1986 data in addition to the earlier weather data for each of the 69 climate zones in Australia. The total rainfall and evaporation for this climate zone is:
    - Annual rainfall (mm) - 728
    - Annual evaporation (mm) – 1,391

- Sydney Water (2009) Rouse Hill 15 minute and daily demand profiles (Kinesis request, unpublished)

- Department of Resources, Energy and Tourism, 2010, Energy in Australia – 2010, ABARE, Canberra

- Kinesis 2014, Additional water end use breakdowns derived from first principle analysis of residential and non-residential building types.

- National Water Commission, 2011, National performance report 2009-2010: urban water utilities, National Water Commission, Canberra

- NSW Department of Planning, BASIX Residential Water Consumption Data (2010)

- Sydney Water Best Practice Guidelines for water conservation in commercial office buildings and shopping centres (2007), http://www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mdu0/~edisp/dd_054580.pdf

- Sydney Water Best Practice Guidelines for holistic open space turf management (2011), www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mdq1/~edisp/dd_045253.pdf

- Water Corporation. (2014). Mapping water use at school. from https://www.watercorporation.com.au/home/teachers/lesson-plans-and-teaching-resources/lesson-plan-search/lesson-plan/?id=%7BD9516524-4A2C-4B98-A113-3891D59F1AAA%7D

Box Hill Water

Appendix 4.2.10(a) Preliminary Risk Assessment Overview

Preliminary Risk Assessment Overview

Purpose

The purpose of undertaking the preliminary risk assessment was to:

- Identify potential risks that may impact the safe and reliable operation of the facility (and associated components), specifically focussed on risks associated with the following:
  - Potential impacts to public health and/or water quality
  - Environmental impacts including noise, odour and general environmental impacts
  - Operational reliability and process performance
  - Financial viability
  - Customer Service
- Identify early, potential risk mitigation/control measures that can be incorporated in the design, construction and operation of the facility in order to sufficiently mitigate these risks.
- Facilitate further dialogue with all key stakeholders to ensure all key risks associated with the project are identified and effectively controlled.

Methodology

The risk assessment approach adopted for conducting the preliminary risk assessment for the project was consistent with the recommendations in the Australian Guidelines for Recycled Water Management (AGRW). The process included the following activities:

- Risk Identification – The identification of a range of risk related to the project *(what might happen?)*
- Risk Categorisation – The categorisation of the risks into various types to aid understanding and to provide context
- Risk Assessment – determination of the likelihood and consequence of the unmitigated/uncontrolled risk, see Attachment A for details of the assessment criteria *(what is the likelihood and impact/consequence?)*
- Managing the Risk / Risk Mitigation – the identification of appropriate controls to be further developed and implemented as appropriate should the project be approved to proceed *(what can be done to stop it happening?)*
- Post Mitigation Risk Assessment – the reassessment of the risk following implementation of appropriate controls to ensure that the risk is sufficiently mitigated *(how effective do we anticipate the controls to be?)*

Outcomes

Identification

In undertaking the preliminary risk assessment a total of 77 key risks were identified across the following areas:

Area	Descriptions
The Catchment	Risks associated with the catchment area including consideration of items such as contamination, volume changes, public health incidents, storage requirements, illegal discharge to sewers etc.
The Sewer Network	Risks associated with the network itself including blockages, pipe or equipment failure, loss of power etc.
Local Water Centre	Consideration of the potential risks associated with the operation of the treatment facility including tank and/or equipment failure, odour, noise, process risks, capacity, power failure, telemetry, vandalism, operator error, flooding etc.
Recycled Water Reticulation and use	Risks associated with the transfer of recycled water from the facility to the users and covered areas such as equipment failure, demand, unauthorised usage, water quality, power failure etc.
Management	General operations management issues risks that may impact operational reliability or supply surety.

Risks have been summarised at Attachment B as the detailed preliminary risk assessment contains information that is commercial in confidence.

Box Hill Water

ATTACHMENT A: RISK ASSESSMENT QUALITATIVE CRITERIA

QUALITATIVE MEASURES OF LIKELIHOOD		
Level	**Descriptor**	**Example description**
A	Rare	May occur only in exceptional circumstances. May occur once in 100 years.
B	Unlikely	Could occur within 20 years or in unusual circumstances.
C	Possible	Might occur or should be expected to occur within a 5 to 10 year period.
D	Likely	Will probably occur within a 1 to 5 year period
E	Almost certain	Is expected to occur with a probability of multiple occurrences within a year.

QUALITATIVE MEASURES OF CONSEQUENCE		
Level	**Descriptor**	**Example description**
1	Insignificant	Insignificant impact or non-detectable.
2	Minor	Health - Minor impact for small population.
		Environment - Potentially harmful to local ecosystem with local impacts contained to site.
		Financial - Cost of event and / or rectification is less than $10K.
3	Moderate	Health - Minor impact for large population.
		Environment - Potentially harmful to regional ecosystem with local impacts primarily contained to site.
		Financial - Cost of event and / or rectification is greater than $10K but less than $100K.
4	Major	Health - Major impact for small population.
		Environment - Potentially lethal impact to local ecosystem, predominantly local, but potential for off-site impacts.
		Financial - Cost of event and / or rectification is greater than $100K but less than $1,000K.
5	Catastrophic	Health - Major impact for large population.
		Environment - Potentially lethal to regional ecosystem or threatened species; widespread on-site and off-site impacts.
		Financial - Cost of event and / or rectification is greater than $1,000K.

QUALITATIVE RISK ESTIMATION					
	Consequence				
Likelihood	1- Insignificant	2 - Minor	3 - Moderate	4 - Major	5 - Catastrophic
A - Rare	Low	Low	Low	High	High
B - Unlikely	Low	Low	Moderate	High	Very High
C - Possible	Low	Moderate	High	Very High	Very High
D - Likely	Low	Moderate	High	Very High	Very High
E - Almost certain	Low	Moderate	High	Very High	Very High

ATTACHMENT B: PRELIMINARY RISK ASSESSMENT SUMMARY

Item	Component	Potential Hazard	Pre-mitigation Risk	Controls	Post-mitigation (Residual) Risk
1	Catchment	Low flow in reticulation generates odour	High	– Regular flushing of reticulation – Interim, staged servicing strategy	Moderate
		Out of specification feed water for treatment process	High	– Testing and monitoring – Disinfection barriers – Education of customer base – Utility approval of new connections – Buffering tank	Low
2	Sewage Local Water Centre	Sewage overflow in community	Very High	– Monitoring – Ability to isolate reticulation built into design – Registration on DBYD – Allow adequate storage in collection tanks	High
		Sewage overflow at household	Very High	– Installation of pumps by authorised personnel – Monitoring of network – Proactive maintenance regime – Plumbing checks for infiltration prior to occupancy	High
		Odour	Very High	– Design to minimise air entrainment – Odour control on air valves – Regular replacement of cartridges	High
3	Recycled Water Local Water Centre	Inability to treat water due to process unit failure	High	– Duty / standby of equipment – Inlet and product water buffer storage – Spares of critical equipment on site – Monitoring and controls – Proactive maintenance regime – Experienced operators – Maintain Asset Protection Zones – Maintain access around LWC for fire fighting – Access to water for fire fighting – Located above 1 in 100 year flood level – Backup generator	Low
		Product water out of specification due to process failure	Very High	– Production shut down – Duty / standby of equipment – Inlet and product water buffer storage – Monitoring and controls – Proactive maintenance regime – Experienced operators	Moderate
		Noise and odour	Very High	– Odour and noise modelling at planning phase – Odour scrubbing – Noise mitigation in building design	High
		Environmental spill from tank rupture	Low	– Quality assurance processes in construction – Isolation from stormwater drainage – Experienced construction contractors and operators – Monitoring of tank levels	Low
4	Recycled water reticulation and use	Compromise of public health through consumption of recycled water	Very High	– Plumbing inspections prior to occupancy – High treatment quality – Education – Signage in public areas	Very High
		Interruption to household recycled water supply due to breakage in reticulation	High	– Monitoring – Ability to isolate reticulation built into design – Registration on DBYD	Low
		Recycled water supply exceeds demand	Moderate	– Buffer storage – System monitoring – Evaluation of offsite uses as the development progresses	Low
		Recycled water demand exceeds supply	Moderate	– Buffer storage – Top up with drinking water	Low
5	Management	Unable to provide services due to business failure	High	– Ongoing auditing of the business in accordance with the network operator's licence – Internal governance regime – Water Industry Competition Act's Operator of Last Resort provisions and step in rights	Moderate

Box Hill Water

Appendix 4.2.11(a) Flow Systems Recycled Water Quality Plan (TOC)

Recycled Water Quality Plan (RWQP)

December 2014

Document Issue Record

Issue Date	Revision	Changes	Issued To	Prepared By	Approved By
24/10/14	1	First revision	Flow	Kirsten Evans	Andrew Horton
12/12/14	2	Minor formatting corrections	Flow	Kirsten Evans	Andrew Horton
30/1/15	3	Added AMP to: Figure 1 Table 1	Flow	Kirsten Evans	Andrew Horton
05/05/15	4	Added TDS figures for HR & LH to: Table 6	Flow	Marcelo Sales	Andrew Horton

Contents

Appendix 4.2.11(b) Box Hill Scheme Management Plan (TOC)

Box Hill
Scheme Management Plan (Scheme MP)

flow systems

Box Hill Water

Document Issue Record

Issue Date	Revision	Issue	Issued To	Prepared By	Approved By
19/12/14	1	First revision	Flow	Darren Wharton	Steve Hall
30/01/15	2	Revised for NOL app	Flow	Darren Wharton	Steve Hall
03/05/15	3	Drinking water removed	Flow	Marcelo Sales	Darren Wharton

Contents

Box Hill Water

Appendix 4.2.12(a) Flow Systems Infrastructure Operating Plan (TOC)

Infrastructure Operating Plan (IOP)

December 2014

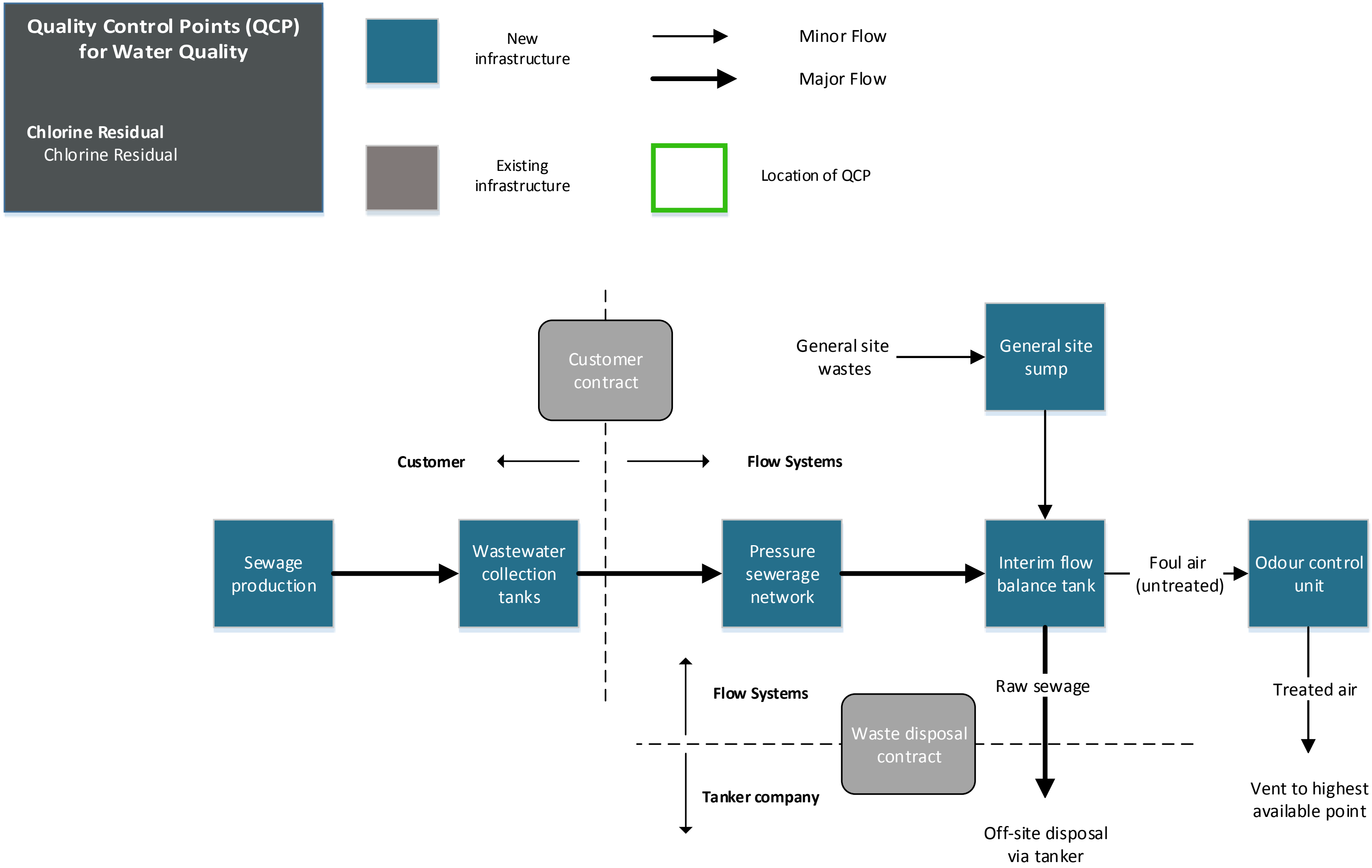
flow systems

Document Issue Record

Issue Date	Revision	Issue	Issued To	Prepared By	Approved By
24/10/14	1	First revision	Flow	Kirsten Evans	Andrew Horton
12/12/14	2	Minor formatting corrections	Flow	Kirsten Evans	Andrew Horton
30/1/15	3	Added AMP to: Figure 1 Table 1 Added: Section 3.4	Flow	Kirsten Evans	Andrew Horton

Contents

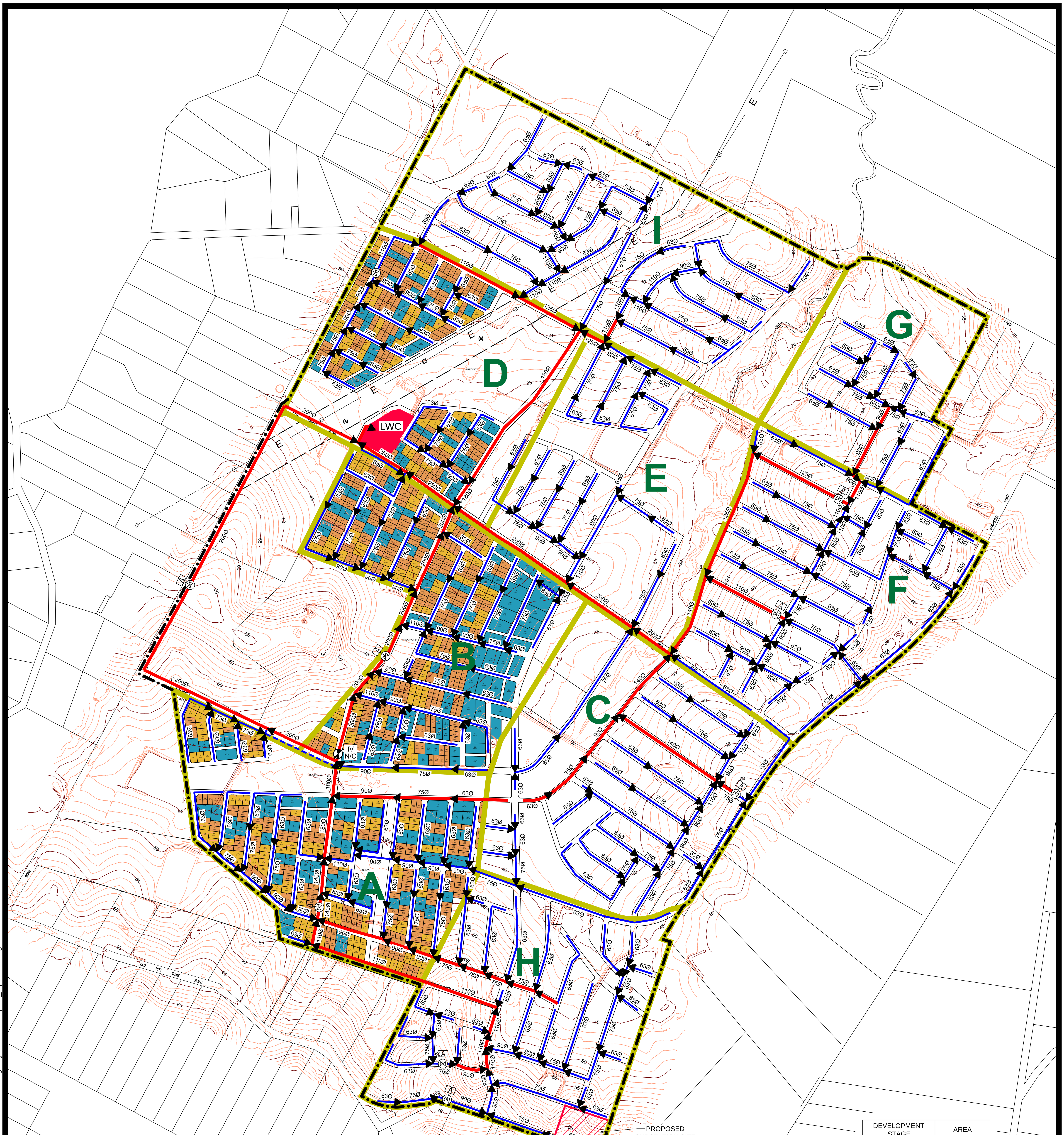
Appendix 4.3.1(a) Process Flow Diagram (Interim Sewer)



Date: 17/12/2014	Interim Sewerage Process Flow Diagram	Revision D

Box Hill Water

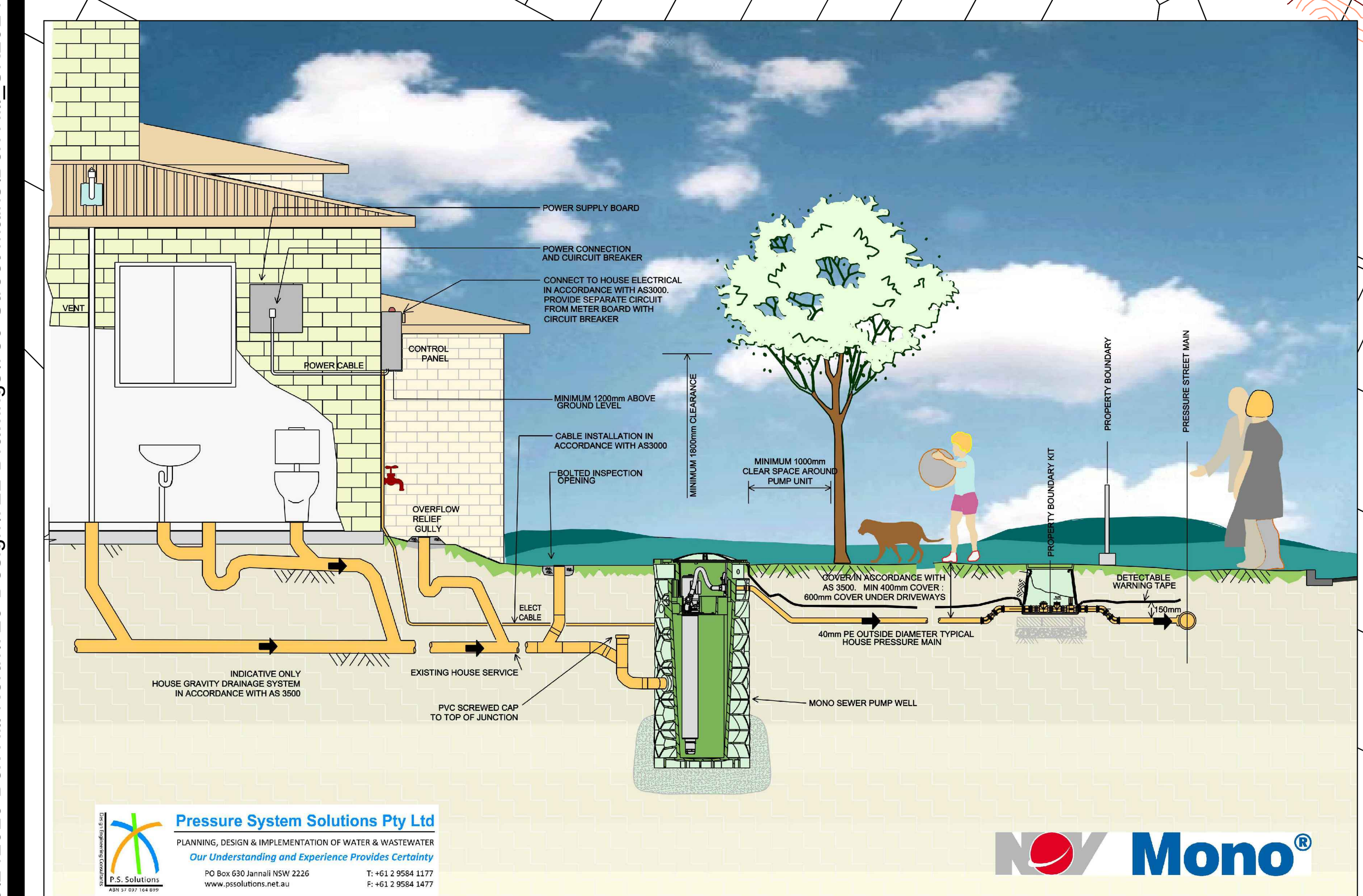
Appendix 4.3.1(b) Pressure Sewer Reticulation Masterplan



DEVELOPMENT STAGE	AREA
1	A, H, C
2	B
3	D
4	E
5	F
6	G
7	I

LEGEND:

- PRESSURE SEWER SPINE MAIN PN16 POLYETHYLENE PIPE
- PRESSURE SEWER MAIN PN16 POLYETHYLENE PIPE
- IV N/C — ISOLATION VALVE - NORMALLY CLOSED
- A — AIR VALVE
- AREA OF OPERATIONS
- DEVELOPMENT STAGE BOUNDARY
- LWC — LOCAL WATER CENTRE



TYPICAL HOUSE CONNECTION DETAIL

FOR WICA APPLICATION

Date: 18/12/2014

Rev: C

Drawing No: SK101

Scale: SCALE 1:4000 AT A0

BOX HILL NORTH
PRESSURE SEWERAGE SYSTEM
MASTERPLAN - WICA APPLICATION

flow systems

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Box Hill Water

Appendix 4.3.10(a) Flow Systems Sewage Management Plan (TOC)

Sewage Management Plan

(Sewage MP)

January 2015

flow systems

Document Issue Record

Issue Date	Revision	Issue	Issued To	Prepared By	Approved By
24/10/14	1	First revision	Flow	Kirsten Evans	Andrew Horton
30/1/15	2	Added AMP to Table 1	Flow	Kirsten Evans	Andrew Horton

Contents

Box Hill Water

Appendix 4.3.13(a) Box Hill Land Capability Assessment

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Land Capability Assessment for Recycled Water Management Scheme at Proposed Box Hill North Master Plan Development, Box Hill, NSW

Prepared for	RPS Australia
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Document Control Sheet

Document and Project Details	
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Author:	David Wainwright
Project Manager:	Mark Saunders
Date of Issue:	17/03/14
Job Reference:	Report_01366_001_Final.docx
Synopsis:	This preliminary report provides the results of our investigations regarding Land Capability for the proposed Box Hill North Master Plan Development, Box Hill.
Client Details	
Client:	RPS Australia
Primary Contact:	Mr Rob Dwyer (RPS Australia)

Document Distribution

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01	22/12/14	Draft	1e	-	-
02	17/03/15	Final	1e	-	-

Document Verification

Checked by: Mark Saunders	***Issued by:*** David Wainwright

Disclaimer

The information contained in this report is based on independent research undertaken by David Wainwright of Whitehead & Associates Environmental Consultants Pty Ltd (W&A). To our knowledge, it does not contain any false, misleading or incomplete information. Recommendations are based on an appraisal of the site conditions subject to the limited scope and resources available for this project, and follow relevant industry standards. The work performed by W&A included a desktop review and limited soil sampling only, and the conclusions made in this report are based on the information gained and the assumptions as outlined. Under no circumstances, can it be considered that these results represent the actual state of the site at all points as subsurface conditions are inherently variable. Concentrations of contaminants may also change with time, and the conclusions in this report have a limited lifespan.

Copyright Note

Table of Contents

List of Tables

1 Introduction

Whitehead & Associates Environmental Consultants Pty Ltd ("W&A") was engaged by RPS Australia Pty Ltd ("the Client") on behalf of Flow Systems to undertake a Land Capability Assessment (LCA) for recycled water management for the proposed staged subdivision named Box Hill North ("the Site"). The Site is some 3km north of Windsor Road at Box Hill and broadly contained by Boundary Road to the West, Old Pitt Town Road to the South, Janpieter Road to the East and Maguires Road to the North. The site is as shown in Figure 1, Appendix A.

This LCA focuses on the Site's capacity to sustainably accommodate 'excess' recycled water generated by a proposed Local Water Centre (LWC) at Box Hill North (owned and operated by Flow Systems), once the LWC is commissioned and operational.

The Site is located on the northern urban fringe of the Baulkham Hills Shire Council ("Council") local government area (LGA), immediately to the west of the Hawkesbury City Council LGA. The Site, as shown on Figure 1, covers an area of around 390 hectares. The site is gently undulating with slopes less than 10% across almost the entire site. An electricity transmission line crosses the north-western corner of the site. Drainage across the site is generally to the north, and the proposed creek lines mirror the existing topography. At present, these natural drainage lines have been intercepted by a number of farm dams and are not permanently connected.

Field investigations were undertaken by David Wainwright and Jasmin Kable of W&A on the 4th December 2014. This LCA report provides the results of our investigations and provides input into a subsequent Staging Plan and report for the preferred Recycled Water Irrigation Zones (RWIZs) that will be developed to manage excess recycled water once the Box Hill LWC recycled water network is operational.

2 Overview of Proposed Development

Figure 1 also shows the general arrangement of streets within the proposed subdivision. The development aims to accommodate 4,100 dwellings within a range of densities and a town centre comprising up to 10,000m^2 of retail/commercial floor space. The development proposal also includes a school, community facilities, sports fields, public open space, environmental buffers and other improvements including roads and infrastructure (utilities).

Flow Systems is assisting the developer, EJ Cooper and Son (EJC) in delivering sewerage, recycled water and drinking water infrastructure to the Box Hill North development. The Box Hill North LWC will treat wastewater generated by the proposed residential and commercial developments (separate trade waste agreements may be required for certain types of commercial uses). The LWC facility is intended to operate 24 hours, 7 days per week, and will be housed in a low-scale, single level building within an open space setting. The proposed LWC will incorporate a dual reticulation ('third pipe') system to distribute recycled water to households for non-potable water reuse such as toilet flushing, washing machine supply, irrigation and external washing, thus reducing potable water demand.

The intended capacity of the LWC is 3,000kL (3ML) per day, although it will achieve this capacity over time in line with the uptake in residential area surrounding the development. At this stage in development planning, it is intended that the remaining excess recycled water will be irrigated in the undeveloped land associated with later development stages, in the proposed RWIZs.

3 Site Description

The Site is dominated by cleared and grassed land that has been used for low-density/rural residential land uses, including grazing land for cattle, horse stables and a small number of market gardens. A Site Plan is provided in Figure 1, Appendix A. Section 4 (below) provides the results of the Land Capability Assessment (LCA) investigations undertaken for the development with respect to recycled water management.

4 Site & Soil Assessment

4.1 Site Physical Characteristics

A Site and Soil Assessment was undertaken on the 4th December, 2014 by David Wainwright and Jasmin Kable of W&A. A description of the Site physical conditions and the degree of limitation they pose to recycled water management is provided in Table 1 below. Reference is made to the rating scales described in NSW DEC (2004) and NSW DLG (1998).

Table 1 Site Physical Conditions & Constraints

Parameter	Constraint
Climate: Mean monthly rainfall data was sourced from the BoM for Glenorie (Old Northern Road) Station 67010 for 1902-2013. Mean monthly evaporation data was sourced from the BoM for Richmond RAAF (067033) for 1970-1994. Mean annual rainfall for Glenorie is 963mm; ranging from an average of 52mm in September to an average of 113mm in February. Mean annual pan evaporation is 1,554mm, ranging from an average of 54mm in June to an average of 217mm in January. On average, there is a net evaporation deficit (soil moisture surplus) in May and June, which is typical for temperate regions.	Minor
Aspect and Exposure: Site aspects vary depending on position on the undulating slopes, but generally have good solar and wind exposure across the property.	Minor
Vegetation: The Site has been almost completely cleared of native bushland and used as open pasture for stock grazing. The proposed RWIZs will be vegetated, either with the existing cover or with new areas of pasture or turf.	Minor
Landform and Slope: The Site contains undulating and rolling low-hills, with moderate slopes typically less than 5%. Recycled water irrigation using moveable or fixed pipes with spray or sprinkler heads is feasible on slopes up to 12%; however, use of a travelling irrigator is constrained to areas of gentler slope. We consider that the slopes less than 5% will be appropriate for travelling irrigator use.	Minor
Rocks and Rock Outcrops: Rock outcrops were rare across the Site, with the exception of soils near TP10 and TP7. These two test pits were located within areas mapped as *Lucas Heights* and *Hawkesbury* soil landscapes respectively (See section 4.2 for a description of Soil Landscapes). Those areas are isolated and account for less than 2% of the total Site area. At these sites, bedrock was encountered at	Moderate

Parameter	Constraint
depths of 0.5 and 0.6m below ground level (BGL), respectively The vast majority of the Site is covered by the *Blacktown* soil landscape, and within the remainder of Test Pits, bedrock was typically observed at depths between 1.0 and 1.5m. However, at locations TP5 and TP8, a layer of shale was encountered at around 0.7-0.8 m depth.	
Fill: We found no evidence of imported fill in the test pits excavated as part of the site investigation.	Minor
Erosion Potential: At present the Site is generally stable with minor existing erosion, which is limited to cleared areas (road verges and property access ways). Minor sheet and gully erosion could be expected on the *Blacktown* Soils that cover most of the Site, if vegetation is not maintained.	Minor
Groundwater and Site Drainage: A search of the National Groundwater Information System database, hosted by the Australian Bureau of Meteorology, was undertaken. Those groundwater bores located in the vicinity of the Site, but outside the site boundary, are shown on Figure 1 (Appendix A). For assessment purposes, buffers of 250m have been applied around those bores. These buffers do overlap the Site slightly in some locations: • GW070265, a groundwater bore supplying water for domestic use. Its buffer intersects a small part of the south western fringes of the Site. • GW100184, a groundwater bore with unknown status. Its buffer intersects a small part of the south eastern fringes of the Site. • GW072199, a groundwater bore supplying water for domestic use. Its buffer intersects a small portion of the Site adjacent to Maguire's Rd. Surface drainage is considered to be generally very good throughout the Site. During the evening preceding our site investigation, some 30-50 mm of rain had fallen in the area yet we found minimal evidence of surface ponding. Mottling within some of the excavated subsoils indicated inhibited subsurface drainage in some locations (discussed in Table 2).	Minor
Proximity to Surface Waters: The Site primarily drains via unnamed tributaries to Cataract and Cattai Creeks. The main tributary drains in a northerly direction with drainage depressions joining this main creek from the east and west. There are some additional minor drainage pathways draining in other directions from the fringes of the Site. Adherence to standard practice (e.g. DLG, 1998) would allow for a 40m buffer around ephemeral waterways although DEC, 2004 notes that a site specific assessment can be made. A buffer of 40m is shown in Figure 1 (Appendix A). Therein, it has been assumed that all existing dams will be decommissioned and filled in during development. Excess recycled water (irrigation) will be applied to undeveloped stages of the Site as the development progresses. Therefore, the staged irrigation plan may also need to consider the status of any existing dams prior to decommissioning. A buffer of 40m would also need to be applied to any dam.	Minor-Moderate

Parameter	Constraint
Flood Potential We have not investigated the flood potential of the Site, and mapping of flood controlled areas does not appear to be available from Council's web site. However, as a first pass assessment, we note that the Site is located at the upper portions of the catchment and we expect that the 1 in 20 year flood, which is typically used as the design event for on-site sewage considerations, would not extend beyond the 40m buffers surrounding the watercourses.	Minor

4.2 Soil Landscape

We reviewed the Soil Landscapes of the Penrith 1:100,000 Sheet (Bannerman and Hazelton, 1990) which indicates that Site soils belong almost entirely to the Blacktown (**bt**) soil landscape. The descriptions below are taken from Bannerman and Hazelton (1990); soil characteristics as surveyed by W&A are provided in Section 4.3.

The '**bt**' soil landscape is located on gently undulating rises upon shales of the Wianamatta Group with slopes usually less than 5% and local relief to 30m. Topography is characterised by broad crests and ridges and gently inclined slopes. The underlying geology can be either (i) Ashfield Shale comprising laminite and dark grey siltstone, (ii) Bringelly Shale comprising shale and occasional calcareous claystone, laminite and sometimes coal, or (iii) Minchinbury Sandstone comprising fine to medium-grained quartz lithic sandstone.

Dominant soils comprise **(i) bt1:** a friable brownish black loam to clay loam with moderately pedal structure as the topsoil (A horizon) overlying, **(ii) bt2:** a hardsetting dark brown to dark reddish brown clay loam to silty clay loam with massive structure as the A2 horizon. Shale fragments may be present overlying, (iii) **bt3:** Strongly pedal, reddish brown to brown light clay with red, yellow or grey mottles as the subsoil (B horizon), overlying (iv) **bt4**: a light grey plastic clay with red yellow or grey mottles and moderate structure occurring as a deep subsoil above the shale bedrock. Weathered ironstone concretions and rock fragments are common.

On crests, up to 30cm of **bt1** typically overlies 10-20cm of **bt2** and 90cm of **bt3**; the total soil depth is typically less than 100cm. On upper slopes and mid slopes, up to 30cm of **bt1** overlies 10-20cm of **bt2** and 20-50cm of **bt3** which, in turn, overlies up to 1m of **bt4**. The total soil depth is normally less than 200cm. On lower side slopes, up to 30cm of **bt1** overlies 10-30cm of **bt2** and 40-100 cm of **bt3**. There is usually >100cm of **bt4** and the total soil depth is more than 2m.

Two other soils of limited distribution are mapped as occurring on the Site:

- Lucas Heights (**lh**): with a small area adjacent to the northern fringe of the Site. 'l**h'** typically comprises yellowish brown sandy loams, grading through sandy clay loams to yellowish brown clays at depth. The total soil depth is typically less than 1m.
- Hawkesbury (**ha**): with a small area adjacent to the eastern fringe of the Site. 'h**a'** typically comprises loose quartz sand overlying earthy, yellowish brown sand resulting in a limited depth profile of less than 50cm on ridges and 70cm on side slopes.

Sections 4.3 and 4.4 below describe the soil physical characteristics as surveyed by W&A on 4th December, 2014.

4.3 Soil Survey & Physical Characteristics

Site soils were observed and examined by excavating ten (10) test pits (TPs) using an excavator. The locations of these test pits are illustrated in Figure 1 (Appendix A). Soil characteristics showed some consistency across the Site although variations were encountered where the **ha** and **lh** soil landscapes were targeted. Within the **bt** landscape, the profile depth and composition tended to vary with position on the slope (crest profiles shallower than depression profiles etc.). The soil survey had two principal aims – to verify regional soil landscape mapping information and to assess local soil conditions and variability in areas where recycled water irrigation might occur.

Generally, topsoils throughout the Site are composed of dark brown, clay loam material ranging from 100-150mm depth. Subsoils tended to comprise sandy clays or sandy clay loams overlying light or medium clays grading to heavy clays with depth. At the two sites on the less dominant soil landscapes (TP7 & TP10), the shallow sandy clay loam subsoils comprised weathered sandstone. At the two sites where shale bedrock was encountered (TP5 and TP8) the subsoils comprised heavy and light clays respectively, extending to the depth of refusal (~800mm). Subsoils were commonly mottled and/or gleyed, but this was most prominent within lower slope areas. This indicates intermittent saturation of the subsoils, increasing with depth.

Our investigation of site conditions indicated that medium to heavy clays are common throughout the Site.

Table 2 summarises the key soil physical and chemical constraints and the degree of limitation they pose to recycled water management is provided in Table 2 below. Reference is made to the rating scales described in NSW DEC (2004) and NSW DLG (1998). Appendix B provides soil borelog summaries for each test pit.

4.4 Soil Chemical Characteristics

Samples of all discrete soil horizons were collected for subsequent laboratory analysis. Fifteen (15) samples from nine (9) of the test pits were analysed in-house for pH, Electrical Conductivity (ECe) and Emerson Aggregate Class. Four composite samples and two discrete samples of the dominant clay and silty clay subsoils were analysed by an independent, NATA accredited soil testing laboratory for sodicity (Exchangeable Sodium Percentage or ESP), Cation Exchange Capacity (CEC) and Phosphorous Sorption Capacity (P-sorption).

Table 2 provides a summary of the results and discussion of the soil chemistry with respect to soil constraints for recycled water irrigation. Reference is made to the rating scales described in NSW DEC (2004) and NSW DLG (1998). Raw data and interpretation is presented in Appendix C.

Table 2 Soil Physical & Chemical Constraints

Parameter	Constraint
Soil Depth: Bedrock was encountered in a number of the TPs during the Site investigations. The shallowest bedrock was encountered in TP's 7 and 10 (0.6 and 0.5m); but minimum refusal depths in all other test pits was greater than 0.8m.	Minor to Moderate
Depth to water table: Ground water was not commonly encountered during the investigation. Where encountered, this was at depths of greater than 1.5m. However, based on soil gleying and mottling characteristics, the depth to seasonal groundwater can be shallower (??m BGL) than this. Based on this, depth to the seasonal watertable is unlikely to pose a significant constraint	Minor

Parameter	Constraint
Coarse Fragments (%): Coarse fragments may impede plant growth by reducing soil water holding capacity, nutrient retention capacity and overall fertility because of the reduced fine earth fraction and increased permeability. The surface soils typically contained <10% coarse fragments, while some subsoils contained up to 50% coarse fragments (typically less than 30mm in diameter). Based on the proposed land application method (irrigation), coarse fragments are expected to present a minor limitation to recycled water management.	Minor
Soil Permeability and Design Loading Rates: Soil permeability was not directly measured but can be inferred from observed soil properties. AS/NZS 1547:2012 describes conservative Design Irrigation Rates (DIRs) for irrigation systems (Table 5.2), depending on two important soil properties – texture and structure. Soil depth, colour, mottling and drainage characteristics are also important to consider and guide selection of appropriate loading rates. Best-practice land application (irrigation) design recommends that the characteristics of the soil occurring at 0.6m below the point of application (limiting horizon) are used to determine appropriate soil loading (recycled water application) rates. This allows for additional renovation of applied irrigation water within the unsaturated (vadose zone) soils and ensures that 'limiting' subsoil permeability is considered. The observed clay loam topsoils were too shallow to be used to determine the DIR (50-200mm). The observed subsoils were dominated by sandy clays and sandy clay loams, grading to clays that get heavier with depth. Within test pits the most commonly dominant subsoil is strongly structured medium clay. AS/NZS 1547:2012 classifies these as Category 6 soils, with an indicative permeability (K_{sat}) ranging from **<0.06m/day** (2.5mm/hr) to **0.5m/day** (21mm/hr). Based upon slope and soil characteristics, the following DIR is recommended for sizing all of the required RWIZs: • **2mm/day** (surface spray irrigation).	Severe
pH: The pH of 1:5 soil/water suspensions were measured in-house using a *Hanna*™ hand held pH / EC meter. The measured pH of the soil samples (topsoils and subsoils) ranged from 6.3 to 4.6, respectively. Soils range from very strongly acidic to moderately acidic; however, plant growth did not appear to be affected by soil acidity and this is not expected to pose a significant constraint to recycled water management.	Moderate
Electrical Conductivity (EC_e): Electrical conductivity of the saturated extract (EC_e) was calculated by first measuring the electrical conductivity of 1:5 soil in water suspensions and using appropriate multiplier factors (based on soil texture) to convert the 1:5 suspension EC to EC_e. Soil samples were found to range from non-saline to highly saline; having EC_e values of 0.00 – 11.6 dS/m. Overall, salinity of the topsoil was non-saline to moderately saline, with moderately saline to highly saline soils becoming more prevalent with depth. Considering the high quality of the recycled water (<TDS), and the fact that the highly saline conditions are present at some depth, we	Minor to Moderate

Parameter	Constraint
consider it unlikely that this will pose a significant limitation to recycled water management. Relatively saline soils are not uncommon in Western Sydney.	
Emerson Aggregate Class: The modified Emerson Aggregate Test (EAT) is a measure of soil dispersibility and susceptibility to erosion and structural degradation. It assesses the physical changes that occur in a single air-dried ped (naturally forming aggregate) of soil when immersed in water; specifically whether the soil slakes and falls apart or disperses and clouds the water. The test was performed on representative samples covering the range of soil horizons encountered in all test pits (TP1 – TP10). Emerson Aggregate Classes of 5 or above for all topsoils, and 2(2) or 3(3) for subsoils were recorded. EAT Class 2 indicates high levels of slaking with moderate dispersion. This poses a moderate constraint for recycled water management (as well as erosion control), though is mitigated by an appropriately low DIR of 2mm/day, in accordance with best-practice irrigation procedure. EAT Class 3 soils are slightly more suitable for the application of wastewater.	Moderate
Sodicity (Exchangeable Sodium Percentage- ESP) (%): The Exchangeable Sodium Percentage (ESP) is the proportion of sodium on the cation exchange sites reported as percentage of exchangeable cations and is an important indicator of sodicity, which affects soil structural stability and susceptibility to dispersion. The ESP is a measure of how readily the soils allow sodium from recycled water to be substituted in the soil lattice for other cations. Once accepted, the weak sodium bonds allow increased structural degradation of the soil, increasing erosion risk. It is calculated as [% Na / CEC] x 100. Hazelton & Murphy (2007) suggest: • ESP values less than 6 are rated as non-sodic; • ESP values between 6 and 15 are rated as sodic; • ESP values between 15 and 25 are rated as strongly sodic; and • ESP values greater than 25 are rated as very strongly sodic. Six (6) composite soil samples were analysed for ESP. Three (3) yielded values <6 (non-sodic), while the remaining three (3) samples yielded values of >15 (strongly and very strongly sodic). The presence of sodic soils presents a moderate to major limitation for recycled water management; however, it can be managed through conservative soil loading rates, soil amendment and pasture management practices. Further discussion on proposed mitigation measures is provided in Section 6.	Moderate to Major
Cation Exchange Capacity (cmol/kg): The Cation Exchange Capacity (CEC) is the capacity of the soil to hold and exchange cations [aluminium, calcium, magnesium, potassium and sodium]. It is a major controlling agent for soil structural stability, nutrient availability for plants and the soils' reaction to fertilisers and other ameliorants (Hazelton & Murphy, 2007). Like ESP, the CEC is a measure of how easily the soils accept excess cations from the recycled water. These cations are used by plants as a nutrient source; so the higher the CEC the more likely plant growth will be aided by the application of recycled water. The CEC of the six (6) composite soil samples analysed, was measured	Moderate

Parameter	Constraint
between 5.9 and 17.2cmol/kg. The samples ranged from a very low to medium CEC rating. The lower CEC values indicate that plant growth may be inhibited by increased soil sodium (sodicity) and a lack of trace nutrients such as magnesium/calcium, and the application of gypsum may be beneficial. This presents a moderate constraint for recycled water management and can be managed through appropriate pasture management practices. Further discussion on proposed mitigation measures is provided in Section 6.	
Phosphorus Sorption Capacity (kg/ha): The Phosphorous Sorption Capacity (P-sorption) is used to calculate the potential immobilisation rate of phosphorous by the soil. The P-sorption capacity of a soil is an important feature that relates to the potential for a soil to bind any phosphorus that may not be utilised by the plants within an available RWIZ. Phosphorous is required only to a limited extent by plants as a trace nutrient, but if there is an excess of phosphorous in environments where other limiting factors are not present (such as waterways), excess phosphorous can result in very high plant growth. Typically, on land, excess phosphorous is taken up by soil adsorption, or is flushed out of the soil into groundwater or surface water bodies. In many instances, P-sorption will be the dominant phosphorus removal mechanism when applying recycled water to the land. P-sorption analysis was undertaken on the six (6) soil samples by Lanfax laboratories, Armidale. For the laboratory sample a five point isotherm of P-sorption capacity was generated. The methodology is described further in Patterson (2001). For the analysed soils, a nominal threshold P-sorption value (in mg/kg) is selected as the value that equates to roughly 70% of complete sorption. The P-sorption of the six (6) composite samples tested ranged from 200 to 730mg/kg. The average of the samples is 460mg/kg and the median is 415mg/kg. For modelling purposes, we have adopted the lowest value of 200mg/kg. In a phosphorus-limiting system, this would be a major limitation; however, the low permeability and relatively low DIR recommended will likely result in a hydraulically-limited irrigation design and therefore the impact is considered minor to moderate.	Minor to Moderate

5 Buffers

Buffer distances from irrigation areas are recommended to minimise risk to public health, maintain public amenity and protect sensitive environments. The Australian Guidelines for Water Recycling (NRMMC et al. 2006) recommends that spray irrigation buffer zones are generally not required for high-quality recycled water suitable for domestic non-drinking water use, as is the case with the proposed LWC/RWI schemes at the Site. However, buffer zones are recommended as they provide a form of mitigation against unidentified hazards and reduce potential pathways of human and environmental exposure.

W&A recommend the following environmental buffers for surface spray irrigation based on NSW DEC (2004) guidelines:

- 250 metres from domestic groundwater bores;
- 50-100 metres from permanent watercourses;
- 40 metres from intermittent watercourses and dams; and

- 50 metres from houses, schools, playing fields, roads and public open space[1].

It should be noted that once development commences, relevant setbacks, in accordance with AGWR (2006), from dwellings will need to be applied. Recommendations to prevent off-lot discharge include the use of low-throw sprinklers, 180º inward-throwing sprinklers and/or tree or shrub screens.

6 Mitigation Measures

6.1 Vegetation Establishment and Management

Vegetation should be established within the proposed RWIZs. A complete vegetation cover is important to reduce the erosion hazard and optimise water and nutrient uptake. A good cover of managed pasture (lucerne, ryegrass etc.) will be suitable for surface irrigation as suggested in this report. Achieving a nutrient balance within an irrigation area relies on nutrients being taken up by vegetation and then exported with the cut vegetation (e.g. baled or rolled). This balance can only be maintained by removing the cut material from the area.

6.2 Soil Improvement

6.2.1 Soil Sodicity

Sodic soils are soils with an excess of sodium compared with calcium and magnesium on the soils' cation exchange sites. Generally, sodic soils can be highly susceptible to dispersion, erosion, structural decline and surface crusting, and can have very low infiltration capacities, low hydraulic conductivity and high shrink/swell properties on wetting and drying. These properties can reduce the soils' capacity to sustainably manage recycled water.

Soil sodicity is variable at the Site, with some topsoil and subsoil samples returning ESP results greater than 6%, the threshold at which soil is considered to be sodic. While soils do not appear to be currently experiencing any significant drainage problems, erosion or structural decline; prolonged application of elevated-sodium recycled water could exacerbate the situation.

Application of gypsum is a recognised way of mitigating the effects of soil sodicity. It does this by supplying calcium to the affected soil and thereby elevating calcium concentrations with respect to sodium. It is recommended that gypsum be applied to soils in the RWIZs to reduce the potential for soil structural degradation and dispersion. Gypsum is only slowly soluble in water so simply broadcasting it at the surface can be relatively difficult as it can take a long time for the calcium to penetrate the soil and reach the deeper soil layers. Therefore, it is necessary to incorporate gypsum into the limiting soil horizon at the time of application. One way to achieve this is to dose the irrigation water with a pre-mixed gypsum solution during the irrigation cycle. At scheme commencement, this practice should be undertaken for each irrigation area at an application rate of approximately $0.5 kg/m^2$ of gypsum. In the long term, soil sodicity within the RWIZs can be managed by the annual surface application of gypsum at a rate not less than $0.2 kg/m^2$.

Incorporation of organic matter (OM) into the upper soil profile is another recognised method for improving soil structural stability as well as improving nutrient retention and available water holding capacity. These benefits serve to improve aeration and biological activity in soils; thereby increasing vegetation health, vigour and rooting depth. Studies have shown that the direct incorporation of OM such as composts. Manure and other recycled organic materials can substantially improve the performance of irrigated pasture areas.

[1] Assumes spray irrigation. If sub-surface irrigation techniques are used, these buffers may be relaxed for some public open space uses.

6.2.2 Recycled Water Salinity

The response of sodic soils to the application of recycled water is also controlled to an extent by soil/water salinity. Studies have shown that with increasing [soil] EC at depth, and the increased occurrence of carbonates and high clay content, dispersion and swelling (in sodic soils) may be suppressed (Rengasamy & Olsson, 1993).

Sodium adsorption ratio (SAR) is the term that applies to the ratio of sodium ions to calcium and magnesium ions in water. The ratio is a numerical value with no units. Rengasamy *et al*., (1984) report that the soil ESP is approximately twice the SAR of a 1:5 soil water suspension. The term SAR applies to water and ESP applies to soil and their different calculation formulas infer they are measuring different properties (Patterson, 2006).

The ANZECC (2000) water quality guidelines (Vol. 1, Figure 4.2.2) suggest that an analysis of recycled water quality should be incorporated into scheme design to determine the extent that soil salinity and the SAR of irrigation water will 'interact' to exert control over soil stability.

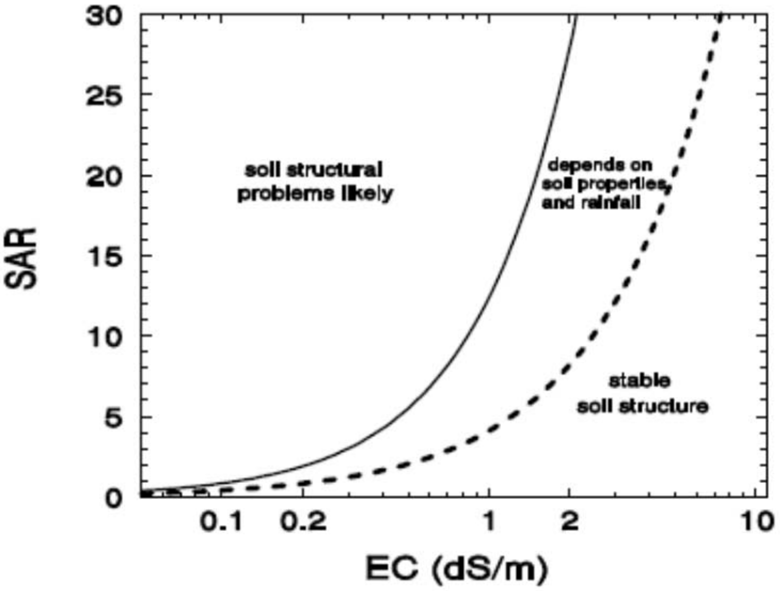

Figure 4.2.2 Relationship between SAR and EC of irrigation water for prediction of soil structural stability (from DNR 1997a, adapted from DNR 1997b; note that 1 dS/m = 1000 µS/cm)

It is recommended that a comprehensive investigation of soil dissolved salt content is undertaken prior to the commissioning of each RWIZ to ensure that soil structural impacts are appropriately mitigated.

7 Conclusions and Recommendations

This report provides the results and recommendations of our preliminary investigations, including detailed site and soil investigations and constraints to recycled water management.

The LCA shows that the Site is diverse in terms of its physical characteristics such as topography, soil depth and characteristics, drainage and the presence of intermittent watercourses; all of which influence the design and proposed location of the RWIZs for surface irrigation of recycled water. However, all required buffers are achievable with regard to the location of the proposed RWIZs.

Having undertaken a land capability assessment of the Site at Box Hill North, W&A consider that, with mitigation, on-site surface irrigation is generally appropriate on identified land throughout the Site.

8 References (Cited and Used)

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Appendix A

Figures & Site Plans

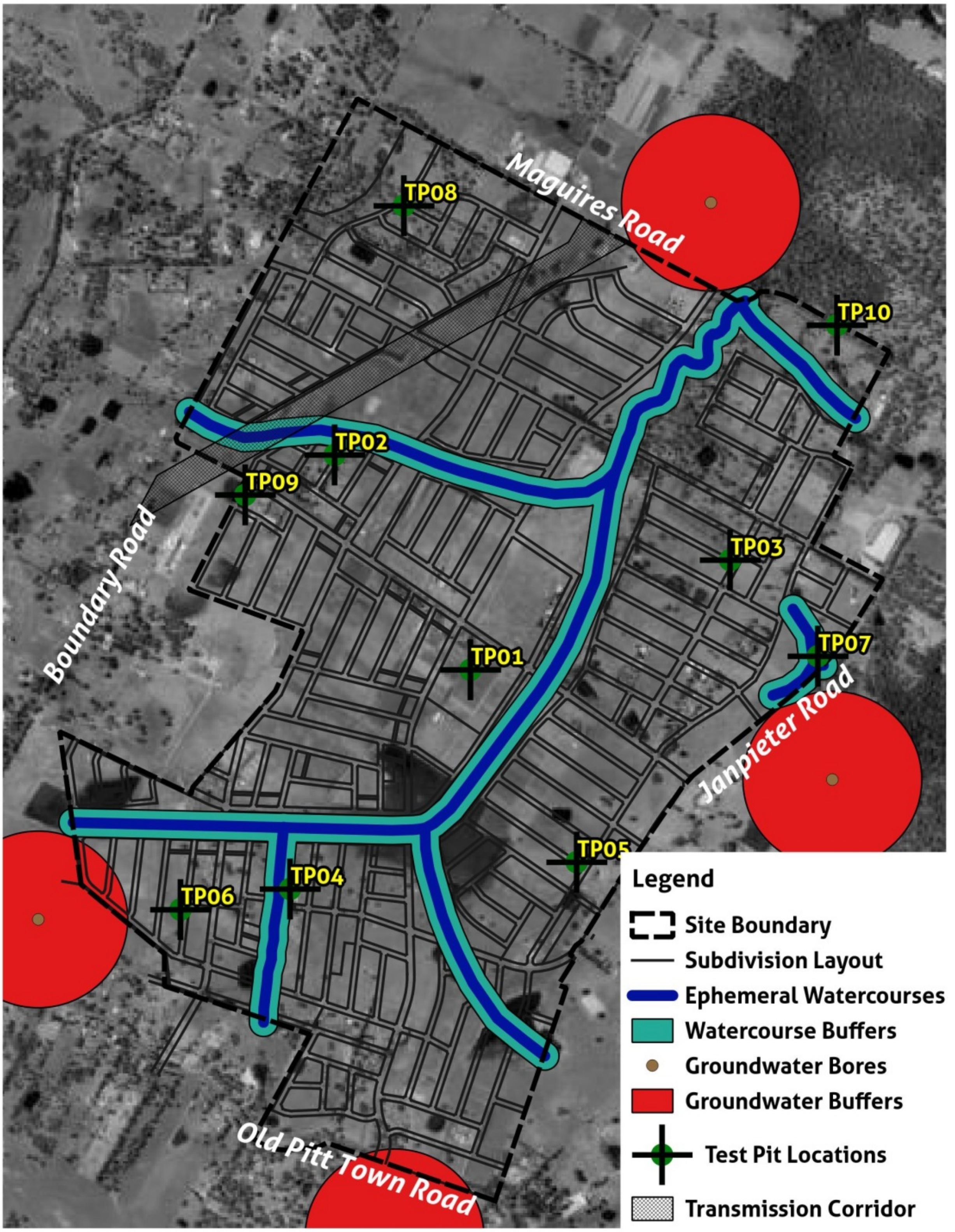

Figure 1: Site Location

Box Hill North Masterplan Land Capability Assessment

Whitehead & Associates
Environmental Consultants

Revision	A
Drawn	DJW
Approved	DJW

Appendix B

Soil Borelogs

Soil Bore Log

Whitehead & Associates
Environmental Consultants Pty Ltd

Client:	RPS	**Test Pit No:**	**TP1**
Site:	Box Hill North	Excavated/logged by:	Jasmin Kable
Date:	19 April 2014	Excavation type:	Excavator
Notes:	Location 150.90746, -33.62649, Mid Slope on Gently undulating topography. Previously Cropped, presently weedy.		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Moisture Condition	Comments
0.1		No External Laboratory Sample	O	SCL	Strong	Very Dark Greyish-Brown	N/A	5%		Similar to Top layer TP7 and TP3
0.2–0.3			A	SC	Friable / Layered	Dark Brown	N/A	30%		Small fragments <2mm. Same as TP2/2, 3/2 & 9/2
0.4–0.8			B1	MC-HC (Sticky)	Strong	Red	Red	<1%		Same as 4/3, 6/2 and 9/3
0.9–1.6			B2	HC	Massive	Light Brown / Greyish Pink	Gleyed and Red Mottles	No		Weathered Bedrock. Similar to 3/4, 4/4 and 9/4

Soil Bore Log

Whitehead & Associates
Environmental Consultants Pty Ltd

Client:	RPS	**Test Pit No:**	**TP2**
Site:	Box Hill North	Excavated/logged by:	Jasmin Kable
Date:	4 December 2014	Excavation type:	Excavator
Notes:	Location 150.90349, -33.62097, Mid Slope on Gently undulating topography. Presently used for Horse Pasture. Kikuyu surface cover.		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Moisture Condition	Comments
0.1			O	SiCL	Strong	Brown to Dark Brown	N/A	<1%	Dry	
0.2–0.6		X	A	SC	Friable / Layered	Dark Brown	N/A	30%		Similar to TP1/2, 3/2 & 9/2
0.7–1.5			B	LC	Strong but Massive when Moist	Orange / Brown	Minimal	<1%	Moist	Similar gleying to TP1

Soil Bore Log

Whitehead & Associates
Environmental Consultants Pty Ltd

Client:	RPS	**Test Pit No:**	**TP3**
Site:	Box Hill North	Excavated/logged by:	Jasmin Kable
Date:	4 December 2014	Excavation type:	Excavator
Notes:	Location 150.91540, -33.62383, Mid Slope on Gently undulating topography. Presently used for Cow Pasture. Grassed (Kikuyu & Couch)		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Moisture Condition	Comments
0.1			O	SCL	Strong	Very Dark Greyish-Brown	N/A			
0.2–0.3		Composite Sample	A	SC	Friable / Layered	Dark Brown	N/A	N/A		Similar to 1/2, 2/2 and 9/2
0.4–0.7		Composite Sample	B	LC	Moderate	Yellowish Brown	N/A	N/A		Similar to 3/2 and 2/2 but Yellower
0.8–1.2		Composite Sample	C	MC	Friable Medium Structure	Very Pale Brown	Variable Mottling, Red / Yellow / Creamy Grey	N/A		Weathered Sandstone

Soil Bore Log

Whitehead & Associates
Environmental Consultants Pty Ltd

Client:	RPS	**Test Pit No:**	**TP4**
Site:	Box Hill North	Excavated/logged by:	Jasmin Kable
Date:	4 December 2014	Excavation type:	Excavator
Notes:	Location 150.90187, -33.63195, Lower Slope on Gently undulating topography. Presently used for Horse Pasture.		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Moisture Condition	Comments
0.1		No External Laboratory Sample	O	SiCL	Strong	Brown to Dark Brown	N/A			
0.2–0.5			A	Fine SCL to SiCL	Strong but Powdery	Dark Yellowish Brown	N/A	N/A	Very Dry	
0.6–1.5			B	MC-HC	Strong	Red	Red		Moist	Same as 1/3, 6/2 and 9/3
Below 1.5			C	HC	Weak	Yellow/Brown	Red Gleying	<20%, <1mm	Wet	Seepage in Base of Pit

Soil Bore Log

Whitehead & Associates
Environmental Consultants Pty Ltd

Client:	RPS	**Test Pit No:**	**TP5**
Site:	Box Hill North	Excavated/logged by:	Jasmin Kable
Date:	4 December 2014	Excavation type:	Excavator
Notes:	Location 150.91057, -33.63140, Mid Slope on Gently undulating topography. At edge of Long Grass behind mown portion of property.		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Moisture Condition	Comments
0.1–0.3		Composite Sample	A	SiCL	Strong	Brown to Dark Brown	N/A	N/A	Dry	Similar to 2/1, 4/1, 6/1, 8/1 and 9/1
0.4–0.8		Composite Sample	B	MC	Strong	Light Yellowish Brown	Minor, Red	Shale up to 5-10 cm	Dry	Grades to Weathered Shale

Soil Bore Log

Whitehead & Associates
Environmental Consultants Pty Ltd

Client:	RPS	**Test Pit No:**	**TP6**
Site:	Box Hill North	Excavated/logged by:	Jasmin Kable
Date:	4 December 2014	Excavation type:	Excavator
Notes:	Location 150.89854, -33.63242, Mid - Upper Slope on Gently undulating topography. Mown grass of backyard.		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Moisture Condition	Comments
0.1–0.2		Composite Sample	A	SiCL	Strong	Brown to Dark Brown	N/A	N/A	Dry	Similar to 2/1, 4/1, 5/1, 8/1 and 9/1
0.3–0.9			B	HC	Strong	Red	N/A	10% large angular 5mm fragments		Refusal Depth at 850mm hitting very stiff gleyed clay

Soil Bore Log

Whitehead & Associates
Environmental Consultants Pty Ltd

Client:	RPS	**Test Pit No:**	**TP7**
Site:	Box Hill North	Excavated/logged by:	Jasmin Kable
Date:	4 December 2014	Excavation type:	Excavator
Notes:	Location 150.91800, -33.62632, Crest on Relatively steep topography. Sandstone rocks present on surface. Lower slope areas have rock outcrops. Sandstone encountered at 600mm		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Moisture Condition	Comments
0.1		Composite Sample	A	SCL	Strong	Very Dark Greyish Brown	N/A	N/A	Dry	Similar to 1/1 and 3/1
0.2 0.3 0.4 0.5 0.6			B	SCL	Weak	Very Dark Greyish Brown	N/A	Large weathered Sandstone Fragments, 70 - 80% at depth	Dry	Weathered Sandstone

Soil Bore Log

Whitehead & Associates
Environmental Consultants Pty Ltd

Client:	RPS	**Test Pit No:**	**TP8**
Site:	Box Hill North	Excavated/logged by:	Jasmin Kable
Date:	4 December 2014	Excavation type:	Excavator
Notes:	Location 150.90573, -33.61468, Lower Slope on Gently undulating topography. Presently used for Cow Pasture Kikuyu		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Moisture Condition	Comments
0.1 0.2 0.3		No External Laboratory Sample	A	SiCL	Strong	Brown to Dark Brown	N/A	N/A	Dry	Similar to 2/1, 4/1, 5/1, 6/1 and 9/1
0.4 0.5 0.6 0.7 0.8			B	LC	Strong	Reddish Brown	Red	Minimal Shall Fragments 50% (5mm to 100mm)		Weathered Shale Refusal at 0.8m

Soil Bore Log

Whitehead & Associates
Environmental Consultants Pty Ltd

Client:	RPS	**Test Pit No:**	**TP9**
Site:	Box Hill North	Excavated/logged by:	Jasmin Kable
Date:	4 December 2014	Excavation type:	Excavator
Notes:	Location 150.90075, -33.62193, Lower Slope on Gently undulating topography.		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Moisture Condition	Comments
0.1			O	SiCL	Strong	Brown to Dark Brown	N/A	N/A	Dry	
0.2 0.3 0.4			A	SC	Friable/ Layered	Dark Brown	N/A	N/A		Similar to TP 1/2, 2/2 and 3/2
0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5		X	B	MC/HC	Strong	Red	Red and Orange with Gleying	N/A		Similar to 1/3, 4/3 and 6/3

Soil Bore Log

Whitehead & Associates
Environmental Consultants Pty Ltd

Client:	RPS	**Test Pit No:**	**TP10**
Site:	Box Hill North	Excavated/logged by:	Jasmin Kable
Date:	4 December 2014	Excavation type:	Excavator
Notes:	Location 150.91880, -33.61790, Crest on Gently undulating topography. Presently used for Horse Pasture. Mown Couch. Rock Outcops on Surface		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Moisture Condition	Comments
0.1		No External Sample	A	LS	Weak	Very Dark Greyish Brown	N/A	Minimal	Dry	
0.2 0.3 0.4 0.5			B	SCL	Weak	Very Dark Greyish Brown	N/A	Large Weathered Sandstone Fragments	Dry	Weathered Sandstone

Appendix C

Raw Soil Data and Analytical Results

Box Hill North Masterplan, Land Capability Assessment												
Site	Sample Name	Sample Depth (mm)	Texture Class	EAT [1]	Rating [2]	pH 1:5 [3]	Rating	EC 1:5 (µS/cm)	ECe (dS/m) [4]	Rating	Other analysis [5]
TP1	1/1	100	CL	5/6	Mod	6.0	Moderately acid	173	1.56	Non-saline	See External Results
	1/2	225	LC	5/6	Mod	6.3	Slightly acid	340	2.72	Slightly saline	
	1/3	650	MC	3(3)	Mod	4.7	Very strongly acid	1368	9.58	Highly saline	
	1/4	1200	HC	2(2)	Mod	5.4	Strongly acid	658	3.95	Slightly saline	
TP2	2/1	100	CL	8	Low	5.2	Strongly acid	77	0.69	Non-saline	
	2/3	1000	LC	3(3)	Mod	4.6	Very strongly acid	1454	11.63	Highly saline	
TP3	3/3	500	LC	3(3)	Mod	5.7	Moderately acid	41	0.33	Non-saline	
	3/4	1000	MC	2(2)	Mod	5.7	Moderately acid	12	0.08	Non-saline	
TP4	4/2	800	CL	5	Low	5.0	Strongly acid	736	6.62	Moderately saline	
	4/4	1000	HC	2(2)	Mod	5.1	Strongly acid	921	5.53	Moderately saline	
TP5	5/2	500	MC	3(3)	Mod	5.1	Strongly acid	57	0.40	Non-saline	
TP6	6/2	500	HC	3(3)	Mod	5.3	Strongly acid	224	1.34	Non-saline	
TP7	7/2	400	CL	-	n/a	5.9	Moderately acid	11	0.10	Non-saline	
TP8	8/2	500	LC	5	Low	5.3	Strongly acid	47	0.38	Non-saline	
TP10	10/1	300	S	8	Low	6.1	Slightly acid	10	0.17	Non-saline	

Notes:- (also refer Interpretation Sheet 1)

[1] The modified Emerson Aggregate Test (EAT) provides an indication of soil susceptibility to dispersion.

[2] Ratings describe the likely hazard associated with land application of treated wastewater.

[3] pH measured on 1:5 soil:water suspensions using a *Hanna Combo* hand-held pH/EC/temp meter.

[4] Electrical conductivity of the saturated extract (ECe) = $EC_{1:5}$(µS/cm) x MF / 1000. Units are dS/m. MF is a soil texture multiplication factor.

[5] External laboratories used for the following analyses, if indicated:

- CEC (Cation exchange capacity)
- Psorb (Phosphorus sorption capacity)
- Bray Phosphorus
- Organic carbon
- Total nitrogen

Interpretation Sheet 1 - pH, EC & Emerson Aggregate Class

Interpretation of Soil pH (1:5 Soil:Water)
(rating based on Hazelton & Murphy (2007))

pH			Rating	
0.00	to	4.50	Extremely acid	
4.51	to	5.00	Very strongly acid	
5.01	to	5.50	Strongly acid	preferred range
5.51	to	6.00	Moderately acid	preferred range
6.01	to	6.50	Slightly acid	preferred range
6.51	to	7.30	Neutral	preferred range
7.31	to	7.80	Mildly alkaline	preferred range
7.81	to	8.40	Moderately alkaline	
8.41	to	9.00	Strongly alkaline	
9.01	to	14.00	Very strongly alkaline	

Multiplier Factors for Calculating ECe
(taken from Hazelton & Murphy (2007))

Texture Class	Applicable Soil Textures	MF
S	Sand, loamy sand, clayey sand	17
SL	sandy loam, fine sandy loam	11
L	loam, loam fine sandy, silty loam	10
CL	clay loam, sandy clay loam	9
LC	light clay, sandy clay	8
MC	medium clay	7
HC	heavy clay	6

Interpretation of ECe (1:5 Soil:Water)
(rating based on Hazelton & Murphy (2007))

Ece (dS/m)			Rating
0.00	to	2.00	Non-saline
2.01	to	4.00	Slightly saline
4.01	to	8.00	Moderately saline
8.01	to	16.00	Highly saline
16.00	up		Extremely saline

increasing hazard ↓

Interpretation of Emerson Aggregate Class
(rating describes likelihood of dispersion)

EAT Class	Rating
1	High
2(1)	Mod
2(2)	Mod
2(3)	High
2(4)	High
3(1)	Low
3(2)	Low
3(3)	Mod
3(4)	Mod
4	Low
5	Low
6	Low
7	Low
8	Low

Box Hill North Masterplan Land Capability Assessment - Results of External Laboratory Analysis

Site	Name	Depth (mm)	CEC (me/100g)	Rating	Ca (mg/kg)	Rating	Mg (mg/kg)	Rating	Na (mg/kg)	Rating	K (mg/kg)	Rating	ESP (%)	Rating	P-sorp. (mg/kg)	Rating
TP 1	Composite	850mm	12.1	M	417	VH	642	H	977	VH	109	L	35.0	VSS	300	MH
TP 5	Composite	750mm	9.7	L	693	VH	372	H	106	M	132	M	4.7	NS	510	H
TP 6	Composite	850mm	10.8	L	338	VH	692	H	428	H	179	M	17.2	SS	730	VH
TP 7	Composite	600mm	5.9	VL	896	VH	121	L	18	VL	76	VL	1.3	NS	320	MH
TP 2/2	Composite	500mm	9.8	L	1015	VH	273	M	99	M	759	H	4.4	NS	200	M
TP 9/3	Composite	900mm	17.2	M	45	VH	1074	VH	###	VH	86	L	44.3	VSS	700	VH

Interpretation Sheet 2 - CEC, P-Sorption, Bray P, Organic carbon, Total nitrogen

Interpretation of CEC

(rating based on Hazelton & Murphy (2007))

Rating	CEC (me/100g)			Ca (mg/kg)			Mg (mg/kg)			Na (mg/kg)			K (mg/kg)		
VL	0.00	to	6.00	0.00	to	400.00	0.00	to	36.50	0.00	to	23.00	0.00	to	78.20
L	6.01	to	12.00	400.01	to	1000.00	36.51	to	121.50	23.01	to	69.00	78.21	to	117.00
M	12.01	to	25.00	1000.01	to	2000.00	121.51	to	365.00	69.01	to	161.00	117.01	to	274.00
H	25.01	to	40.00	2000.01	to	4000.00	365.01	to	972.00	161.01	to	460.00	274.01	to	782.00
VH	40.01	up		4000.01	up		972.01	up		460.01	up		782.01	up	

VL=very low, L=low, M=medium, H=high, VH=very high

Interpretation of ESP

(rating based on Hazelton & Murphy (2007))

Rating	ESP (%)			Description
NS	0.00	to	6.00	Non-sodic
S	6.01	to	15.00	Sodic
SS	15.01	to	25.00	Strongly sodic
VSS	25.01	up		Very strongly sodic

increasing hazard

Interpretation of Phosphorus Sorption Capacity

(rating based on Hazelton & Murphy (2007))

Rating	P-sorption (mg/kg)			Description
L	0.00	to	125.00	Low
M	125.01	to	250.00	Medium
MH	250.01	to	400.00	Medium-High
H	400.01	to	600.00	High
VH	600.01	up		Very high

increasing hazard

Interpretation of Bray Phosphorus

(rating based on Hazelton & Murphy (2007))

Rating	Bray P (mg/kg)			Description
VL	0.00	to	5.00	Very Low
L	5.01	to	10.00	Low
M	10.01	to	17.00	Moderate
H	17.01	to	25.00	High
VH	25.01	up		Very high

Interpretation of Soil Nitrogen (TN)

(rating based on Hazelton & Murphy (2007))

Rating	TN (%)			Description
VL	0.000	to	0.050	Very Low
L	0.051	to	0.150	Low
M	0.151	to	0.250	Medium
H	0.251	to	0.500	High
VH	0.501	up		Very high

Interpretation of Soil Organic Carbon (OC)

(rating based on Hazelton & Murphy (2007))

Rating	OC (%)			Description
VL	0.00	to	1.50	Very Low
L	1.51	to	2.00	Low
M	2.01	to	3.00	Medium
H	3.01	to	5.00	High
VH	5.01	up		Very high

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Staging Assessment for Recycled Water Management Scheme at Proposed Box Hill North Development, NSW

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Disclaimer

The information contained in this report is based on independent research undertaken by David Wainwright of Whitehead & Associates Environmental Consultants Pty Ltd (W&A). To our knowledge, it does not contain any false, misleading or incomplete information. Recommendations are based on an appraisal of the site conditions subject to the limited scope and resources available for this project, and follow relevant industry standards. The work performed by W&A included a desktop review and limited soil sampling only, and the conclusions made in this report are based on the information gained and the assumptions as outlined. Under no circumstances, can it be considered that these results represent the actual state of the site at all points as subsurface conditions are inherently variable. Concentrations of contaminants may also change with time, and the conclusions in this report have a limited lifespan.

Copyright Note

Executive Summary

Whitehead & Associates were engaged by RPS Australia Pty Ltd to undertake a Land Capability Assessment and Staging Assessment for a Recycled Water Scheme at the proposed Box Hill North Development, bounded generally by Boundary Road, Maguires Road, Janpieter Road and Old Pitt Town Road in Box Hill. A corresponding Land Capability Assessment (LCA) report has been prepared. Based on plans provided by RPS, it is proposed to subdivide the existing, approximately 390ha Site in multiple stages for primarily residential development, comprising approximately 4,100 lots, accompanied by an area designated for commercial/retail development and associated open space, recreational facilities and infrastructure.

It is proposed to develop a water supply and recycling scheme for the entire development. The recycled water would be produced at a proposed Local Water Centre (LWC). The LWC would supply the subdivision with a reticulated recycled water supply (i.e. 'third pipe'). As the development progresses, any unused recycled water (i.e. that not being reused internally or externally on individual residential properties) will be irrigated on managed pasture in the land set aside for the subsequent development stages of the subdivision. Two sets of wastewater load data were used in modelling, one derived from first principles by W&A and a second set of data provided by Box Hill North Water. Our analysis found that permanent irrigation areas would need to be established on community or/and privately owned lands (e.g. parks, sporting fields) for any unused recycled water towards the latter stages of the development. Using W&A's load data, this was found to be necessary prior to construction of Stage 6 of the development. Alternatively, modelling with the data of Box Hill North Water found that this could be deferred to before the construction of Stage 7. The analysis used to estimate the amount of land required is in accordance with standard practice and conservative (risk-averse) by nature. It is possible that further field testing to confirm / refine the estimated soil infiltration rates would result in a lower estimate of the amount of required irrigation area. Alternatively, a different customer for the excess recycled water may be found at build out stage, or the excess recycled water could be discharged to sewer or the environment in compliance with the environmental protection legislation in force at that time.

A site and soil assessment was conducted on the 4th December, 2014, in accordance with the Australian Guidelines for Water Recycling (2006) under the requirements of the Water Industry Competition Act (WICA, 2006), to determine the limitations (if any) for the irrigation of the Site. Overall, the Site constraints for Recycled Water Irrigation (RWI) were generally minor with the exception of soil sodicity. It is recommended that a comprehensive investigation of dissolved salts in the soil and its interaction with recycled water be undertaken to inform the steps needed to appropriately mitigate soils.

Design household (ET) water demands and wastewater generation rates were determined in accordance with the Building Sustainability (BASIX) and Water Efficiency Labelling Scheme (WELS) requirements. The household water demands have been estimated as 741L/ET/day based on the determined occupancy data and 'pre BASIX' benchmark home condition. Each design household has a potential to offset approximately 40% of the total potable water demand using recycled water, on an annual basis.

Monthly water and nutrient balances as well as daily-timestep modelling have been undertaken to determine sustainable irrigation rates for community land in the subdivision and ultimate irrigation capacity to determine the maximum development potential of the subdivision before an alternative end-use must be found for the recycled water.

The assessment demonstrates that the hydraulic load is limiting across the Site. Daily modelling indicates that irrigation of recycled water can be sustainably managed on site for the first 5 stages of the development. This assumes that stages will be developed in approximately the order in which they are listed in this Report and on the Site plans.

Model results indicate that nutrient loads in surface surcharge and deep drainage of recycled water represent <1% increase on the background nutrient loads in runoff from the Site. This figure is considered to be relatively insignificant. It is assumed that further attenuation rates for nutrients in soil are more than sufficient to capture these minor nutrient contributions. It is anticipated that the nutrient loads in the recycled water will have no appreciable impact on environmental and/or public health.

Table of Contents

List of Tables

1 Introduction

Whitehead & Associates Environmental Consultants Pty Ltd ("W&A") were engaged by RPS Australia Pty Ltd ("the Client") on behalf of Flow Systems to undertake a Land Capability and Staging Assessment for recycled water management for the proposed staged subdivision to be known as Box Hill North ("the Site"). The Site is bounded generally by Boundary Road, Maguires Road, Janpieter Road and Old Pitt Town Road in Box Hill, as shown in Figure 3 (Page 19).

This Staging Assessment report focuses on the Site's capacity to sustainably accommodate recycled water that is not reused internally or externally by residential developments, once the proposed Local Water Centre (LWC) at Box Hill is commissioned and operational. The LWC will be owned and operated by Flow Systems Operations, trading as Box Hill North Water. The proportion of recycled water that is reused by households will fluctuate throughout the year (and can be as high as 100% in warmer months); however this report deals with averages for simplicity.

The Site is located entirely within the Hills Shire Council ("Council") local government area (LGA). Field investigations were undertaken by David Wainwright and Jasmin Kable of W&A on the 4th December 2014. The Land Capability Assessment summarises those investigations and this report provides the results of our analysis and recommendations for Recycled Water Irrigation Zones (RWIZs) proposed to be developed to manage unused recycled water once the Box Hill North LWC recycled water scheme is operational. It should be read in conjunction with the Land Capability Assessment (LCA) Report prepared for the project (Report_01366_001).

2 Overview of Proposed Development

Figure 1 shows the general arrangement of streets within the proposed subdivision and the different stages of development. The development aims to accommodate 4,100 dwellings with a range of densities and a town centre comprising up to 10,000m^2 of retail/commercial floor space. The development proposal also includes a school, community facilities, sports fields, public open space, environmental buffers and other improvements including roads and infrastructure. Development is expected to be staged in 8 separate areas (A-H on Figure 1), totalling 390 hectares.

Box Hill North Water is assisting the developer, EJC Developments (EJC) in delivering sewerage, recycled water and drinking water infrastructure to the Box Hill North development. The Box Hill North LWC will treat wastewater generated by the proposed residential and commercial developments (separate trade waste agreements may be required for certain types of commercial uses). The LWC facility is intended to operate 24 hours, 7 days per week, housed in a low-scale, single level building within an open space setting. The proposed LWC will incorporate a dual reticulation ('third pipe') system to distribute recycled water to households for non-potable water reuse such as toilet flushing, washing machine supply, irrigation and car washing, thus reducing potable water demand. The eventual hydraulic capacity of the LWC will be around 3,000kL per day although this will be achieved as residential uptake within the development increases. At this stage in development planning, it is intended that the remaining excess recycled water will be irrigated in the undeveloped land associated with later development stages, in the proposed RWIZs.

3 Regulatory Requirements and Guidelines

The Independent Pricing and Regulatory Tribunal (IPART, NSW) regulate the licensing of private water schemes under the *Water Industry Competition Act (WICA) 2006*. Under the Act, a corporation must obtain a licence to construct, maintain or operate any water industry infrastructure (network operators' licence), or to supply potable or non-potable water, or provide sewerage services by means of any water industry infrastructure (retail suppliers licence). Both the network operators' and retail suppliers' licences are applicable for the development of the recycled water scheme at the Site.

Under the *Water Industry Competition (General) Regulation (WICR) 2008*, network operator licensees for sewerage schemes are required to produce a Sewage Management Plan (SMP) and subsequent audit reports on the SMP before commercial operation of the scheme. The sustainability assessment is an audit of relevant components of the SMP, with the aim of helping to determine whether the proposed infrastructure will provide sewerage services which are sustainable and do not present a risk to the environment.

This report, along with the LCA report, will address the 'sustainability assessment' requirements set out by *WICR (2008)*, that deal with the application of recycled water to land, including water balance calculations for the scheme. The sustainable rate of application of the recycled water will be determined; and general storage capacity requirements will also be outlined for the recycled water scheme based on the water balance calculations. The remaining sections of the sustainability assessment will be completed by the licensee. The outstanding SMP audit components can be completed after commencement of construction.

The Australian Guidelines for Water Recycling: Managing health and environmental risks (Phase 1) (NRMMC, 2006), were developed to provide guidance on the supply, use and regulation of recycled water schemes. The guidelines use a risk management framework comprising twelve (12) elements with multiple barriers to control hazards. The framework is summarised by four (4) main categories: commitment to responsible use and management of recycled water; system analysis and management; supporting requirements; and review.

The principles of sustainable use of recycled water are based on the following principles:

- protection of public and environmental health is of paramount importance and should never be compromised;
- protection of public and environmental health depends on implementing a preventative risk management approach; and
- application of preventative measures and requirements for water quality should be commensurate with the source of recycled water and the intended uses.

Land application (irrigation) of tertiary treated and disinfected recycled water, as proposed for Box Hill North, requires relatively few restrictions in regards to public health. End use controls and onsite constraints can also be used to minimise both human exposure to hazards and the impact on receiving environments; such as signage, use of appropriate buffer zones as necessary, and control of plumbing and distribution systems.

The licensed network operator must submit to IPART an Infrastructure Operating Plan and a Water Quality Plan which is consistent with the AGWR (2006) and addressing the Framework for Management of Recycled Water Quality and Use.

4 Recycled Water Analysis

4.1 Local Water Centre

It is our understanding that Box Hill North Water will supply the LWC, which will incorporate a multi-stage process incorporating screening, anaerobic and aerobic processing, chemical treatment, membrane filtration, ultraviolet disinfection and chlorination for the treatment of wastewater from the Box Hill North development. The Membrane Bioreactor (MBR) system effectively combines two proven wastewater treatment processes (i.e. microbial digestion and membrane separation) into a single process where suspended solids and microorganisms responsible for biodegradation are separated from the treated water by an ultra-filtration (UF) system.

We understand that the proposed LWC will be designed to accommodate the maximum daily load from Box Hill North at build out, with required provisions for peak flow management (flow-balancing) and emergency storage.

4.2 Recycled Water Generation

Wastewater generation for the proposed development will include domestic sources as well as commercial and community sources within the designated precinct. Generally, wastewater from each future lot will be generated from the entire (combined) wastewater stream including blackwater (toilet flushing and kitchen wastes), and greywater (laundry and shower/bath/hand basin wastes). The exception to this may include particular types of trade waste generated in commercial premises, which may require separate collection and disposal. At this stage, the exact types of commercial premises to occupy the Commercial Centre are not known. However, most (if not all) of them are expected to generate wastes that are appropriate for treatment in the LWC (such as supermarkets, retail, takeaway food, etc.). Box Hill North Water has provided estimations of the equivalent tenement (ET) for the proposed retail and community developments, which have been used in our analysis.

It is proposed to provide dual reticulation to distribute recycled water to households and public open space, whilst any unused recycled water will be irrigated in the undeveloped land associated with later development stages (and ultimately to other permanent uses once build-out is complete).

4.3 Recycled Water Quality

The recycled water produced by the LWC will be of tertiary quality; that is, it is expected to meet, or exceed, the following criteria:

- Total Nitrogen: ≤15mg/L;
- Total Phosphorus: <5mg/L;
- BOD_5: ≤10mg/L;
- Suspended Solids: ≤10mg/L;
- Faecal Coliforms: ≤10cfu/100mL;
- Total Dissolved Solids: 700mg/L; and
- EC: ~1,000µS/cm.

RWIZs will likely be accessible to the public and residents either through direct exposure or inadvertent/secondary contact. Appropriate signage must be employed to identify the use of recycled water for irrigation. The proposed LWC will treat recycled water to a quality which would be considered low risk for direct human contact (DWE, 2008). The proposed recycled water quality will enable urban irrigation of community areas with unrestricted access.

4.4 Recycled Water Quantity

The Building & Sustainability Index (BASIX), implemented under the NSW State Environmental Planning Policy Sustainability Index 2004 (BASIX SEPP), mandates water and energy saving targets for all new residential construction in NSW. BASIX requires fixtures, fittings and appliances to have minimum ratings in accordance with AS/NZS 6400:2005 (Water Efficient Products) under the Water Efficiency Labelling and Standards (WELS) scheme.

For BASIX approval a new residential development is required to demonstrate up to 40% less potable water usage than the average 'pre BASIX' benchmark home of 90.34kL/person/year or 247L/person/day. The 'pre BASIX' benchmark home was determined from data collated by the then NSW Department of Water and Energy (DWE) and included regional data reflecting both demographic and climate considerations. The whole of The Hills Shire Local Government Area is located within a 40% water reduction target zone. The BASIX reduction targets were determined from data provided by state and federal water and energy utilities as well as long-term climate data obtained from the Bureau of Meteorology. It is noted that the reduction targets are currently under review, with a proposal to increase the target to 50% in some areas currently prescribed with a 40% reduction target.

BASIX encourages reductions in the consumption of potable water through any of the following strategies: landscape uses, fixtures, alternative water sources, shades and covers for pools and spas, and central systems. The Site will utilise an alternative water source through the reticulation of recycled water, for garden and lawns, toilets and laundry (cold water only) use, to meet the BASIX reduction targets. Additional listed strategies, i.e. fixtures, may also need to be used in addition to the alternative water source to meet the target.

4.4.1 Residential Development

Design Household

An ET occupancy value (capita per new residence) was determined based on population density information collated by W&A from the most recent ABS Census of Population and Housing (2011). An ET occupancy value of three (3) persons per new residence was adopted, the same as that recorded for the more developed statistical local area of The Hills Shire (The Hills Shire (A) – Central) in the 2011 census. We consider that this is an appropriate figure to adopt for design purposes for the proposed Box Hill North development.

Household Water Usage

Subsequently, peak seasonal (summer) household water demand has been estimated for each new residence as 741L/ET/day (3 persons x 247L/person/day). Assuming a minimum requirement to meet the 40% BASIX reduction target, a reduction of 297L/ET/day is required from the total household water demand for each new residence. Figure 4 illustrates the proportional breakdown of the water use within a residential household based on BASIX targets and WELS scheme criteria.

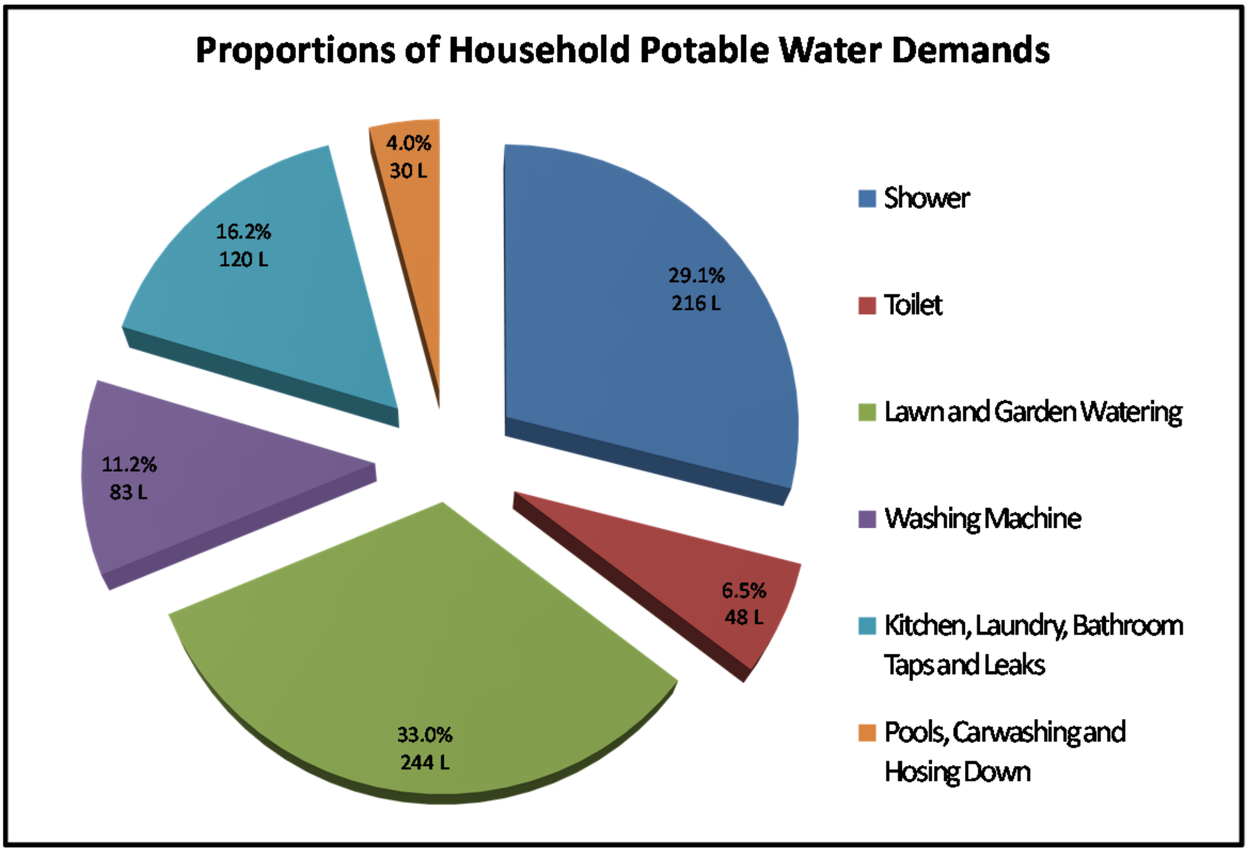

Figure 1 Proportion water usage within a residential household (internal and external water use)

The calculations and assumptions used by BASIX and WELS to proportion expected household usage are further described below.

Toilets

Based on the installation of retrofitted flush valves for single flush toilets only, 5.5L/full flush is the maximum WELS scheme registered water consumption for toilets. The maximum water consumption for dual flush toilets, which will likely be installed, is 4L/flush (6L full flush / 3L half flush). We have assumed an average of 4 flushes/person/day (13 per weekend and 3 per weekday, averaged over the week). Therefore, the total water demand for toilets would be 48L/ET/day. This equates to approximately 6.5% of the total household water demand.

Showers

The minimum NSW requirement, as per the Building Code Australia, for showerheads in new developments is a 3-star rating with a water consumption ranging between 4.5-9L/min. As per BASIX calculations, for an assumed shower duration of 8 minutes (one shower a day), with a maximum allowable showerhead flow rate of 9L/min, the total water consumption for showers would be 216L/ET/day. This equates to approximately 29.1% of the total household water demand.

Washing Machines

BASIX requires the following WELS scheme (star) ratings to be met for washing machines: a load capacity greater than 5kg requires a greater than 3-star rating and for capacities less than 5kg a rating greater than 2.5-star is required. The maximum consumption per load for a 2.5-star and a 3-star washing machine is 76 and 97L/load, respectively. We have assumed the larger machine would be installed in each new residence and also that a 'typical' 3-person household would do six (6) loads per week. Based on this, we estimate that, at 97L/load, the total household water consumption for washing machines would be 83L/ET/day. This equates to approximately 11.2% of the total household water demand. Approximately one-third of washing machine water usage is assumed to be hot water (28L/ET/day) with the remaining two-thirds being cold water (55L/ET/day).

Kitchen, Laundry, Bathroom Taps and Leaks

The minimum BASIX requirements for taps are 3-star outlet tap sets with a maximum water consumption of 9.5L/min and an average of 8.4L/min. Assuming a 'typical' resident uses the taps for approximately 4min/day at 8.4L/min, then the estimated water consumption for taps is approximately 101L/ET/day. This equates to approximately 13.5% of the total household water demand.

The water consumption of a dishwasher as a proportion of the total 'kitchen, laundry, bathroom taps and leaks' component was also determined. The minimum WELS scheme rating for dishwashers is 1.5-star, with a maximum water consumption of 18.6L/wash. We have assumed a typical 3-person household does at least one wash per day. Therefore, the total water consumption for dishwashers is 18.6L/ET/day. This equates to approximately 2.5% of the total household water demand. When combined with expected tap uses, this results in an estimated 16.2% total household water demand for 'kitchen, laundry, bathroom taps and leaks'.

The estimate of 16.2% for this particular household demand is validated by Sydney Water (2008) and Brisbane Water (QLD Department of Housing and Public Works, 2006) figures.

Pool, Car Washing and Hosing Down

An approximate demand of 4% was adopted for (non-garden) external uses such as pool, car washing and hosing down. This equates to approximately 30L/ET/day of the total household water demand. This was based on figures adopted by both Sydney Water (2008) and Brisbane Water (QLD Department of Housing and Public Works, 2006). (Note that we have not assumed any reuse of recycled water for this purpose at this stage).

Lawn and Garden Watering

As lawn and garden watering can include seasonal variability, it was the most difficult type of water demand to estimate. By adopting the aforementioned proportions, the remaining 33% of on-lot usage is assigned for lawn and garden watering, which equates to approximately 244L/ET/day. This value compares to an (approximate) average of other published values from Brisbane Water 42% (QLD Department of Housing and Public Works, 2006) and Sydney Water 24% (2008), respectively.

Household Wastewater Generation

For the purposes of this report, the expected wastewater generation from the design household (ET) with a reticulated water supply is 467L/ET/day, which is approximately 63% of the total potable water demand of 741L/ET/day. The breakdown of the wastewater generating components of household fixtures is shown in Figure 5. The values are based on the BASIX and WELS scheme requirements and applied in the relative proportions as discussed in the previous section. It should be noted that the external household uses, lawn and garden watering and pools, car washing, and hosing down, do not contribute to the wastewater load.

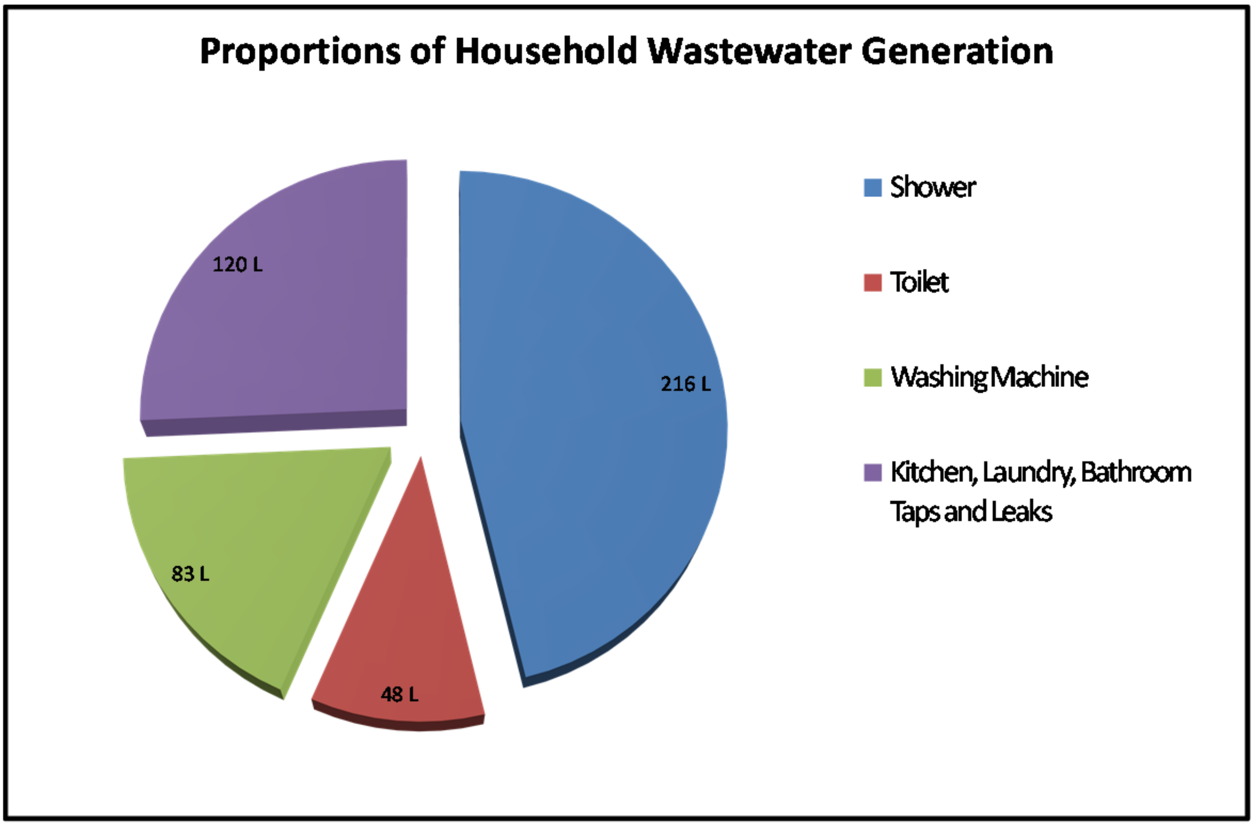

Figure 2 Proportional wastewater generation within a residential household

To determine the potential demand for recycled water returned to the dwellings in a dual-reticulation (third pipe) scenario, we investigated three different reuse scenarios representing annual seasonality (peak, shoulder and low). The 'shoulder' season (autumn and spring outdoor use) has been adopted as an appropriate figure for approximating year-round reuse rates. Table 1 below shows the breakdown of wastewater generation and recycled water reuse for proposed residential development. This includes the reuse of recycled water to replace potable water demand for the following uses: toilet (6.5%), lawn and garden watering (25% in shoulder seasons) and cold water washing machine only (7.5%).

The total reuse potential (indoor and outdoor) based on the shoulder ('average') scenario is 286L/ET/day with the remaining 181L/ET/day unused recycled water requiring irrigation within an undeveloped stage elsewhere in Box Hill North (and ultimately beyond the Box Hill North development as it is progressively built out).

Based on our assessment, each household has a potential to off-set approximately 40% of the total potable water demand through the use of an alternative water (recycled water) source, on an annual basis.

Therefore, the BASIX target of a 40% reduction in the total household water demand is achievable under the shoulder scenario. However, other methods, such as the installation of higher WELS scheme star rated fixtures, may need to be implemented in order to ensure that the BASIX target criteria is met for the entire year.

Table 1 Household (ET) Potable / Recycled Water Demand Scenarios

Water Use	Potable Water Use (L/ET/day)	Wastewater Generation (L/ET/day)	Shoulder[1] (Autumn/Spring) recycled Water Reuse Potential
Shower/Bath	216	216	0
Toilet	48	48	48
Lawn & Garden Watering[1]	244	0	183
Washing Machine[2]	83	83	55
Kitchen, Laundry, Bathroom Taps & Leaks	120	120	0
Pools, Car-washing and hosing down	30	0	0
TOTAL	741	467	286
Recycled Water Requiring Irrigation (L/ET/day)			181
Potable Water Demand After Reuse of Recycled Water (L/ET/day)			455

[1]75% of external uses (annual average, including 50% in winter and 100% in summer);

[2]Washing machine reuse is for cold water supply only; therefore reuse potential is estimated as 2/3 of total demand for washing machine.

4.5 Wastewater Loads from Box Hill North Water (Flow Systems)

As the owner/operator of similar Recycled Water Centres at a number of communities around New South Wales, Flow Systems (t/as Box Hill North Water) have experience in the determination of actual demands and wastewater generation rates once these systems are installed. Box Hill North Water provided water demand, including recycled water demand, and wastewater generation data based on their own calculations for comparative modelling. Box Hill North Water has advised that their values:

> *"recognise that BASIX 40 has driven and will continue to drive (over the course of the 20-year development roll-out) a change in behaviour and a change in water fittings and appliances available in the market. The 'average' installation therefore has a lower water demand in new developments"*

Ultimately, the balance of excess irrigation water predicted results from the difference between wastewater generated (which needs to be recycled) and the demand for recycled water. Wastewater generation rates are clearly influenced by the overall demand for water. A comparison between the rates derived by W&A and those derived by Box Hill North Water are presented in **Table 2**. We highlight that the figures from the right column of **Table 2** have been modelled to provide an alternative analysis, specifically at the request of Box Hill North Water.

Table 2 Comparison between W&A and Box Hill North Water Demand Figures

Quantity	W&A Figures (L/ET/day)	Box Hill North Water Figures (L/ET/day)
Total Water Demand	741	499
Recycled Water Demand	286	248
Wastewater Generated	467	302
Balance for Irrigation	181	54

5 Buffers

A risk based approach was followed and buffer zones from irrigation areas are recommended as they provide a form of mitigation against unidentified hazards and minimise risk to public health, maintain public amenity and protect sensitive environments. The AGWR (2006) guideline recommends restricted access and 25-30m (Table 3.5 & 3.8) buffer zones from the land application area to the nearest point of public access for spray irrigation of high-quality recycled water suitable for domestic non-drinking water use, as is the case with the proposed LWC/RWI schemes at the Site. The application of the recommended buffer zones will provide a minimum 1-log (equivalent) reduction in pathogen loads from the RWIZs. Recommendations to prevent off-lot discharge also include the use of low-throw sprinklers, part-circle (180º inward-throwing) sprinklers and/or tree or shrub screens.

W&A also recommends the following environmental buffers for surface spray irrigation based on NSW DEC (2004) guidelines;

- 250 metres from domestic groundwater bores;
- 50-100 metres from permanent watercourses; and
- 40 metres from intermittent watercourses and dams.

This recommendation is principally due to limitations identified in the site and soil assessment, including periodically waterlogged soils and potential inundation of low-lying areas following intense rainfall.

The land parcel containing the LWC and associated infrastructure, and the buffer zones, were excluded from the determination of the available RWIZs. Based on advice from RPS Australia, apart from the normal buffers outlined above, no additional limitations to irrigation areas (e.g. for endangered ecological communities, or associated offsets) were considered.

6 Recycled Water Management

6.1 Recommended Recycled Water Irrigation Zones

As discussed, all recycled water that is not used on residential lots via dual reticulation is to be irrigated at sustainable loading rates on undeveloped (future) stages of the proposed Box Hill North development. Due to the nature of the development, which is to proceed in stages over a number of years, the (preliminary) recycled water irrigation scheme has been developed in a manner compatible with the proposed development staging plan.

For modelling, each *stage* of development has been represented by the complete build out of a number of *development areas*. Each *development area* has been delineated as a potential discrete Recycled Water Irrigation Zone (RWIZ), (as shown on Figure 1). The characteristics of each *development area*, including the breakdown of proposed allotment types, total ET, and the total area (without consideration of buffers) are summarised in Table 43.

Each of the development areas includes land parcels earmarked for residential development. The number of lots and appropriate ET value for each development area were provided to us in a range of diverse formats, required some processing in GIS and spreadsheet software before they could be used.

Values for the number of Traditional/Courtyard and Villa Lots in *planned* development areas A, B and D were provided to us directly by PS Solutions at the request of Box Hill North Water. The ET for villas in these areas was set at the number of lots multiplied by 0.85 on the basis of the apparent multiplication factor used within remaining development areas.

For the remaining ("*unplanned*") development areas, data were provided to us as a CAD file where lots were agglomerated into "blocks" with an accompanying number of lots and ET value for each block provided in a spreadsheet. Following processing in GIS to determine the development area containing each "block", and then summarising in Microsoft Excel, the residential values for each unplanned area in Table 3 were completed.

For other types of land uses (such as the proposed primary school), the presence and size varies between stages. The ET associated with other uses was determined directly from annotations provided in the CAD file as follows:

- Sports Field (Development Area C): 2ET;
- School (Development Area C): 9ET;
- Retail/Commercial (Development Area E): 35ET; and
- Apartments (Development Area E): 200ET.

Table 3 Development Areas, Equivalent Tenement and Usable Area Analysis

Development Area[1]	Traditional/ Courtyard / Low Density / Environmental Living (No. Lots)	Villas and Rear Loaded (No. Lots)	Residential ET	Other ET (see text)	Total ET	Gross Area[2] (ha)
A	285	248	496	0	496	43
B	304	376	624	0	624	42
C	402	116	489	11	500	54
D	180	132	292	0	292	36
E	159	115	257	235	492	44
F	381	153	493	0	493	42
G	137	0	137	0	137	24
H	435	0	435	0	435	42
I	473	0	473	0	473	65

[1]Areas A, B and D are referred to as “planned” in CAD drawings provided to W&A; the remaining areas are referred to as “unplanned”;

[2]Does not include the Effect of Buffers.

The proposed staging, including Total ET, excess recycled water load and remaining area for irrigation are outlined in Table 4. Note that the remaining area is affected in a non-uniform way by development areas as they are being built out due to the changing boundary of the developed area. A 50m buffer has been applied to the total developed area for each stage. This is based on an assumption that impact sprinklers will be used for irrigation and the potential of these sprinklers to aerosolise, following the recommendations of DEC (2004).

The remaining RWIZ of each stage was calculated using GIS. That area includes parts of the development which are considered unsuitable for recycled water irrigation due to physical constraints such as rock outcrops and setback buffers from intermittent drainage lines or stage boundaries. The recommended setback buffers were applied from water courses and drainage lines, and stage/development boundaries using GIS. The residual areas considered ‘usable’ for recycled water irrigation during each stage were then calculated using GIS and are also provided in Table 4. In determining useable areas, small snippets (<< 1ha in size) of land that were effectively orphaned from larger contiguous potential irrigation areas were not considered.

Figure 3: Development Stages

Box Hill North Masterplan Staging Assessment

Whitehead & Associates
Environmental Consultants

0 250 500 750 m
(Approx Scale)

N

Revision	A
Drawn	DJW
Approved	DJW

Table 4 Excess Recycled Water Loads and Available RWIZ for Development Stages

Stage	Built out Development Areas	Total ET	Remaining RWIZ Area (ha)[1]	Excess Recycled Water Load (L/day)[2]	
				W&A	Box Hill North Water
1	A,H,C	1,431	181	259,011	77,274
2	Stage 1 + B	2,055	148	371,955	110,970
3	Stage 2 + D	2,347	122	424,807	126,738
4	Stage 3 + E	2,839	88	513,859	153,306
5	Stage 4 + F	3,332	56	603,092	179,928
6	Stage 5 + G	3,469	40	627,889	187,326
7	Stage 6 + I	3,942	0	713,502	212,868

[1]Includes Effect of Buffers

[2]Refer to Section 4 for a discussion on the source of per ET rates of Excess Recycled Water

6.2 Water and Nutrient Balance for Irrigation Area Sizing

The capacity of the RWIZs to manage the predicted hydraulic loads under seasonal variation has been assessed to determine the sustainability of the proposed recycled water irrigation scheme at the Site. Both water and nutrient balances have been undertaken to determine sustainable irrigation rates for the remaining RWIZ area in the subdivision and the ultimate irrigation capacity to determine the maximum development potential of the subdivision before an alternative end-use must be found for the recycled water. The key assumptions of the water and nutrient balance modelling are as follows:

- Average total recycled water reuse of ~40% for residential development demand (Section 4.4);
- Average Design Recycled Water Irrigation load (ET_{IRR}) of either 181L/ET/day (W&A loads) or 54L/ET/day (Box Hill North Water loads); and
- 'Worst-case' soil characteristics (including profile depth and chemistry) throughout the Site.

For preliminary design analysis, the water balance used is a 'lumped' monthly model adapted from the "Nominated Area Method" described in DLG (1998). These calculations determine minimum irrigation area requirements for given recycled water loads for each month of the year. The water balance can be expressed by the following equation:

Precipitation + Recycled Water Applied = Evapotranspiration + Percolation + Storage

Ideally, irrigation areas are calculated to achieve no net excess of water (recycled water and percolated rainfall) and hence zero need for wet weather storage for all months. A Design Irrigation Rate (DIR) of 2mm/day was adopted for the Site based on the most limiting site and soil characteristics as described in the associated LCA report.

Conservative nutrient balances (annual mass balance) were also undertaken to calculate the minimum area requirements to enable nutrients to be assimilated by the Site soils and vegetation. The nutrient balance used is based on the DLG (1998) methodology, but improves on this by more accurately accounting for natural nutrient cycles and processes. It acknowledges that a proportion of nitrogen will be retained in the soil through processes such as ammonification (the conversion of organic nitrogen to ammonia) and that a certain amount will be lost by denitrification, microbial digestion and volatilisation (Patterson, 2003). Patterson (2002) estimated that these processes may account for up to 40% loss of total nitrogen. We have adopted a more conservative estimate of 15% for the nitrogen losses due to soil processes. Tables 5and 6 below provide details of the inputs for the preliminary water and nutrient balances for the RWI systems.

Table 5 Data Inputs for Monthly Water Balance

Data Parameter	Units	Value	Comments
Design Recycled Water Irrigation load (ET_{IRR})	L/ET/day	181 (W&A) / 54 (Box Hill North Water)	Refer to Section 4 for source/derivations
Precipitation	mm/month	Mean rainfall	From BoM Monitoring Station (Glenorie #067010) precipitation data (111 years)
Pan Evaporation	mm/month	Mean pan evaporation	From BoM Monitoring Station ((Richmond RAAF #067033) evaporation data (24 years)
Retained Rainfall	unitless	0.8	Proportion of rainfall that falls on the RWIZs and infiltrates the soil (80%), allowing for up to 20% runoff from a well pastured gently sloping site
Crop Factor	unitless	0.7-0.8	Expected annual range based on good ground cover and exposure
Design Irrigation Rate (DIR)	mm/day	2	Category 6 soils from AS1547:2012, for most constrained conditions in proposed RWIZs

Table 6 Data Inputs for Annual Nutrient Balance

Data Parameter	Units	Value	Comments
Recycled Water total nitrogen (TN)	mg/L	15	Minimum target recycled water quality from tertiary treatment system
Nitrogen lost to soil processes (denitrification and volatilisation)	annual percentage	15	Minimum expected, per Patterson (2002). Very conservative
Recycled Water total phosphorus (TP)	mg/L	5 (expected 2–5)	Upper end of target range recycled water quality from tertiary treatment system
Soil phosphorus sorption capacity	mg/kg	140	Conservative 'worst-case' i.e. lowest P-sorb result (range 140-780mg/kg)
Nitrogen uptake rate by plants	kg/Ha/yr	250	Less than half that expected of irrigated pasture grass (DECCW, 2004 Table 4.2)
Phosphorus uptake rate by plants	kg/Ha/yr	25	Less than half that expected of irrigated pasture grass (DECCW, 2004 Table 4.2)

The model results show that the hydraulic load is limiting across the Site. The nitrogen and phosphorus balances require less area for sustainable assimilation, and therefore are not considered limiting.

Table 7 summarises the results of the monthly water balances for the unused recycled water to be irrigated, assuming the average value of 181L/ET/day.

Table 7 Results of Water Balance for Box Hill North

Stage	Irrigation Area Required (m^2)[1]		Available RWIZ area (m^2) once stage is developed
	W&A	Box Hill North Water	
1	360,500	107,524	1,814,185
2	517,563	154,411	1,483,828
3	591,104	176,352	1,223,991
4	715,017	213,320	882,235
5	839,182	250,364	557,755
6	873,686	260,658	404,041
7	992,814	296,199	0

Based on the results of the monthly water balance model, it is predicted that the maximum capacity of the Box Hill North development to sustain irrigation of unused recycled water would be reached:

- once stage 4 is built out, based on the wastewater loads calculated by W&A
- Once stage 6 is build out based on the wastewater loads provided by Box Hill North Water.

These analyses assume that stages are developed in the order in which they are listed in Table 7. However, the monthly water balance is a coarse, often conservative assessment, and more accurate, daily time step modelling which doesn't average out the monthly irrigation volumes, has been undertaken as described below.

A copy of the monthly water balance for the complete build out of the development is provided in Appendix A.

6.3 Daily Time Step Modelling

6.3.1 Overview of the DSM Model

The DSM is a GIS-based tool that was developed jointly by W&A and BMT WBM for the purpose of providing a rapid-assessment tool to predict the performance of on-site and decentralised wastewater management systems under varying environmental conditions. It has the ability to assess long-term environmental and human health performance of wastewater treatment and land application systems. Background information and general methodology of the DSM is provided in the DSM User Manual (BMT WBM, 2011).

[1] Based on a 2mm/day loading rate; the hydraulic load is limiting, therefore the results for nutrient balances are not included.

The inputs to, and results of, the preliminary water and nutrient balances were used as to guide use of the DSM.

The DSM does not predict the minimum area required to achieve zero surface runoff or deep drainage, instead, like the nominated area approach of the monthly water balance, the model predicts the surface and subsurface discharges based on a set of nominated conditions such as receiving node sensitivity, soil, slope, weather, recycled water input and land application area. The model developed for this study simulates a 64 year time period and is designed to provide conservative estimates of the performance of the proposed recycled water irrigation scheme over that timeframe.

For this project, the model was used primarily to confirm the 'carrying capacity' of the Site and individual stages to sustainably accommodate unused recycled water, as well as the minimum irrigation area required following complete build out of the Site. These modelling scenarios take into consideration the available storage to be provided by the proposed recycled water storage tanks. The model has capacity to use a fluctuating application rate, depending on soil moisture (measured by in-ground sensors); however, we have maintained a nominal 2mm/day application rate due to the limiting soil chemical constraints, namely sodicity. The recycled water will contain sodium and other compounds which can be problematic for sodic soils at higher loading rates. Options for soil amelioration are discussed in the LCA report.

A summary of the model inputs is provided in Table 8.

6.3.2 Model Results

The DSM was run iteratively, using input values corresponding to the sequential development of each stage and the associated reduction in available RWIZs. There were two aims:

1. To determine at what stage irrigation becomes unsustainable;
2. To determine how much land, (assumed to have similar soil and landscape characteristics to that present on the site) would be needed to sustainably dispose of the recycled water at build out.

To address item 1, simulations began with Stage 4, the sustainability *tipping point* derived from monthly balance modelling using the W&A derived wastewater loads. In comparison, the Box Hill North Water' derived wastewater load simulation commenced at Stage 6. Sustainability was defined as the following:

1. Zero Surface Surcharge; and
2. Less than 5% increase in nutrient export above background values.

The background nutrient export values were derived following the methods of Fletcher et al. 2004. The estimated values for the entire development, were 468kg/yr of Phosphorus (before Development, falling to 342 kg/yr after development) and 2,452kg/yr of Nitrogen (before development falling to 2,110kg/yr after development). These values assumed around 50% imperviousness of the developed site.

<u>Nutrient Loading</u>

A summary of the nutrient export results of the DSM is provided in Table 9. The simulation was run for a period of 64 years (1950-2013). When compared to the background values, it is clear that all are several orders of magnitude lower than the background values, with the exception of phosphorus for Stage 6, when adopting the W&A wastewater loads. In this case, it is the relatively high rate of irrigation which acts to flush phosphorus from the soil profile, resulting in phosphorus entering the environment via the deep drainage pathway. Nevertheless, the results here (45.6kg/yr c.f. 342kg/yr) indicate that building out stage 6 without finding alternative areas for effluent irrigation (in addition to "Area I") would have an unacceptable impact on the environment. Conversely, the simulated export of nutrients when applying the Box Hill North Water wastewater loads results in minimal additional nutrient export.

Hydraulic Loading: Deep Drainage and Surface Surcharge

A summary of the deep drainage and surface surcharge results of the DSM is provided in Table 10. Again, the simulation was run for a period of 64 years (1950-2013).

Table 8 DSM Inputs

Input Parameter	Unit	Onsite Scenario
Unused Recycled Water for Irrigation	L/day	As per Table 5 (for modelled stage)
Recycled Water Total Nitrogen Concentration	mg/L	15
Design Irrigation Rate[3]	mm/day	2.0
Recycled Water Total Phosphorus Concentration	mg/L	5
Recycled Water Virus Concentration[1]	MPN/100ml	<10
Daily Rainfall (1889-2013)	mm	From SILO Data Drill, Box Hill North
Daily Pan Evaporation (1889-2013)	mm	From SILO Data Drill, Box Hill North
Average Air Temperature (in lieu of ground temperature) (1889-2013)	ºC	From SILO Data Drill, Box Hill North
Crop Factor[2]	unitless	1.0
Buffer From Waterways	m	≥40
Buffer From Boundaries of Existing Development and Overall Site Boundary	m	50
Slope	%	Digital Elevation Model
Required Recycled Water Irrigation Area	m^2	Various
Available Recycled Water Irrigation Area	m^2	Various
Soil Phosphorus Adsorption (P-sorb) Capacity	mg/kg	140
Soil Depth for P-sorb (assumed)	m	0.7
Crop Nitrogen Uptake	kg/ha/year	250
Crop Phosphorus Uptake	kg/ha/year	25
Total Recycled Water Storage Capacity	ML	5.0

Notes

[1] Most Probable Number.
[2] Daily effective evapotranspiration ET_0 values have been used from SILO data, meaning that the effect of crops is already considered. Crop Factors of 1.0 have been used.
[3] Target DIR. Will be exceeded if storage tank overflows, and is limited if tank empties.

Table 9 Average Annual Nutrient Export Results

Nutrient Concentration	Parameter	Background Loads (Fletcher et al., 2004)	Stage 4 (W&A Loads)	Stage 5 (W&A Loads)	Stage 6 (W&A Loads)	Stage 6 (Box Hill North Water Loads)
TP (kg/year)	**DSM Surface Surcharge + Deep Drainage Outputs**	468	0.03	0.24	45.6	0.000
TN (kg/year)	**DSM Surface Surcharge + Deep Drainage Outputs**	2452	0.000	0.003	0.068	0.000

Table 10 Average Annual Hydraulic Export Results

Parameter	Stage 4 (W&A Loads)	Stage 5 (W&A Loads)	Stage 6 (W&A Loads)	Stage 6 (Box Hill North Water Loads)
Annual Surface Surcharge (m^3)	0	0.003	0.16	0.00
Annual Deep Drainage (m^3)	59.6	121.8	223.4	52.40

Although we aim for a “zero surface surcharge” condition, interrogation of the results indicates that surcharge occurred during just one of the 64 years simulated during the Stage 5 build out scenario that used the W&A wastewater loads. Furthermore, the single year during which surcharge occurred results in a simulated total surcharge of 0.17m^3 (170L).

In perspective this would be a surcharge of 17mm, for one day, over a single square metre of ground. Considering the high quality of effluent being used for irrigation, we believe this is acceptable. Conversely, surcharge occurs during eight years for the simulation where Stage 6 is complete, and the W&A loads are used, and the total volume is a couple of orders of magnitude larger than for the Stage 5 build out scenario. On this basis, we consider that hydraulic constraints at the site will mean that additional area for irrigation may need to be sought prior to the construction of Stage 6.

It is useful to provide further analysis of the Stage 6 build out scenario, examining the volume of excess recycled water that causes surcharge. Essentially, surcharge occurs when the amount of storage present in the soil pores is exceeded. For this analysis the soil storage equals difference in volume held when the soil profile is saturated (“Saturated Capacity”) and the volume held once the profile is allowed to drain under the influence of gravity (“field capacity”).

The model results indicate that, for the Stage 6 build out scenario, if Area “I” is the only irrigation area available, that the soil store is rarely full. Indeed, the results indicate that, for 50% of the time, the soil store is empty (i.e. moisture is at or below field capacity). Furthermore, for only 10% of the time, is the soil store more than around 2.6% full. The proportion that the soil store is full for the remaining 10% of the time is charted in Figure 4.

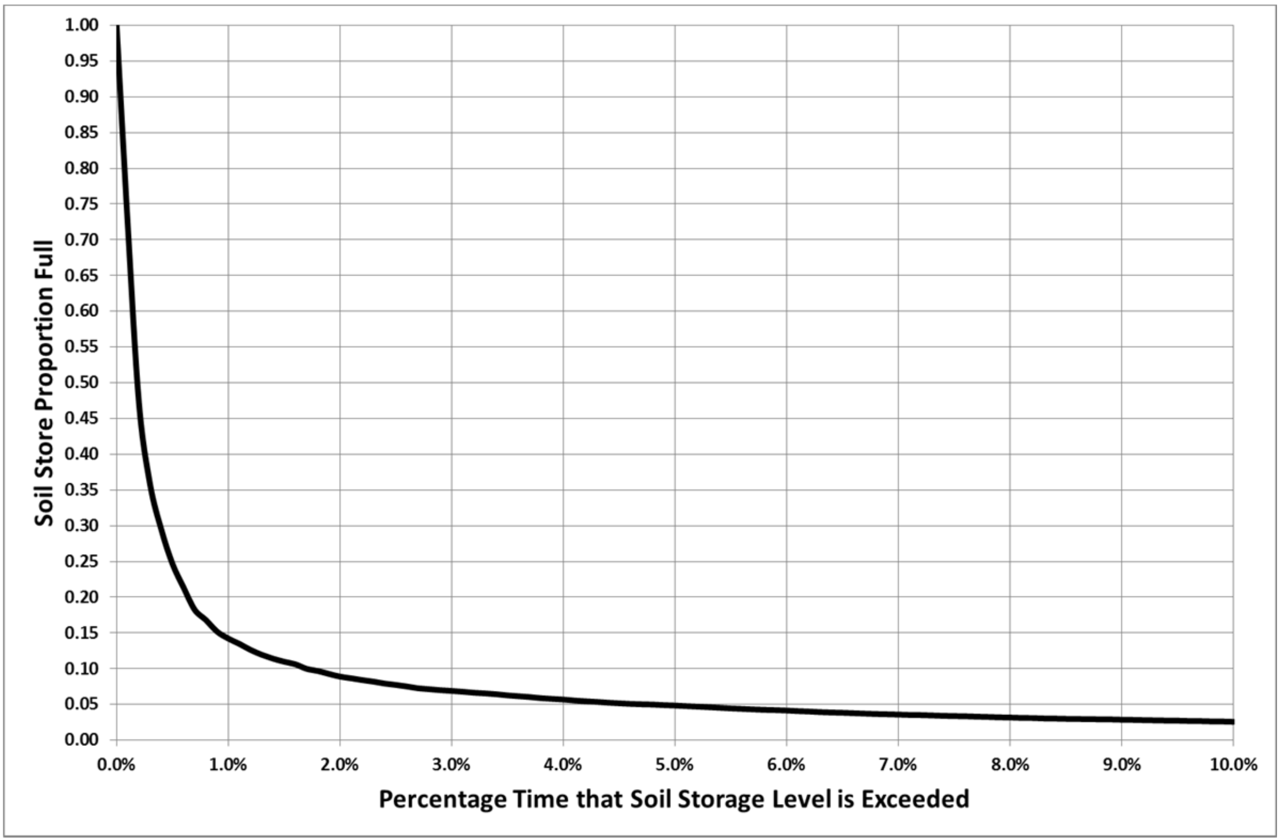

Figure 4 Proportional Fullness of Soil Store vs. Percentage of Time Exceeded (Stage 6 build out, using W&A wastewater loads)

Figure 4, indicates that, over the 64 year period modelled the soil store is more than 50% full for less than 0.25% of the time.

Analysis of the excess water associated with surcharge events is also instructive. The model indicates that surcharge would have occurred on 10 days throughout the 64 year period (less than 0.05% of days) or less than once every 6 years. The predicted surcharge volumes over the entire irrigation area (40 hectares at the build out of Stage 6 for those 10 years) are listed in Table 11.

That table shows a maximum surcharge volume of less than $2m^3$ (2kL, or 0.002ML). This volume is very small when considering the amount of area over which it is to be applied, and the daily load of generated recycled water. Through management of the irrigation by monitoring soil moisture to control irrigation, these types of surcharge events could be avoided.

Table 11 Modelled Surcharge Events – Stage 6 build out with Irrigation of Area "I" only. W&A wastewater loads

Modelled Surcharge Date	Surcharge Volume (m^3)
30/08/63	0.30
14/08/52	0.52
02/04/89	0.98
14/05/62	1.08
30/04/88	1.22
08/05/63	1.24
28/04/63	1.28
08/08/98	1.29
05/06/74	1.61
12/06/64	1.84

Alternatively, if applying the Box Hill North Water' derived wastewater loads, the model results indicate that the increase above background is minimal, and development could proceed to the completion of Stage 6 before an alternative use is sought for excess recycled water.

<u>Irrigation Area Requirements for full build out assuming W&A wastewater loads</u>

For the build out of the entire estate, we have estimated the amount of irrigation area (assuming similar soils to those within the site being developed) based on the almost perfect balance between irrigation area and water requiring land application for the Stage 5 build out scenario, when applying the W&A derived wastewater loads. For Stage 5, an irrigation load of 603,092L is managed sustainably on an irrigation area of 557,755m^2. Proportionally, the Stage 7 build out irrigation load of 713,502 would correspond to an irrigation area of 659,865m^2, or around 66 hectares. 66 hectares was subsequently simulated with the Stage 7 irrigation load as a test. As expected, the model results showed minimal surcharge during one year, as for the Stage 5 build out scenarios, and it is estimated that around 66 hectares of land, in an area with similar soil characteristics to Box Hill North would be required to dispose of the excess irrigation water from the fully built development. However, given that the surcharge events resulting from build out of Stage 6 are relatively small, it appears likely that a excess recycled water could be managed on a significantly lower area (~45 ha), if additional management strategies (e.g. monitoring of soil moisture to prevent surcharge with additional backup storage) are implemented within the final irrigation area.

<u>Irrigation Area Requirements for full build out assuming Box Hill North Water wastewater loads</u>

Using the alternative figures of Box Hill North Water, the model was run iteratively assuming that around 213kL/day would require land application (refer Table 4). To achieve zero surface discharge, an offsite irrigation area of around 20ha would be required; assuming an area with similar soil characteristics to Box Hill North is found. It is possible that a site with more favourable soil conditions could be identified; however constraints relating to water course buffers and the like would need to be assessed at the chosen site to confirm sustainability.

Summary

For this site, the monthly water and nutrient balance method provided a conservative estimate of when additional area, beyond the development bounds, would need to be sought to sustainably manage recycled irrigation water. The monthly balances indicated that the site was hydraulically limited and that additional area would need to be sought before construction of Stage 5. In comparison, the daily balance modelling, which included the effects of 5ML recycled water storage volume, indicated that this could be delayed until before the construction of Stage 6. Again, the daily balance model indicated that the site was hydraulically limited. Alternatively, if the demand and wastewater generation figures provided by Box Hill North Water prove to be more accurate, then the search for alternative uses/sites for excess recycled water needn't occur until before the construction of Stage 7. Area "I", which is earmarked as the last area to be built out, has nearly twice the area required to sustainably manage the excess recycled water in this case.

In all cases of our analysis, including the original monthly water balance calculations, we note that the capacity to assimilate the water for irrigation is controlled by the volume of water and the rates at which water can infiltrate the surface and/or drain further into the soil profile (below the root zone), without significantly impacting shallow groundwater. Accordingly, while we have selected conservative values for the nutrient analysis (e.g. P-sorption values), the capacity of irrigation areas at this site to assimilate nutrients is far less constrained than the capacity to assimilate water. When selecting a future area for the land application of excess water, possibly not required until construction of the final stage for the entire development, we recommend a thorough investigation of that area, including constant head permeameter testing, to confirm the hydraulic conductivity of the soils.

6.4 Pathogen Transport Modelling

6.4.1 Overview

We have modelled the fate of viral pathogens in the environment to assess the performance of the proposed recycled water irrigation systems at the Site and to assess potential impact (if any) on receiving waters. The modelling is based on the viral die-off method developed by Beavers and Gardner (1993) and refined by Cromer et al. (2001). Details of the methodology can be found in Cromer et al. (2001).

The model generally applies to recycled water moving in saturated soils, i.e. in shallow groundwater beneath a land application area. These conditions are considered most conducive to pathogen transport. In unsaturated (vadose zone) soils the travel distance will be substantially less. As such, the method is very conservative when applied to areas with well drained soils and deep groundwater tables, such as the Site. Surface transport in rainfall/stormwater runoff is another obvious transport pathway for pathogens; however, irrigation of recycled water will cease during rainfall and while the soil is saturated.

6.4.2 Assumptions and Inputs

Some key assumptions used in the modelling are provided below:

- Bacteria have lesser die-off times than viruses and can therefore be assumed to be eliminated within a shorter distance than viruses (Cromer *et al*., 2001);
- Viral reduction has been set at one order of magnitude, due to the high quality of the recycled water with disinfection (resulting in very low pathogen levels prior to reuse and irrigation);
- The average groundwater temperature is conservatively estimated as 11°C, based on the average minimum air temperature recorded at the nearby BOM station at Glenorie (#067010). Cooler temperatures allow viruses to reside longer in the soil, hence provide potentially greater travel distances. Groundwater temperatures are significantly less variable than air temperatures and are rarely less than 13°C in temperate areas, therefore the adoption of this figure is considered to be conservative;
- We have used the expected hydraulic conductivity (K_{sat}) of the dominant upper soil horizon materials, sandy and silty clay loams (depths ranging from ~200mm), based on Table 5.2 of AS/NZS 1547:2012,; and
- Depth to groundwater is conservatively assumed to be 0.5m, as mottling was present at depths of at least 500mm (generally at deeper depths or not encountered at all), indicating seasonally perched watertables or saturated soil conditions at some of the lower locations in the landscape.

The assumptions used in the pathogen transport modelling and predicted maximum viral transport distances are provided in Table 12. Appendix B provides full results of the pathogen transport modelling.

Table 12 Assumptions and Results of Pathogen Transport Modelling

Model Input Parameter	Value
Groundwater temperature (^{o}C)	11
Porosity of soil (decimal)	0.61 (40%)
Saturated Hydraulic Conductivity (K_{sat}) (m/day)	1.5
Groundwater gradient (%)	0.1
Depth to groundwater (m)	0.5
Horizontal distance travelled in groundwater to achieve a log 1 reduction in viral numbers (m)	4.9

* based on highest rate for soil category 5, from *AS/NZS 1547:2012*.

6.4.3 Interpretation of Results

The pathogen transport and die-off modelling demonstrates that log 1 reduction of pathogens is expected to occur within 5m horizontal distance, under saturated (worst-case) soil conditions. We note that shallow groundwater (i.e. saturated soil) was not encountered within 1m of the ground surface anywhere on the Site during our investigations (although mottling indicates that this occurs at some locations on a seasonal basis).

At Box Hill North, the proposed recycled water plant will produce high quality and disinfected recycled water with greater than 6.5 log removal of viruses, 5.5 log removal of protozoa and complete bacterial elimination, thus providing an even higher level of security. Ziebell et al. in USEPA (2002) describe the widely acknowledged principle that by lowering hydraulic loading rates and ensuring unsaturated flows through the soil, better in-soil removal of bacteria and other pathogens can be achieved.

7 Conclusions and Recommendations

This report provides the results and recommendations of our preliminary investigations, including constraints relating to recycled water management at different stages of the Box Hill North development.

Having undertaken a Land Capability Assessment (previous report) and Staging Assessment of the Site at Box Hill North, W&A consider that on-site surface irrigation is generally appropriate on identified land throughout the Site. The site and soil investigation in the LCA report shows that the Site is diverse in terms of its physical characteristics such as topography, soil depth and characteristics, drainage and the presence of intermittent watercourses; all of which influence the design and proposed location of the RWIZs for surface irrigation of recycled water. However, all required buffers are achievable with these constraints.

This report provides assessment of the recycled water volumes from various stages of the development and the associated ability to manage recycled water within the development's boundaries at different stages of development. Our daily balance modelling predicts that on-site surface irrigation should be achievable up to, and including, the completion of Stage 5 if internal and external reuse of recycled water is provided to each new property (via dual-reticulation). This is based on the assumption that no conservation areas which would preclude the use of recycled water for irrigation will be present outside of the normal buffers applied to features such as watercourses. A plan for the sustainable and permanent usage of recycled water generated by Stages 6-7 would need to be finalised prior to the commencement of construction on Stage 6 of the development. Within this plan, we recommend that soil moisture monitoring to control irrigation be considered. It is highly likely that, if this strategy is adopted, the need to source additional area (or alternative uses) for recycled water could be delayed until after Stage 6 has been developed, as only 10 modelled surcharge events resulted from modelling a 64 year simulation period and all of these surcharge events involved surface surcharge volumes that were very small (< $2m^3$). When considered over an area of some 40 hectares (i.e. "Area I"), these surcharges are insignificant.

Alternatively, using demand figures provided by Box Hill North Water, we found that the need to develop this plan could certainly be postponed until commencement of construction on Stage 7 (the final stage) of the development, if the Box Hill North Water values are found to be more realistic.

Pathogen die-off modelling undertaken as part of the analysis indicated that viral numbers would decrease by a factor of 10 within 5m of the boundaries of the irrigation areas. This compares favourably to the buffer of 50m which has been adopted between irrigation areas and any areas of existing development (including the boundary of the entire developable site).

In all cases of our analysis, including the original monthly water balance calculations, we note that the capacity to assimilate the water for irrigation is controlled by the volume of water and the rates at which water can infiltrate the surface and/or drain further into the soil profile (below the root zone). Accordingly, while we have selected conservative values for the nutrient analysis (e.g. P-sorption values), the capacity of irrigation at this site to assimilate nutrients is far less constrained than the capacity for assimilate water. When selecting a further area for the land application of excess water, at build out stage for the development, we recommend a thorough investigation of that area, including constant head permeameter testing, to confirm the hydraulic conductivity of the soils.

Throughout the present assessment, W&A have adopted conservative values, informed by our own judgment and standard practice which is conservative by nature. The methodology adopted aims to minimise any risk associated with human contact of recycled water or effects on the environment. Accordingly, the result will err on the conservative side. As experience with the site progresses, and monitoring data gathered, the constraints on the rate of recycled water irrigation per unit area could be relaxed if warranted. One key area where this could be improved is by properly assessing the rate of deep drainage, which ultimately controls the flow of water through the base of the soil profile, when saturated. For our purposes, we have adopted a very low hydraulic conductivity values in this layer (~60mm/day, corresponding to a poorly structured medium to heavy clay). While this errs on the side of conservatism, constant head permeameter testing may provide the data necessary to confidently relax this value. Unfortunately, such testing can take a significant amount of time, particularly when testing slowly draining soils.

In addition to testing areas for future irrigation, the total amount of land that may need to be acquired could be limited by planting and maintaining a vegetation screen. Such a screen would reduce the distance buffer required between an irrigation area and any existing development. Furthermore, selecting land that is sufficiently distant from any watercourses (either permanent or ephemeral) will also minimise the amount of additional land requiring acquisition.

Alternatively, a different customer for the excess recycled water may be found at build out stage, or the excess recycled water could be discharged to sewer or the environment in compliance with the environmental protection legislation in force at that time.

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Appendix A

Monthly Water & Nutrient Balance Modelling

Nominated Area Water Balance & Storage Calculations - W&A Wastewater Loads

Site Address: Box Hill North: Stage 4

INPUT DATA

Design Wastewater Flow	Q	513,859	L/day	
Design Irrigation Rate	DIPR	14	mm/week	
Daily DIR		2.0	mm/day	Litres per sq.m. per day - based on Table M1 AS/NZS 1547:2012 for secondary effluent
Nominated Land Application Area	L	882,235	m sq	
Crop Factor	C	0.7-0.8	unitless	Estimates evapotranspiration as a fraction of pan evaporation; varies with season and crop type
Runoff Coefficient		0.8	untiless	Proportion of rainfall that remains onsite and infiltrates; function of slope/cover, allowing for any runoff
Rainfall Data	Glenorie (067010)			Mean Monthly Data (1902 - 2013
Evaporation Data	Richmond RAAF (067033)			Mean Monthly Data (1970 - 1994)

Parameter	Symbol	Formula	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Days in month	D	\	days	31	28	31	30	31	30	31	31	30	31	30	31	**365**
Rainfall	R	\	mm/month	99	113.2	105	81.4	78.2	95.3	52	60.8	51.5	70.8	80	75.4	**962.6**
Evaporation	E	\	mm/month	195.3	151.2	136.4	99	65.1	54	65.1	96.1	129	167.4	177	217	**1,552.6**
Daily Evaporation				6.3	5.4	4.4	3.3	2.1	1.8	2.1	3.1	4.3	5.4	5.9	7	
Crop Factor	C			0.80	0.80	0.70	0.70	0.70	0.70	0.70	0.70	0.80	0.80	0.80	0.80	
OUTPUTS																
Evapotranspiration	ET	ExC	mm/month	156	121	95	69	46	38	46	67	103	134	142	174	**1,190.5**
Percolation	B	(DPR/7)xD	mm/month	62.0	56	62.0	60.0	62.0	60.0	62.0	62.0	60.0	62.0	60.0	62.0	**730.0**
Outputs		ET+B	mm/month	218.2	176.96	157.5	129.3	107.6	97.8	107.6	129.3	163.2	195.9	201.6	235.6	**1,920.5**
INPUTS																
Retained Rainfall	RR	R*runoff coef	mm/month	79.2	90.56	84	65.12	62.56	76.24	41.6	48.64	41.2	56.64	64	60.32	**770.1**
Effluent Irrigation	W	(QxD)/L	mm/month	18.1	16.3	18.1	17.5	18.1	17.5	18.1	18.1	17.5	18.1	17.5	18.1	**212.6**
Inputs		RR+W	mm/month	97.3	106.9	102.1	82.6	80.6	93.7	59.7	66.7	58.7	74.7	81.5	78.4	**982.7**
STORAGE CALCULATION																
Storage remaining from previous month			mm/month	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Storage for the month	S	(RR+W)-(ET+B)	mm/month	-121.0	-70.1	-55.4	-46.7	-27.0	-4.1	-47.9	-62.6	-104.5	-121.2	-120.1	-157.2	**-313.8**
Cumulative Storage	M		mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Maximum Storage for Nominated Area	N		mm	**0.00**												
	V	NxL	L	**0**												
LAND AREA REQUIRED FOR ZERO STORAGE			m^2	114569	166528	216789	240196	353913	715017	241468	197565	126359	114371	112033	90881	

MINIMUM AREA REQUIRED FOR ZERO STORAGE: **715,017** m^2

Nutrient Balance - W&A Wastewater Loads

Site Address: Box Hill North: Stage 4

Please read the attached notes before using this spreadsheet.

SUMMARY - LAND APPLICATION AREA REQUIRED BASED ON THE MOST LIMITING BALANCE = 236,220 m^2

INPUT DATA [1]

Wastewater Loading			Nutrient Crop Uptake					
Hydraulic Load	513,859	L/Day	Crop N Uptake	250	kg/ha/yr	which equals	68	$mg/m^2/day$
Effluent N Concentration	15	mg/L	Crop P Uptake	25	kg/ha/yr	which equals	7	$mg/m^2/day$
% Lost to Soil Processes (Geary & Gardner 1996)	0.15	Decimal	**Phosphorus Sorption**					
Total N Loss to Soil	1,156,183	mg/day	P-sorption result	140	mg/kg	which equals	1,470	kg/ha
Remaining N Load after soil loss	6,551,702	mg/day	Bulk Density	1.5	g/cm3		or	
Effluent P Concentration	5	mg/L	Depth of Soil	0.7	m		1,470	kg/ha
Design Life of System	50	yrs	% of Predicted P-sorp. [2]	0.5	Decimal		140	mg/kg

METHOD 1: NUTRIENT BALANCE BASED ON ANNUAL CROP UPTAKE RATES

Minimum Area required with zero buffer

Nitrogen	95,655	m^2
Phosphorus	236,220	m^2

Determination of Buffer Zone Size for a Nominated Land Application Area (LAA)

Nominated LAA Size	252	m^2
Predicted N Export from LAA	2385.07	kg/year
Predicted P Export from LAA	936.79	kg/year
Phosphorus Longevity for LAA	0	Years
Minimum Buffer Required for excess nutrient	235968	m^2

PHOSPHORUS BALANCE

STEP 1: Using the nominated LAA Size

Nominated LAA Size	**252**	m^2
Daily P Load	2.569295	kg/day
Daily Uptake	0.001726027	kg/day
Measured p-sorption capacity	0.147	kg/m^2
Assumed p-sorption capacity	0.074	kg/m^2
Site P-sorption capacity	18.52	kg
P-load to be sorbed	937.16	kg/year

→ Phosphorus generated over life of system	46889.6338	kg
→ Phosphorus vegetative uptake for life of system	0.125	kg/m^2
→ Phosphorus adsorbed in 50 years	0.074	kg/m^2
→ Desired Annual P Application Rate	1.000	kg/year
which equals	0.00274	kg/day

NOTES

[1]. Model sensitivity to input parameters will affect the accuracy of the result obtained. Where possible site specific data should be used. Otherwise data should be obtained from a reliable source such as,

- *Environment and Health Protection Guidelines: Onsite Sewage Management for Single Households*
- *Appropriate Peer Reviewed Papers*
- *EPA Guidelines for Effluent Irrigation*
- *USEPA Onsite Systems Manual.*

[2]. Conservative estimate based on work by Geary & Gardner (1996) and Patterson (2002).

[3]. A multiplier, normally between 0.25 and 0.75, is used to estimate actual P-sorption under field conditions which is assumed to be less than laboratory estimates.

Nominated Area Water Balance & Storage Calculations - BHN Water Loads

Site Address: Box Hill North: Stage 7

INPUT DATA

Design Wastewater Flow	Q	212,868	L/day	
Design Irrigation Rate	DIPR	14	mm/week	
Daily DIR		2.0	mm/day	Litres per sq.m. per day - based on Table M1 AS/NZS 1547:2012 for secondary effluent
Nominated Land Application Area	L	296,199	m sq	
Crop Factor	C	0.7-0.8	unitless	Estimates evapotranspiration as a fraction of pan evaporation; varies with season and crop type
Runoff Coefficient		0.8	untiless	Proportion of rainfall that remains onsite and infiltrates; function of slope/cover, allowing for any runoff
Rainfall Data		Glenorie (067010)		Mean Monthly Data (1902 - 2013)
Evaporation Data		Richmond RAAF (067033)		Mean Monthly Data (1970 - 1994)

Parameter	Symbol	Formula	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Days in month	D	\	days	31	28	31	30	31	30	31	31	30	31	30	31	**365**
Rainfall	R	\	mm/month	99	113.2	105	81.4	78.2	95.3	52	60.8	51.5	70.8	80	75.4	**962.6**
Evaporation	E	\	mm/month	195.3	151.2	136.4	99	65.1	54	65.1	96.1	129	167.4	177	217	**1,552.6**
Daily Evaporation				6.3	5.4	4.4	3.3	2.1	1.8	2.1	3.1	4.3	5.4	5.9	7	
Crop Factor	C			0.80	0.80	0.70	0.70	0.70	0.70	0.70	0.70	0.80	0.80	0.80	0.80	
OUTPUTS																
Evapotranspiration	ET	ExC	mm/month	156	121	95	69	46	38	46	67	103	134	142	174	**1,190.5**
Percolation	B	(DPR/7)xD	mm/month	62.0	56	62.0	60.0	62.0	60.0	62.0	62.0	60.0	62.0	60.0	62.0	**730.0**
Outputs		ET+B	mm/month	218.2	176.96	157.5	129.3	107.6	97.8	107.6	129.3	163.2	195.9	201.6	235.6	**1,920.5**
INPUTS																
Retained Rainfall	RR	R*runoff coef	mm/month	79.2	90.56	84	65.12	62.56	76.24	41.6	48.64	41.2	56.64	64	60.32	**770.1**
Effluent Irrigation	W	(QxD)/L	mm/month	22.3	20.1	22.3	21.6	22.3	21.6	22.3	22.3	21.6	22.3	21.6	22.3	**262.3**
Inputs		RR+W	mm/month	101.5	110.7	106.3	86.7	84.8	97.8	63.9	70.9	62.8	78.9	85.6	82.6	**1,032.4**
STORAGE CALCULATION																
Storage remaining from previous month			mm/month	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Storage for the month	S	(RR+W)-(ET+B)	mm/month	-116.8	-66.3	-51.2	-42.6	-22.7	0.0	-43.7	-58.4	-100.4	-117.0	-116.0	-153.0	**-284.9**
Cumulative Storage	M		mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Maximum Storage for Nominated Area	N		mm	**0.00**												
	V	NxL	L	**0**												
LAND AREA REQUIRED FOR ZERO STORAGE			m^2	47461	68985	89805	99502	146610	296199	100029	81842	52345	47379	46410	37648	

MINIMUM AREA REQUIRED FOR ZERO STORAGE: **296,199** m^2

Nutrient Balance - BHN Water Loads

Site Address: Box Hill North: Stage 7

Please read the attached notes before using this spreadsheet.

SUMMARY - LAND APPLICATION AREA REQUIRED BASED ON THE MOST LIMITING BALANCE = 97,855 m^2

INPUT DATA [1]

Wastewater Loading			Nutrient Crop Uptake					
Hydraulic Load	212,868	L/Day	Crop N Uptake	250	kg/ha/yr	which equals	68	$mg/m^2/day$
Effluent N Concentration	15	mg/L	Crop P Uptake	25	kg/ha/yr	which equals	7	$mg/m^2/day$
% Lost to Soil Processes (Geary & Gardner 1996)	0.15	Decimal	**Phosphorus Sorption**					
Total N Loss to Soil	478,953	mg/day	P-sorption result	140	mg/kg	which equals	1,470	kg/ha
Remaining N Load after soil loss	2,714,067	mg/day	Bulk Density	1.5	g/cm3		or	
Effluent P Concentration	5	mg/L	Depth of Soil	0.7	m		1,470	kg/ha
Design Life of System	50	yrs	% of Predicted P-sorp. [2]	0.5	Decimal		140	mg/kg

METHOD 1: NUTRIENT BALANCE BASED ON ANNUAL CROP UPTAKE RATES

Minimum Area required with zero buffer		
Nitrogen	39,625	m^2
Phosphorus	97,855	m^2

Determination of Buffer Zone Size for a Nominated Land Application Area (LAA)		
Nominated LAA Size	252	m^2
Predicted N Export from LAA	984.33	kg/year
Predicted P Export from LAA	387.48	kg/year
Phosphorus Longevity for LAA	0	Years
Minimum Buffer Required for excess nutrient	97603	m^2

PHOSPHORUS BALANCE
STEP 1: Using the nominated LAA Size

Nominated LAA Size	**252**	m^2			
Daily P Load	1.06434	kg/day	→ Phosphorus generated over life of system	19424.205	kg
Daily Uptake	0.001726027	kg/day	→ Phosphorus vegetative uptake for life of system	0.125	kg/m^2
Measured p-sorption capacity	0.147	kg/m^2			
Assumed p-sorption capacity	0.074	kg/m^2	→ Phosphorus adsorbed in 50 years	0.074	kg/m^2
Site P-sorption capacity	18.52	kg	→ Desired Annual P Application Rate	1.000	kg/year
			which equals	0.00274	kg/day
P-load to be sorbed	387.85	kg/year			

NOTES

[1]. Model sensitivity to input parameters will affect the accuracy of the result obtained. Where possible site specific data should be used. Otherwise data should be obtained from a reliable source such as,

- *Environment and Health Protection Guidelines: Onsite Sewage Management for Single Households*
- *Appropriate Peer Reviewed Papers*
- *EPA Guidelines for Effluent Irrigation*
- *USEPA Onsite Systems Manual.*

[2]. Conservative estimate based on work by Geary & Gardner (1996) and Patterson (2002).

[3]. A multiplier, normally between 0.25 and 0.75, is used to estimate actual P-sorption under field conditions which is assumed to be less than laboratory estimates.

Appendix B

Viral Die-Off Modelling

Beavers, Cromer, Gardner Viral Dieoff Model (refer Cromer *et al.* , 2001)

Site: Box Hill North.

Step 1	Use Figure 1 in Cromer *et al.* (2001) (reproduced below) to determine days travel time using groundwater temperature* and a selected order of magnitude reduction.		
	* If mean groundwater temperature is unavailable, mean daily air temperature can be used in most cases.		
Groundwater Temperature (^{o}C)		11	
Order of magnitude reduction		1	
Days required for viral reduction		**20**	(from Figure 1, below)

Step 2	Calculate the predicted travel distance using Equation 4 from Cromer*et al.* (2001). Dg = (t-d_v.P/K)/(P/K.I)				
	Time in days	t =	20	days	See notes below for description of values
	Effective porosity of soil (fraction)	P =	0.61		
	Saturated hydraulic conductivity	K =	1.5	m/day	
	Groundwater gradient (fraction)	I =	0.1		
	Vertical drainage before entering groundwater	d_v =	0.5	m	

Setback Distance	**Distance travelled in groundwater**	**d_g =**	**4.9**	**m**

<u>Notes:</u>

Porosity (P):	Porosity of 0.61 adopted as maximum for a loam
Ksat (K):	Maximum for clay loam insitu surface layer soils
Groundwater gradient (I):	Assume groundwater gradient of 10% (Maximum across site).
Vertical drainage (d_v):	Assume 0.5m of unsaturated flow before reaching groundwater (based on minimum depth to mottling observed in test pits)

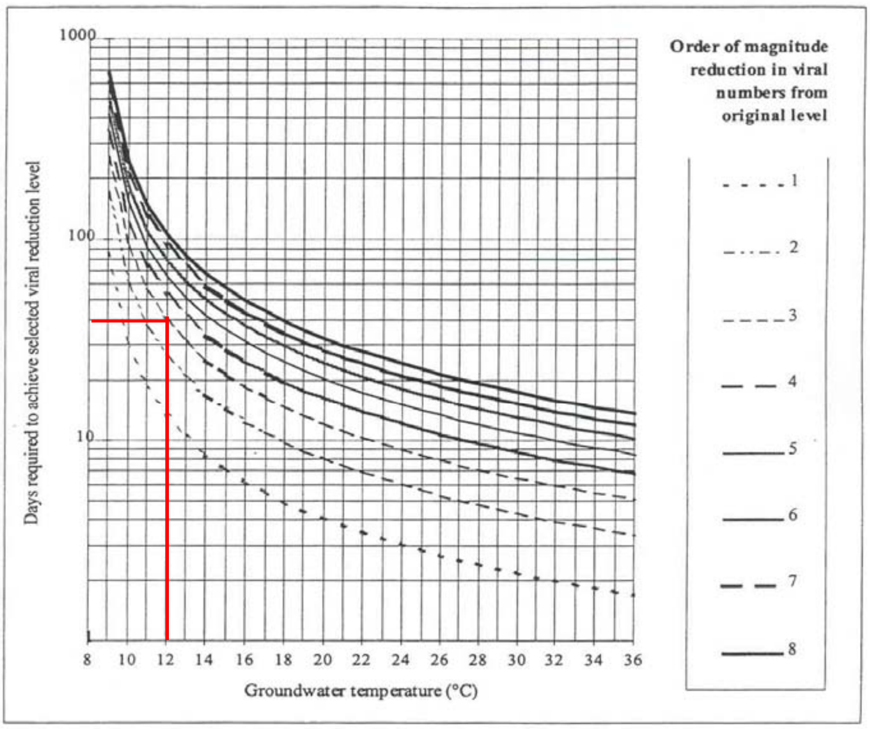

Figure 1. Relationship between Groundwater Temperature and Viral Die-Off Time for Various Order-of-Magnitude Reductions in Viral Numbers

(Figure 1 taken from Cromer et al., 2001)