
A Waterways Impact Statement

for

**Lot 810 (No 74) in DP 752038 Willandra Road
NARRAWEENA NSW 2099**



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Document Registration

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This Waterways Impact Statement has been prepared in March 2017 as a report on the current situation and potential development impact on any waterways within Lot 810 in DP 752038 (No. 74) Willandra Road NARRAWEENA NSW 2099.

It is time and site specific and must not be used for any other purpose.

Executive summary

This Waterways Impact Statement concerns Lot 810 in DP 752038 (No 74) Willandra Road NARRAWEENA NSW 2099 (application DA2014/1164 (as modified)). A boarding house is proposed for lot 810. There are minor creases and depressions in lot 810 however these are not continuous and become indiscernible. They do not have defined beds or banks. They are therefore not considered to be 'waterways'.

This lack of waterways is consistent with Council's own mapping of streamlines in the area. Council's WETLAND BUFFER CONSTRAINT MAP (WC, 2006), shows a wetland buffer extending into the SW portion of lot 810. The development area is downslope of any wetland area and construction of a single building in the eastern portion of the lot, adjacent to Willandra Road, would have no impact on the wetland. It is also likely that the street drainage system along Lady Penrhyn Drive has captured a high proportion of flow from the upper catchment and conveyed it directly to the pipe under Willandra Road. Consequently the reason for the buffer area in the western portion of lot 810 is no longer present.

An assessment of the potential impacts from construction and occupation of the dwelling determined that a combination of:

- An approved Erosion and Sediment Control Plan (ESCP) for BOTH the boarding house and the access route,
- Inclusion of at least 6000 L of rainwater tanks connected to toilets and garden hoses and,
- Use of rubble drains and level spreaders to disperse any overflow from the tanks,
- Turfing cleared areas with stolonaceous grass such as native couch is required to prevent mobilisation of unconsolidated sand,
- Installation of an appropriate drainage system to convey and then disperse any lot runoff around the dwelling

means there will be minimal risk of impact to any waterway or wetland buffer. The distance from the riparian zone at the extreme north of lot 810 means that the development is consistent with both the state (Office of Water, 2012b) and Warringah Council (undated) requirements.

It is recommended that the ESCP, the 6000 L rainwater tanks, the rubble drains, the level spreaders and the drainage system designed to convey runoff around the dwelling all be required as part of the site approval conditions.

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1. Background

Notes from a Development Assessment Report p (DA 2014/1164) contains the following paragraphs:

- 7. Issue:** *“The site will not manage wastewater effluent disposal and it will cause pollution of stormwater and affect water quality of the Narrabeen Lagoon catchment, including natural hydrology and vegetation of the Sandstone Gully Forest type”.*

Comment: The proposal has been submitted with a *Wastewater Management Plan* (dated 3.10.2014) and a later report dated 19.9.2014 but received 6.2.2015) and a *Waterways Impact Statement* (dated 22.9.2014) to address water quality risks as well as provide details of the effluent disposal system proposed. The application was referred to Council’s Environmental Health and Protection Section and NEU section for comment. Both Sections have raised objection and detailed concerns in relation to matters concerning water or sewerage facilities including potential health and pollution issues. The site drains into Wheeler Creek and eventually the Narrabeen Lagoon and areas of the catchment in the vicinity of the site are of a “Category A”, high conservation significance.

It is considered that the high intensity of the use will exacerbate adverse impacts on the natural environment and therefore this matter warrants refusal of the application.

The proponents have taken Council’s comments ‘on-board’ and have made significant changes to address Council’s basis for the refusal of the DA. Significant changes include:

1. Connection of the proposed dwelling to Sydney Water Corporation sewerage system.
2. Reduction in the number of bedrooms and therefore the likely impact on the subject suite.

This Waterways Impact Statement addresses remaining concerns on downstream conditions, taking the above changes into account.

The report format follows Warringah Council’s

‘GUIDELINES for Preparing a Waterways Impact Statement’.

2. Current site conditions

Location and context

The subject site is at 74 (lot 810,DP752038) Willandra Road NARRAWEENA.



Figure 2.1. The location of the lot that is subject of this Waterways Impact Statement.

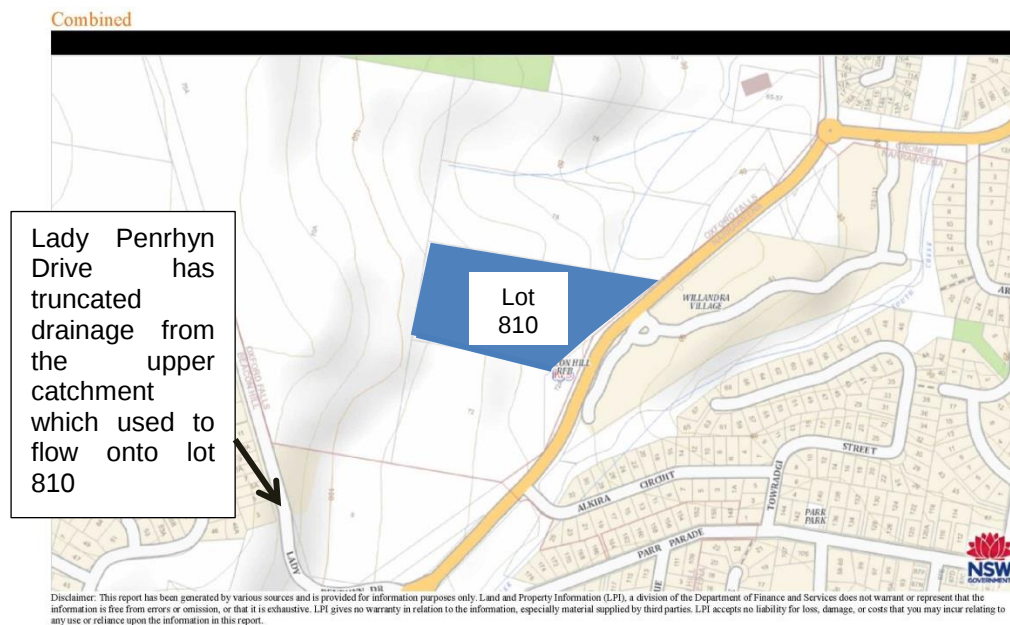


Figure 2.2. The lot showing its relation to other developments and drainage systems in the area.

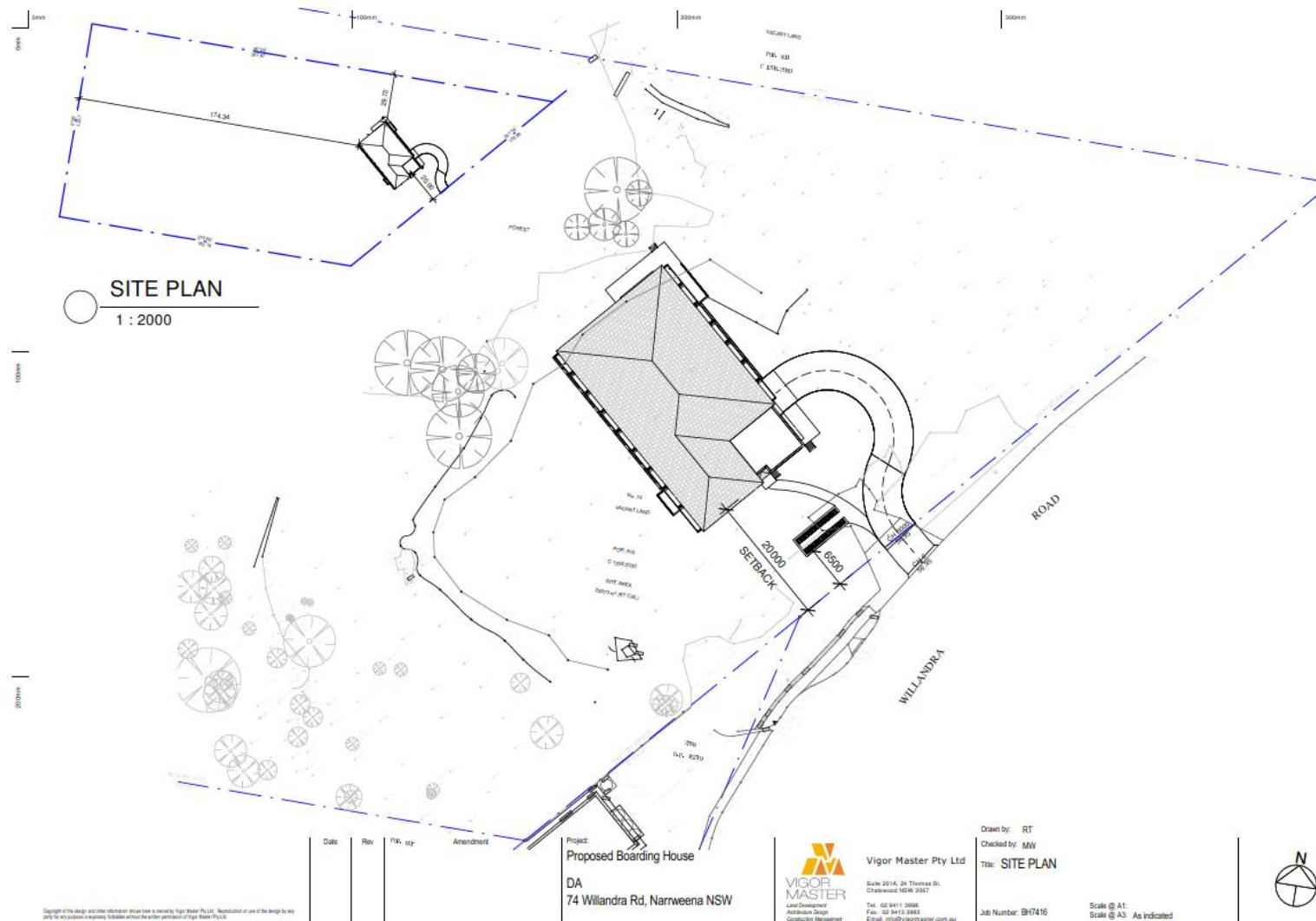


Figure 2.3. Proposed plan of the development. Note the insert showing the scale of the proposed development in terms of the size of the entire lot.



Figure 2.4. Indicative footprint of the proposed dwelling.

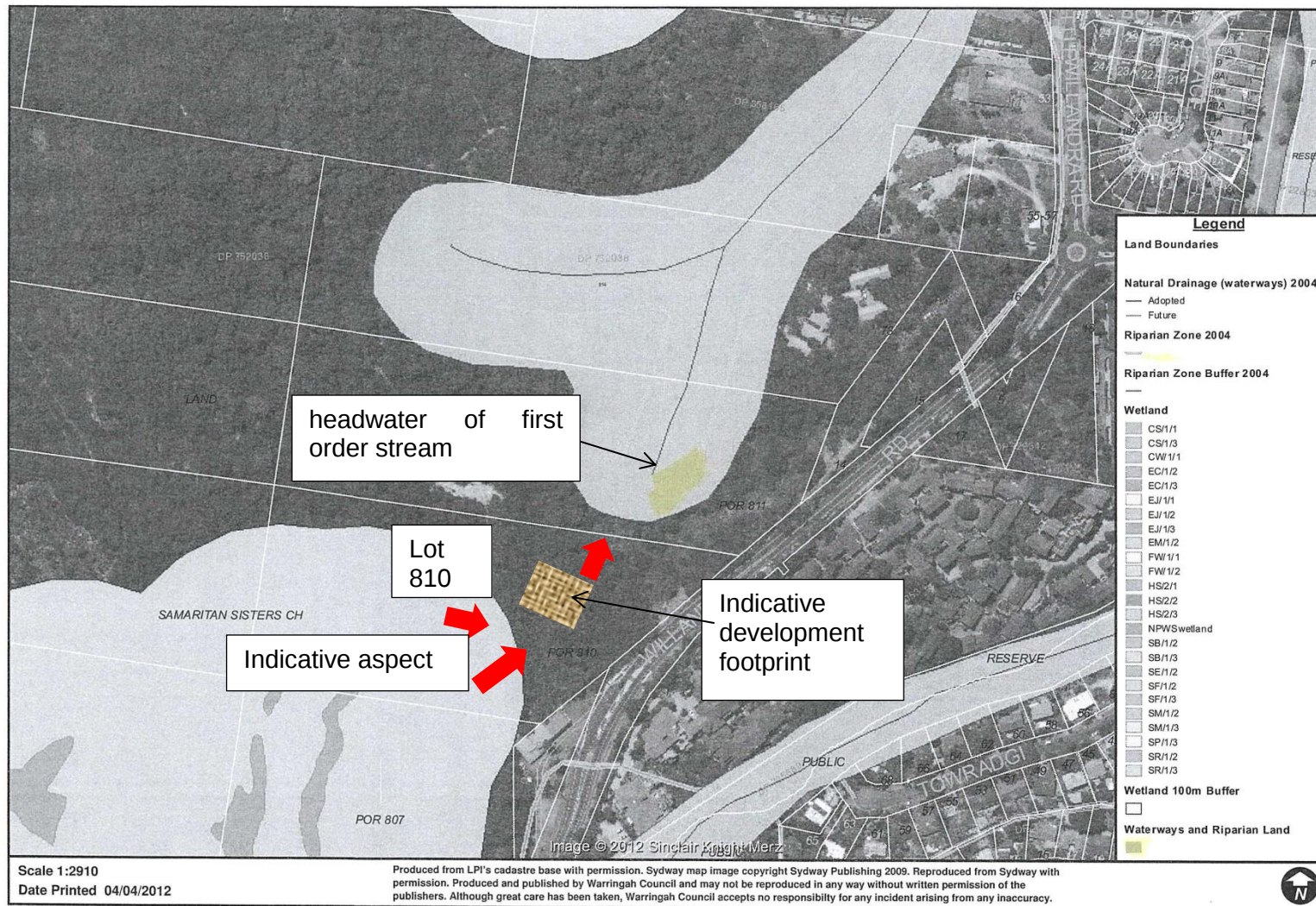


Figure 2.5. The site showing the wetland buffer extent on Council's maps.

Note that the proposed development is downslope of the wetland buffer. The arrows in red show the general slope on this portion of lot 810.

Photo essay on lot 810

The site was inspected in March 2017. The aim was to determine if there were any waterways that could be impacted by the proposed development.

Figure 2.5, above, shows that the proposed dwelling footprint lies beyond and downslope of the wetland buffer zone shown on Council's maps.



Figure 2.6. Prior to clearing the site had large quantities of building rubbish dumped on it. This has now been removed.



Figure 2.7. Weeds were a major issue in the northern portion of the lot. These have now been cleared.



Figure 2.8. The development area has been cleared and graded to an even easterly aspect slope. The RFS building can be seen in the background.



Figure 2.9. Overview of site looking approximately north west from the SE entry point off Willandra Road. Photo date 20.3.2017.



Figure 2.10. Overview of site looking south west and upslope from the SE entry point off Willandra Road. The RFS building is in the upper LHS of the photo. Photo date 20.3.2017.



Figure 2.11. Overview of site looking north from the entry point from the SE entry point off Willandra Road. Photo date 20.3.2017.



Figure 2.12. The northern border area of the lot in August 2014.



Figure 2.13. There is a bare slope near the northern border of the development area. This has been eroded since exposure in 2014. It needs to be turfed to prevent further loss of soil.



Figure 2.14. The silt fence parallel to the northern border in March 2017. The native couch grass sward is providing an effective sediment trap. There is minimal 'escape' of sand off the lot and moving north.

Any 'escaped' sediment is trapped within a few metres.

3. Surface drainage in the development area of lot 810.

Figure 2.5 shows that the local topography slopes towards the development footprint from the southwest and the north west.

Runoff onto the cleared area is via non-concentrated flows and largely dissipates within the relatively flat development areas. This is illustrated in the figures below.



Figure 3.1. Runoff water flowing over rocks and entering the cleared area (photo 20.3.2017).



Figure 3.2. Seepage from the adjacent sandstone hills flows onto the flatter portion of the site and forms braided flow paths. Photo date 20.3.2017.



Figure 3.3. Storm runoff flows within the development area consist of extremely shallow, shifting depressions which have a braided planform. Photo date 20.3.2017.



Figure 3.4. After prolonged rainfall in March 2017, the widest flow path was 150 to 200 mm wide and a maximum of 3mm deep. Photo date 20.3.2017.



Figure 3.5. The stormwater runoff has created saturated sands in some areas during March 2017. Photo date 20.3.2017.

Comments on the surface drainage conditions in the development area within lot 810.

- There are no defined waterways within lot 810.
- Any overland flow on the remainder of the lot infiltrates into the sandy soil wherever the slope becomes less steep.
- There are no continuous drainage lines on the lot, rather the storm runoff forms a series of braided flow paths which disappear as soon as the dry weather returns.
- There is an exposed bank near the northern border of the development area. This needs to be turfed with a stolonaceous species such as native couch (*Cynodon dactylon*).
- Native couch is playing a significant role in trapping the sandy sediment. It should be the key vegetation in areas where runoff is likely to occur.

4. Waterway analysis

Catchment

The drainage system near lot 810 arises from two directions as shown in figure 2.5.

The runoff onto the development area of lot 810 is via diffuse flow from the north west and the south west. The development footprint is within an area with a 2 to 4% slope to the north. This combination of low slope, diffuse flow and often relatively deep sand means that surface flow is only evident during prolonged periods of wet weather such as in March 2017.

Hawkesbury Sandstone underlies the entire area. The rock armours the base of the braided flow paths inhibiting further incision.

Any outflow from lot 810 eventually joins the headwaters of a first order stream which flows in an approximate NE direction across lot 811.

Impacts of proposed development

Extend of development

The proposed development on lot 810 consists of a single building as shown in figure 2.3. Based on the previously approved DA, an access driveway and an asset protection zone (APZ) has been cleared around the proposed building footprint.

The area cleared is some 0.50 ha or some 17% of the 2.86 ha lot.

Proposed activities that could impact on the waterways

Figure 2.3 shows the location of the development. The development activities include:

1. Clearing an APZ to Council's specifications,
2. Construction of an access track,
3. Installation of services including water, sewerage, electricity and telecommunications,
4. Construction of a single building
5. Provision of an onsite sewage management system

Potential impacts of the development

Figure 2.4 shows that the footprint of the development area is over 8 m away from the commencement point of the waterway. This is more than five times the 10m riparian zone width for a first order stream (Office of Water Guidelines for Riparian Corridors on Waterfront Land (2012a).

The dwelling footprint is within bushland which has been the subject of a separate ecological study. Its position in bushland means that it should have significant rainwater tanks for fire fighting. Additionally tanks can be used to manage stormwater impacts. The tanks should be connected to the toilets and also used for garden water supplies. The fire fighting volume needs to be considered separately from the stormwater storage capacity.

An Erosion and Sediment Control Plan is essential prior to construction of the dwelling. The ESCP should also address management of impacts of the access track.

The soil landscape is 'Lambert' (Chapman and Murphy, 1989). This soil landscape has a very high soil erosion hazard, largely because the sandy soil has minimal coherence, and would be readily mobilised by concentrated flow. In the current situation, the vegetative debris and low to moderate slopes on the eastern portion of lot 810 reduce erosion risk.

Apart from the construction footprint, the entire development area should be turfed.

Connectivity between the drainage system and the bushland.

Figure 2.4 shows that connection between the bushland and any runoff occurs in the northern half of the adjacent site, lot 811. This is over 100m from the development footprint on lot 810.

Additionally some of lot 810 drains towards Willandra Road. However the sandy soil and relatively low slope in the eastern portion of the lot (facing Willandra Road) means there is no coherent surface drainage system.

Erosion issues

Figures 2.7 to 2.9 shows that the southern portion of the lot has been cleared. The clearing has exposed sandy soils. These should be kept covered with vegetative litter and plants to reduce erosion risk.

As mentioned above, an ESCP will be required for the building and the access route.

5. Assessment of impacts

Impact on water quality

Provided

- the dwelling on lot 810 is located as per figure 2.3.
- the dwelling has an appropriate ESCP
- the access route is included in the ESCP
- the dwelling has rainwater tanks of at least 6000 L capacity PLUS fire fighting volume
- the dwelling is connected to SWC sewer.

the impact on water quality will not be measurable.

The reasons for this conclusion are:

- The dwelling on lot 810 is over 58 m away from the commencement of any 'waterway' as figure 2.5 shows.
- The eastern portion of the site has a low grade and once the vegetative cover is restored there will be minimal sediment mobilisation.
- The APZ border is at least 100m from the commencement of any 'waterway'.
- The conveyance of sewage to SWC sewers will minimise the risk to the local environment.

Impact on channel form

The dwelling would normally add to stormwater runoff. However the combination of

- sandy, high infiltration soils,
- no defined drainage lines,
- rainwater tanks,
- use of stolonaceous native couch as the lawn for the cleared area
- use of rubble drains to spread tank overflows, and
- the more than 58 m buffer distance to the nearest drainage line

means that there will be no measureable impacts provided an adequate erosion and sediment control plan is implemented prior to construction.

Impact on stormwater discharge points

It is expected that overflow from the dwelling's rainwater tanks on lot 810 will be added to a rubble drain that is installed along the contour (effectively acting as a level spreader). This will be designed to ensure that there are no concentrated flows from the area.

The access route should include a combination of cross fall to the lower side and, mitre drains to ensure there is minimal flow concentration.

Ecological impacts of the development

This issue is reported upon via the ecological study prepared by another organisation.

Landscape impacts of the development

The development on lot 810 has required clearing bushland to establish an access route, dwelling construction and creation of an APZ. It is understood that these

activities are consistent with Council's LEP and the 10/50 vegetation clearing entitlement area (as per the RFS website, accessed 3.10.2014).

The access route will be designed to have minimal cut and fill. The dwelling will also require minimal impact on the landscape.

Flood assessment

The development envelope is on a mid hillslope position. Following intense rainfall there will be free water on the site. A drainage system will convey water around the proposed dwelling and dissipate it via a level spreader across the slope.

Bank stability

The dwelling on lot 810 is over 58 m away from the commencement of any drainage line as figure 2.5 shows. No impact of the dwelling on bank stability is expected.

Vegetation removal

Vegetation has been removed for the access route, the APZ and the dwelling.

This issue is reported upon via the ecological study prepared by another organisation.

Modifications to natural creeklines or overland flow

The dwelling on lot 810 is over 58 m from where a small drainage system arises.

This result indicates that there is no need to modify creeklines.

Overland flow increases from roof runoff will be addressed via a combination of rainwater tanks, shallow rubble drains and level spreaders

The stormwater system on lot 810 is designed to ensure no measurable impacts occur.

6. Provision of mitigation measures

Outcome 1. Protection of native species and communities

The proposed responses to each of the performance criteria are listed below in table 6.1.

Table 6.1. Potential impacts on native species and the proposed responses.

Performance criteria	Response
Maintain natural habitats	No damage to riparian habitat on lot 810 is anticipated as there is no riparian habitat on the lot. The main concern is to prevent further mobilisation of loose sand. This will be achieved by turfing the exposed areas with a stolonaceous species such as native couch. Clearing to create an APZ is necessary and consistent with Council requirements and the RFS web site guidelines. There is some 24 m of bushland between the northern border of the APZ and the commencement of any waterway. The on-site sewage system will installed, rather the wastes will be piped to SWC sewers.
Provide fauna movement routes	No impact on connection of riparian zones OR fish movement is anticipated
Prevent unnatural erosion or sediment deposition	An ESCP and the rainwater tanks are designed to ensure there is no additional erosion or sediment deposition. No additional peak flows or total sediment loads are anticipated PROVIDED the development envelope beyond the building footprint is turfed areas with a stolonaceous species such as native couch.
Maintain acceptable water quality	Lodge AND implement a council approved sediment and erosion control plan. Include turfing as outlined above. Install at least a 6,000 L rainwater harvest system. Include level spreaders to dissipate roof drainage.
Maintain connectivity between waterways and floodplains	No impact is anticipated. The minimum of 50m from any stream line to any disturbance will assist this process.

Outcome 2: Prevent loss of natural diversity through protecting waterway and riparian vegetation (including non-native vegetation)

The proposed responses to each of the performance criteria are listed below in table 6.2.

Table 6.2. Potential impacts on natural diversity and the proposed responses.

Performance criteria	Response
Avoid introducing plants or animals which may displace natural species	Require construction vehicles entering lot 810 to be clean. Be vigilant for weeds introduced during construction. Plants used in association with any gardens to be local indigenous plants. Ensure that the APZ is not over maintained. (i.e. encourage growth of low growing locally indigenous plants). Install native couch (C dactylon) as the turf species.
No increase in nutrient loads to riparian soils and waterways	Use agreed ESCP and include at least 6000 L rainwater tanks connected to toilets, laundry and external taps. No additional peak flows or total sediment loads are anticipated provided the development area is turfed
Avoid displacing species by habitat changes	No riparian buffer on development area. Current habitat is largely bare sand. Native couch will stabilise this.
Protect natural areas from contamination	• No activities which may contaminate soils or vegetation • No onsite sewage system'.
Prevent the loss of any rare or threatened natural features	No loss is anticipated
Protect downstream protected areas	The more than 58 m distance to any defined drainage system and the use of 6000 L rainwater tanks will ensure no measureable impact.

Outcome 3: Minimise damage to public and private property by waterway processes through maintaining the relative stability of the bed and banks.

The proposed responses to each of the performance criteria are listed below in table 5.3.

Table 6.3. Potential impacts on bank stability and the proposed responses.

Performance criteria	Response
Avoid increases in peak channel flows and sediment exports for events smaller than 2 year Average Recurrence Interval (ARI).	The minimum of 58 m distance to any drainage system and the use of 6000 L rainwater tanks will ensure no measureable impact for the proposed development on lot 810 (see figure 2.5). The sandy soil means there is minimal overland flow until the entire site is saturated
Avoid local erosion at stormwater outlets	Use agreed ESCP and include at least 6000 L rainwater tanks connected to toilets, laundry and external taps. The dwelling is over 58 m from the defined drainage system and so will not impact on it. Rubble drains and level spreaders will dissipate flows within the APZ. Turfing with native couch will stabilise the cleared area.
Avoid export of weeds from private properties into waterways	No disposal of garden refuse into drainage systems. Install a vegetated swale along the E-W edge of the development area.
Channel banks are not over steepened	E designated drainage line commences some 58 m away. Therefore the proposed stormwater management items combined with dissipation of flow over stolonaceous turf will minimise risk to channel banks.
Channel banks are stable	No loss of bank stability is anticipated Ensure native couch turf is used to line any swale.

Outcome 4: Preserve natural ecological processes.

The proposed responses to each of the performance criteria are listed below in table 6.4.

Table 6.4. Potential impacts on natural ecological processes within lot 810.

Performance criteria	Response
Streamflow and water quality are natural.	• No artificial barriers to capture water • No removal of water for consumptive use • Impervious surfaces offset by stormwater management controls so there is no net change in peak loads or pollutant loads in waterways • Site design adheres to best practice Water Sensitive Urban Design principles AND • On-site activities do not involve specific risks to water quality (e.g. chemicals, organic materials, exposed soil, sewage is sent to sewer) NOTE: The more than 58 m distance to any drainage system and the use of 6000 L rainwater tanks will ensure no measureable impact.
Aquatic and riparian vegetation are undisturbed and unmodified	All development is at least 58 m from any drainage line and is therefore consistent with Office of Water (2012) guidelines. Rubble drains and level spreaders will dissipate flows within the APZ.
Aquatic and riparian fauna habitat and movement corridors are retained	No impact on stream beds or banks is anticipated.

Outcome 5: Create opportunities for public access and recreation in waterway corridors.

The proposed responses to each of the performance criteria are listed below in table 6.5.

Table 6.5. Opportunities for public access and recreation on lot 810.

Performance criteria	Response
Provide public access along creek corridors where appropriate.	Not applicable because: • No creeks present • Private property • No tracks

7. Wetlands

Figure 2.5 and 7.1 show that the development footprint on lot 810 is downslope of any identified wetland buffer. The development will therefore have no impact on wetland hydrology.

Conclusion

The proposed development and its APZ will have no impact on the wetlands or wetland buffer shown on Council's 2006 map.

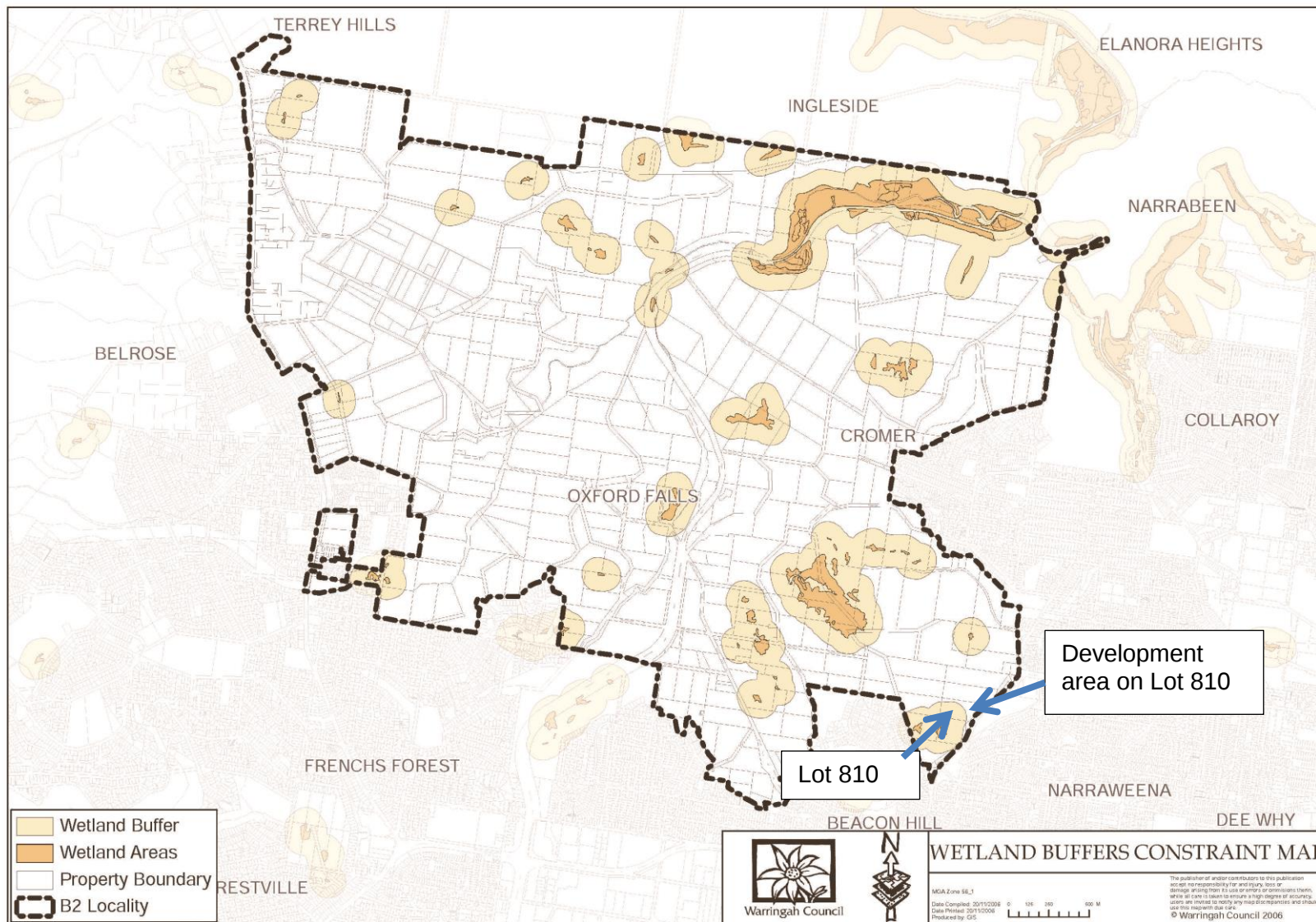


Figure 7.1. Warringah Council's Wetland Buffers Constraint Map (Source: WARRINGAH Council's web page, accessed 13.2.2013).

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Dr. Peter Bacon: Curriculum Vitae

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Born

Sydney, Australia

Qualifications

- Bachelor of Science in Agriculture, University of Sydney
- Master of Science in Agriculture, University of Sydney (Irrigation and nutrition)
- Doctor of Philosophy, University of New England (Soil, water and land management)

Professional certifications

- Certified Environmental Practitioner
- Certified Practising Soil Scientist (Stage 3 Leading professional)
- Certified Professional in Sediment and Erosion Control

Associations

- Stormwater Industry Association
- Environment Institute of Australia
- Australian Association of Natural Resource Management
- River Basin Society
- Soil Science Society of Australia
- International Erosion Control Association
- Churchill Fellows Association of NSW.
- Institute of Foresters of Australia.

Experience

Dr. Peter Bacon has over 35 years' experience in managing water and soil systems. In this time he has published over 250 articles, ranging from expert systems to international reviews. (Full list is available on request).

Between 1973 and 1994 Peter was employed by the (now) NSW Department of Industry and Investment. In 1988 he was promoted to Senior Research Scientist.

In 1991 he was made leader of the Soils and Hydrology section of State Forests research.

In 1992 he was awarded a Churchill Fellowship to study water management in South Africa, Israel, Portugal and the USA. Specific aspects included modelling urban water quality changes on land and in wetlands and the effects of effluent and biosolids on aquatic ecosystems.

In 1993 he established Woodlots & Wetlands, an environmental consultancy specifically aiming at development of environmentally sound solutions to problems associated with the water cycle.

In 1993 he co-ordinated and was senior author on the Land-use Issues Strategy for Wetlands in the Murray Darling Basin.

In 1995 he was engaged by ANCA to produce the NSW chapter of the second edition of '*A DIRECTORY OF IMPORTANT WETLANDS IN AUSTRALIA*'. This required assessment of information in the original document, and has resulted in a document including assessment features such as Location, Area, Physical Features, Significance rating, Hydrological characteristics, Ecological description, Conservation value and management input requirements, Disturbances and threats, Land tenure, Current land use, Management Authority and Jurisdiction.

He has applied the flow component analysis and the assessment of impacts on key habitat to numerous rivers impacted by dams and regulated discharge.

More recently he undertook assessment and modelling of landuse impacts on ecological health of the Macquarie Marshes. He also provided expert witness to an Environment Australia case involving degradation of the Gwydir River Wetlands. In 2006/07 he undertook a major investigation, assessment and prioritisation of wetlands in western NSW. As part of this project he produced a field manual for environmental assessment of wetlands.

In 2008/09 he undertook detailed investigations on the environmental requirements of streams and wetlands in the Border Rivers region of northern NSW. In 2011/12 he assessed environmental flow needs for streams in NSW and Tasmania.

Dr. Bacon is currently managing director of Woodlots & Wetlands Pty. Ltd., an environmental consultancy and management company with a focus on land and water management. He is also Chair of the national professional certification committee for the International Erosion Control Association, Australasian Branch.

He guest lectures on environmental risk and on wetland management to post graduate environmental engineers at UTS. He is an honorary fellow of this university. In 2014 he guest lectured at the School of Environmental Law at Macquarie University.

Fields of Special Competence

- Managing stormwater impacts from urbanisation
- Erosion management in relation to urbanisation
- Stormwater management especially in relation to Water Sensitive Urban Design (WSUD)
- Modelling stormwater behaviour and its impacts on water quality
- Stream management
- Integrated Water Cycle Management (IWCM)

Professional Experience

Indicative projects include:

- **Fluvial geomorphological investigations along the Wingecarribee, Shoalhaven, Kedumba and Nattai Rivers and Werri Berri Creeks**

These studies were part of a project aimed at long term improvement of waterways within the SCA hydrological catchment.

- **Establishment of environmental flow needs for the Nepean River below the Nepean Dam.**

Peter led a multidisciplinary team in this study. The project used physical habitat simulation to calculate the flows needed to meet agreed environmental objectives. Peter undertook the fluvial geomorphological investigations and modelled the hydraulics and hydrology of the river.

- **Establishment of environmental flow needs for the Cordeaux River below the Cordeaux Dam.**

Peter undertook this investigation with a team of specialist aquatic biologists. He undertook the hydrological and hydraulic investigations and developed habitat preference curves for a range of local aquatic biota. The results were published in the Australian Stream Management Conference in Launceston.

- **Establishment of regulated discharge from Wingecarribee Reservoir on the downstream aquatic environment.**

Peter measured regulated discharges from the reservoir and related stream velocities and depths to habitat preference curves. He examined the stream velocities and modelled these against observed bank erosion rates. He then developed a series of operating guidelines relating discharge conditions to aquatic habitat maintenance.

- **Impact of regulated discharge on flow regime and the aquatic habitat downstream of Cataract Dam.**

This study involved an understanding of the aquatic and environmental conditions both up and down stream of the Cataract Dam. Peter undertook detailed vegetation assessment and hydraulic investigations to establish the impacts of the regulated discharges on fluvial geomorphology and aquatic habitat.

- **Identification of environmental flow needs downstream of a 10,000 ML dam on Dunns Creek in the Upper Ringarooma Catchment**

Peter used the Eflows and physical habitat assessment procedures to determine the environmental flow requirements in the Upper Ringarooma Catchment. A key component of the project was development of understanding of how changes in flow regime would impact on fluvial geomorphology

Identification of environmental flow needs for 7 Tasmanian Dams

This project aimed to quantify impacts and environmental flow needs of 7 NE Tasmanian Rivers onto which it was proposed to construct a series of dams. Peter led a team from UTAS and Fluvial Systems.

- **Need for environmental flows in the Avon River.**

This river has a dam from which there is no regulated discharge. The project aimed to identify the minimum discharge needed to maintain the downstream aquatic habitat. Peter undertook studies on the aquatic and riparian flora to identify their needs. He then assessed the stream hydraulics using the RAP package and developed flow recommendations for this river system.

- **Assessment of Crooked Creek geomorphology and potential for improving aquatic conditions**

Crooked Creek is an effluent stream of the Macquarie River. It currently conveys an average of 14.6 GL/year. This flow is up to 3 times the indicative predevelopment flow. The current regulated flows have resulted in stream widening and shallowing. Peter undertook a geomorphological investigation to establish the potential impacts and benefits from re-establishing a more natural flow regime.

- **Ecological requirements, values and flood responses of floodplain vegetation on the Upper Darling River**

This project was undertaken as a subcontract to URS. Peter identified the flood needs of key ecosystems and developed approaches to minimise floodplain impacts.

- **Ecological requirements of Macquarie Marsh flora.**

This project was undertaken as a Subconsultant to DHI. Peter identified the riparian and aquatic vegetation associations and the position on the landscape relative to a range of flood intensities. He then developed models of the water requirements for different ecological communities.

- **REF for Copeton Dam upgrade**

The project involved managing a multidisciplinary team of ecologists, fish biologists, planners, hydraulic engineers and planners to establish the potential impacts and mitigation actions for a \$54m upgrade.

- **REF for safety upgrade of Split Rock Dam**

The project involved managing a multidisciplinary team of ecologists, fish biologists, planners, hydraulic engineers and planners to establish the potential impacts and possible mitigation actions for a \$14m upgrade.

- **REF for safety upgrade of Wyangala Dam**

The project involved managing a multidisciplinary team of ecologists, fish biologists, planners, hydraulic engineers and planners to establish the potential impacts and possible mitigation actions for a \$20m upgrade.

. There are hundreds of other projects that Peter has undertaken. However the above list provides an indicative 'feel' of the type of work undertaken in aquatic and riparian environments.

Management of natural wetlands

- **Wingecarribee Shire Wetlands Management Strategy.**

Woodlots & Wetlands assessed over 450 wetlands in the shire and then developed a management strategy based on maintaining ecological values of the wetlands consistent with their current condition and uses. This study required assessment of numerous types of montane wetlands including peat swamps

- **Assessment and prioritisation of wetlands in western NSW.**

Woodlots & Wetlands have been engaged by the Western CMA to inspect, assess and prioritise wetlands in western NSW to ensure funding is appropriately targets to environmentally and culturally significant sites. Over 110 wetlands have been assessed. A wetland assessment manual has been produced.

- **Assessment and prioritisation culturally important wetlands in the Border Rivers Gwydir CMA.**

Peter Bacon and Sue Hudson undertook cultural and environment investigations of 195 wetlands in the catchment. The report forms the bases for CMA investment in protection of cultural values.

- **Assessment of flood management on the ecological health of Macquarie Marshes.**

Woodlots & Wetlands were contracted by NPWS to assess the impacts of lack of flooding on River Red gum vegetation.

- **Assessment of cropping impacts on portion of the Gwydir Wetlands.**

Environment Australia engaged Woodlots & Wetlands to assess the damage to wetland functionality of unauthorised ploughing of some 4000 ha of this Ramsar listed wetland.

- **Assessment of the impacts of NSW Water Management Plan for the Murrumbidgee Valley on the Lowbidgee Wetlands.**

This 39,000 ha wetland is under threat from abstraction of water for irrigation. Peter's task was to assess the current and potential future long term impacts of reduced water availability on the long term viability of this wetland.

- **Plan of Management for Jerrabomberra Wetlands.**

Environment ACT contracted Woodlots & Wetlands to prepare a revised PoM for the 172 ha wetland located adjacent to Lake Burley Griffin.

- **Assessment of State Forest's logging practices on the long term sustainability of the Murray River Forests.**

The federal Department of Environment, Water, Heritage and the Arts commissioned Dr Bacon to examine the impacts of logging intensity on the forest system including the habitat of the superb parrot.

Management of streams and rivers

- **Development of a Riparian Zone Management Plan for Farmers Creek Lithgow.**

This study involved the main urban water way in Lithgow. The plan provided an integrated scheme for rehabilitation of riparian vegetation, repair of creek banks, reduction in contaminant load and managing flood flows. Peter undertook hydraulic capacity studies as part of the assessment.

- **Resource inventory and action plan for water quality improvements - Goulburn City Waterways.**

This study was undertaken on behalf of Goulburn City Council. Woodlots & Wetlands led the project team. Dr Bacon's roles included: Community consultation, project management, catchment assessment, stream geomorphological assessment, water quality assessment, urban impact assessment, identification of potential stormwater quality control points and suitable Stormwater Quality Improvement Devices.

- **Development of a vegetation management strategy for Maxwells Creek.**

Woodlots & Wetlands are part of a team determining the optimum methodology for re aligning Maxwells Creek following urban development. The issues addressed by Woodlots & Wetlands include aquatics plant configuration, scour protection, location and dimensions of riffle and pool sequences. Woodlots & Wetlands were also responsible for developing a detailed site action sequence for the erosion and sediment control system. .

- **Assessment of stream condition in the Hornsby Shire.**

Woodlots & Wetlands were part of a team that examined the status of 20 waterways within the Hornsby Shire. Woodlots & Wetlands roles include assessment of stream condition, the health of the riparian vegetation, and the likely impacts of pollution on water chemistry.

- **Vegetation Restoration Plan for a portion of the Hunter River.**

This was a plan developed for Coal & Allied Mines who wished to restore approximately 10 km of degraded bank along the Hunter River. Peter was responsible for the planning, design and implementation of the project.

- **A vegetation restoration plan for portion of South Creek.**

This was a practical plan designed to stabilise the banks and improve water quality within the lower portion of South Creek. Hawkesbury City Council has adopted the plan in full.

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- **Restoration of minor streams as part of urban development procedures.**

Dr Bacon has been engaged by several companies to develop stream restoration plans that ensure urban developments do not result in increased bank erosion.

- **Cooma Creek Vegetation Management Plan.**

Woodlots & Wetlands were engaged to prepare a vegetation management plan for the Creek following realignment and deepening as part of a flood mitigation program. The design considered issues such as species suitability, effects on stream ecology and effect of vegetation configuration on Manning 'n'.

- **Rehabilitation of Duck River.**

Woodlots & Wetlands undertook detailed planning for the stabilisation, decontamination and restoration of Duck River for Auburn Council.

- **Assessment of environmental impacts of dredging in Duck River and its tributaries.**

This study was undertaken for Parramatta City Council. It involved integration of social and environmental issues to determine the most suitable procedure for removing accumulated sediment.

- **Stabilisation of Freshwater Creek, Chullora.**

National Rail is developing a freight terminal in Western Sydney. The new rail lines will impact on adjacent waterways. Woodlots & Wetlands were engaged to design creek profiles that would enable stabilisation, following changes in the catchment. The designs take into account new culverts, bank stabilisation and vegetation.

- **Stabilisation of Shipwrights Bay drainage system.**

This drainage system was deeply incising into landfill and rubbish dumped in Shipwrights Bay Reserve. Woodlots & Wetlands modelled and designed stream bed stabilisation along the drainage line. Dr Bacon personally supervised the installation of the rock and stabilising vegetation.

- **Assessment of dam removal projects**

An illegal 11 ML dam required removal and the site reinstated in accordance with a Court Order. Dr Bacon undertook the entire design and supervision of the project including catchment hydrological and hydraulic investigations and provision of a VMP.

- **Impact of dam removal on downstream conditions**

As part of a large urban development there was a need to remove several large farm dams. Dr Bacon undertook the site investigations and provided reports on stream impacts.

Water Sensitive Urban Design (WSUD) projects

- Design of an integrated water management system for a 3000 dwelling development near Sydney that is not connected to a centralised sewerage system. The development will rely on recycled water for non-potable uses such as toilet flushing and garden watering.
- Investigation of potable and non-potable water needs for a 52 ha site at Kemps Creek. The site is to have 26 ha of warehouses. There is no centralised sewerage system and no town water.
- Design and retrofitting of WSUD elements to Taylor Street for Leichhardt Council. This project is in a highly urbanised catchment with a combination of street tree watering and bioswale development is required.
- Design of bioretention swales and raingardens for a highly urbanised area in the City of Sydney LGA.
- Design of bioretention swales and raingardens for 7 sites in Marrickville LGA
- Design of Stormwater collection, treatment and reuse train for the southern portion of Sutherland CBD. Woodlots & Wetlands undertook concept then detailed design for this project. It involved a combination of GPTs, Permeable paving in a car park, bioretention swales, bypasses, subsurface detention storage and irrigation onto adjacent fields.
- Design of an integrated water cycle management strategy for a 62 ha industrial development at Eastern Creek.
- Use of WSUD for modelling of water cycle for a 440 unit retirement village at Forresters Beach. An ecologically significant wetland was located below the development and the designs needed to ensure its preservation.
- Water Sensitive Urban Design strategy for a 75 ha development site west of Bathurst.
- WSUD principles application to a major redevelopment site at Kurnell. This study developed the concept of 'internal' processing of stormwater using the site's sandy soil in combination with underground stormwater tanks, swales and bioretention system to effectively disconnect the development from the regional stormwater system. Issues include adjacent marine areas, potential acid sulfate soils, flooding, contaminated soil and high rainfall.
- WSUD for urban developments by Wagga City Council. Woodlots & Wetlands were engaged by NSW Planning to develop detailed WSUD design for over 40 ha of urban developments. (See below).
- Application of WSUD to urban developments at Charlestown, Glendale, The Entrance and Terrigal.
- Design of WSUD elements for a 120 dwelling subdivision in central Queensland.

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- Development of an integrated water cycle management strategy for a 60 dwelling plus hotel and resort at Avoca. This site has challenging issues such as steep slope, no sewage system and no reticulated water supply.

Development Impact Management

- Water cycle management for a 200 lot subdivision at Figtree. Involved detailed modelling of stormwater systems to ensure Basix requirements were met. Development of swales and wetlands to minimise runoff impacts on streams. Flood risk, riparian vegetation and the need for water recycling were all addressed.
- Assessment of urban pond management systems for Marrickville Council. Key issues included algal blooms and pollutant management.
- Detailed design of a remediation strategy for Newland Reserve pond. This study required detailed investigation of pond bathymetry and hydraulics in order to develop a strategy to increase inflows and circulation within the pond.
- Detailed design of stormwater management systems for industrial developments in Sefton. This required assessment and evaluation of options to achieve results consistent with the Water Management Act (2000).
- Development of a strategy to enable redevelopment of a large scale industrial subdivision at Moorebank. The site is adjacent to Moore Lake and the design needed to be consistent with the Water Management Act 2000.
- Design of WSUD elements including stream bank stabilisation and rehabilitation for a major shopping centre development in Mittagong. The design needed to ensure peak outflows were not increased and that the development did not de-stabilise the adjacent stream bank.
- Assessment and development of management strategies for a series of industrial developments adjacent to Toongabbie Creek.
- Development of detailed water, soil and vegetation management for a large scale industrial subdivision in Minto.
- External review of water cycle components of a 2200 home development for Auckland City Council.
- Design of water and wastewater management systems for a sustainable 32 unit apartment development in the Rocks.
- Audit of urban impacts on the condition of 20 streams and their associated sediments in Hornsby Shire. This study required an assessment of physical and chemical impacts of urbanisation on stream condition including aspects such as bank stability, habitat retention and water quality. Prioritisation of stream remediation was based on the ability to reduce current and likely impacts.
- Assessment of urban impacts on stream chemistry and condition at Goulburn and Lithgow.
- Preliminary design concepts for managing urbanisation in saline landscapes of western Sydney. This project involved modelling water management and salinisation over a 400

ha site. Key components included optimisation of the water cycle to create water features, playing fields and urban development without accelerating salinisation. The results were published by Dr Bacon in the proceedings of the 4th International Conference on Water Sensitive Urban Design, April, 2006.

- Provision of specialist consultancy services and advice to Department of Environment and Climate Change and local government regarding wetland management and health. Issues include changing landuse, stormwater management, erosion and sediment control and vegetation management.
- Design of integrated stormwater treatment systems for several 10 to 20 ha urban sectors in Warriewood Valley. (These involve sizing of water tanks, bioretention swales, dry retention basins, GPTs and wetlands to meet water quality criteria set by Pittwater Council).
- Design, obtaining approvals and installation of stormwater treatment devices in both Metropolitan and Country areas of NSW. These covered a wide range of sites where the quality of urban runoff is an issue; examples include sediment transport into Lake Macquarie, high faecal coliform populations in gutters of unsewered towns and leachate from landfills entering urban drainage lines.
- Stormwater management for industrial sites adjacent to drainage reserves. Numerous projects designed to ensure developments occur with minimal impact on adjacent waterbodies.
- Environmental assessment of the realignment of Maxwells Creek, Casula for the M7 and for industrial development. Peter assesses stream line stability, the use of rocks and the development of riffle zones. He supervised the maintenance periods for the site.
- Urban Capability Assessment of soils in western Sydney. These studies considered aspects including ecologically sensitive water bodies downstream of the sites and the need for water sensitive urban designs. Other aspects include site specific issues such as acid sulfate soils and salinisation. Total area was over 500 ha.
- Assessment of a series of Blacktown City Council industrial subdivisions in the Eastern Creek Catchment to ensure zero increase in peak runoff. These studies involved a combination of wetlands and swales to minimise impacts on adjacent creeklines.

Stormwater Management and other Water Cycle Management Projects

- Stormwater management strategies for Green Point. Peter provided soil and water management expertise to a team investigating management options for Green Point Reserve, Lake Macquarie.
- Stormwater management plans for Liverpool, Lower Parramatta, Griffith, Leeton, Walcha and Salt Pan Creek Catchments. These Plans are designed to provide strategic guidance to Councils in managing stormwater within their local area. A range of both structural and non-structural approaches was developed. Peter undertook community consultation over 15 times during the plan development.
- Development of stormwater management and monitoring strategies for the Lower Parramatta and Homebush Bay Catchments. Woodlots & Wetlands undertook these two projects for Sydney Water. They identified strategies to management water quality and quantity to minimise urban impacts on adjacent receiving waters.

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- Integrated Water Cycle Management studies for a range of Councils including Gunnedah, Warrumbungle, Glen Innes Severn and Liverpool Plains.
 - Assessment of the suitability of stormwater for a variety of end uses including golf course irrigation, and ecological enhancement. These studies required assessment of water quality and the potential risks in relation to end use, the development of treatment trains to minimise the risks and the practical design and implementation of these plans.
 - Design of wetlands to process specialised waste products for food factories, rifle ranges, refineries, wineries and starch manufacturers.
 - Design of stormwater treatment trains to treat and enable reuse onto sports fields as part of the Tempe Lands rehabilitation Project. Woodlots & Wetlands undertook stormwater treatment pond modelling and design to reduce contaminants exiting a major storage terminal adjacent to Sydney airport.
 - Provided external review for an 11 ha wetland designed to treat urban runoff from a 760 ha urban catchment in Auckland.
 - Prioritisation of urban stormwater management activities in the Lake Macquarie catchment. Peter undertook detailed investigation of sites throughout the catchment identifying and prioritising stormwater strategies for LMCC.
 - Development of a water balance and a water quality model for a 123 ha urbanised catchment on behalf of Marrickville Council.
 - Concept design of a water management system for Camdenville Park St Peters. Woodlots & Wetlands undertook water quality modelling, and concept design of the stormwater detention and reuse systems. The project will recycle water for use on an adjacent sports field.
 - Concept design for stormwater collection and use at Auburn Golf Course.
 - Assessment of the Alexandra Canal Catchment. This major study was undertaken for South Sydney Development Corporation. It identified and prioritised key contaminant sources and developed strategic plans to reduce their impact.
 - Jerrabomberra Wetland Management Plan. This project was undertaken as a joint venture with UBMC. It focussed on the potential for improving the wetland values despite urbanisation of the surrounding catchment and impacts for Lake Burley Griffin
 - Design of ponds and stormwater treatment systems at various sites for Bankstown Council. Woodlots & Wetlands designed water sensitive stormwater treatment systems to treat contaminated runoff.
 - Audit of all industrial operations in the Auburn Council LGA for their potential to impact on stormwater quality.
 - Assessment of options to supply sports fields with non-potable water. Options investigated included sewer mining, stormwater, industrial water, semi-saline creek water and recycled water supplied by SWC. Project required risk assessment, modelling of water quality and hydrology and detailed design of water treatment storage and transfer systems.

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- Development of water management systems associated with land management issues for the Albury, Scone, Merriwa, Dungog, Lismore, Coffs Harbour, Lithgow, Marulan, Goulburn, Yass, Clarence Valley, Byron, Gilgandra and Bathurst LGAs in NSW.
 - Design of a 5 ha stormwater treatment system to reduce contaminant load leaving the Narrandera township stormwater system.
 - Design and implementation of management systems to rehabilitate and stabilise urban streams. These streams were subject to pressure from sedimentation, or redevelopment of adjacent lands for activities including development of railway yards and industrial estates. Stabilising stream beds subject to increased flows was a key component of Peter's work.

Concluding remarks

Peter Bacon has a wide range of skills aimed at combining good science, concern for the environment and an understanding of engineering hydrology to find practical and economically feasible solutions to soil and water management in developing urban environments.

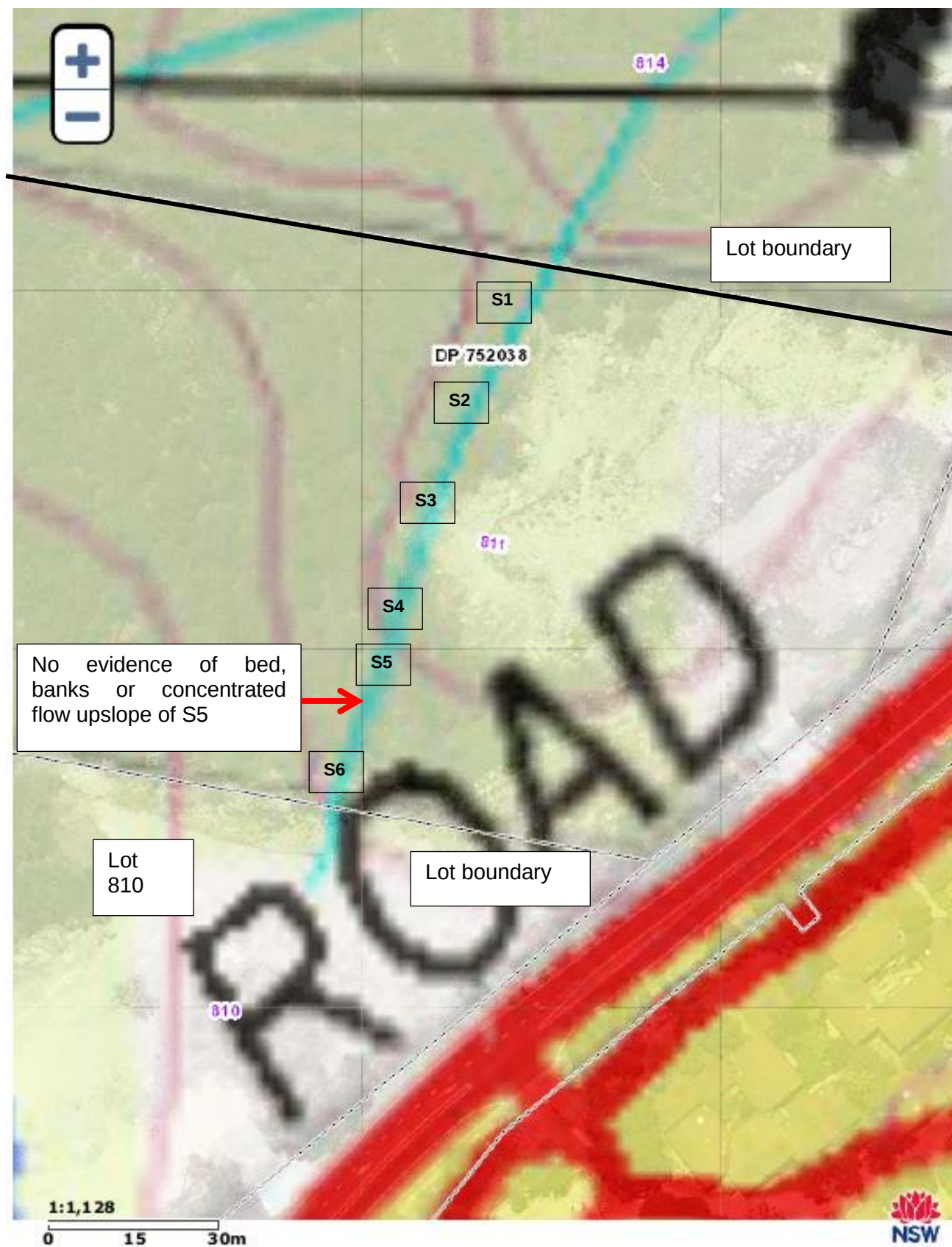


Figure 2. Portion of the lot showing the blue line on it. The six sampling points reported on below are shown as S1 to S6 (Image Source: NSW Dept. Lands, 2016).



Figure 3. Site 1.(339341 6264972) flow on, to below and among rocks. The large rock with the GPs on it has water flowing over it. There has been some sand mobilisation during intense rain events.

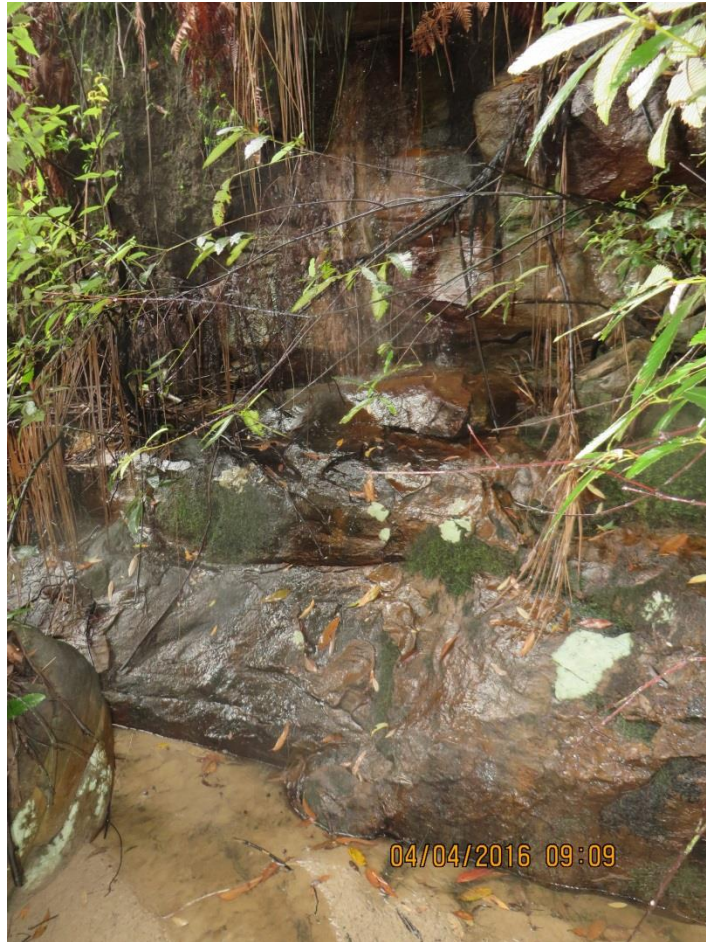


Figure 4. Site 2. (399329 6264952). A 3.5m waterfall. Note sandy sediment.



Figure 5. Site 4. The confluence of 2 minor drainage lines. Some sub-surface flow is evident (339315 6264907).



Figure 6. Site 4. The heavy rainfall has cause local instability of the banks (339315 6264907).



Figure 7. Site 5 (339311 6264897). There were no watercourse bed or banks at this point. There are some small potholes with water in them. The iron staining suggests seepage from the nearby slope. There was no surface flow. The watercourse appears to commence slightly downslope of the point, near site 4.

Site 6 is the toe of an embankment on the boundary between lot 810 and 811. There is no evidence of concentrated flow at this point.

Conclusions

The drainage line is evident up to site 5 (339311 6264897). Beyond this point there is no evidence of concentrated flow. This 'commencement' of the drainage line occurs some 20m NE of the boundary between lot 811 and 810.