DRAINAGE REFORM PLAN
Peel-Harvey Coastal Catchment
Volume Two: Best Management Practices

A report by Ironbark Environmental
to the Peel-Harvey Catchment Council

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Abbreviations used in this report

AHD	Australian Height Datum
AMG	Australian Map Grid
AMP	Asset Management Plan (term used by Water Corporation)
ARI	Average Recurrent Interval
ASS	Acid Sulphate Soils
BMP	Best Management Practice
CCW	Conservation Category Wetland (State Government policy term)
CCI	Coastal Catchments Initiative
CSO	Community Service Obligation
DMA	Drainage Management Authority
EPA	Environmental Protection Authority
EPP	Environmental Protection Policy
FTE	Full-time equivalent
LCDC	Land Conservation District Committee
LPP	Local Planning Policy
LMU	Load measuring unit
PDC	Peel Development Commission
PHCC	Peel-Harvey Catchment Council
PRI	Phosphorus Retention Index
RDG	Regional Drainage Group (term used in this report)
REW	Resource Enhancement Category Wetland (State Government policy term)
SCDMP	Sub-Catchment Drainage Management Plan
WAWA	Water Authority of Western Australia
WSUD	Water Sensitive Urban Design
WQIP	Water Quality Improvement Plan

1. Introduction

This report is part of a two-volume study into the reform of drainage management in the coastal plain portion of the Peel-Harvey Catchment (Peel-Harvey Coastal Catchment).

The study has been commissioned by the Peel-Harvey Catchment Council to encourage reforms to drainage management to reduced nutrient inputs into the Peel-Harvey Estuary and lower-river reaches. It complements other catchment management initiatives, including the Peel-Harvey Water Quality Recovery Program, that are addressing nutrient management in the Peel region.

Volume One provides a:

- Background to the region's drainage system and related natural resource management issues; and
- A number of proposals to reform the planning and governance of management of the region's drainage system.

In this second volume, Best Management Practices have been presented to demonstrate the ranges of tools and management practices that are applicable to the land management practices and environmental conditions of the catchment. There are twenty-six basic BMPs presented in this volume, and some of these can be adapted to various land use or management regimes (e.g. from the Gazetted Drainage system to on-farm use, or even urban settings).

Reform of the way that drainage management is planned and undertaken is required as the Region's modified drainage system is a primary cause of the high level of nutrients entering the estuary. This is because the drainage system:

- reduces the nutrient filtering capacity of the region's natural wetlands; and
- Acts as the primary transport route for nutrients and sediment entering the Estuary.

Reviewing the management of the drainage system offers a significant opportunity to do something about the problem.

Volumes One and Two apply to all of the catchment's waterways within Gazetted Drainage Districts, have been constructed, or have been significantly modified from natural channels. The term 'drain' is used to describe waterways that have been constructed or have been significantly modified from natural channels.

There are 1330 kilometres of waterways (artificial and natural) in the Peel-Harvey Coastal Catchment, including at least 1015 km of waterways which make up the Mundijong, Waroona & Harvey Gazetted Drainage Districts. These gazetted waterways are managed by the State Government's drainage service provider.

Management of sediment and vegetation in the bed of the region's drainage system may provide a significant opportunity to reduce nutrients entering the estuary. It is estimated that of the 870 tonnes of phosphorus that enters the drainage system on an annual basis, only 140 make it to the estuary. Seven hundred and thirty (730) tonnes of phosphorus is therefore contained within the sediments and vegetation in the bed of the waterway channels each year. A ten percent improvement in the attenuation capacity of the drainage system would halve the amount of phosphorus entering the estuarine system.

Changes are required to be made to management of all components of the region's drainage system. The key opportunity in the feeder waterways (usually non-gazetted waterways, privately owned) is to avoid fertilizer spread and control stock access to the waterway corridor via fencing. The key opportunity on lower reaches (usually the gazetted waterways) is to manage the waterway's sediments and conveyance functions.

1.1 Introduction to best drainage management practices

Sections 2 to 7 of this report present a range of best management practices (BMPs) that consider water quality objectives in light of conveyance requirements. Whilst some of the BMPs have been trialled in the Study Area, others are as yet untested. The effectiveness of every BMP to reduce the loss or movement of nutrients will be dependent upon the site-specific characteristics of the waterway and its catchment. Sub-Catchment Drainage Management Plans should be used to determine where and how to apply the BMPs across the region (For more information on Sub-Catchment Drainage Management Plans, see Volume One, Section 10).

The considerations underlying the selection of these drainage BMPS are:

- Increase opportunities for of water and suspended material to be slowed or trapped, whilst maintaining sufficient conveyance;
- Increase opportunities for sediment and nutrients to be assimilated, whilst maintaining sufficient conveyance;
- Reduce soil erosion;
- Increase stability of channel banks and bed;
- Minimise up-front costs and improve farm productivity; and
- Cost-effectiveness.

The BMPs have been selected for their application to the waterway bed, banks, buffer or a structure that may be attached directly to water inflow. In many instances, management of the buffer to the waterway, even within 10 metres of a small drain, can have a significant impact on the sediment and nutrient input into the waterway.

It is assumed in this study, that catchment BMPs (e.g. improved fertiliser application) are used in conjunction with drainage BMPs. It is important that land-based catchment BMPs are in place so that drainage BMP's are not overloaded with nutrients and sediments.

BMPs to reduce nutrient input to the drains which apply to land outside the drainage corridor are not within the scope of this report but are considered to be of significant priority and have been addressed in other recent catchment publications especially PDC, 2006; (and EPA, 2007 in prep; Summers, undated).

To assist in the identification of short-term and long-term actions, drainage BMPs are grouped in this Volume as either:

1) Modifications to current drainage management practices – these are actions that can usually be taken with relatively few cost implications, or actions that are simple modifications to current practices , or
2) More significant changes to management of existing systems, or new systems.

The recommended BMPs are further distinguished as being most appropriate to:

- The gazetted drainage system (State Government)
- On-farm drainage systems (private landowners)
- Residential areas and local roadside drains (Local Government)

BMPs that are applicable to different management scenarios have been cross-referenced (e.g. Some BMPs will be applicable to both the gazetted drainage system and on-farm drains). Some of the selected BMPs are also referenced to the Peel-Harvey Coastal Catchment WSUD Technical Guidelines (PDC, 2006).

Table 1 summarises the BMPs in Sections 2 to 7 and provides an indication of the applicability of each BMP to the different types of waterways across the drainage system.

Table 1: Summary of BMPs and their applicability to different waterway types across the drainage system

(✓✓✓**=** very applicable**,** ✓✓ **-** applicable**;** ✓ **=** limited applicability, NA = not applicable, - = not relevant**)**

Management practice	**Section reference**	**Main drains**	**Branch drains**	**Feeder drains (First order**	**Rivers and creeks**
Banded drain clearing technique	**2.1.1**	✓✓✓	✓✓✓	✓	NA
Channel broadening technique	**2.1.2**	✓	✓✓✓	✓✓✓	NA
Spot clearing & 'in-out' maintenance	**2.1.3**	✓	✓✓	✓✓	✓✓
Typha control – drowning (gazetted and on-farm)	**2.1.4**	✓✓✓	✓✓	**-**	✓✓
Typha control – replacement with sedge beds*	**2.1.1**	✓✓✓	✓✓✓	**-**	✓✓✓*
Low impact access track maintenance	**2.2.1**	✓✓✓	✓✓✓	**-**	NA
Targeted exotic plant control	**2.2.2**	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Grazing control – enforcement in gazetted drains	**2.3.1**	✓✓✓	✓✓✓	**-**	✓✓✓
Fencing gazetted & on-farm drains	**2.3.2**	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Identifying natural reaches	**2.3.3**	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Proactive inspection program	**2.3.4**	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Reshaping drains with graders – (on-farm)	**3.1.1**	NA	NA	✓✓✓	NA
Roadside drains – revegetation	**4.1**	**-**	**-**	✓✓	**-**
Rock riffles	**5.2.1**	✓✓✓	✓✓	✓✓	✓✓✓
Reshaping (e.g. meandering)	**5.2.2**	✓	✓	✓✓✓	NA
Re-directing	**6.1**	✓	✓	✓✓✓	NA
Spoil removal	**5.3**	✓	✓	✓✓✓	NA
Silt traps	**6.3**	✓	✓	✓✓✓	NA

Management practice	Section reference	Main drains	Branch drains	Feeder drains (First order	Rivers and creeks
Vegetated discharge areas (in paddocks prior to discharge into drains)	**6.2**	NA	✓✓✓	✓✓	✓✓✓
Streamlining	**6.5**	✓✓	✓✓✓	✓✓✓	✓✓✓
Constructed/re-creating wetlands	**7.1.1/ 5.2.3**				
Amended substrates	**7.1.2**	✓	✓✓	✓✓✓	NA
Gross pollutant traps	**7.1.3**	✓✓	✓✓✓	✓	NA
Vegetated swales (new, urban)	**7.2.1**	NA	NA	✓✓✓	NA
Filter strips & filter beds	**7.2.2**	NA	✓	✓✓✓	✓✓

*** = to replace *Typha orientalis***

2. Modifying maintenance of the gazetted drainage system

There are over 1015 kilometres of waterways managed by the Water Corporation on behalf of the State Government within the Peel-Harvey Coastal Catchment. This section describes a number of relatively simple measures that could be trialled, or in some cases implemented, with little structural adjustment to the channels or machinery. Before implementation of each of these BMPs, the applicability of the BMP to the waterway reach, including the conveyance function of the drain, must be assessed.

Recommendation: The PHCC works with the Department of Water and Water Corporation to trial the application of these ‘modified management techniques’. Given the diversity of channel and land use scenarios, the trials should be designed as a comprehensive 3-5 year project, managed through the Department of Water.

2.1 Sediment and bed vegetation management

Sediment is generated from the catchment and the waterways. Maintenance of vegetative cover in paddocks, feeder drains and the gazetted drainage system all are required to reduce the heavy sediment loads which are evident in many parts of the system.

Efforts to promote sustainable land management practices need to be continued throughout the catchment. These include soil amendment and modified fertiliser use in agricultural and urban settings, sustainable stocking rates, and use of perennial pastures.

In the past, sediment has been removed from the channel because it reduces the cross-sectional area of the drain and provides a substrate for vegetation to grow in the base of the drain. Particular types of vegetation, such as Typha, need to also be controlled, as they can further reduce the cross-sectional area of the drain.

In the gazetted system, the primary cause of drain bed and bank disturbance is mechanical clearing of vegetation in the drainage bed and the removal of sediment which has been deposited in slower-flowing drainage reaches. Extensive lengths of drains are cleared at a time, and this is believed to generate a significant source of sediment which progressively moves downstream into larger waterways and ultimately the lower river reaches and estuary. It is also possible that this exposes fresh phosphorus retentive surfaces that could reduce phosphorus loss (David Weaver, pers. comm.)

Two approaches are suggested that would enable clearing of blocking vegetation or sediment build-up to be managed in ways which should significantly reduce the downstream movement of sediment.

2.1.1 Banded drain clearing techniques

This technique is a simple modification to the current approach of mechanically clearing long stretches (e.g. 400 – 1000 m) of the drains every 4 or 5 years. It is most applicable to the largest drains (main drains) but should also be effective on the branch drains. The technique involves clearing only half of a constrained drainage reach, in bands, to retain vegetated cells. The remainder of the constrained drain can be cleared within a set timeframe.

This approach is designed to retain a portion of the waterway's filtering and buffering capacity so that sediments are trapped closer to their source.

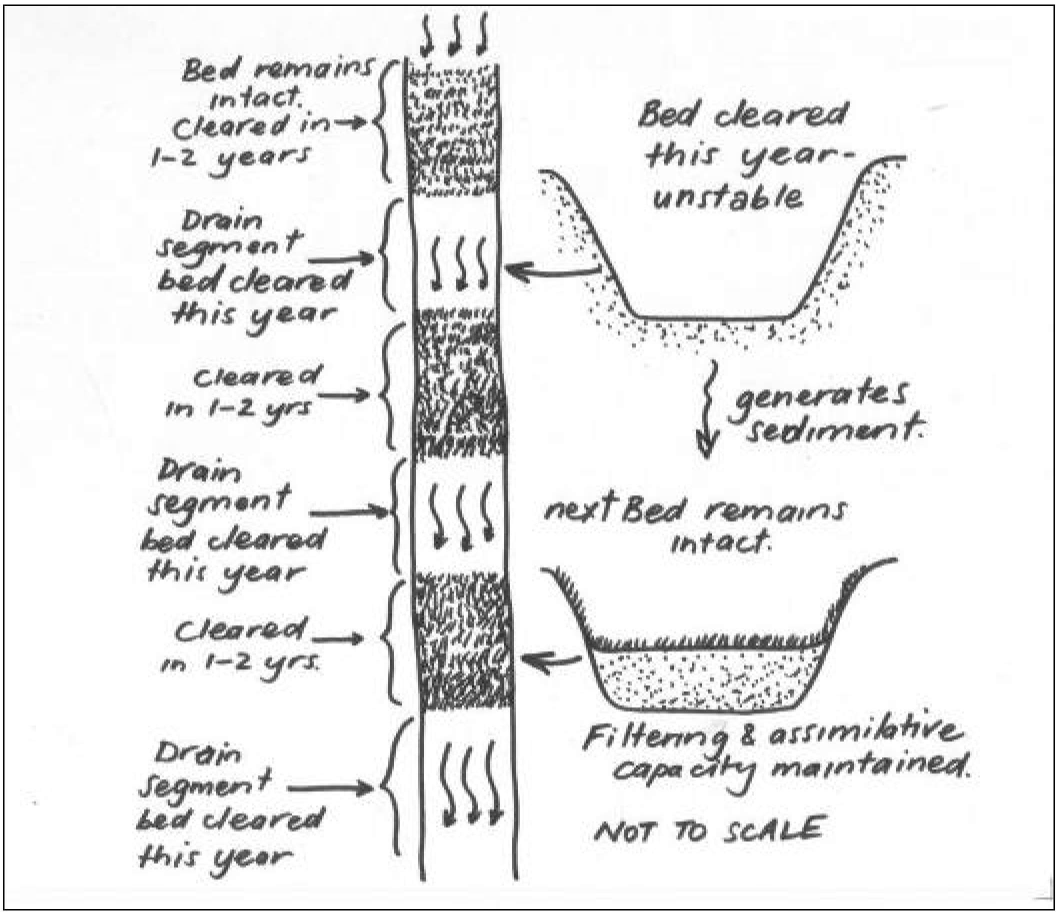

Figure 1: Application of the banded drain clearing technique to a straight artificial waterway.

For example, rather than clearing out all of a 600 metre length in one session, three lengths of 100 metres each are cleared now, and three lengths of 100 m are cleared out in two years time. Refer to Figure 1.
A disadvantage of this approach is that it doubles the mobilisation of machinery to a specific site. However, over time this should be less of a disadvantage as mechanical clearing becomes more targeted and specific across the sub-catchments. An example of where this approach should be trialled is the Peel Main Drain, which undergoes significant mechanical clearing every 4 to 6 years.

Where Typha is present, this technique could be used in conjunction with Typha control methods described in Section 5.1.1.

Like other BMPs suggested as applicable to the region's larger drains, it is important that this BMP be trialled to assess its effectiveness in reducing nett downstream movement of nutrients. The trial should also assess other factors such as cost, environmental implications and practical application issues.

2.1.2 Channel broadening techniques

This technique is also a slight variation to existing mechanical maintenance approaches. Instead of removing the sediment from the drain bed, this technique widens the drain on one or both sides where the width of the reserve permits. The principle behind this approach is that a wider drain will have the same flow capacity, but a greater ability to trap sediment and assimilate nutrients because there is greater water-to-vegetation contact. Wider drains also flow at slower rates.

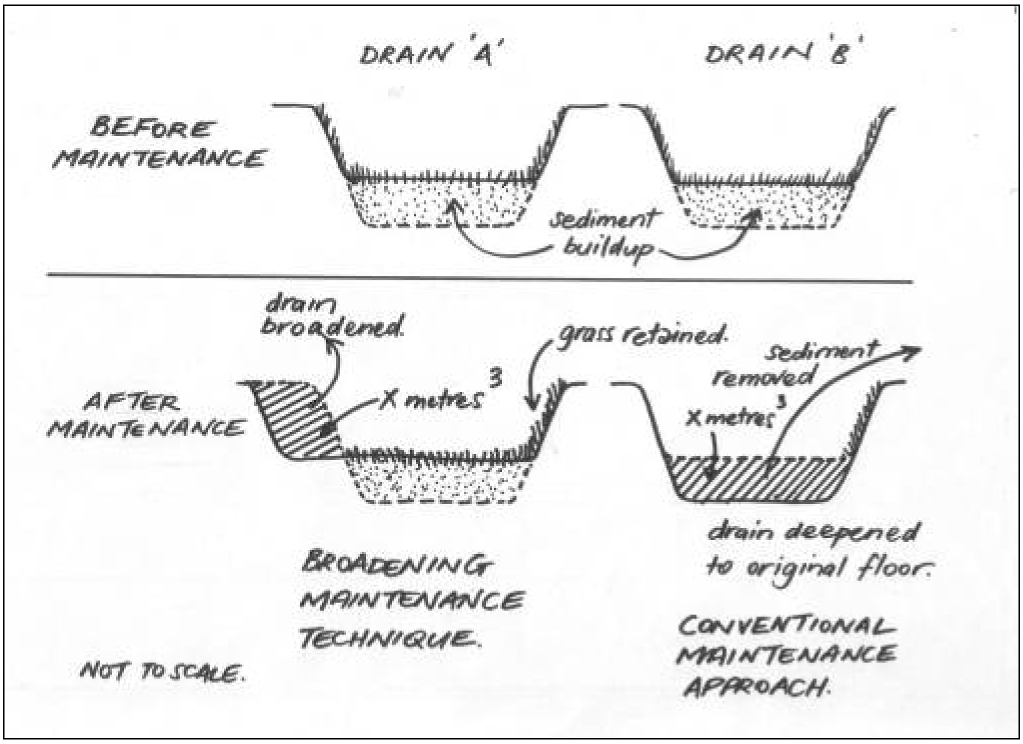

Figure 2: Illustration of the waterway channel broadening technique

Widening the bed of a drainage section by even 20% (e.g. a 1 metre increase of a drain that was previously 5 metres, will increase the drain bed by 0.1 hectare over a 1 kilometre length. See Figure 2.

A number of considerations apply to this BMP:

1) There needs to be sufficient width in a drainage corridor to carry out this altered practice;
2) Side excavation works need to ensure the channel bank is left in a stable form; and
3) Spoil generated from the works should be placed so as not to increase sediment and nutrient movement into the waterway.

This approach could be combined with revegetation approaches, giving consideration to maintaining sufficient room for future maintenance works. Side clearing is more likely to be feasible on branch drains and feeder drains, where channel depth is low to medium. A possible disadvantage of this approach is that it may increase the need to carry out either selected spot maintenance or banded maintenance. (Note: The approach is a change to an existing mechanical clearing practice, and is not to be confused with reshaping drains (see Section 5.2.2).

USE OF SMALLER MACHINERY TO REDUCE DISTURBANCE

A more sensitive approach was used on the lower Hymus Drain on the Lowlands property in the summer of 2005/06 (Richardson M, pers. comm. 2006). In this case, the drain is a Branch Drain that occurs on private property (with no drainage easement or reserve) and receives water from less than 20 properties. The drain is a relatively broad channel, some 4 – 5 metres wide and between 2 and 3 metres below the prevailing surface level. In 1996, stock was excluded from the drain and a 30 metre wide, vegetated corridor was created and planted with locally indigenous trees and shrubs. Since the revegetation efforts, and the exclusion of stock, some parts of the corridor have been colonized by indigenous flooded gums and paperbarks. A maintenance access corridor was not intentionally left on one side of the waterway channel (as promoted in textbook streamlining), although there is sufficient spacings between plantings to allow machinery access to lengths of the drain bank.

The waterway channel clearing work in 2005/06 was necessitated by the subsidence of the Western Power bridge. The machine, with tracks rather than tyres, was able to sit in the drain bed and clear specific constriction points or stretches, and where necessary travel out of the drain to work on the next constriction. In this way, parts of the channel bed were left undisturbed, and the small machine was able to manoeuvre around planted and naturally growing trees and shrubs.

The drain is located in a predominantly sandy catchment, and it was a classic example of how water couch growing in the drain bottom was trapping sediment, thus lifting the channel bed over time.

Other comments to note from this example are:

1) Was maintenance triggered by an actual or perceived need?
2) Landcare works should leave an access way;
3) Could more proactive spraying of Typha avoid the need to mechanically clear the waterways as is currently occurring?

2.1.3 Spot clearing and 'in and out' maintenance: Use of smaller machinery

This approach simply involves targeting blockage points on small to medium sized drains, rather than uniformly clearing a large drainage reach. It is made possible through use of small excavators (such as a Model PC 45 Mini-excavator) which are able to travel in and out of small drains with relative ease. This approach was used on the Lowlands and Kalga properties in August 2005 on the Hymus Drain, Mardella.

This approach is limited to small or medium-sized gazetted drains where the machine can access the drainage bed at multiple points. The advantages of this approach are that:

- the clearing can be very specific, creating minimal disturbance to the bed; and
- vegetation on the banks and verge can be retained.

2.1.4 Control of Typha, water couch and other bed vegetation

Typha, and to a lesser degree Water Couch, are two of the most aggressive species that grow in drain beds. In most cases, they are dug out, as herbicide usage requires targeted and repeated application. This approach disturbs the waterway bed, thus destabilising sediments which invariably move further downstream.

A suggested control method which does not create any significant disturbance to the waterway bed is to cut the biomass at least 10cm below the water level, and maintain flooded conditions for several months. A consideration is that this method is likely to cost more than mechanical removal.

This method is not suitable for areas where water depths are insufficient. In these situations, the best approach is to contain the spread of Typha by attacking the spread of clones. This may be done by wiping the new culms (stems) with neat Roundup®. (Regeneration Technology, 2002, unpubl.)

Figure 3: Typha blocking a branch drain

A longer-term approach which would cause even less long-term disturbance to the drainage bed and greater water-sediment contact is suggested in Section 5.1.1.

(Note that *Typha domingensis* is a local native species which can be easily confused with *Typha orientalis* an exotic species. *T. orientalis* can be distinguished by a broader leaf and larger seed head than its less-invasive local cousin.)

2.2 Bank and verge management

Management of the zone immediately adjacent to the waterway bed has a significant bearing on water quality (See Section 7, Volume One).

From a conveyance and water quality perspective, the main issues associated with managing drain banks and verges are:

- Maintaining a stable bank that does not contribute sediment to flows;
- Maintaining verge access tracks and low fire fuel zones;
- Controlling grazing stock;
- Controlling weeds to meet legislative responsibilities;
- Controlling environmental weeds in environmentally sensitive areas;
- Controlling feral animals.

Recommended alterations to current management practices that should be employed are suggested below.

2.2.1 Low impact access track maintenance

The maintenance of a trafficable corridor is important for maintenance access and fire control. Using mulching-mowers and herbicides to maintain access tracks or firebreaks is a suggested improvement on current practices.

Currently most access tracks double as firebreaks, and firebreaks are graded annually. This is problematic as it exposes bare soil that can generate sediment with the first heavy rains of the season. It is suggested that all bare-earth fire-breaks be created through the use of mulching mowers (or slashers if more practical and just as effective), and that this is followed up with herbicide application of Round-up Bi-active®. This arrangement would need to be developed with the support of Local Fire and Emergency Services officers.

2.2.2 Targeted exotic plant control

Within Drainage Reserves vested in the Water Corporation, it is the responsibility of the Corporation to control some exotic species of plants and animals by law. These species are gazetted under the State Government's *Agricultural and Related Resources Protection Act 1976* in relation to the control of Declared Plants and Animals and Pest Plants Local Laws administered by Local Government.

In some instances, a higher level of weed control should be undertaken. This may apply to the control of environmental weeds in environmentally sensitive areas or revegetation sites.

For example, Bridal Creeper, Victorian Tea Tree, and in some cases Watsonia can be easily removed from the drainage reserve vegetation where it is part of an environmentally sensitive area. The drainage service provider should proactively identify and address this issue as part of routine inspections.

This BMP also applies to private landowners and Local Governments.

2.3 Management of the drainage corridor unit

2.3.1 Grazing permission enforcement

Limited, episodic grazing (crash grazing) is the only way of maintaining low ground fuel levels whilst limiting ground disturbance and the input of faeces/urine into the waterway.

As described in Section 6.1.1, Volume One, a number of stock owners overgraze fenced drainage reserves. The simple solution is to establish and enforce a system which allows responsible stock owners to continue the practice, and other people to lose this privilege where they have demonstrated that they do not manage the land responsibly. A challenge exists in that few resources are available to ensure compliance.

The responsibility for the enforcement of a 'permission' or 'licencing' system should rest with the drainage service provider. A key consideration will be the existence of a serviceable fence.

Figure 4: Stock on the Serpentine River Diversion Drain (Photo by Kevin Firth)

2.3.2 Fencing drainage reserves and drainage easements

Whilst the greatest nutrient reduction benefit may come from fencing highest-order waterways, Government should lead by example and require, and part-fund, the fencing all of drainage reserves. Under the current arrangements, the Water Corporation is bound by the *Dividing Fences Act 1961.* A funding and stewardship program should be established to also support the fencing of other gazetted drains in easements and private land (See Volume One, Section 12). It is somewhat ironic that the Government currently funds farmers to fence waterways to control stock access and permits unregulated drainage reserves for stock grazing.

2.3.3 Identification and management of natural channel reaches

The Water Corporation already identifies environmentally sensitive sites within or adjacent to the gazetted drainage system (Scott Davie, pers. comm. 2006). These include Bush Forever sites and revegetation sites created by community groups and other organisations. Proposed management at these sites is usually negotiated with other parties, such as the Department of Environment and Conservation or a local Landcare group.

However, there are other parts of the gazetted system, such as the Lower Harvey River, which are more appropriately managed as natural waterways than drains and are not considered 'environmentally sensitive areas' by the drainage service provider (Jesse Steele, pers. comm., 2006).

It is recommended that the gazetted system drainage service provider undertake an exercise in identifying those parts of the gazetted system which should be recognised as 'natural waterways', and managed accordingly.

Criteria for identification of these waterways would include:

- Percentage or coverage of local indigenous flora;
- Local species plant diversity;
- Habitat for rare or threatened fauna or flora;
- Links between (existing) areas of remnant vegetation;
- Native fauna habitat (aquatic and terrestrial) – e.g. presence of mature vegetation.

The criteria should be applied collectively to identify a 'natural waterway', unless a site has a single, outstanding natural feature, such as habitat for a rare species of flora.

These channel reaches should then be managed according to ecological engineering principles, rather than standard drainage clearing techniques. Most of these sites should also be regarded as environmentally sensitive areas.

Recommendation: That the State Government's drainage service provider be requested to undertake an exercise in identifying those parts of the gazetted system which should be recognised as 'natural waterways', and managed accordingly. The exercise should include developing a new appropriate schedule of maintenance for these waterways. The involvement of the community should be encouraged. This exercise could be undertaken as part of the above recommendation.

2.3.4 Proactive inspection and management of environmentally sensitive sites

It is suggested that more proactive inspection and assessment of vegetation and bank stability on these should lead to less overall disturbance due to the use of preventative maintenance rather than reactive maintenance approaches.

Initially, it is proposed that inspections by a person(s) qualified in ecological / environmental engineering and bushland management be carried out every two years for all environmentally sensitive sites. Where these are also managed by an organisation or community group, then representatives from those groups should be included.

This may assist in at least two ways:

1. It may bring forward difficult vegetation management decisions before they become more serious. The case below is used as an example.
2. The approach of periodic inspection of sites with other stakeholders is also likely to foster a greater working relationship between the Water Corporation and the local community.

Active vegetation management in environmentally sensitive sites.

Large, woody native vegetation growing on the drain banks or verge is generally not a cause of problems, but can enter flow paths and cause blockages or erosion points if left unchecked and unmanaged. Inspection and assessment is required to determine when tree lopping or other vegetation management is required to avoid more serious vegetation management measures. The Mundijong Road Flora Reserve is used as a case in point. The drain reserve abuts the Flora Reserve and the Water Corporation has avoided undertaking any maintenance of the drain at the request of the State Government's environmental agencies. While the drain bed does not require clearing, (as it has eroded to bedrock in many locations), large woody vegetation is growing in parts of the drain and causing some side cutting and erosion of the banks. These points on the drain should be inspected by an environmental engineer and bushland management experts to ascertain the need, timing and scale of vegetation management works, or erosion control works.

The challenge here is that the Water Corporation are not able to allocate extra staff to this work. Corporation officers have also expressed concern over the temporary nature of local community efforts to manage sites within the drainage system. These significant issues may be resolved through the preparation of sub-catchment management plans.

The issue of increased inspection of the condition of the gazetted drainage system is discussed further in Section 2.3.4.

3. Modifying management of on-farm drains

Most natural and artificial drains on farms are not fenced and are managed as part of the paddock. Fencing the waterway is often the most simple, effective measure to reduce nutrient and sediment movement. Unfortunately, it is not an appealing or affordable option for many farmers. This BMP is discussed in 3.2.1. There is need for a permanent assistance program to work with landowners to help them implement and manage these on-farm BMPs (see Volume One Section 11.6).

3.1 Sediment and bed vegetation management

3.1.1 Reshaping drains (using graders or farm machinery)

This approach alters the cross-sectional shape of the paddock or farm drain from trapezoidal to a wider, V-shaped structure or similar. This allows greater growth of pasture in the drainage flow and therefore increased opportunities for settling of sediments, and uptake or assimilation of nutrients.

This approach is suitable to both sandy and heavy soil types, but will be more effective in sandier soils as it should create a more stable drainage slope. The approach is also most suitable for first order drains (i.e. those that are the smallest).

The re-shaped drains can be managed as part of a larger paddock, or ideally, can be fenced so that grazing over the waterway channel is separately controlled. Landowners also have the option of revegetating the drainage corridor with local native species, but this is not essential to achieve greater trapping and assimilation of nutrients.

3.1.2 Banded or side clearing techniques

These suggested practices are more applicable to the larger trapezoidal drains on farms, which in most cases are managed by the Government's drainage service provider. However, in some cases, private landowners are responsible for managing larger drains (e.g. many drains of the North Dandalup catchment). Refer to Sections 2.1.1 and 2.1.2 for details of these suggested techniques.

3.1.3 Controlled grazing to manage Typha, water couch and other bed vegetation

Where drains are fenced and revegetated with shrubs and trees, active vegetation control is required to ensure that water conveyance is maintained and weed loads are kept low.

Crash grazing is an effective way of quickly reducing ground fuel loads. However, this should only be employed at certain times of the year to prevent bank slumpage and erosion (e.g. Spring, when ground surface has begun to firm-up and dry out).

Longer-term weed control problems may suggest that infill planting with bushy shrub species is required.

3.2 Management of the drainage corridor unit

3.2.1 Fencing waterway reserves

Implementation of this BMP should be a priority for all waterways on the coastal plain catchment because nutrients placed closest to waterways are those most likely to end up in the waterway (Summers et al 1999). The highest priority is the highest order waterways because these have a higher waterway channel to surface catchment ratio. However, stock should be excluded from all waterways to enable controlled access.

Fencing of a drainage corridor (without revegetation of trees and shrubs) in itself will yield a water quality benefit because the controlled exclusion of stock, and the growth of grasses will create a vegetated filter. It also acts as a physical barrier to the application of nutrients. A further reduction in nutrients exported will be achieved if the grassed drainage corridor is not fertilized;

Stock access to the waterway corridor should be limited to brief periods in Spring when bank soils have firmed, and then only when warranted by fuel loads. Stock should only be placed in the drainage paddock for the sole purpose of removing the potential fire hazard.

Past practice has been to revegetate these fenced drainage corridors with locally indigenous trees, shrubs, sedges and even understorey plants. This yields the following additional benefits:

1) need to stock the corridor for fuel-level reduction should be avoided if revegetation is planted to a high density;
2) water temperature reduction; and
3) ecological benefit from the re-creation of lost habitats.

From a farmer's perspective, revegetation with local species may be seen as a disadvantage due to a real or perceived fire risk, and the loss of the opportunity to obtain some grazing value from the long paddock. Given that nearly 90% of the gazetted system's drains are not fenced, firm positive action should occur to encourage and ultimately require the fencing of all the catchment's waterways.

3.2.2 Identification and management of natural channel reaches

This should be undertaken to assist in targeting landowners to offer assistance and incentives. Responsibility for implementing this BMP could form part of the drainage service licence, or rest with the catchment manager.

4. Modifying management of urban and local reserve drains

Most of the BMPs suggested for the gazetted drainage system also apply to Local Government managed drains of similar scale. Mechanical clearing of sediment and bed vegetation are of particular relevance, and use of banded clearing techniques may be a useful change to current practices.

4.1. Roadside vegetation in new subdivisions

Where opportunities arise, Local Governments should consider revegetation of roadsides that is compatible with safety for road-users and ongoing maintenance of the road shoulders. Well planned and positioned revegetation can reduce the growth of kikuyu and other grassy weeds in the table drain.

In the Shire of Serpentine-Jarrahdale, roadside revegetation is a requirement placed on developers of new Rural Living estates (Ross Montgomery, pers. comm.). This can mean planting of sedges, shrubs and low trees away from the roadside swale drain (between the drain and fence) and can be achieved in new Rural Living subdivisions, or where major roads are being upgraded. Direct seeding techniques can also provide a cost-effective means of establishing vegetation where thorough weed control has occurred.

By out-competing weeds and shading of the ground, revegetation can reduce the growth of grasses and create a stable leaf litter layer. Maintenance of revegetation (weed control & infill planting) in the first three years is essential to reap the benefits of revegetation.

5. Significant changes to management of gazetted drainage system

5.1 Vegetated Filters

5.1.1 Typha management: Installation of sedge beds

The control of Typha is currently a significant driver of bed clearing and disturbance. Use of herbicides to control Typha is problematic and of low effectiveness.

It is suggested that in areas where Typha is known to grow or colonise, that alternative lower-growing, indigenous sedge species should be encouraged which occupy a similar niche. This would reduce the re-growth of Typha. The alternative species could be planted after the Typha had been sufficiently controlled.

Key requirements would be:

a) surveying of the drain's capacity; and

b) selecting native plant species that provide quick coverage of sedges to create a stable bed and can provide strong competition to Typha.

5.1.2 Fencing programs

Almost 90% of the gazetted drainage system remains unfenced. It is a priority to fence these areas. The Water Corporation is bound by *Dividing Fences Act 1961*. It is suggested that the State Government, possibly via the Water Corporation CSO contribute towards a 'Peel Healthy Drains for Clean Water' program. Among other BMPs, the program would part-fund the fencing of the gazetted drainage system. Revegetation of fenced waterways should also be considered where it will shade the waterway bed, and lower water temperature.

5.2 In-stream works

5.2.1 Drop structures, locks and constructed rock riffles.

In the Peel Region, most rock riffles have been installed on waterways with large flows (rivers and main drains). These include the Harvey River, Serpentine River, Dirk Brook Subsection B 902055, Dirk Brook Main Drain, and Mealup Drain.

Construction of riffles is most useful where a waterway may be cutting back or unstable and the waterway channel itself can be used to store water without danger of causing serious upstream flooding.

The riffle in Figure 5 is a prime example of how this approach can be used in a large artificial waterway. Key issues to be considered before implementation of riffles or lock structures are:

- Maintenance of sufficient conveyance in waterway;
- Obtaining the approval of upstream and downstream landowners where the structure could have impacts on private land; and
- Ongoing management responsibility.

The installation of riffles or lock structures offers a significant option to hold back water and nutrients for on-farm use or direct recharge of groundwater.

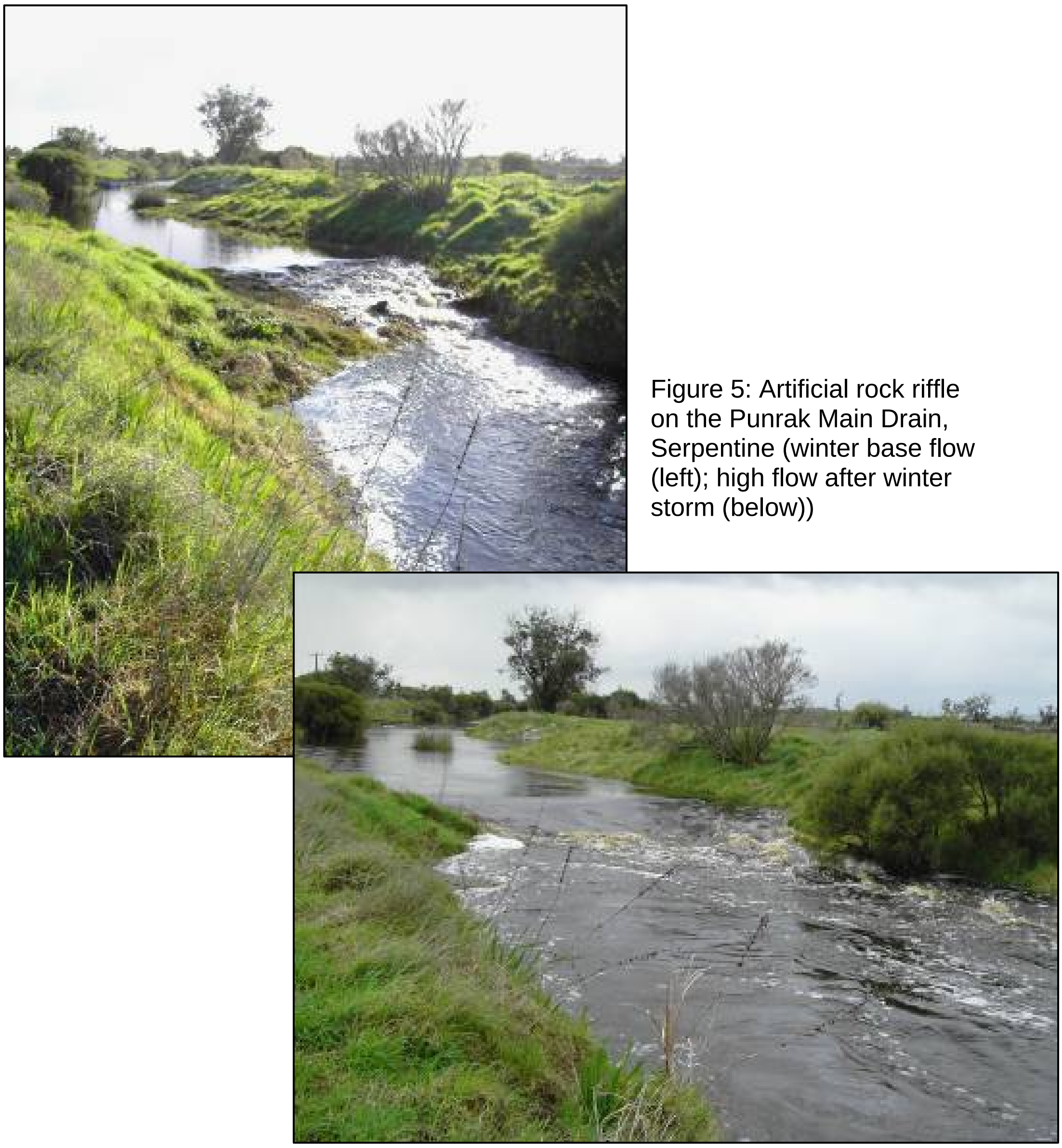

Figure 5: Artificial rock riffle on the Punrak Main Drain, Serpentine (winter base flow (left); high flow after winter storm (below))

5.2.2 Re-shaping, re-contouring & re-directing channels

These types of BMPs are more usually applicable to smaller artificial drains, and as such may be of limited application in the gazetted drainage system. However, there may still be gazetted waterway reaches to which these practices apply.

Reshaping involves grading the waterway banks to shallower slopes (see Section 3.1.1).

Redirecting involves constructing a new waterway channel through an area which may have suitable characteristics for storage, settling or bio-filtration of water (See Section 7.1). The potential of this approach could be investigated in areas such as the Peel Main Drain and its diversion through the Alcoa wetlands in Baldivis.

Such approaches to redirect drainage or control drainage flow can also be used to re-create natural wetlands.

5.2.3 Re-creation or restoration of natural wetlands

Given that much of the artificially constructed parts of the drainage system drained natural wetlands, there is some potential to alter drainage flows to re-establish these wetlands and their nutrient attenuation capacities. Natural wetlands have a significant, albeit limited capacity to attenuate and assimilate nutrients, as has been shown at the Spectacles Wetlands in Kwinana. Work by Chambers & Hale (1995) showed that as the Peel Main Drain flows through The Spectacles wetland, a 60-75% decrease occurs in the nitrogen and phosphorus load of the drainage water.

Work needs to be undertaken to identify potential locations in the Study Area where wetland re-creation is most likely to be a cost-effective means of reducing nutrient throughputs. Geomorphic wetland mapping of should provide a useful tool in this search process, especially where sumplands (seasonally inundated basins) have been mapped in close proximity to drains (Hill et al, 1996).

5.3 Removal of spoil from drainage corridor

The nutrient content of sediment removed from waterway beds is likely to be high. Most of this has been placed on the berms, or raised verges of artificial drains. It is suggested that new spoil generated from maintenance be removed away from the drainage corridor and other areas where it can quickly re-enter the drainage system.

There are also significant amounts of soil-based spoil in the system which may have some potential as fill. For example, the Lower Harvey River has approximately 1,900,000 m^3 of spoil (Steele & Perry 2006). However, the high-organic content in many cases is likely to be a preventative factor as it makes the soil unsuitable for construction of roads and dwellings.

5.4 Monitoring and inspections

Regular inspection of the drainage system underpins improved management. Thorough assessments of the condition of the drainage system are no longer carried out due to resourcing constraints in the Corporation. As a result, current maintenance scheduling is developed from annual reports from contractors and in response to complaints from landholders. This may introduce a conflict of interest, given that those undertaking the work are largely defining the need and scope of works.

Increased resources need to be allocated to on-ground personnel so that maintenance scheduling can include more of the innovative techniques described above, and there can be greater contact between the drainage managers and landowners.

6. Significant changes to management of on-farm drains

Two main approaches are suggested to over-haul management of on-farm drains. These are re-forming paddock drains with graders or similar machinery, and re-directing drainage through paddocks to create longer pathways.

6.1 Re-directing drains (through production areas)

While this approach requires more planning than reshaping of the drain, and is a greater alteration to the farm operation, it has the potential to yield a far greater nutrient reduction benefit. This practice may be feasible in parts of the catchment where there is very low grade over a paddock, and the landowner is able to accept a higher level of waterlogging.

Re-directing drains within paddocks or farms simply means altering the path of the drain so that it travels through a longer route before discharging off the property. When combined with the planting of high-water use crops or perennial pastures, an additional water quality improvement is achieved and nutrients are retained on-farm.

This approach is suitable in both sandy and heavy soils, but would be more suitable in heavier soils where the grade and route of the new channel can be maintained. The major costs of this BMP are surveying of the paddock and drain, and earthworks.

This approach has been trialled on the Kalga property in Mundijong. The drain has been re-directed wide through the tree rows of a new agro-forestry paddock. The drain formerly had a length of approximately 300 metres, and is now effectively 1000 metres (Rupert Richardson, pers. comm.)

A variation of the approach may involve changing the discharge point of paddock runoff or drainage into the receiving drain so that the runoff is required to pass through a grassed waterway or similar. This approach is also suitable where paddock slopes are minimal, the landowner is farming for the future, and funds for the work can be found. The major costs are earthmoving, to alter the paddock drainage and construct the new waterway.

6.2 Vegetated discharge areas

In many instances, paddock drainage discharges into a gazetted drain through natural flow across the paddock, often assisted via minor paddock drains. The concept is to create a vegetated area through which the paddock drainage can flow (sheet flow preferred) prior to discharge into the gazetted drain. This work can be assisted by re-contouring of the area so as not to increase the overall risk of blockages to the outlet occurring. The fenced area created can either be managed as pastured paddock or revegetated with more substantial perennial vegetation. The advantages of this concept is that it does not require wholesale changes to paddock levels and creates a compact area which can still be used productively.

The equivalent of such an area in an urban setting is referred to as a filter strip or bed and is described in PDC (2006) and Section 7.2.2.

6.3 Silt traps

Silt traps may be feasible in areas where water can be detained prior to discharge into larger drains. They work by cutting down water velocity and allowing silt to settle out (WML Consultants 2005). They are best sited where there are existing structures such as culverts or road crossings, as these will also allow easy access for maintenance. Silt should be removed from site and not left as berms (Krish Seewraj, pers. comm.) They may also be used in conjunction with, or independently of vegetated areas described above in both property outlets and road table drains.

6.4 Controlled stock access to water or alternative water points

This complements the fencing of waterways and ensures that a water supply is maintained for stock. It can be achieved either through allowing restricted access to a point on the drain, preferably with a stone or concrete base, or creating an off-drain water supply.

In many cases, stock crossing points can also serve to provide alternative water points. Hence stock access to drain water does not have to be a stand-alone infrastructure cost (Krish Seewraj, pers. comm.)

Uncontrolled stock access to an un-vegetated drain in the Coolup Drain catchment is a serious cause of sediment loss and has been shown to increase sediment in a drain in the Coolup Catchment by up to 13 times (Cronin 1998).

6.5 Streamlining: fencing and revegetation of waterways

Streamlining is an approach that includes a combination of:

- Physical waterway modification
- Exclusion of stock
- Revegetation of waterway banks and reserves.

The term was first coined by Heady and Guise (1994) as part of the work of the Pinjarra Community Catchment Centre with local farmers. See Figure 6 for an example.

Figure 6: Streamlined artificial waterway, Hymus Drain.

To ensure that streamlining improves water quality, the ecology of the waterway and local environment while also maintaining the conveyance function of the waterway, the following approach is considered the most effective and efficient streamlining design:

- The streamlined waterway is planned (fences, revegetation, access ways, and where appropriate in-stream works) so that all elements can be maintained into the long term as part of an ongoing maintenance program. Long-term access to the drain, or key points is an essential aspect;
- Local native vegetation (trees, shrubs and groundcovers) are planted on one side of the waterway only, where possible planting should be on the north side to reduce waterway temperatures;
- Sedges are planted into the waterway bed as much as possible to add stability to the bed whilst maintaining the waterway channel.

Consideration must be given as much to the location of planting as to the sedge species to be used;

- Formation or designation of an access track to allow access by maintenance vehicles and machinery;
- Fencing of the waterway to exclude stock.

7. Significant changes to management of urban and local drains

Future urban drains will hopefully be more able to mimic natural waterway systems given the promotion of water sensitive designs in urban developments. Drains in new urban developments will also be only one part of a total water management system.

Given that drainage BMPs for future developments are described in Peel-Harvey Coastal Catchment Water Sensitive Urban Design Technical Guidelines (PDC 2006), they are only listed herein with a reference to the appropriate section in the Technical Guidelines. Note that PDC (2006) also describes a range of BMPs related to management of water on-site and water re-use.

While these BMPs can also be retrofitted to existing urban drains, it usually incurs a higher cost, and requires careful assessment of cost-effectiveness.

7.1 In-stream structures or treatment

7.1.1 Constructed wetlands

Constructed wetlands are discussed extensively in PDC (2006) and Steele (2006) and readers are encouraged to view those documents.

Local research and comment indicate that:

1) While artificial wetlands can improve water quality, they are likely to be most effective when treating small catchments with high nutrient export (Chambers, Wrigley & McComb, 1993);

2) Artificial wetlands are often constructed for a number of reasons (aesthetic, water quality & stormwater retention), not just water quality improvement (Steele 2006);

3) The ratio of the artificial wetland's size to the size of its catchment is an important factor in it's effectiveness to reduce nutrients; and

4) The artificial wetland must be carefully designed if water quality gains are to be maximised. Considerations include drying cycles, maximising water residence time, and suitable habitat for epiphytic vegetation (PDC 2006).

Constructed wetlands have been used in a small scale urban setting in the Rainforest Reserve, Byford. The site was a previously cleared local discharge zone within the foothills.

Artificial wetlands are planned as part of many new urban developments. Given the above four points, it is important that they be off-line (at least in low-flows), and expertly designed to have the best chance of reducing and assimilating nutrients. They should also be designed as seasonal wetlands so as to frequently dry out and avoid eutrophication.

7.1.2 Amended substrates in waterway beds or banks

This approach aims to increase the ability of the drain to lock up or assimilate nutrients. In 1994, Davies and Muir suggested using red mud from bauxite residue, however they questioned the practicality and cost of such an operation on a broad-scale. It is as yet untested in the Peel-Harvey and may be worth trialling in newly designed drainage systems.

Amending soils of the near drain zone to intercept groundwater may also be effective in lowering levels of nutrients entering the channel. The Water Corporation has commenced a trial of constructing three 100 metre trenches in the Mills Street Drain and filling them with woodchips, pea gravel and other materials to intercept nutrient laden groundwater (Water Corporation 2006).

Subsoil amendment is also promoted for widespread use across new urban estates to increase the Phosphorus Retention Index for the entire site [See PDC (2006) section 7.1.7].

7.1.3 Gross pollutant traps

Gross pollutant traps (GPT) are devices installed in the waterway flow to remove litter and other relatively large suspended materials. The most effective and popular systems are continuous deflective separation devices installed in the drain flow, usually in piped drainage settings. [See PDC (2006) section 7.1.4]. Removal efficiencies of 90% of solids greater than 900 micron have been reported (Wong, 1996). GPT s are not powered but require ongoing maintenance to remove collected material.

7.1.4 Riffles and other impoundments

Rock riffles and bunds have been used in urban settings on roadside drains and local reserves. For example, rock riffles are used in the Chestnuts development in Jarrahdale.

Riffles may have a place in roadside drains where there is sufficient roadside width, adequate slope, and the potential for erosion of open channels.

7.2 Vegetated filters

7.2.1 Vegetated swale / biofiltration trench

Vegetated swales are used to convey stormwater in lieu of pipes and to provide for removal of coarse and medium sediment and are commonly combined with buffer strips [See PDC (2006), section 7.1.5].

A key issue is locating sufficient land area within intensive developments in which to place swales. For example, new development in Byford is guided by the Byford Urban Stormwater Strategy which recommends the use of bio-filtration swales within the central median strips of local distributor roads, or on the edge of multiple use corridors. These swales intercept roadside run-off that would otherwise flow directly into the Multiple Use Corridor and the waterway channel (Ross Montgomery, pers. comm.). Locating swales within narrow (14 m) road reserves is impractical and raises on-going maintenance concerns.

7.2.2 Filter strip/beds

Filter strips are blocks of vegetation planted across stormwater discharge routes, before water is discharged to rivers, or larger waterways. Their design must balance the role of the vegetation to act as a filter versus its ability to block flows. An advantage of this BMP is that it can placed at multiple points on multiple low-flow drains throughout a residential development. Other considerations are described in PDC (2006), section 7.3. The equivalent in a farming situation is described in Section 6.2 of this report.

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