Appendix C

Water balance report

Googong Township water cycle project

Environmental Assesment

November 2010

GOOGONG NEW TOWN CONCEPT DESIGN

SITE WATER BALANCE ASSESSMENT

A1081402

Rev 7

FEBRUARY 2010

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REVISION SCHEDULE

REV. NO.	DATE	DESCRIPTION	PREPARED BY	REVIEWED BY	APPROVED BY
1.0	3 Sep 2009	Draft	Russell Beatty	Adam Joyner	Rachel Perrin
2.0	27 Oct 2009	Final	Russell Beatty	Adam Joyner	Rachel Perrin
3.0	30 Nov 2009	Final – Revised	Russell Beatty		
3a	1 Dec 2009	Final – Revised – format changed	Russell Beatty		Rachel Perrin
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5.0	22 Dec 2009	Final – Appendix D added	Rachel Perrin	Adam Joyner	Rachel Perrin
6.0	22 Jan 2010	Final – Appendix D updated	Rachel Perrin	Rachel Perrin	Rachel Perrin
7.0	1 Feb 2010	Final – Appendix D & text updated	Adam Joyner		

MWH

EXECUTIVE SUMMARY

The planned Googong New Town will be employing a number of innovative water cycle management measures. These measures are anticipated to:

- Reduce the volume of potable water use through a series of water conservation, recycling and rainwater use initiatives;
- Improve the quality of runoff into the adjacent Queanbeyan River through the retention of stormwater on site through rainwater use and a series of Water-Sensitive Urban Design (WSUD) measures; and
- Minimise the discharges of wastewater through the use of recycled water for toilet flushing and irrigation.

This report has been commissioned to examine the impact of the water cycle management measures on the volumes of water entering and leaving the new town site.

The analysis underlying the report used inputs from a number of specialists in the fields of:

- Urban irrigation;
- Water-Sensitive Urban Design; and
- Integrated Water Cycle Management.

These inputs were brought together using a series of computer models that allowed the daily behaviour of the water cycle in the proposed community to be examined. The results of this modelling will be used for a number of different purposes in the planning for the new community. These include better understanding the salinity balance in the water recycling treatment process to be used and understanding the impact of the new community on the aquatic ecosystems in the Queanbeyan River.

Four scenarios were examined:

1. Neighbourhood 1A with:
    - Rainwater tanks on residential properties connected to cold water for washing machines and outdoor use; and
    - Recycled water used for all public open space irrigation and toilet flushing (residential and non-residential).
2. Neighbourhood 1A with:
    - Recycled water used on residential properties for toilet flushing, cold water for washing machines and all outdoor use; and
    - Recycled water used for all public open space irrigation and non-residential toilet flushing.

3. Full development with:

    - Rainwater tanks on residential properties connected to cold water for washing machines and outdoor use; and

    - Recycled water used for all public open space irrigation and toilet flushing (residential and non-residential).

4. Full development with:

    - Recycled water used on residential properties for toilet flushing, cold water for washing machines and outdoor all outdoor use; and

    - Recycled water used for all public open space irrigation and non-residential toilet flushing.

For Scenarios 1 and 3, where rainwater tanks are empty and rainwater is not available, recycled water is to be used. Where recycled water demand is greater than the available water, potable water is used to top up the recycled water system.

At the current time the use of rainwater tanks (Scenarios 1 and 3) are the preferred scenarios for water cycle management in the new town development. The scenarios that excluded the use of rainwater tanks were also examined to:

- Generate estimates of the best and worst cases for the volumes of recycled water to be discharged to receiving waters;

- Gain an appreciation of the trade-offs between the reduction in recycled water discharges and the overall volumes of water to be saved associated with the use of rainwater tanks; and

- Provide quantitative estimates for use in evaluating the impact of recycled water use on soils and groundwater systems.

The modelling results indicate that:

- The range of water cycle management measures to be employed in the Googong New Town results in a reduction in demand of approximately 60%[1];

- The recycled water system uses approximately 62 to 65% of the wastewater generated in the new town; and

- Eliminating the use of rainwater tanks as a substitute for some water uses in preference to the use of recycled water increases the volume of wastewater recycled in the new town to 80% at the same time as decreasing water demand reductions to approximately 55%.

The results clearly show that there are trade-offs in the management of the water cycle on the site. The use of rainwater tanks:

- Reduces stormwater discharges;

[1] *Compared to traditional development using the same methodology used in the estimate of water savings under the NSW Government's BASIX scheme.*

- Increases recycled water system discharges; and

- Increases the total volume of potable water saved in the new community.

A reduction in potable system water use is one of the key drivers of the range of water conservation, recycling and rainwater use initiatives planned for the new community. Overall, the Googong New Town can be expected to use approximately 60% less potable water than a traditional development of the same population if rainwater tanks are used.

Without the use of rainwater tanks, there is an increased need for the top-up of the recycled water system with potable water. In this case, the reduction in potable water use is approximately 55%.

It would be possible to increase the proportion of potable water saved beyond 60% by:

1. Offering new residents the option of utilising rainwater (with a top-up from the potable water system) for hot water use in addition to use for clothes washing;

2. Utilising stormwater ponds on the site for providing seasonal storage for recycled water; and

3. Utilising stormwater runoff held in stormwater basins throughout the site.

These options for further reducing the volume of potable water use on site including using rainwater in hot water systems, utilising stormwater ponds on site for storing recycled water and harvesting stormwater increase the volume of water saved to between 61% and 68%.

MUSIC modelling has been used to estimate the impact of stormwater and recycled water discharges from the new town development on the Queanbeyan River receiving water environment. Comparisons between the MUSIC modelled cases indicate that the proposed WSUD measures are effective in reducing annual pollutant loads. Compared to the existing development case, the water quality modelling results also indicate a reduction in annual suspended solids and gross pollutant loads, and an increase in nutrient loads and annual flows. Initial assessment of theoretical nutrient dilution, indicates similar nutrient concentrations to existing development.

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1. INTRODUCTION

This report presents estimates of the expected water balance outcomes for the Googong New Town and has been prepared by MWH for the Canberra Investment Corporation (CIC). The goal of the investigations outlined in the report is to provide an understanding of the interactions of water use, wastewater generation, water recycling, rainwater harvesting and stormwater flows for the new community. This understanding will be an important contribution in determining the impact of the new community on the water quality and aquatic ecosystems in the Queanbeyan River receiving water environment.

The report builds on previous water cycle modelling undertaken by MWH for this project. This includes:

- The original integrated water cycle management report (MWH 2004)
- Water balance work undertaken for examining trade-offs between recycled water supply reliability and storage (MWH 2006); and
- Report into design standards for the potable and recycled water system (MWH 2007).

The water balance updates undertaken in this study include:

- The use of the latest lot yields and development areas;
- An update of the irrigation demand estimates;
- Inclusion of stormwater system flows; and
- Confirmation of rainwater tank savings using the Probabilistic Urban Rainwater and Wastewater Reuse Simulator (PURRS) simulation of rainwater tanks

Key inputs to the modelling undertaken for this report were provided by:

- *Bonacci Water*, who provided assistance in the setup of the PURRS model and who developed the six minute pluviograph data set for use in the PURRS model;
- *AGSOL*, who provided the irrigation demands based on lot scale irrigation modelling; and
- *Brown Consulting* who provided irrigation areas and catchment stormwater flow and loads generated using the MUSIC concept level urban stormwater system simulation model.
- *Roberts Day* who provided urban planning lot sizes and yields.

Outputs from the water balance modelling are anticipated to be used in:

- Support of water recycling plant (WRP) approvals (site water balance and discharge effluent to river mass balance estimates)
- Demonstration of potable water savings and re-use requirements
- WRP concept design Total Dissolved Solids (TDS) balance;
- Confirmation of bulk potable water system concept design;
- Verification of the land capability assessment (AGSOL 2009) water balance;
- Stormwater system design; and
- Development of site irrigation strategy.

It should be noted that the water balance modelling results represent the best estimates of the expected behaviour of the water cycle for the development scenarios modelled. The figures included in this report should not be used directly for water and wastewater system design.

2. WATER CYCLE DESCRIPTION

Innovative water cycle management will be one of the cornerstones of the proposed Googong New Town. Early planning work identified a number of measures to improve water management outcomes and these were subsequently adopted by CIC as the basis for the ongoing design and development. The measures included:

- The use of water efficient fixtures and appliances;
- Landscaping controls;
- The use of reduced infiltration gravity sewer systems;
- Water sensitive urban design to improve stormwater quality;
- The use of rainwater tanks in residential properties to both reduce water use and to reduce the volume and velocity of stormwater runoff; and
- The widespread use of recycled water for toilet flushing, open space irrigation and for the topping up of rainwater tanks.

3. WATER BALANCE MODELLING

3.1 APPROACH

Integrated water cycle modelling requires that each aspect of the water cycle is adequately simulated. This includes water demand (including for irrigation), wastewater flows, rainwater tanks and stormwater flows. The accuracy of the predictions provided by the water cycle modelling are dependent on each of the models providing an accurate simulation of the expected behaviour of each part of the water cycle.

The time scale of the simulation is also important. An example of this is found in the volume of recycled water produced and its uses. While the total annual volume of recycled water generated on the site is less than the demand for that recycled water, there will still be discharges from the site due to the seasonal patterns of both recycled water generation and demand.

Four scenarios were examined:

1. Neighbourhood 1A with:
    - Rainwater tanks on residential properties connected to cold water for washing machines and outdoor use; and
    - Recycled water used for all public open space irrigation and toilet flushing (residential and non-residential).
2. Neighbourhood 1A with:
    - Recycled water used on residential properties for toilet flushing, cold water for washing machines and all outdoor use; and
    - Recycled water used for all public open space irrigation and non-residential toilet flushing.

3. Full development with:

    - Rainwater tanks on residential properties connected to cold water for washing machines and outdoor use; and

    - Recycled water used for all public open space irrigation and toilet flushing (residential and non-residential).

4. Full development with:

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For Scenarios 1 and 3, where rainwater tanks are empty and rainwater is not available, recycled water is to be used. Where recycled water demand is greater than the available water, potable water is used to top up the recycled water system.

At the current time the use of rainwater tanks (Scenarios 1 and 3) are the preferred scenarios for water cycle management in the new town development. The scenarios that excluded the use of rainwater tanks were also examined to:

- Generate estimates of the best and worst cases for the volumes of recycled water to be discharged to receiving waters;

- Gain an appreciation of the trade-offs between the reduction in recycled water discharges and the overall volumes of water to be saved associated with the use of rainwater tanks; and

- Provide quantitative estimates for use in evaluating the impact of recycled water use on soils and groundwater systems.

A number of additional measures were also modelled to determine their impact on the total volume of water saved (Section 3.2.6):

1. Offering new residents the option of utilising rainwater (with a top-up from the potable water system) for hot water use in addition to use for clothes washing;

2. Utilising stormwater ponds on the site for providing seasonal storage for recycled water; and

3. Utilising stormwater runoff held in stormwater basins throughout the site.

3.1.1 MODELLING FRAMEWORK

In seeking to understand the functioning of the water cycle in a more integrated fashion, there is an advantage in applying a number of computer models that simulate different aspects of the water cycle. In the current study, the models that have been used are set out in Figure 1 and are described in the sections to follow.

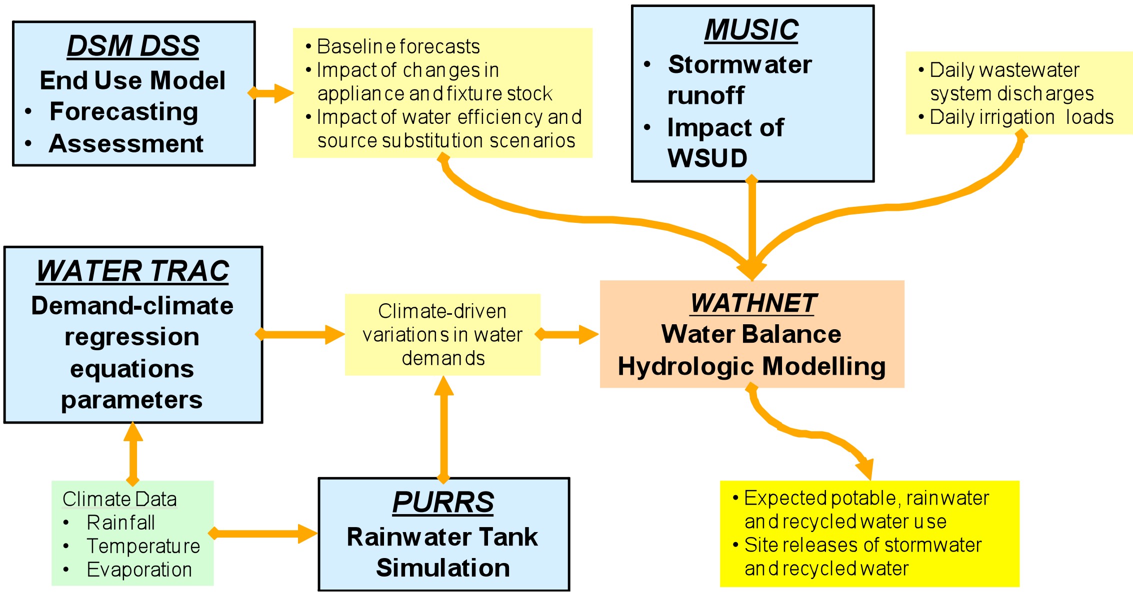

Figure 1: Water Balance Modelling Framework

3.1.1.1 THE BULK WATER TREND TRACKING MODEL (WATERTRAC)

The Bulk Water Trend Tracking Model (WaterTrac) is used to provide a detailed understanding of the drivers of daily water demand and wastewater flows. It uses daily records of bulk water production and wastewater flow and generates a correlation with climate influence and other demand drivers. WaterTrac uses a unique non-linear multi-variable regression analysis approach to explain the day to day climate influences on water demands and wastewater flows.

3.1.1.2 THE PROBABILISTIC URBAN RAINWATER AND WASTEWATER RE-USE SIMULATOR (PURRS)

PURRS is a unique model for simulating the impacts of rainwater tanks, water efficient appliances, stormwater harvesting and wastewater recycling on water demands (Coombes 2006). The PURRS suite of models includes climate and socioeconomic dependent water demand algorithms and the capability to analyse a wide range of climate change scenarios. In its simulations, rather than utilise the performance of a single connection extrapolated to approximate large numbers of connections, it is designed to simulate the collective performance of large numbers of different customer types servicing a large number of different demand regimes. The probabilistic simulation is undertaken at a 6 minute time step and is an ideal engine for generating climate-driven demand regimes for use in hydrological simulations.

3.1.1.3 THE DEMAND SIDE MANAGEMENT DECISION SUPPORT SYSTEM (DSM DSS)

The DSM DSS has a set architecture for generating demand forecasts and assessing the impact of demand management and source substitution initiatives.

The model starts with the generation of a baseline or "business as usual" forecast, which is the reference case for the demands to follow. The baseline forecast represents the demand that would occur in the event that there was no demand management or source substitution intervention. The DSM DSS model generates a detailed assessment of a range of water conservation and source substitution measures. These include:

- Retrofit and rebate programs;
- Regulations governing the water efficiency of new development;
- Community education programs;
- Rainwater and water recycling initiatives;
- Water pricing changes; and

- System water loss reduction programs.

The DSM DSS has a formal structure for the economic assessment of different options. A key component of these assessments is the avoided costs. Avoided costs occur when demand management or source substitution options result in:

- Reductions in water and wastewater treatment and transfer costs;
- Delays to and downsizing of capital expenditure; and
- Reductions in customer water heating.

The avoided costs module also has the capability to identify reductions in greenhouse gas emissions and to assign economic benefits associated with water and/or emissions trading.

3.1.1.4 WATHNET - WATER SUPPLY HEADWORKS AND WATER BALANCE SIMULATION

WATHNET is a suite of Windows programs for simulating water balances and systems with competing users including water supply headworks systems. It allows for the analysis of a wide range of water resource options at multiple scales. It uses network linear programming to intelligently allocate water from multiple sources to competing demands making allowance for capacity and operational constraints. Data entry and output are based on a graphical schematic of the headworks system. Full support is provided for Monte Carlo analysis including generation of multi-site hydroclimatic data and probabilistic assessment of future performance.

3.1.1.5 MUSIC – CONCEPT LEVEL SIMULATION OF URBAN STORMWATER SYSTEMS

MUSIC is an urban stormwater system model designed to simulate the daily water discharges and quality for key pollutants. MUSIC is also used to simulate the impact of a variety of stormwater management and Water Sensitive Urban Design (WSUD) options on daily disharge volumes and pollutant loads.

3.1.2 KEY ASSUMPTIONS AND INPUTS

A water balance investigation of this type requires information from a diverse range of sources. The key assumptions and data inputs for this study are set out in Table 3-1 below.

Table 3-1: Data Used in the Study

DATA SET	DESCRIPTION	SOURCE	DETAILS
Climate	Daily rainfall	Bureau of Meteorology	Queanbeyan Bowling Club 1967 – 2007
	Daily temperature	Bureau of Meteorology	Canberra Airport 1967 – 2007
	Daily evaporation	Bureau of Meteorology	Canberra Airport 1967 – 2007
	Virtual climate station data (rainfall, temperature and evaporation) for infill of missing records	SILO Services for Agriculture	149.25°E, 35.40°S 1900 - 2008
Development	Number of dwellings and non-residential land areas	CIC	Refer to section 3.1.2.3
	Lot sizes	CIC	Refer to section 3.1.2.3
	Roof areas	CIC	Refer to section 3.1.2.3
Residential irrigation areas	By lot type	Agsol	Refer to section 3.1.2.3

3.1.2.1 DAILY WASTEWATER FLOW VOLUMES

Daily wastewater flow volumes were generated by applying the Anderson-Ruge equation for “tight” wastewater systems to daily rainfall data (Anderson and Ruge 1994). The Anderson-Ruge research report outlines a number of equations for predicting daily wastewater flows for different types and conditions of wastewater systems. The “tight” system equation represents the most appropriate type to represent the performance of the planned reduced infiltration gravity sewer system in Googong. The equation takes the following form:

$$Q_t = Q_{d,t}\left(\frac{850R_t + 550R_{t-1} + 275R_{t-2} + 135R_{t-3} + 70R_{t-4} + 35R_{t-5}}{10{,}000}\right)$$

Where: Q_t = Wastewater system flow on day t

$Q_{d,t}$ = Dry weather wastewater system flow on day t

R_t = Rainfall on day t (mm)

$R_{t\text{-}n}$ = Rainfall on day $t\text{-}1$ (mm)

3.1.2.2 DAILY WATER DEMAND FLUCTUATIONS

Daily water demand fluctuations have been generated using a daily water demand regression equation based on fluctuations in daily demands from the ACT water supply system using the MWH WaterTrac model (MWH 2009). Climate and soil moisture index variables are used to derive climate-driven demands. Additional details can be found in Appendix A.

3.1.2.3 DEVELOPMENT CHARACTERISTICS AND RAINWATER TANK SIZES

Other underlying development data such as roof areas, rainwater tank volumes and the number of dwellings necessary for the water balance assessment are shown in Table 3-2 to Table 3-6.

Table 3-2: Assumed Household Size, Dwelling Roof Areas and Rainwater Tank Sizes

DWELLING TYPE	HOUSEHOLD SIZE	ROOF AREA PER DWELLING (m^2)	RAINWATER TANK VOLUME PER DWELLING (kL*)
Apartments	1.89	50	0.5
Townhouse/Terrace	2.55	75	1.0
Small Courtyard	2.60	100	2.0
Large Courtyard	2.69	125	3.5
Single Lot	3.15	150	5.0
Large Lot	3.26	200	10.0
Estate Homes	3.26	300	15.0
Rural	3.26	300	20.0

*kL = kilo litres = one thousand litres

Table 3-3: Number of Dwellings – Neighbourhood 1A

CUSTOMER CATEGORY	NUMBER OF DWELLINGS	IRRIGATED AREA PER DWELLING (m^2)	TOTAL IRRIGATED AREA (Ha*)
Apartments	26	11.3	0.03
Townhouse/Terrace	51	17.1	0.09
Small Courtyard	211	40.2	0.85
Large Courtyard	293	67.8	1.99
Single Lot	452	98.5	4.45
Large Lot	243	156.0	3.79
Estate Homes	0	360.0	0.00
Rural	0	720.0	0.00
Total	1,276	NA	11.2

*Ha = hectares = 10,000 m^2

Table 3-4: Non-Residential Land Areas – Neighbourhood 1A

CUSTOMER CATEGORY	GROSS AREAS (Ha)	TOTAL IRRIGATED AREA (Ha)
Schools	5	2.5
Open Spaces	13.5	13.5
Commercial Use	1	0.1
Total	19.5	16.1

Table 3-5: Number of Dwellings – Total Development

CUSTOMER CATEGORY	NUMBER OF DWELLINGS	IRRIGATED AREA PER DWELLING (m^2)	TOTAL IRRIGATED AREA (HA)
Apartments	566	11.3	0.64
Townhouse/Terrace	477	17.1	0.82
Small Courtyard	852	40.2	3.43
Large Courtyard	1,311	67.8	8.89
Single Lot	1,833	98.5	18.05
Large Lot	818	156.0	12.76
Estate Homes	281	360.0	10.12
Rural	58	720.0	4.18
Total	6,196	NA	58.9

Table 3-6: Non-Residential Land Areas – Total Development

CUSTOMER CATEGORY	GROSS AREAS (Ha)	TOTAL IRRIGATED AREA (Ha)
Schools	21	10.5
Open Spaces	45	45.0
Commercial Use	14	1.0
Total	80	56.4

3.1.2.4 AVERAGE DEMANDS

Average daily water demands for each type of customer in the proposed new town were developed using the DSM DSS End Use model. Internal water demands were generated using an assessment of available information from End Use studies in Australia and external water demands were generated based on the irrigation modelling undertaken by Agsol (2009). The assumed application rates are shown in Table 3-7. Average daily demands for each type of water use by development type is provided in Table 3-8.

Table 3-7: Assumed Irrigation Application Rates

IRRIGATION TYPE	ASSUMED IRRIGATION STRATEGY	ANNUAL APPLICATION RATE (mm/year)
Household Gardens	Medium watering	467
Turf/Playing Fields (sprinkler)	Well watered	568
Landscaping (sprinkler)	Restricted watering	418
Landscaping (near buildings and roadways – subsurface)	Restricted watering	459

*Available irrigation strategies included well watered, medium watering and restricted watering

Table 3-8: Average Daily Water Demands Per Dwelling (Residential) or per Gross Ha (Non-Residential) by Development Type

Customer Type	Internal			External			Total			Total
	Potable (L/d)	Direct Recycled (L/d)	Potential Rainwater (L/d)	Potable (L/d)	Direct Recycled (L/d)	Potential Rainwater (L/d)	Potable (L/d)	Direct Recycled (L/d)	Potential Rainwater (L/d)	
Apartments	185.5	51.5	54.3	9.9	0.0	17.1	195.4	51.5	71.4	318.2
Townhouse/Terrace	250.3	69.4	73.2	13.4	0.0	25.8	263.6	69.4	99.0	432.1
Small Courtyard	255.2	70.8	74.6	13.7	0.0	58.7	268.8	70.8	133.3	472.9
Large Courtyard	264.0	73.2	77.2	14.1	0.0	98.0	278.1	73.2	175.2	526.5
Single Lot	309.1	85.8	90.4	16.5	0.0	141.9	325.7	85.8	232.3	643.7
Large Lot	319.9	88.8	93.6	17.1	0.0	223.7	337.1	88.8	317.3	743.1
Estate Homes	319.9	88.8	93.6	17.1	0.0	513.7	337.1	88.8	607.3	1,033.1
Rural	319.9	88.8	93.6	17.1	0.0	1,025.5	337.1	88.8	1,119.1	1,544.9
Schools	4,205.1	5,148.3	0.0	1,803.9	7,499.4	0.0	6,009.0	12,647.7	0.0	18,656.7
Open Space	0.0	0.0	0.0	0.0	14,587.5	0.0	0.0	14,587.5	0.0	14,587.5
Commercial	2,827.3	3,124.9	0.0	1,147.9	1,118.2	0.0	3,975.2	4,243.1	0.0	8,218.3

*L/d = litres per day

System leakage for water distribution systems was assumed to be:

- 10% of average daily production for the potable water system; and
- 10% of the average daily production (with rainwater tanks assumed empty) for the recycled water system.

3.1.3 WATHNET MODEL CONFIGURATION

The configuration of the WATHNET model including a description of the model structure and nodes can be found in Appendix B. The WATHNET model uses a distributed storage model to simulate the impact of rainwater tanks on water demands and wastewater flows. A number of lumped storages are used to simulate the impact of both low and high water using households.

Rainwater harvesting is non-linear in nature and highly dependent on the demands. High demand households rapidly draw down tanks making space available to harvest more water. Low demand households tend to harvest less water by virtue of the fact that their tanks are fuller. Thus on any one dry day there will be a number of tanks that are empty and a number that have more water. On wet days there will be a number of tanks that have high water levels and will spill more readily and others that will have little on no spill due to their low levels.

The simulation was undertaken using 41 years of historical climate data from 1967 to 2007. Modelling was undertaken for "normal" water supply system operation in the absence of water restrictions.

3.2 RESULTS

The integrated water system modelling results are for planning purposes and provide a basis for comparison of approaches. Performance of the actual system is likely to vary for a number of reasons including:

- Modelling limitations, in particular associated with the ability to replicate the extent and completeness of the future systems.
- Errors associated with model input assumptions. For instance, the inputs include assumptions in the way people will use water, which may vary in the future.
- Variation in the assumed development lot yields, as well as arrangement, sizing and operation of the final integrated system components.

Recognising the potential differences in modelling system performance and actual performance, a staged approach to development of the integrated water cycle system is proposed, along with smart metering to allow evaluation of system performance in the early years of the development (MWH 2007; MWH 2009b).

Modelling results are discussed below.

3.2.1 IMPACT OF RAINWATER TANKS

The impact of rainwater tanks in reducing those demands connected to rainwater tanks (cold water for clothes washing and outdoor use) was estimated in the WATHNET model and verified in the PURRS model. The results are shown in Table 3-9. The results show that the WATHNET modelling provides a higher estimate of the impact of rainwater tanks than PURRS for the Neighbourhood 1A case and a lower estimate for the full development case. This difference is most likely a combination of the impact of the dwelling mixes at the early stages of development and the finer resolution provided by the six minute time step utilised in PURRS. The WATHNET rainwater tank simulation is included in the overall water balance simulation.

Table 3-9: Impact of Rainwater Tanks on Targeted Uses

DEVELOPMENT	REDUCTION IN CONNECTED USES – WATHNET	REDUCTION IN CONNECTED USES – PURRS
Neighbourhood 1A	46.1%	42.1%
Full Development	40.4%	41.7%

3.2.2 DAILY WATER BALANCE SIMULATIONS

A number of examples of the performance of the proposed water management system at full development with the use of rainwater tanks are shown in Figure 2 to Figure 4. These examples, shown over the first five years of the 41 year simulation period for clarity, show results that are markedly similar to the known behaviour of water, wastewater and stormwater systems. In the charts, “Direct Potable” and “Recycled Water” demands are those that are supplied to the end uses originally targeted. “Top-up” demands are those used to top up either the rainwater tanks (with recycled water) or the recycled water system (with potable water).

Figure 2 shows the predicted wastewater flows generated using the Anderson-Ruge equation. It shows the characteristics commonly associated with wastewater systems including the periodic inflows due to the infiltration of stormwater during wet weather.

Figure 3 shows the volumes of potable water used, consisting of direct potable uses and that used to top-up the recycled water system. It shows that the need for the top-up of the recycled water system is most significant during the summer months, although the results vary substantially from year to year depending on the climate conditions. Figure 4 shows the volumes of recycled water use, including that used to top-up rainwater tanks. It shows that the top-up of rainwater tanks is highest during the summer, but also that there are often winter periods where top-up is required. The volume of recycled water required also varies significantly from year to year based on climate conditions.

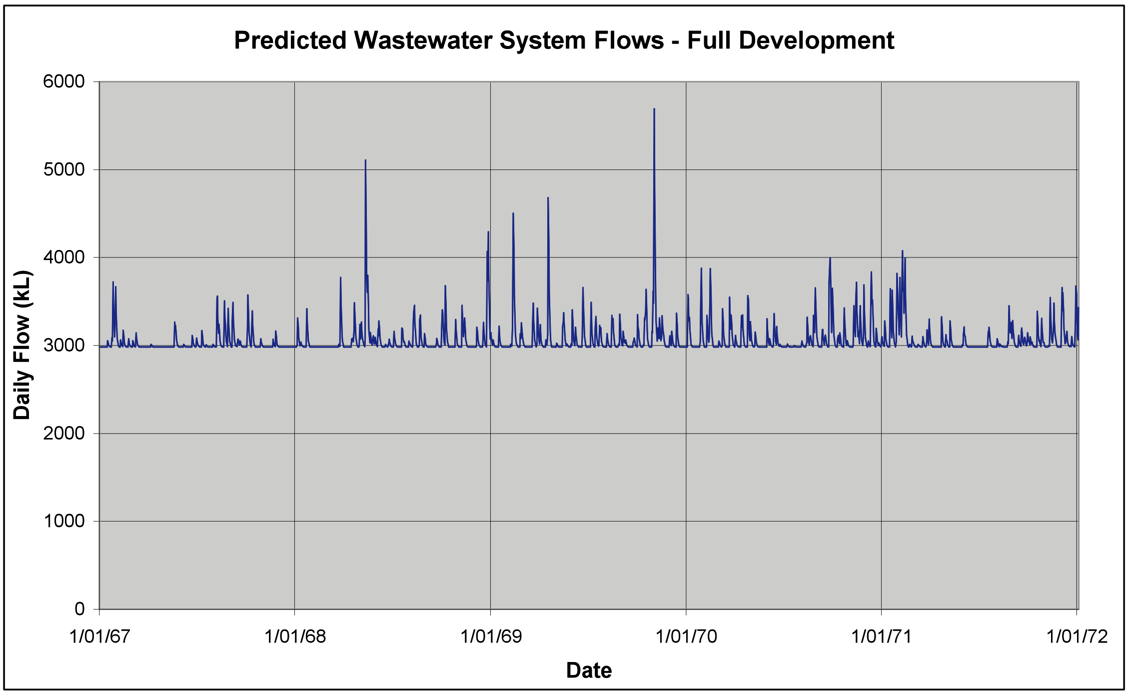

Figure 2: Simulated Wastewater System Flows at Full Development (1967 to 1971 Climate Conditions)

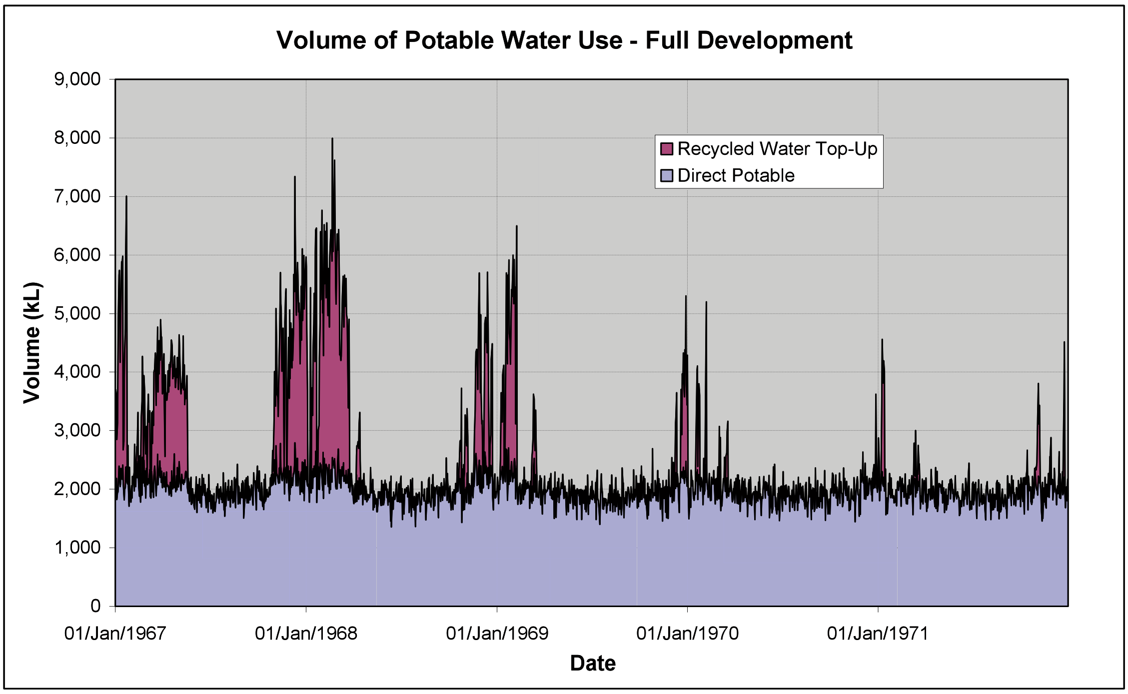

Figure 3: Simulated Volumes of Potable Water Use at Full Development (1967 to 1971 Climate Conditions)

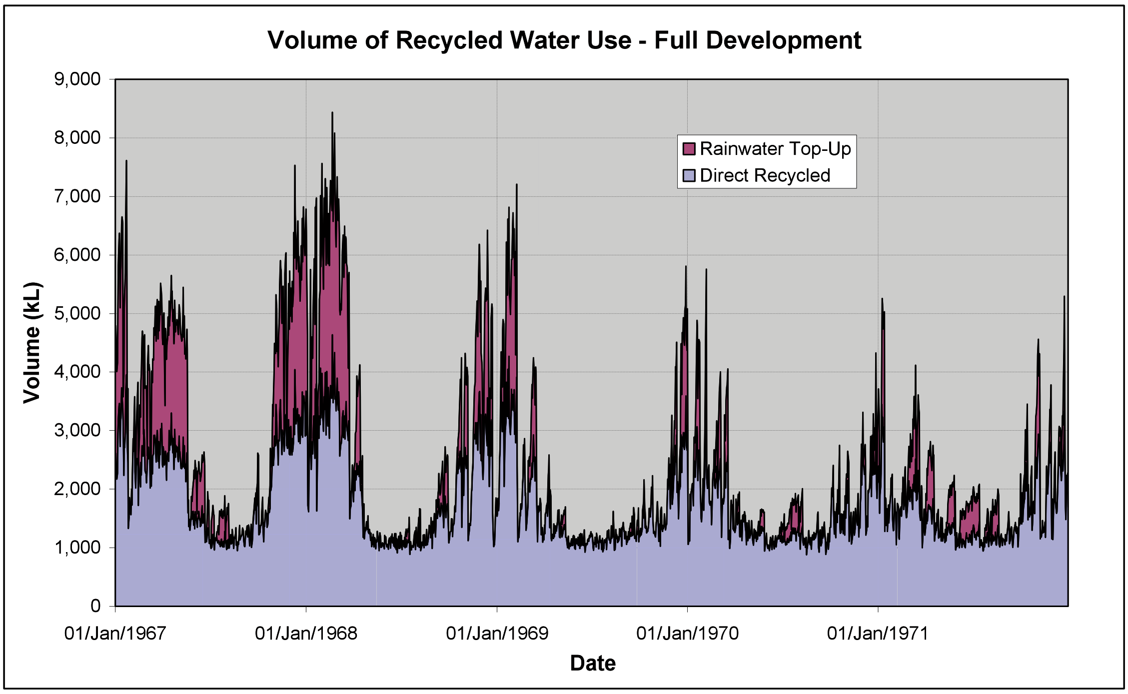

Figure 4: Simulated Volumes of Recycled Water Use at Full Development (1967 to 1971 Climate Conditions)

3.2.3 TOTAL SITE DISCHARGE

The total discharges from the site can be estimated by adding together the results of the WATHNET and MUSIC model outputs. Daily discharges for the first five years of simulation with the use of rainwater tanks at full development are shown in Figure 5. The figure shows that the discharge volumes vary significantly depending on climate and that the volumes of recycled water are small in the largest rainfall events (highest stormwater flows have been omitted for clarity). In the driest summer periods (e.g. 1967/68) there is little or no discharge of recycled water. Thus there is a positive correlation between discharge and rainfall, an effect amplified by the use of rainwater in the new town.

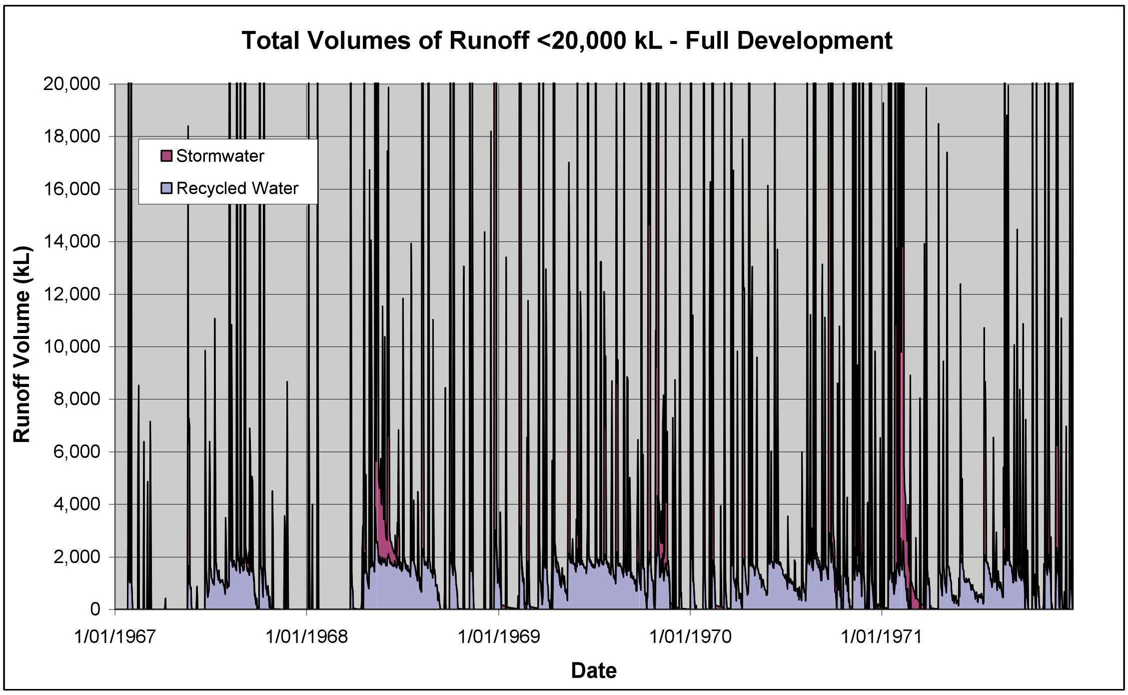

Figure 5: Simulated Total Volumes of Runoff at Full Development (1967 to 1971 Climate Conditions)

3.2.4 SUMMARY OF WATER BALANCE RESULTS

Results of the water balance analysis showing minimum, maximum and average demands and flows for the full period of the simulation (1967 to 2007) are provided in Table 3-10 and Table 3-11. It is important to note that all stormwater runoff cases are for the sum of the total Googong and Montgomery Creek Catchments and not just for the developed areas.
Two important conclusions on the use of rainwater tanks can be drawn from the results (discussed in more detail in Section 3.2.5). These are that the use of rainwater tanks:

- Reduce the volume of potable water use; and
- Increase the volume of recycled water discharges.

Table 3-10: Water Balance – Summary of Demands and Flows – Neighbourhood 1A

WATER CYCLE COMPONENT	MINIMUM (kL/d*)	MAXIMUM (kL/d)	AVERAGE (kL/d)
Direct potable water demand	313	651	467
Potable water demand plus recycled top-up – with rainwater tanks (Scenario 1)	313	1,955	582
Potable water demand plus recycled top-up – no rainwater tanks (Scenario 2)	313	1,958	639
Direct recycled water system demand	180	1,279	435
Recycled water system demand plus rainwater top-up	180	2,691	550
Wastewater system flow	630	1,471	651
Recycled water discharge – with rainwater tanks (Scenario 1)	0	1,245	227
Recycled water discharge – no rainwater tanks (Scenario 2)	0	1,097	121
Rainwater use (Scenario 1)	0	605	162
Stormwater discharge (without rainwater tanks)	0	1,280,945	4,447

*kL/d = kilolitres per day

Table 3-11: Water Balance – Summary of Demands and Flows – Full Development

WATER CYCLE COMPONENT	MINIMUM (kL/d)	MAXIMUM (kL/d)	AVERAGE (kL/d)
Direct potable water demand	1,487	3,110	2,220
Potable water demand plus recycled top-up – with rainwater tanks (Scenario 3)	1,487	8,234	2,647
Potable water demand plus recycled top-up – no rainwater tanks (Scenario 4)	1,487	8,388	2,873
Direct recycled water system demand	809	4,748	1,768
Recycled water system demand plus rainwater top-up	809	10,388	2,195
Wastewater system flow	2,981	6,963	3,083
Recycled water discharge – with rainwater tanks (Scenario 3)	0	5,950	1,183
Recycled water discharge – no rainwater tanks (Scenario 4)	0	5,268	630
Rainwater use (Scenario 3)	0	2,959	780
Stormwater discharge (without rainwater tanks)	0	1,281,728	5,149

3.2.5 IMPACT OF RAINWATER TANKS ON RECYCLED WATER AVAILABILITY AND DISCHARGES

The use of rainwater tanks with a top-up from the recycled water system will result in an increase in the volume of recycled water discharged from the site in comparison to scenarios where rainwater tanks are not used. Estimates of this change are provided in Table 3-12. The use of rainwater tanks also reduces both the volume and the frequency of days requiring top-up from the potable supply system (Table 3-13).

Table 3-12: Impact of Rainwater Tanks on Recycled Water System Discharges

LEVEL OF DEVELOPMENT	VOLUME OF WASTEWATER GENERATED (ML/a*)	% WASTEWATER RECYCLED WITH RAINWATER TANKS (SCENARIOS 1 & 3)	% WASTEWATER RECYCLED WITHOUT RAINWATER TANKS (SCENARIOS 2 & 4)
Neighbourhood 1A	1,784	65%	81%
Full Development	8,446	62%	80%

*ML/a = megalitres per annum. One megalitre = 1 million litres

Table 3-13: Impact of Rainwater Tanks on Recycled Water Availability

LEVEL OF DEVELOPMENT	% OF TOP-UP VOLUME REQUIRED	% OF DAYS WITH RECYCLED WATER SHORTFALL
Neighbourhood 1A – With Tanks (Scenario 1)	21%	27%
Neighbourhood 1A – No Tanks (Scenario 2)	28%	42%
Full Development – With Tanks (Scenario 3)	19%	24%
Full Development – No Tanks (Scenario 4)	27%	38%

3.2.6 OVERALL POTABLE WATER SAVINGS

A reduction in potable system water use is one of the key drivers of the range of water conservation, recycling and rainwater use initiatives planned for the new community. The NSW BASIX scheme outlines a goal of achieving a 40% reduction in residential potable water use relative to an estimate of the traditional level of water use. By generating an estimate of the traditional level of water use that would have been used in the new community in the absence of the improved water cycle management initiatives, a reduction in use can be generated. The traditional level of water use was generated by adjusting the assumptions in the DSM DSS model regarding the market penetration of water using fixtures and appliances. The results of this analysis can be found in Table 3-14.

Overall, the Googong New Town can be expected to use approximately 60% less potable water than a traditional development of the same population if rainwater tanks are used.
Without the use of rainwater tanks, there is an increased need for the top-up of the recycled water system with potable water. In this case, the reduction in potable water use is approximately 55%.

Table 3-14: Overall Potable Water Savings Relative to Estimated BASIX Base Case

ITEM	NEIGHBOURHOOD 1A	FULL DEVELOPMENT
Estimated traditional water use (ML/a)	519	2,385
Expected Googong water use – with rainwater tanks (ML/a)	212	966
Water Savings – with rainwater tanks	59%	60%
Expected Googong water use – without rainwater tanks (ML/a)	233	1,049
Water savings – without rainwater tanks	55%	56%

It would be possible to increase the proportion of potable water saved beyond 60% by:

1. Offering new residents the option of utilising rainwater (with a top-up from the potable water system) for hot water use in addition to use for clothes washing. For these customers recycled water could be supplied directly for toilet flushing and irrigation. It is anticipated that if a significant number of customers selected this option it would result in further reductions in both potable water use and recycled water discharges;

2. Utilising stormwater basins on-site to provide seasonal storage for recycled water; and

3. Utilising stormwater runoff held in stormwater basins throughout the site; and

For items 2 and 3 above, an analysis of available stormwater freeboard on the Googong Creek catchment has shown that there is approximately 9ML of storage available for storing recycled water and stormwater. These additional scenarios have been evaluated and the results are shown in Table 3-15.

The results show that the level of savings can be increased with the options discussed. Interestingly, the volume of stormwater storage available on site (9ML) offers the most significant stormwater harvesting benefits at the NH1A level of development. At full development the availability of larger volumes of recycled water for storage reduces the volume of stormwater harvested to lower levels.

Table 3-15: Overall Potable Water Savings Relative to Estimated BASIX Base Case – Additional Scenarios

ITEM	NEIGHBOURHOOD 1A	FULL DEVELOPMENT
With Rainwater Tanks	*59%*	*60%*
No Rainwater Tanks	*55%*	*56%*
Rainwater to the Hot Water System	68%	69%
Utilising On-Site Storage for Recycled Water	61%	61%
Utilising On-Site Storage for Recycled Water and Stormwater	64%	61%

4. OPERATIONAL CONSIDERATIONS

4.1 FLOW DILUTION AND DISCHARGE WATER QUALITY

The Googong New Town development site discharges into the Queanbeyan River some six kilometres to the south of Queanbeyan. To estimate the impact of the new development on receiving water quality, the outputs from a series of MUSIC models was analysed to determine the change in pollutant loads (TSS, TN, TP, gross pollutants) that would occur with the new development. This was achieved by:

1. Running a MUSIC model to estimate the pollutant load contribution from existing land uses;

2. Running a series of MUSIC models (for different stages of development and WSUD measures) to estimate the pollutant loads resulting from the urban development area;

3. Comparison of the results of 1 and 2 above to determine the likely change in pollutant loads; and

4. Estimate the impact on the change in pollutant loads on the historical water quality data at the Wickerslack Lane site immediately downstream from the development using a simple mass balance.

A summary of the MUSIC modelling and associated assumptions is discussed below, with details provided in Appendix D. The MUSIC model runs for the proposed urban development took account of the periodic discharge of recycled water and the impact of the rainwater harvesting and WSUD measures to be employed in the new development area. Water quality estimates were prepared at Googong Road Dam and at the confluence of the two creeks draining the site with the Queanbeyan River. Flow dilution calculations have been prepared for the rainwater tank scenarios (Scenarios 1 and 3).

Runoff parameters and pollutant concentrations for the new town (other than for the Recycled Water System discharges) were based on the ACT Planning and Land Authorities Water Sensitive Urban Design General Code (Appendix D). Water quality parameters for recycled water discharges were:

- Total Suspended Solids (TSS): 5 mg/L
- Total Nitrogen (TN): 10 mg/L; and
- Total Phosphorus (TP): 0.2 mg/L.

Recycled water was assumed to be discharged into the proposed stormwater detention Basin 4 – immediately adjacent to and to the North of the proposed Town Centre in Neighbourhood 2.

A summary of the theoretical average annual loads derived through MUSIC modelling is tabled below.

Table 4-1: MUSIC Modelling Pollutant Load Comparison

Water Quality Parameter	Existing Development Loads	Full Development (without WSUD)	Full Development (with WSUD and ReW)
At Googong Road Dam			
TSS (kg/year)	37,800	171,000	9,500
TN (kg/year)	738	2,030	897
TP (kg/year)	43	150	71
Gross Pollutants (kg/year)	1,950	24,800	0
Annual Flow (kg/year)	179	680	908
At Queanbeyan River			
TSS (kg/year)	64,300	202,000	41,100
TN (kg/year)	1,193	2,580	1,640
TP (kg/year)	72	184	105
Gross Pollutants (kg/year)	4,750	29,200	4,390
Annual Flow (kg/year)	329	851	1,080

Comparisons between the MUSIC modelled cases indicate that the proposed WSUD measures are effective in reducing annual pollutant loads. Water quality modelling results also indicate a reduction in suspended solids and gross pollutant loads, with an increase in nutrient loads and annual flow, compared to existing development case. Pollutant dilution is discussed below. For further discussion of MUSIC modelling results and additional modelling cases refer to Appendix D.

Using the daily MUSIC modelling results (inclusive of recycled water discharge), mass balances (combined Googong Creek, Montgomery Creek and Queanbeyan River) were estimated for days where water quality monitoring results at Queanbeyan River are available. Several significant assumptions are associated with this theoretical assessment including:

- There is limited water quality data available for the Wickerslack Lane site, with between 19 and 24 measurements taken of each of the modelled parameters between 2000 and 2006.
- The MUSIC models are not calibrated to receiving water conditions.
- The assessment does not allow for in-stream processes (physical, biological and chemical) in the Queanbeyan River between both creek confluences and Wickerslack Lane.

- Complete mixing occurs.

These assumptions do not provide a solid base for firm conclusions to be drawn. However, the river monitoring results provide the available baseline for consideration, and theoretical mass balance estimates provide an indicative and initial comparison between the theoretical cases.

The data available (Table 4-2) suggests that the existing Queanbeyan River water quality:

- Does not meet ANZECC guidelines for Total Nitrogen (TN); and
- Meets ACT Water Quality but exceeds ANZECC guidelines for Total Phosphorus (TP).

For the Existing Development, Neighbourhood Area 1A (with WSUD) and Full Development (with WSUD) cases, a comparison of pollutant mass balances is also provided in Table 4-2.

Table 4-2: Queanbeyan River Water Quality Mass Balance Comparison

Data Source	Statistic	Water Quality Parameter			
		TSS (mg/L)	TN (mg/L)	TP (mg/L)	TN:TP Ratio
ACT Water Quality Guidelines	N/A	-	-	0.1	>12
ANZECC Guidelines	N/A	-	0.25	0.02	-
Number of Samples	N/A	19	24	23	23
River Observations	80th Percentile	5.7	0.7	0.03	35.2
River Observations	Max	15.0	1.7	0.18	66.0
Simple Mass Balance Assessment					
Theoretical Existing Development	*80th Percentile*	*70.8*	*0.8*	*0.05*	*34.1*
Theoretical Existing Development	*Max*	*186.9*	*3.6*	*0.21*	*64.8*
Theoretical Neighbourhood 1A Development	*80th Percentile*	*50.2*	*0.7*	*0.04*	*34.1*
Theoretical Neighbourhood 1A Development	*Max*	*114.8*	*2.6*	*0.17*	*65.0*
Theoretical Full Development	*80th Percentile*	*19.6*	*0.8*	*0.05*	*31.4*
Therotical Full Development	*Max*	*62.6*	*1.3*	*0.14*	*55.2*

The theoretical water quality results indicate the proposed development results in similar nutrient levels and generally lower suspended solids levels than the existing development case.

4.2 WATER RESTRICTIONS

The use of recycled water and rainwater raises some interesting issues with respect to the use of water restrictions. Restrictions on urban water use have traditionally been used in Australia as a tool to reduce the capital expenditure required on water supply infrastructure. The use of water restrictions in periods of drought to reduce demand increases the viability of supply infrastructure. The restrictions are seen as a temporary interruption to water supply and are intended to be for short periods of time.

Where recycled water and/or rainwater is being used, there are many times where potable water is used to top-up the supply. When this occurs, potable water could be viewed as being used in violation of water restrictions. If water restrictions were to be imposed in the Googong New Town at the same time as being imposed on other potable supply-only customers in the ACT and Queanbeyan, it would result in a reduction in recycled water use and thus an increase in wastewater discharges. Clearly there are two competing objectives at play. The first is the preservation of the reliability of the water supply, and the second is the protection of aquatic ecosystems from excessive discharges of treated water.

A number of water utilities around Australia have policies that deal with water restrictions and their implications for the use of recycled water and rainwater. Details are provided in Appendix C. Any policy adopted with respect to the Googong New Town development will need to take account of the competing water security/water quality objectives.