USING WSUD TO RESOLVE COMPETING OBJECTIVES: A CASE STUDY OF A SUSTAINABLE INDUSTRIAL DEVELOPMENT

R Wiese [1]*M Brown*[1]*,M Liebman*[1]
[1]STORM_CONSULTING, rod@stormconsulting.com.au

Abstract

Located within the Hunter River floodplain at Heatherbrae and overlying the Tomago sand bed drinking water aquifer, the development of the Kinross Business Park was frustrated by numerous environmental constraints for many years. This site was constrained by the sensitive underlying shallow aquifer, a sensitive receiving water and by the need to maintain floodplain storage and peak flows. Being a sandy site, the pre-development hydrological regime was one of infiltration. Runoff, it was predicted, would have occurred from this sandy site less frequently than once in ten years. It was not considered possible to develop this site using conventional drainage systems. However, the careful, well-planned application of water sensitive urban design has enabled each of the constraints to be overcome.

Introduction

Kinross Business and Industrial Park is a 30Ha brownfield industrial development located in the Heatherbrae industrial area on the eastern edge of Raymond Terrace, New South Wales (Figure 1). The development overlies the Tomago sand beds which are a drinking water aquifer under the management of Hunter Water. Soils on site are all sands with the aquifer generally at 2m below the soil surface. The pre-development hydrological regime was one of infiltration with surface flows predicted to occur once in tens years. Any surface flows drain over very flat land to Windeyers Creek, a tributary of the Hunter River. Development of the site beyond the existing Weathertex factory commenced in 2006.

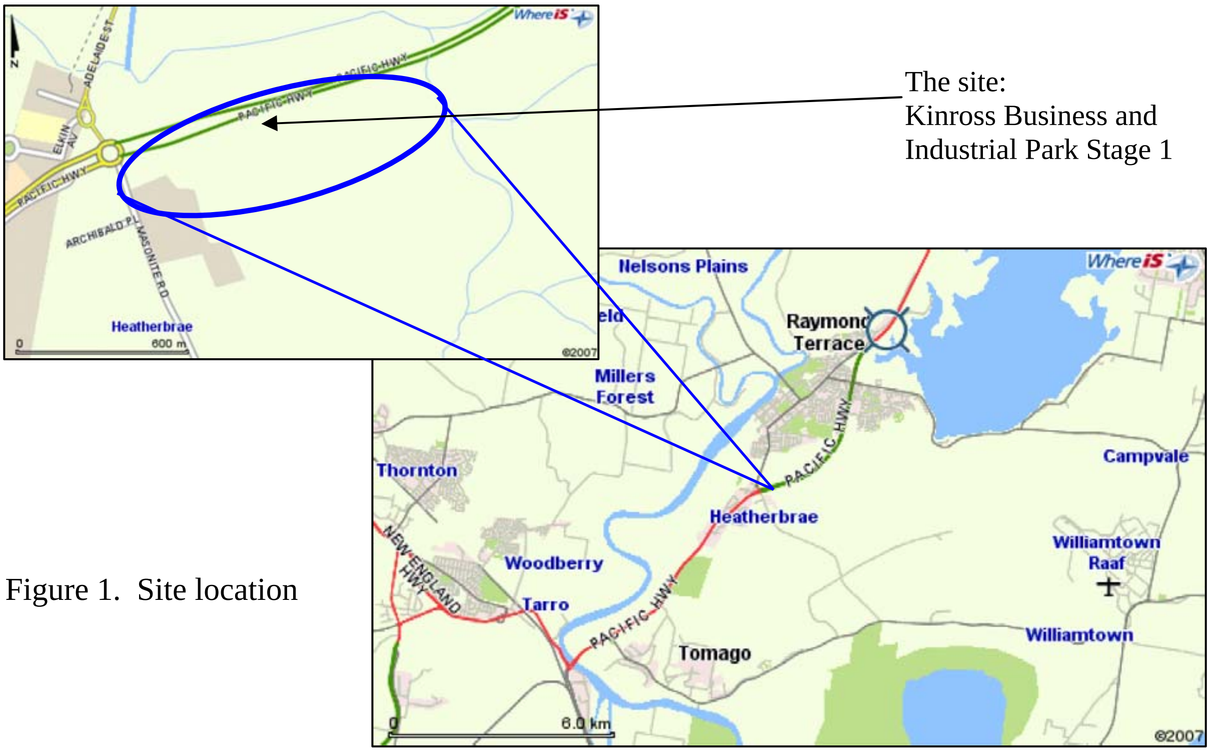

Figure 1. Site location

Planning context

NSW Government officers initially preferred the site to be fully sealed preventing any infiltration of stormwater and therefore reducing the risk of contamination of the drinking water aquifer. Their preferred solution was to prevent infiltration and direct surface water from roads and lots to wetlands for water quality treatment prior to discharging to Windeyers Creek.

A site specific Development Control Plan (DCP LD13 Development Guidelines - Water Quality - Kinross Industrial Estate, Heatherbrae" April 2003) applies to the site with a key provision:

"The stormwater management strategy for the DCP area shall allow for no infiltration of subdivision stormwater (lots and roads) at source points, through conveyance or through end of pipe controls. Discharge shall be to Windeyers Creek. Any variation to this principle…will require significant justification and endorsement from the Department of Land and Water Conservation…"

Its purpose is;

"to maintain the water quality of the groundwater area within the Tomago Catchment… due to its use for drinking water."

The Development Control Plan further requires that development applications for individual allotments must include a Stormwater Management Plan (SMP) to demonstrate compliance with water quality objectives (Table 1).

Table 1: DCP water quality objectives

Pollutants	Retention Criteria
Coarse sediment	80% of average annual load for particles less than or equal to 0.5mm
Fine sediment	50% of average annual load for particles less than or equal to 0.1mm
Total Phosphorus	45% of average annual pollutant load
Total Nitrogen	45% of average annual pollutant load
Litter	70% of average annual litter load greater?
Hydrocarbons	90% of average annual pollutant load

Competing objectives

The NSW Government's proposed solution of site sealing and traditional drainage was difficult to achieve in a physical sense. The flat site made it difficult to achieve the required pipe grades. Sealing the proposed industrial estate and consequently maximising the rate and volume of runoff conflicted with other key objectives for the site such as the need to protect Windeyers Creek from excessive site runoff.

Council's main objective was to ensure that flooding or environmental harm was not caused as a result of the proposed development. To achieve this aim and be consistent with the State Governments proposed solution, it was necessary to detain peak flows for all storms up to the 100 year ARI to similar of the pre-developed state. The infiltration rate into the sand is very high (180 to 3600mm/hour). Because of such high infiltration rates, the site generates very little runoff in its undeveloped state. Maintaining these near zero runoff characteristics post-development, where a large proportion of the surface is covered by impervious surfaces required substantial detention capacity with a significant land take thus making development extremely difficult and likely unfeasible.

The creation of extensive areas of imperviousness reduces site infiltration. Although the concept was to protect the aquifer, implementing the NSW Government's proposed solution would likely compromise the recharge potential of Tomago aquifer.

STORM's team realised that the proposed solution was creating too many conflicts, and so began to investigate alternative approaches and to convince Government officers of their benefits. The approach developed was to maintain the existing hydrological regime of this site by firstly treating and polishing the stormwater and then continuing to allow infiltration of treated stormwater into the aquifer below. The notion of treating industrial area runoff to a suitable level for release by infiltration into a drinking water aquifer became the key issue to resolve in achieving approval of the entire development.

Water Sensitive Urban Design strategy

WSUD solution concept

The adopted solution was to implement Water Sensitive Urban design (WSUD) by maintaining the existing hydrological regime by firstly treating the stormwater (including nutrient removal) and then infiltrating treated stormwater for all events up to the 1 in 100 year ARI. The design philosophy employs an integrated treatment train approach for water quantity and quality management. The WSUD system for Kinross Business & Industrial Park can be broken down into three sub-systems:

- Roof-water system – this is a system to manage runoff from all roof areas within each Lot by storing and then infiltrating the excess
- Hardstand runoff system – this is a system separate from the roof water system designed to treat runoff from all ground areas within each Lot prior to infiltration in the vegetated easements
- Road runoff system – this is a system to treat all road runoff external of the lots prior to infiltration.

The WSUD strategy protects the underlying drinking water aquifer and conserves and reuses stormwater. It protects the receiving waters and is designed to limit the 1:100 year post-development flow to less than that which occurred prior to development.

WSUD system components and configuration

Rain and stormwater from each of the three sub-systems is treated in a treatment train employing a number of components. Beginning independently, the Hard Stand and Road sub-systems link towards the end of each system. The Roof-Water sub-system is independent of the other two. The components of each of the WSUD sub-systems are shown in Figure 2. Figures 3, 4 and 5 show the configuration of sub-system components.

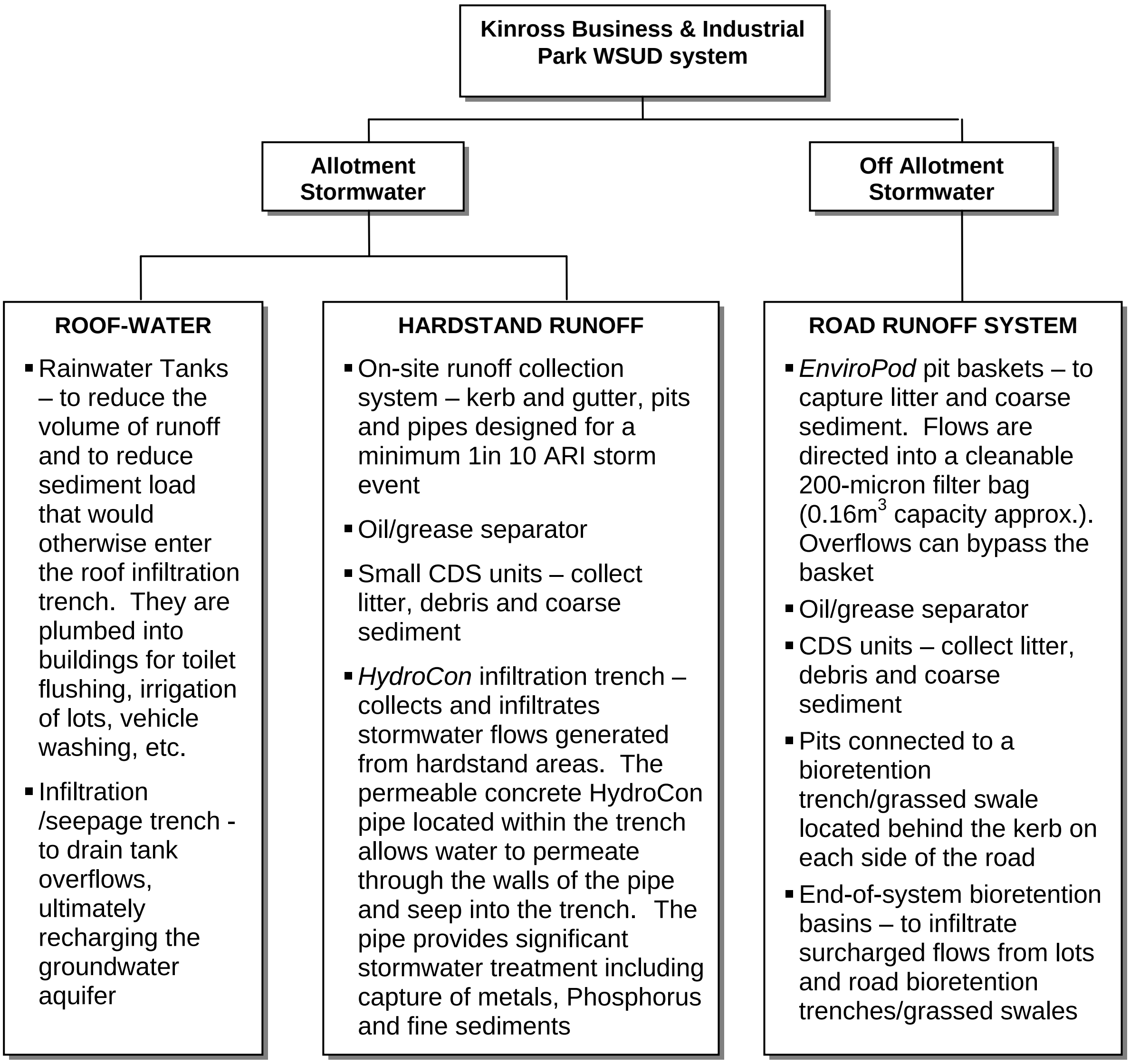

Figure 2. WSUD sub-system and their components which comprise the Kinross WSUD treatment train.

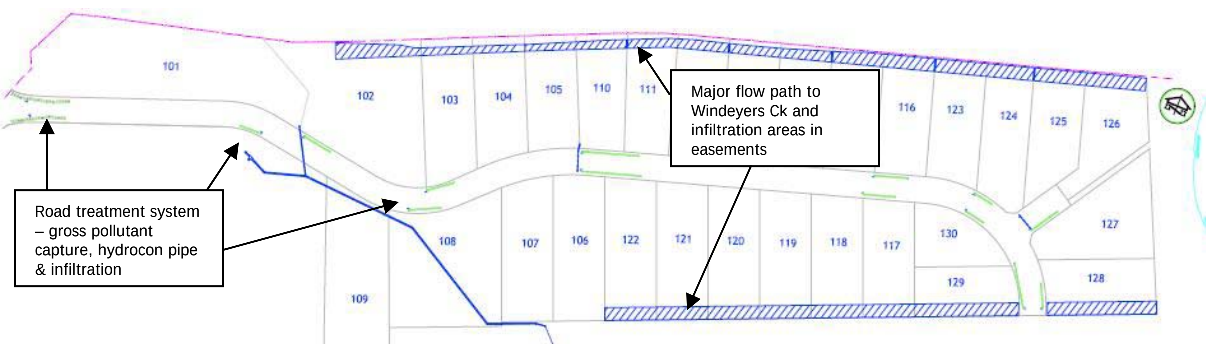

Figure 3. Location of road runoff treatment system and major overland path

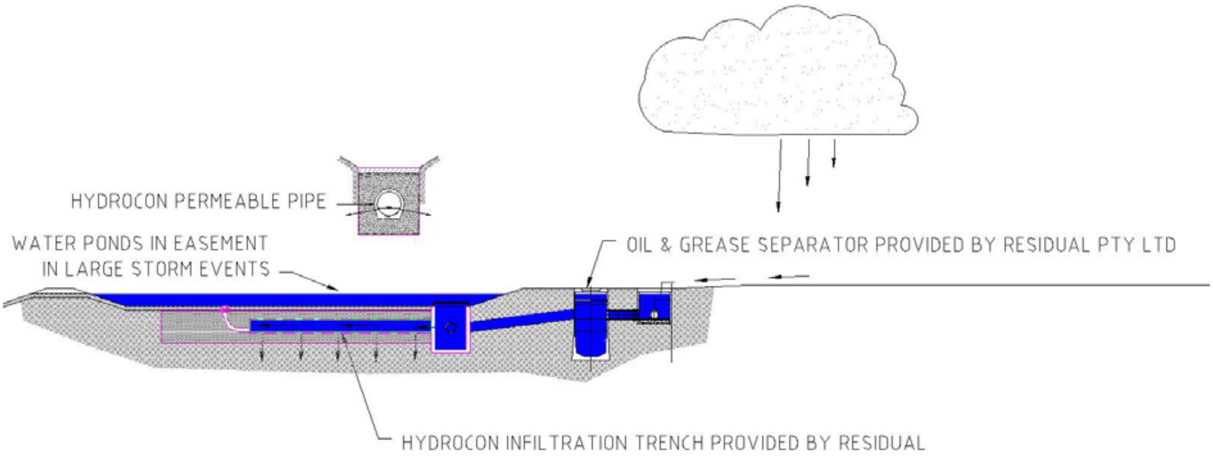

Figure 4. Lot treatment system for hardstand runoff (similar configuration used on roads)

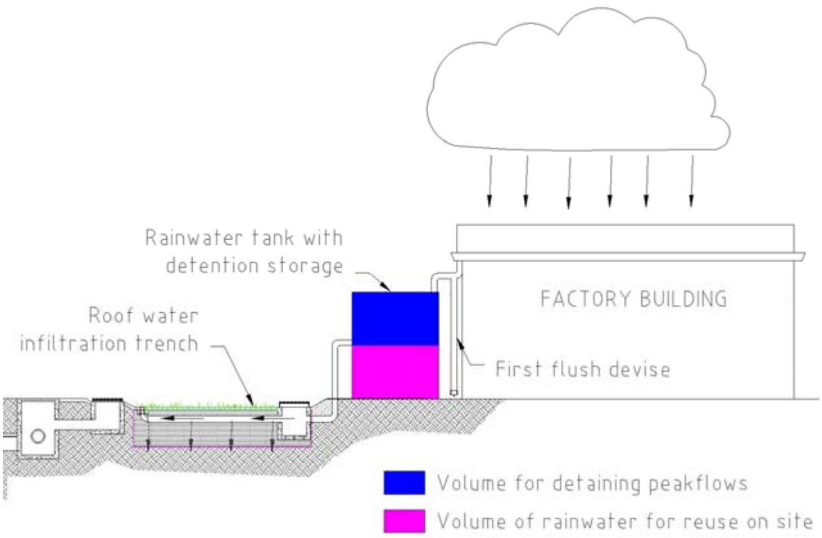

Figure 5. Roof water system of allotments

WSUD system performance

Hydrology

<u>*Design Storms*</u>

The following objectives were adopted in the design of system components.

- gravel trenches - 1 year ARI storm events
- *HydroCon* pipes - 1 in 3 month ARI storm event
- The lot based infiltration trench - no overflow in a 5 year ARI storm event.

<u>*Peak Flows*</u>

The proposed road drainage system has been designed to infiltrate the whole of the 100 year ARI.

The pre-development flows are not exceeded. The post development flows achieve effective treatment and infiltration to replenish Tomago aquifer (Table 2).

Table 2: Comparison of pre- and post-100 year ARI peak flows

Storm duration	Pre-development peak flow rate (m^3/s)	Post-development peak flow rate (m^3/s)
1hr	1.650	0.985
2hr	1.901	1.633
6hr	1.027	1.609
12hr	0.927	1.231
24hr	0.696	1.127
Maximum	1.901	1.633

Water Quality

<u>*Lot-based system*</u>

Estimated performance of the lot-based system proposed for Kinross Industrial and Business Park is summarised in Table 3.

Table 3: Estimated pollutant retention percentages from the Lot-based stormwater system components

Pollutant	Sediment	Phosphorus	Nitrogen	Visible Oils/Grease
Sediment and Oil Trap	100% coarse sediment	20% to 30% on attached particles	20% to 30% on attached particles	100% of visible & treat min 90% of flow
HydroCon pipe system	80% of fine sediment	50% of remaining Phosphorus	No retention	N/A
Sand media surrounding pipe	N/A	Minimal adsorption by sand	Up to 45% retention of TN	N/A
Council SMP requirement	50% of ave ann load for particles ≤0.1mm	45%	45%	90% average annual pollutant load
Total Retention	Up to 80% of fine sediment	> 50%	45%	100% of visible & treat min 90% of flow

The HydroCon treatment system confers the following water quality benefits:

- The pH of water in the pipes is altered by the alkalinity of the pipes themselves. This facilitates the settling of pollutants from the water column.
- The velocity of flow through the pipe wall is so low that velocities inside the pipe are also very low. This enhances the settlement process described above as well as allowing for the settlement of very fine particles inside the pipe.
- Water passing through the pipe wall experiences an adsorption process *via* anionic exchange facilitating the adsorption of Phosphorus and metals.

The HydroCon pipes are also predicted to remove close to all sediment including very fine particles and 99% of metals. The pipes will not remove Nitrogen other than that associated with sediments that are removed. Nitrogen levels on this industrial estate are not expected to be high and Nitrogen removal will occur in the sand media that surrounds the pipe and as it percolates to the aquifer below. A minimum buffer of 1m of sand is to be maintained in each location on this site to buffer the aquifer and remove residual nitrogen from the flow.

Modelling of a sand filter constructed at Kiama and designed by STORM with a 1m depth of sand was predicted to remove greater than 45% of the nitrogen from the water column (STORM, 2002). Monitoring results from a sand filter treating stormwater in Kiama supports this retention rate (Dunphy *et al*, 2005).

Road runoff system

Table 4 details the expected performance of the proposed combined bioretention and HydroCon pipe system. The proposed system will enable compliance with Council's SMP requirements with Windeyers Creek and the Tomago drinking water aquifer significantly benefiting from the adoption of an infiltration approach.

Table 4: Estimated pollutant retention percentages from the road stormwater system components

Pollutant	Sediment	Phosphorus	Nitrogen	Visible Oils/Grease
Bioretention system	100% coarse sediment	20% to 30% on attached particles	20% to 30% on attached particles	100% visible & treat min 90% of flow
HydroCon pipe system	80% of fine sediment	50% of remaining Phosphorus	No retention	N/A
Sand media surrounding pipe	N/A	Minimal adsorption by sand	45% retention of total nitrogen.	N/A
Council SMP requirement	50% of ave ann load for particles ≤0.1mm	45%	45%	90% average annual pollutant load
Total Retention	Up to 80% of fine sediment	> 50%	45%	100% of visible & treat min 90% of flow

Facilitation of approval

Since this type of stormwater treatment system had never been previously implemented, considerable effort and resources were invested into demonstrating to NSW Government and Council officers that the WSUD strategy would protect the underlying Tomago drinking water aquifer.

To facilitate demonstrating the effectiveness of the WSUD strategy, the site developer invested in an Australian Research Council (ARC) trial which was realised by way of designing and constructing a pilot scale system within the grounds of the Weathertex factory site. ARC research project partners from University of Technology Sydney monitored this project (Dunphy *et al* 2005).

Conclusions

The WSUD strategy implemented at Kinross Industrial and Business Park demonstrates how a carefully designed and constructed WSUD strategy was able to resolve several competing environmental and physical site constraints. The adopted WSUD strategy represents a significant departure from the Government recommended approach of a traditional sealed development with detention and wetland treatment. It relies on roof water reuse and high levels of pre-treatment in a WSUD treatment train prior to infiltration to the drinking water aquifer below. The ultimate approval of the WSUD strategy was facilitated by the results of a pilot scale research trial.

References

Port Stephens Shire Council (2003): Development Control Plan LD13 Development Guidelines - Water Quality - Kinross Industrial Estate, Heatherbrae, April 2003.

STORM CONSULTING 2002: Hindmarsh Park Sand Filter Design Report – Prepared for: The Stormwater Trust and Kiama Council, Sydney; STORM CONSULTING Pty Ltd, 2002

Dunphy *et al* (2005): Confined Water Sensitive Urban Design (WSUD) Stormwater Filtration/Infiltration Systems for Australian Conditions; 10th International Conference on Urban Drainage, Copenhagen/Denmark, 21-26 August 2005; A. Dunphy & S. Beecham (Faculty of Engineering, University of Technology Sydney), C. Jones (Kiama Municipal Council), A. Collins (Hornsby Shire Council), M. Liebman (Storm Consulting Pty. Ltd.), J. Wells (HydroCon Australasia Pty. Ltd.), P. Michael (Residual Pty. Ltd.).