Winchester City (North)

Water cycle analysis

Report EX 5000
Rev 0.0
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HR Wallingford

Contents

1. Introduction

This report describes additional work undertaken on the impacts of the proposed Winchester City (North) development on the water cycle in response to a written request from Winchester City Council dated 24 June 2004 under Regulation 19 of the EIA Regulations 1999. Background information on the site and the outline design of the stormwater and foul drainage systems are described in HR Wallingford report EX4734 (January, 2004). Further information and clarification was required on several aspects of the outline design.

This report provides further information on:

- Water supply and demand
- Foul water discharge rates
- Groundwater recharge
- The impact of changing land use on pollution loads

These topics are discussed in Sections 2 to 6. All additional calculations are based on an estimate of the number of households, occupancy rates and commercial development for each year of development (Table 1.1).

Table 1.1 Number of households for each year of development (Commencement year 2006)

Financial Year ending	Household Units	Population @ 2 people per household	Population @ 2.21 people per household
2008	100	200	221
2009	375	750	829
2010	700	1400	1547
2011	1075	2150	2376
2012	1450	2900	3205
2013	1750	3500	3868
2014	1950	3900	4310
2015	2000	4000	4420

For consistency with the Environmental Statement, our water demand and foul water discharge calculations have assumed and occupancy rate of 2.21. This is considered to represent a "maximum" population multiplier and demonstrates a 'worst-case' estimate in terms of water consumption per household. The calculations also assume 13,000 m^2 of commercial floorspace (including a 2,000 m^2 food store, 2,000 m^2 of other retail, 4,000 m^2 business and 5,000 m^2 of 'community' uses) and a two form entry primary school.

2. Water supply and demand

2.1 AIM

Provide estimates of water consumption for each year of the development, with and without water efficiency measures.

2.2 CALCULATION

The demand for water was estimated based on industry "best practice" approaches to provide figures that can be used to establish the site's potential impact on the local water supply. The following design demands were calculated for each year of the proposed development, with and without water efficiency measures:

- Normal Year Average Demand
- Average Dry Year Demand
- Average Dry Year Peak Week Demand

The Normal Year Average Demand provides an estimate of average consumption excluding any leakage or supply pipe losses. For water resources planning the "Dry Year" demands determine the future investment by Southern Water into water supply or demand management measures. The Dry Year demand is based on a standard multiplication factor of 1.1 to estimate average consumption in a dry year and a further 1.3 is applied to estimate consumption in a peak week.

The domestic demands were calculated for each financial year of the development based on the number of households, occupancy rate, per capita consumption, components of water demand and the impact of water efficiency measures. The following measures were considered:

Basic measures
- Low flush toilets
- Sprinkler taps in wash basins
- Water efficient showers

Appliance measures
- Water efficient "white goods"

Re-use measures
- Grey water recycling
- Rainwater harvesting

The impact of these measures on consumption was built up incrementally by firstly applying "basic measures" which are elements provided to the homeowner by the developer; then considering the option of white goods which are normally provided by the homeowner; and finally, implementing Re-use measures to maximise low water use. This last element has additional costs but implementing all measures will create homes that meet or exceed the existing "Ecohomes" standard[1].

It was assumed that all new homes would be metered, and therefore a baseline figure for average water consumption of 150 litres per head per day was used for the calculations.

[1] http://www.sustainableconstruction.co.uk/sheepdog.htm

This is consistent with water company and Environment Agency estimates for metered per capita consumption in the region.

Water consumption was calculated for occupancy rates of 2.0 and 2.21. The headline figures quoted in this report use the latter figure for consistency with the Environmental Statement. This is a conservative assumption that adds approximately 10% to the demand for water and provides adequate freeboard for any uncertainty in the calculations such as growth in demand and climate change.

Table 2.1 shows the main components of domestic water use and summarises the water efficiency savings for different measures.

Table 2.1 Components of domestic demand and summary of water efficiency measures

			Water efficiency savings l/h/d		
Components of domestic demand	% of per capita consumption	Baseline per capita consumption l/h/d	Basic measures	Appliance measures	Re-use measures
Kitchen	15%	23	0.0	0.0	0.0
Outside use	6%	9	0.0	0.0	0.0
Wash basin	8%	12	6.0	6.0	6.0
Toilet	35%	53	14.5	14.5	14.5
Dishwasher	4%	6	0.0	0.6	0.6
Washing Machine	12%	18	0.0	1.8	1.8
Shower	5%	8	1.8	1.8	1.8
Bath	15%	23	0.0	0.0	0.0
Total	100%	150	22.3	24.7	24.7
Grey water recycling		0	0	0	20
Rainwater harvesting		0	0	0	1
					46
Demand l/h/d		150	127.7	125.3	104
% Saving		n/a	15%	16%	30%

The assumptions used for water efficiency savings were conservative. For example, the average toilet uses approximately 8.3 litres of water; we assumed the installation of 6 litre toilets rather than lower flush 4 litre toilets to produce a saving of 14.5 l/h/d.

Partial grey water recycling is included based on using wastewater from the kitchen and bathroom for outside use and toilet flushing. It is assumed that 20 l/h/d of water can be recycled in this way.

Rainwater recycling is included based on the provision of water butts and the use of rainwater for a small proportion of outside water use. Greater use could be made of rainwater, particularly if grey water recycling was not implemented. However, this is a detailed design issue that depends upon roof areas, drainage design and the amount of storage included in the design.

The overall impact of these water efficiency measures is a reduction in domestic demand by between 15% and 30% depending on the measures implemented. A saving of 30% would meet the highest "Ecohomes" standard. A slightly higher level of reduction was achieved in the Greenwich Millennium Village by using more enhanced grey water recycling (HR Wallingford, 2003).

The demand for water from commercial development was based on 500 litres per day per 100 m^2 of commercial floorspace. The demand from the school was based on 200 people using a conservative100 litres per head per day. The same percentage water efficiency savings were assumed for commercial development and the school.

2.3 RESULTS

The results are shown in Figure 2.1 based on an occupancy rate of 2.21.

The total demand (average demand in a normal year) of Winchester City (North) would be 0.75 Ml/d with metering but no water efficiency measures. Introduction of water efficiency measures could reduce demand to:

Water Efficiency Measure	Average Demand (Ml/d)
Basic	0.64
Addition of White Goods	0.61
Combined	0.52

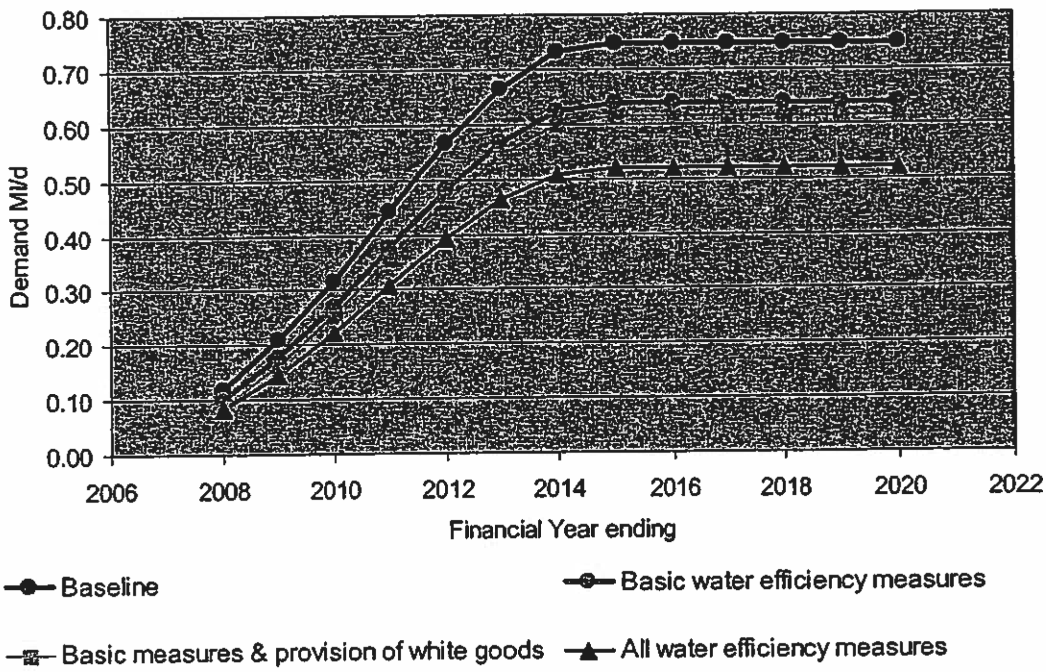

Figure 2.1 The domestic and commercial demand for water with and without water efficiency measures

2.4 CONCLUSION

The proposed development includes 2000 households and commercial development. Southern Waterwould supply water to the site from surface and groundwater sources in the south of Hampshire. The largest resource in the area is Otterbourne on the River

Itchen which includes a direct surface water abstraction and groundwater abstraction from several boreholes.

The site would place additional demand on the local water supply system from 2007/8. In order to reduce the development's impact on the supply-demand balance scheme design would:

- include a range of water efficiency measures including some grey water recycling
- incorporate Sustainable Drainage Systems (SuDS) that enhance recharge during the summer months (see Section 4 on groundwater recharge) benefiting river flows and groundwater levels in the Itchen.

The water industry plans new schemes on a five year rolling basis. The period 2004/5 to 2009/10 is the known as the "AMP4" period and 2010/11 to 2015/16 is the "AMP5" period. Increased demands of between 0.27 Ml/d (for basic water efficiency measures) and 0.22 Ml/d (all measures) in 2009/10 would be unlikely to have a major impact on Southern Water's AMP4 business plan.

3. Foul discharge rates

Waste water discharge flows are normally referred to as Dry Weather Flow (DWF). The DWF figure is not the same as the water demand for an area, the difference being primarily caused by garden watering and car washing along with issues of infiltration and exfiltration from the collection system. The value of DWF is not used for either the design of the collection system or the design of the treatment system.

A rule of thumb figure for DWF for an area is 200 or so l/hd/day. This incorporates the infiltration, exfiltration and commercial discharges as well as the waste flow from the population. However it is preferable to build up the figure from the constituent elements of the flow as certain assumptions can be made with regard to the North Winchester development.

A figure of 140 l/hd/day is a reasonable assumption for the population discharge making a provision for some use for garden watering resulting in 94% of the water demand being passed to the works. If one assumes 100% of the water demand for commercial and school areas being discharged to the network, the total DWF, excluding other sources of water, is 7.21 l/s (from 4420 people) plus 0.75 l/s (from the school and commercial area). As with the water demand analysis, it is assumed that any small growth in water demand will be off-set by water conservation measures and the conservative assumption of 2.21 persons per dwelling.

3.1 DESIGN FLOW FOR HARESTOCK

The design flows for the sewage treatment works (STW) need to be based on the peak flow rate from the site. It therefore needs to take into account the pattern of behaviour which is created by daily routine as well as any additional sources of water. The diurnal variation of flows in waste water systems is well understood, but varies depending on the size of the catchment served by the STW. STWs for very large cities have virtually no daily variation in inflow to the works, while small works, like Harestock will have peak flows up to or greater than 2 times DWF. As Harestock is so small a conservative peak factor of 2.5 times DWF is proposed.

Pipe networks are never laid perfectly and infiltration is common place. In old systems this can be very significant, but as this is a new network (and also due to the need to protect the important aquifer from unnecessary pollution), this network is likely to be built well. However an allowance will still be made for infiltration using 20l/hd/day as this may occur in wet periods. Infiltration is unlikely to occur for much of the year as the chalk is highly permeable and therefore any water passing into the ground after periods of rainfall will tend to pass down to the groundwater rather than pass into the collection system. An allowance of 20l/hd/day for infiltration amounts to an additional flow rate of 1.023l/s.

Although water conservation measures are proposed, a conservative assumption regarding the impact on the works is to assume that current practices prevail. However reductions in the order of 20% to 35% can be applied if this is felt to be appropriate.

In addition, it has been recognised that even in high density developments, subsequent extensions and patio construction often result in mis-connected runoff being directed to the foul system. An allowance is therefore made of 1% of the impermeable area (usually limited to roof area) contributing additional inflow based on an average rainfall intensity of around 40mm/hr. This amounts to an additional flow rate of 18.344l/s for 1% of the area for 16.51ha of roofs.

Thus, assuming a peaking factor of 2.5, an infiltration rate of 20l/hd/day and mis-connected hard areas, the peak inflow to the STW is 39.9 l/s. Figure 3.1 illustrates the growth in peak flow passing to the STW based on the growth in the population as detailed in Table 1.1. It also provides the DWF value excluding infiltration and allowance for rainfall. It is based on the population figure of 2.21 persons per dwelling.

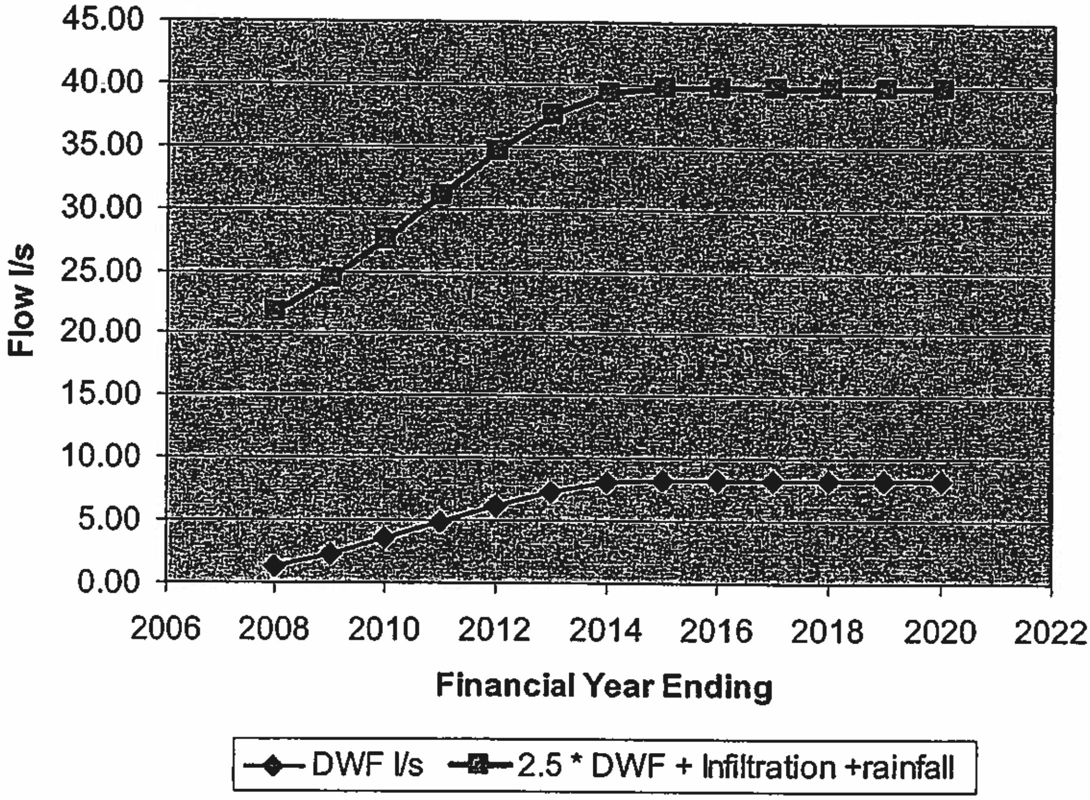

Figure 3.1 The build up of foul water discharges between 2007/8 and 2014/15 (check calculation sheets – difference in figures due to commercial assumptions)

3.2 THE DESIGN OF WASTEWATER COLLECTION SYSTEMS

This report is aimed at providing wastewater flow information for the purposes of assessing the requirements of the STW. However for completeness a brief summary of the design approach to the collection system is also provided.

Sewers for Adoption is the definitive document which specifies the design requirements for wastewater collection systems for developments. It stipulates that the system should be designed for 4000l/dwelling/day. The objective of using such a conservative figure is to take all the issues such as dwelling occupancy, the probability of joint discharges from appliances occurring simultaneously and infiltration into account. Using the traditional value of 200l/hd/day and 3 persons per property, this provides a peaking factor of around 6 is usually used for the sizing of pipes in the upper reaches of the collection system. This peaking factor normally reduces quite rapidly as the area served increases.

4. Groundwater recharge

4.1 AIM

To estimate the change in seasonal groundwater recharge following the development of Winchester City (North).

4.2 CALCULATION

The amount of water that recharges the Hampshire Chalk aquifer depends upon the balance between rainfall and evaporation. The average monthly recharge was calculated for "pre-" and post development conditions using a monthly water balance model (Thornwaite and Mather, 1957) for "green field" recharge rates and the Rational Method for recharge from the developed areas.

The average monthly rainfall was based on 30 years of data from Otterbourne rain gauge. Potential evapotranspiration (PET) was estimated for short grass based on literature values for Hampshire.

The existing land use is arable and the type of crops grown will affect the rates of actual evapotranspiration. For simplicity it was assumed that the current land use was grassland which provides a reasonable estimate for a range of arable crops.

The post development recharge calculations assumed the following general land cover classes:

Buildings & paved areas	50 ha
Suburban green space	14 ha
Open green space	20 ha
Area developed	60%
Green space	40%

Post development the recharge per unit area of 34 ha of the site will remain largely unchanged because the water balance of gardens and other green spaces will be similar to the existing arable land uses.

The buildings and paved areas will be drained using Sustainable Drainage Systems (SuDs) that will rely of infiltration of water into the Chalk. The SuDS include piped, trench and pond components. In general the SuDS should enhance recharge because water would no longer be stored in the soil there would be lower evaporation losses. Evaporation losses may be greater for retention ponds but these cover a very small surface area and their impact would be correspondingly small.

The net recharge for the developed areas was estimated based on monthly rainfall and assumed losses of 10% in winter (October to March) and 25% in the summer months (April to September).

4.3 RESULTS

Figure 4.1 shows the baseline monthly water balance of the site before development. There is no recharge to the Chalk in the summer months because evaporation and transpiration losses are greater than rainfall. During the summer the soils dry out and there may be a need to irrigate some of the crops currently cultivated at Barton Farm. Recharge starts in September and ends at the end of March with the greatest recharge in December.

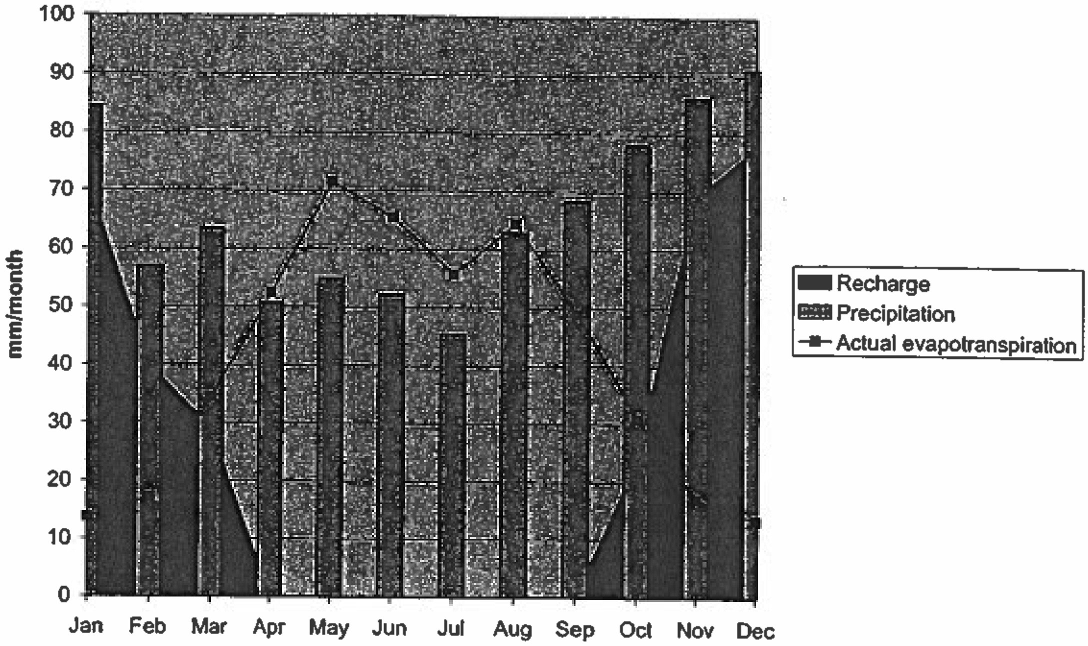

Figure 4.1 Baseline estimates of long term average rainfall, actual evapotranspiration and groundwater recharge

Figure 4.2 shows the recharge per unit area before development (blue area), the recharge from the paved areas of the site (black line) and the average recharge from the whole site post development (green area). There is an enhanced rate of recharge during the summer months from the developed areas that will augment recharge to the Hampshire Chalk aquifer.

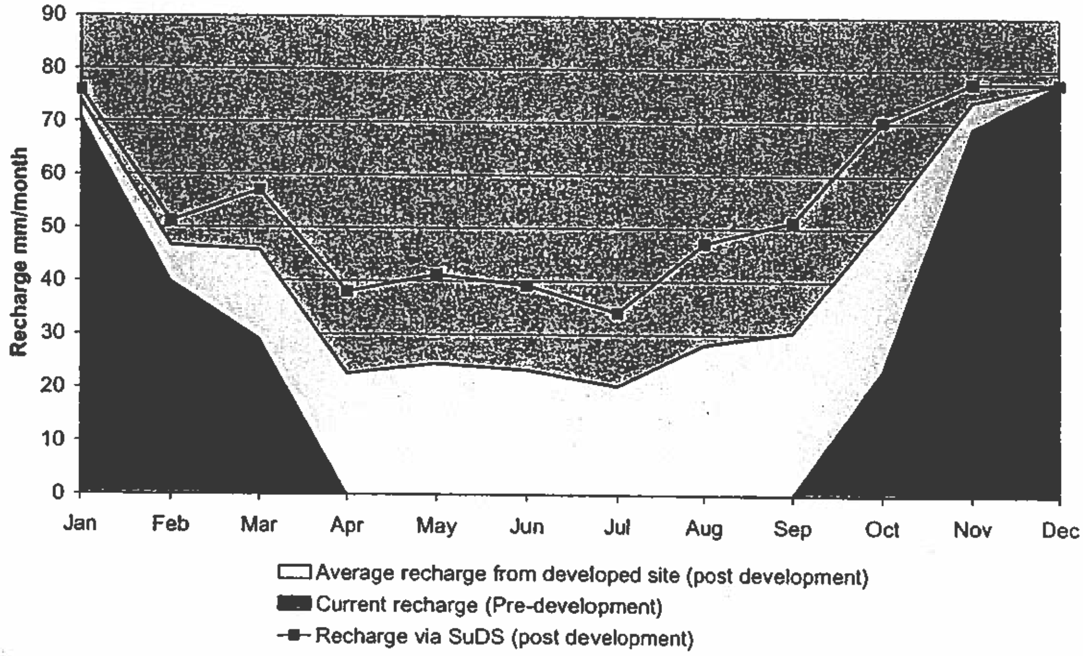

Figure 4.2 Seasonal recharge (per unit area) before and after the development

Figure 4.3 converts the estimate of additional site recharge post development (green area minus the blue area) into a volume of water in Ml/d and compares this to the demand for water from the site in 2014/15 with all water efficiency measures in place. The return flow from the sewage works to the River Itchen is ignored in this comparison. Nevertheless the comparison shows the site could have a net benefit to the water balance during the summer and autumn when flows on the Itchen are at their most critical.

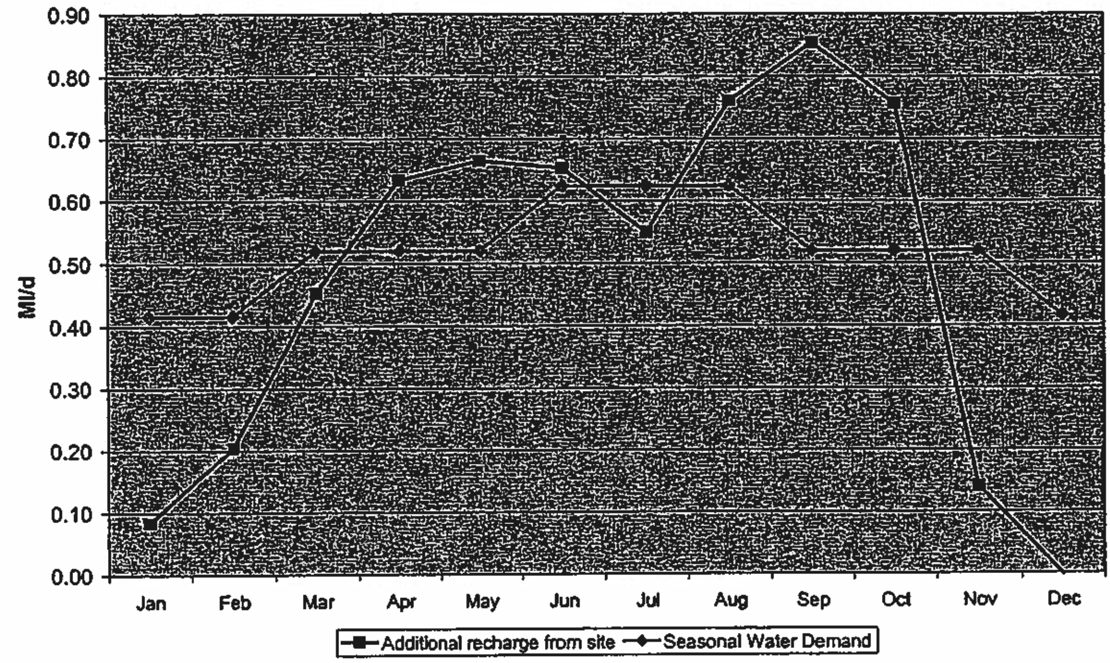

Figure 4.3 Comparison of additional recharge from SuDs and the demand for water

5. The impact of changing land use of pollution loads

5.1 AIM

To estimate loads of Total Nitrogen and Total Phosphorous before and after development.

5.2 CALCULATION

The amount of nitrogen and phosphorous that leaches to groundwater depends upon land cover and management practices. In agricultural areas, fertilisers are the main source of both nitrogen and phosphorous and, in simple terms, a percentage of the nutrients applied in fertilisers will leach to groundwater every year. In developed areas, the main source of nitrogen and phosphorous are point sources, particularly sewage treatment works. Diffuse nitrogen and phosphorous pollution from urban areas would also occur, particularly from roads if ammonia based de-icing agents are used, but the average concentrations tend to be lower than from arable land.

The diffuse pollution loads and average concentrations of nitrogen and phosphorous were calculated based on literature values of mean annual loads (for agriculture) and event mean concentrations for the paved areas. The figures derived for recharge were used to convert estimates of load into average concentrations and vice-a-versa.

Table 5.1 Assumptions used to estimate nitrogen and phosphorous loads before and after development

Land cover areas	Area Units	Comments
Paved area	50 ha	
Suburban green space	14 ha	
Open green space	20 ha	
Area paved	60%	
Green space	40%	
Pollutant assumptions		
Arable N load	50.00 kg/ha/a	Expert opinion – typical value for wheat (Burt et al., 1997)
Green space N load	30.00 kg/ha/a	Expert opinion
Urban N mean concentration	2.85 mg/l	Total N (HR Wallingford, 2003)
Arable P load	1.24 kg/ha/a	Average value for agriculture (Defra, 2003)
Green space P load	0.50 kg/ha/a	Expert opinion
Urban P mean concentration	0.34 mg/l	Total P (HR Wallingford, 2003)

5.3 RESULTS

The estimated loads and concentrations are summarised in Table 5.2.

Table 5.2 Estimates of nitrogen and phosphorous loads, pre- and post development

Total Nitrogen Loads	Area ha	Mean Load kg/ha/a	Mean concentration mg/l	Total load kg
Pre-development (arable agriculture)	84	50.00	16.15	4200
Post development				
Paved area	50	19.7	3.2	984
Suburban green space	14	30.00	9.69	420
Open green space	20	30.00	9.69	600
Total	84	23.86	5.83	2004
Total Phosphorous Loads	**Area ha**	**Mean Load kg/ha/a**	**Mean concentration mg/l**	**Total load kg**
Pre-development (arable agriculture)	84	1.24	0.40	104
Post development				
Paved area	50	0.3	0.34	14
Suburban green space	14	0.50	0.16	7
Open green space	20	0.50	0.16	10
Total	84	0.37	0.27	31

The results show that there would be a 52% reduction in diffuse N and a 70% reduction in diffuse P.

5.4 CONCLUSION

Diffuse nutrient pollution from the developed site would be lower than for arable agriculture. Nitrogen and phosphorous in sewage would be treated at Harestock wastewater treatment works to a high standard and therefore the overall impact of the site is likely to be neutral or beneficial in terms of reducing nutrient loads to the Itchen.

6. References

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CHAPTER 14 – HYDROLOGY AND DRAINAGE

Supplementary Information

Drainage Strategy

1) The site of Winchester City (North) splits into two catchments; the first of which falls towards the railway line in the vicinity of the existing underpass and the second, which falls northwards towards Well House Lane.
2) In the case of the first catchment, foul drainage would drain to one or two low points within the catchment and be pumped up to an existing sewer, probably in Andover Road.
3) The design and phasing of the pump station construction would depend on the phasing of the development within that particular catchment. Its design would be such as to allow impeller changes to take account of increasing flow through time in accordance with figures given in the accompanying Technical Report on Water Cycle Impacts (EX5000).
4) Similarly, the second catchment would drain either to a pumping station or by gravity to a local sewer on Well House Lane, as appropriate.
5) Connections to the Southern Water foul drainage system from the site would be dependent on the existing capacity of foul sewer on Andover Road and Well House Lane. It is quite possible that their capacities would not be sufficient and therefore a new sewer might be required to drain the site to the Harestock Works. Discussions with Southern Water in this regard will be necessary to establish their preferred requirements regarding these details at the preliminary design stage.