GLEN INNES SEVERN COUNCIL
Landfill Environmental Management Plan (LEMP)
Glen Innes Landfill

RESOLUTION NUMBER: 24.04/11	MEETING: 28 April 2011

Please see attached document.

General Manager

2-5-2011

Date

Reference Number:	Version Number: 1 Date of Effect: 28/4/11	Review Date:	Responsible Officer: DDES
Related Documents:			

Helping You Protect Your Environment

LANDFILL ENVIRONMENTAL MANAGEMENT PLAN (LEMP)

GLEN INNES LANDFILL

December 2010

for Glen Innes Severn Council

CodyHart Consulting Pty Ltd ACN: 076 662 989 ABN: 23 809 060 895
Trading as CodyHart Environmental
Groundwater and Landfill Environmental Monitoring Specialists

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Presented by: Barbara Hart
Hydrogeologist & Environmental Scientist

Date: 14 December 2010
Report: CodyHart 10.2044.5

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CodyHart Consulting Pty Ltd, PO Box 1073, 3/29 Township Drive, BURLEIGH HEADS QLD 4220
Phone: (07) 5520 5532 Mobile: 042 777 5120 Email: pelican@codyhart.com.au

1. EXECUTIVE SUMMARY

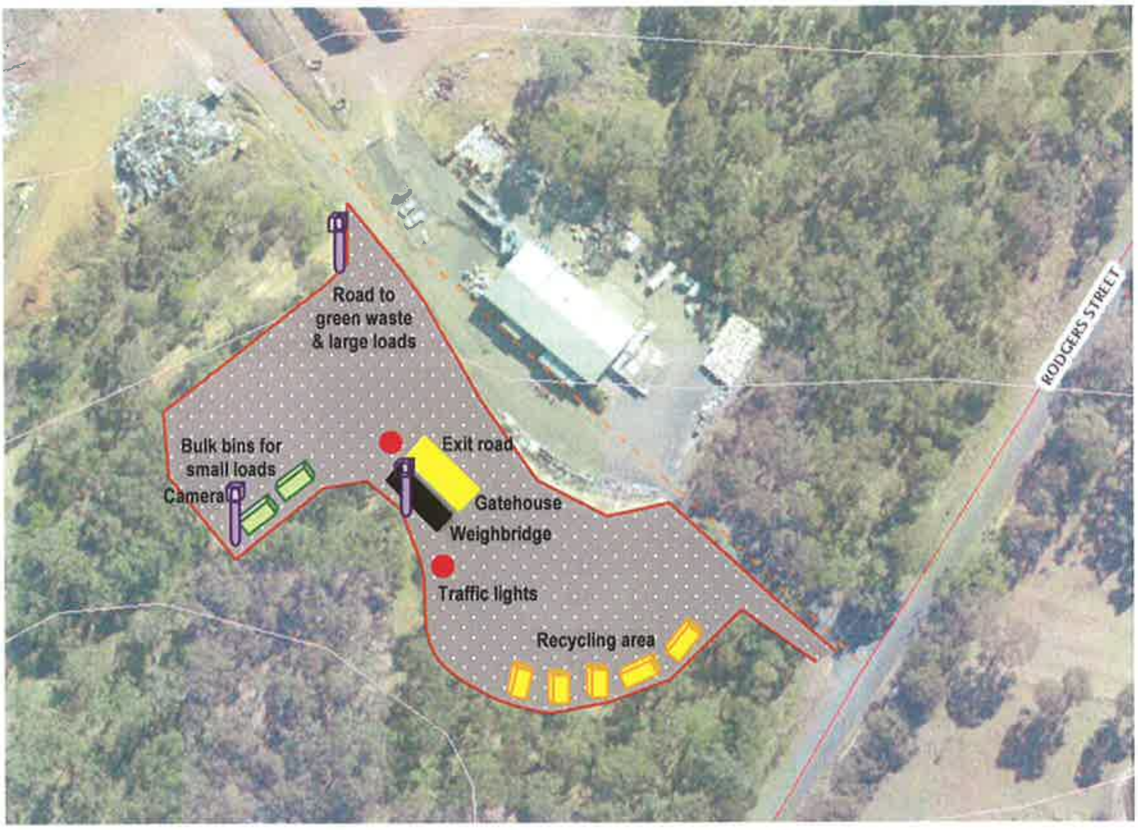
This document is the Year 2010 Landfill Environmental Management Plan (LEMP) specific to operations that impact on environmental issues of the Glen Innes Landfill owned and operated by the Glen Innes Severn Council.

The landfill covers approximately 4.2 hectares between Blue Hills and Rodgers Road (Figure 1). Any new landfills or landfill extensions post September 2000 require a base barrier system and a leachate collection system. Glen Innes Council was ahead of these requirements. In the 1990s the southern section of the landfill was lined with a one metre thick clay liner, a bund wall placed between the new landfill cell and the remaining quarry, and a leachate collection and treatment system was installed.

The central road area is over previous landfill. By re-engineering the roadway to contain solid waste and direct leachate to the current leachate sump, the current northern and southern sections of the landfill can become one. This will allow better management and deposition of a greater volume of solid waste.

Quarterly environmental monitoring for leachate, groundwater, surface water and methane has been conducted since Year 2001, and shows that the leachate removal and treatment system is working effectively. No leachate ingress into surface water or groundwater has been detected. A geophysical resistivity survey conducted in Year 2003 corroborated that groundwater was not being affected. A risk assessment in the same year concluded that the leachate pump-out is efficient. Even in a wet period, pumping was only required for approximately four hours a day. The recommended two extra downgradient wells closer to the landfill have been installed. The quarry dam pump-out management plan has been written and implemented.

Manning and fencing of the landfill have improved operations. However, more recyclables would be recovered and operations greatly enhanced by charging rates similar to those of Armidale Dumaresq Council and having a demountable gatehouse, weighbridge and a bulk bin receival area for small loads. A hypothetical layout is depicted below.

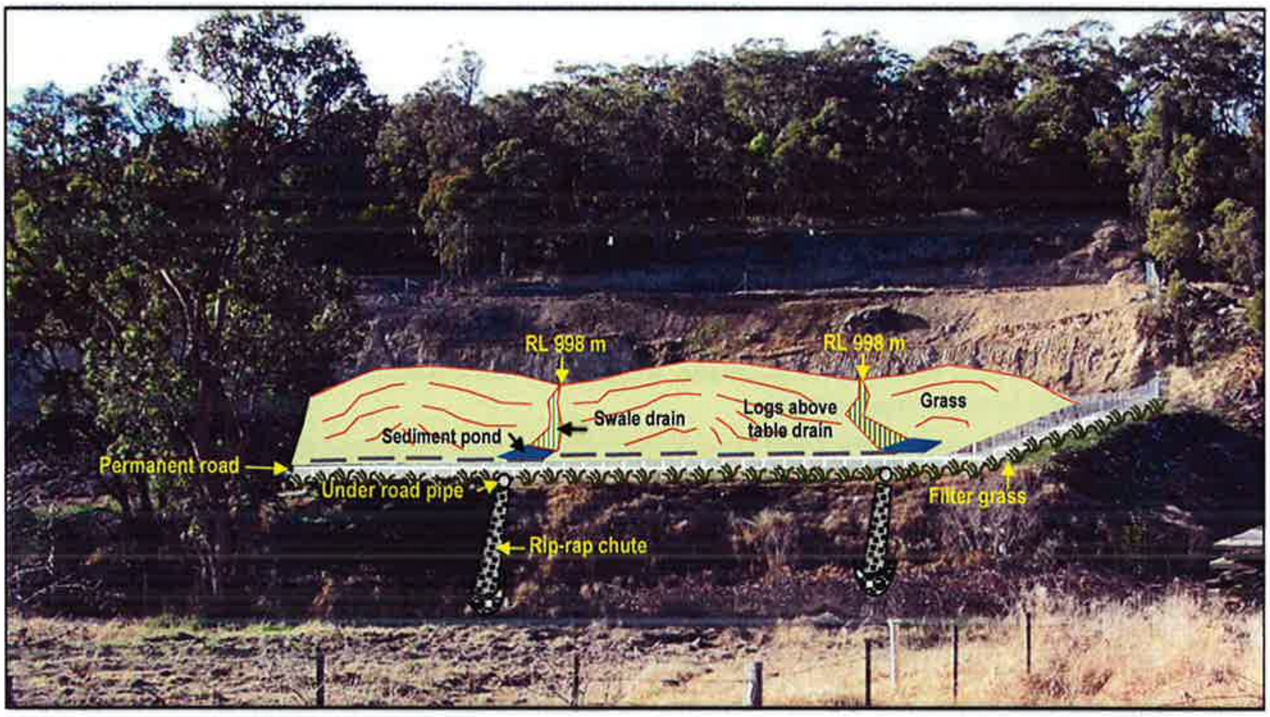


Base map from SIX © NSW Dept of Lands 2006, downloaded December 2010

Managing the landfill as a single mass, the landfill will last 19 more years if filling to RL 996 m with a track dozer. Alternatively using a heavy, steel wheeled compactor, the landfill will last 35 more years, thus providing an extra 16 years of landfilling. A brand new, fifty tonne, steel wheeled compactor costs ~$1 M to $1.2 M.

A new landfill, lasting say 100 years, has to take into account the cost of the land, approvals, site development, best practice liner, leachate collection, and landfill gas recovery and groundwater monitoring wells. A 2009 study for the Federal Government estimated these establishment costs for a small landfill to be in the order of $40 per tonne for the life of the landfill. Delaying the need for a new landfill for an extra 16 years by managing the present Glen Innes Landfill as a single mass and using a heavy, steel wheeled compactor will save in the order of $4.08 M to $6.93 M.

Some of the savings can be well spent assuring the stability of the current landfill and improving its surface water and landfill gas controls. This LEMP provides information on the type, location and sizing of these controls and a staged program for their installation. Proposed surface water controls on the southern section of the landfill are depicted below.



A landfill can be managed as both a landfill and park land. By minimising the size of waste cells, a greater proportion of the site can be in grass restoration phase using water sensitive urban design.


(GCCC 2007)

2. INTRODUCTION

This LEMP

- Provides direction on the selection and implementation of appropriate environmental management techniques during the remaining operational life of the landfill.
- Reflects the requirements of the Environment Protection Licence 5939 for the Glen Innes Waste Management Depot, under Section 55 Protection of the Environment Operations Act 1997.
- Reflects Glen Innes Severn Council commitment to improving the performance and sustainability of the landfill.

Glen Innes Council submitted a LEMP to EPA Armidale in February 1998 which was last updated in Year 2002. This Year 2010 LEMP draws on historical information provided in the 1992 LEMP and generally follows LEMP requirements outlined in the *Environmental Guidelines: Solid Waste Landfills* (EPA NSW 1996).

3. SITE OVERVIEW

The land occupied by the landfill forms part of Lot 7014 DP1028490 (Figure 1) under the Glenn Innes Severn Local Environmental Plan. The Lot also accommodates a recycling facility, three dams that treat leachate pumped from the base of the landfill, **'the town common' land on the** north of the lot, and vacant land used for Council stock**piling on the lot's southeast.**

Figure 1: Location of Glen Innes Landfill

Base map SIX (Spatial Information Exchange) © NSW Department of Lands 2006, downloaded 1 October 2010

The site was formerly owned and operated by the Glen Innes Municipal Council, but also received solid waste from the Severn Shire Council. The two Councils amalgamated in 2004 to become the Glen Innes Severn Council.

3.1 Zoning

The Lot was previously called Reserve R87449 which was gazetted on 10th October 1969 as a Rubbish Depot (Appendix A). It is currently zoned as Special Uses 5(a) and the surrounding zoning is Rural 1(a).

3.2 Area

The current portion of land under landfill is approximately 4.2 hectares (Figure 2). This is similar to the area designated as a landfill on a map first drawn by Council in 1995 (Appendix A).

Figure 2: Landfilled area (shaded)

Base map from SIX (Spatial Information Exchange) © NSW Dept of Lands 2006, downloaded November 2010

3.3 Surrounding environmental characteristics

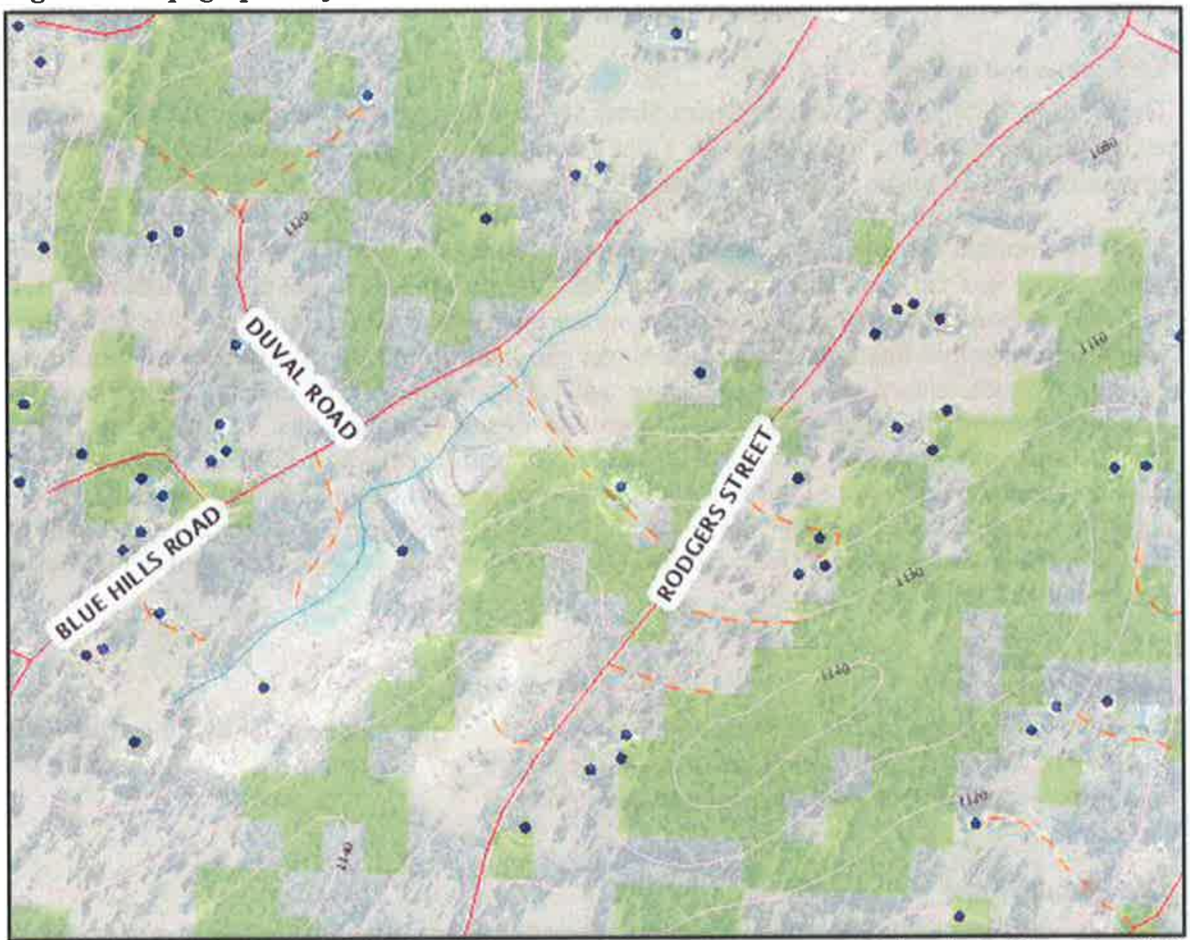
Glen Innes is located in the New England Tablelands of northern New South Wales. Prior to landfilling, the site was a road base gravel quarry for the Glen Innes Municipal Council.

The landfill site is between Blue Hills Road to the west and Rodgers Road to the east (Figure 2). It is adjoined to the south by a quarry previously owned by the Severn Shire Council (Figure 1). **What is referred to as 'the town common' adjoins** to the north. In earlier days surface tin mining was carried out in the town common by individuals, and in the 1980s three exploratory drill holes for tin, to a maximum depth of 254 metres were drilled.

3.3.1 Topography

Topographical fall starts at 1130 AHD (Australian height Distance) on the non-landfilled south eastern portion of the site, and finishes 40 metres lower at 1090 AHD on the northern section of the landfill (Figure 3).

Figure 3: Topographical fall



Base map from SIX © NSW Dept of Lands 2006, downloaded November 2010

3.3.2 Climate

Glen Innes climate information is sourced from the Glen Innes Ag Research DPI facility (Bureau of Meteorology Station No. 056013) (http://www.dpi.nsw.gov.au/research/centres/glen-innes/climate). Its additional evaporation data assists with water balance calculations, and frost information assists in understanding climate extremes encountered by plants, water pipes and landfill equipment. Rainfall data is based on 96 years of records and the temperature data is based on 35 years.

Table 1: Glen Innes Ag Research Station climate data

	J	F	M	A	M	J	J	A	S	O	N	D	Total
Max temp °C	25.2	24.4	23.1	19.8	16.2	13.1	12.4	13.9	16.8	19.8	22.1	24.4	
Min temp °C	13.5	13.3	11.4	7.9	4.9	1.8	0.7	1.2	4.1	7.1	9.8	12.0	
Rainfall (mm)	106	94	72	41	50	43	57	49	54	78	88	108	848
Evaporation (mm)	171	134	133	93	62	48	53	75	105	137	153	174	1336
Number of frosts	0	0	1	4	11	17	21	20	12	5	1	1	93

The Northern Tablelands is a cool temperate highlands region. Climatic conditions include average annual rainfall of 848 mm with marked summer incidence, a wide temperature range, and precipitation exceeding evaporation only in winter months. There is a 200-day frost interval (April - October) and intensely cold winter conditions.

3.3.3 Soils and geology

The Grafton 1:250,000 Geological Series Sheet SH 56-6 defines the Glen Innes Landfill site area as being dominated by igneous rocks - undifferentiated granites or granodiorites laid down approximately 215 million years ago during the Permian period.

There is minimal topsoil in the landfill environs. When drilling for groundwater monitoring wells, diorite was the main base rock encountered - diorite has less quartz than granodiorite. Both vertical and horizontal fractures are evident in the quarry and road cuttings on Blue Hills Road which indicates that this may be the case under the landfill and its surrounds. The diorite was overlain by sedimentary clay and shale that are composed mostly of mineral grains and rock fragments derived from the weathering and erosion of pre-existing rocks. Bands of rhyolite, an igneous rock, were noted in the diorite of well GW2 and the clays of GW3 (Figures 4-6). The clay/diorite interface in most of the area of the town common just downgradient of the landfill is at a depth of approximately 20-21 m. The 20 to 21 m of upper clay provides a natural cut-off wall for landfill leachate that may egress from the site. On the western side at GW2, the clay/diorite interface was higher at 2.5 m.

3.3.4 Surface water

An ephemeral stream on the western border of the landfill site runs parallel to Blue Hills Road (Figure 3). Its catchment comprises mainly the higher gradient properties to the south and southwest and pump-out from the southern quarry dam.

3.3.5 Groundwater

A study of solely groundwater levels surrounding the landfill was undertaken in Year 2002. Wells GW3 and GW4R were installed in Year 2004. Their groundwater levels were incorporated into the groundwater flow direction computation (Figure 4).

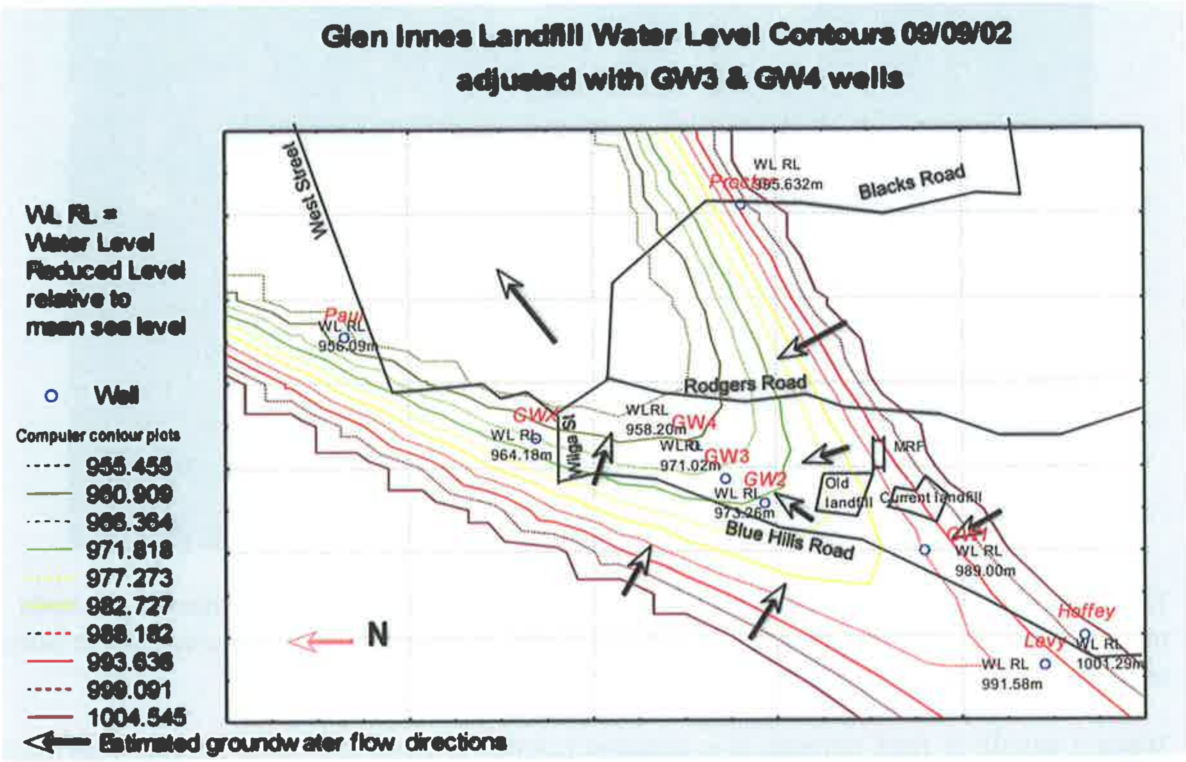
Groundwater generally moves north, northwest in the vicinity of the landfill, then under and down the valley. Taking the general groundwater flow direction into account, the beneficial uses to be protected are:

1. irrigation water if owners of downgradient wells choose to irrigate
2. the Rocky Ponds Creek.

These beneficial uses are quite distant from the landfill and there are now three wells directly downgradient from the landfill to act as an early warning system.

Groundwater velocity is moderate along the western side of the site: at well GW1 53.56 m/year, GW2 120.67 m/year, and GW3 89.27 m/year. Downgradient of the leachate dams at the centre of the site, groundwater velocity is very slow at well GW4R at 0.10 m/year.

Figure 4: Groundwater flow direction, September 2002, adjusted to include GW3 & GW4



(Hart 2010)

3.3.6 Flora and fauna

Remnant bushland is found immediately surrounding the landfill, then small rural holdings, and finally smaller residential lots as one proceeds towards the Glen Innes central business district to the northeast (Figures 1 & 2).

Flora surrounding the site includes wattles, varieties of eucalypts and spear and tussock grass. The town common to the south has eroded ephemeral stream beds. (Photograph 1) Car bodies and other metal objects protrude from the banks of the ephemeral stream on the southwest section of the town common.

Photograph 1: Central ephemeral stream – northern section Glen Innes Landfill Lot

Fauna include kangaroos, wallabies, tiger and brown snakes, and many species of birds - magpies, magpie lark, eastern rosellas, wrens, finches, sulphur crested cockatoos, butcher birds, and galahs.

When a landfill is final covered; it is common practice to plant only grass species. Tree roots would pierce the clay of the final cover, and provide pathways for rainfall ingress and therefore increase the landfill leachate volume.

4. LANDFILL STRUCTURE AND OPERATIONS OVERVIEW

This overview outlines current structure and operations and recommends improvements.

4.1 Leachate barrier, leachate collection and treatment

Under licence condition O5.1, installation of a leachate barrier does not apply to surfaces of landfills where waste was emplaced before 25 September 2000. However, in the 1990s the southern section of the landfill was lined with a one metre thick clay liner and a bund wall placed between the new landfill cell and the remaining quarry which was then being operated by the Severn Shire Council. A concrete leachate collection sump 900 mm in diameter was placed at the bottom and extensions have been added over the years as the solid waste increases in height. The leachate is automatically pumped out to a three dam treatment system and then irrigated on the northern section of the landfill. So the southern section of the landfill does have a base barrier system and a leachate collection system.

4.2 Waste tonnage

Estimated solid waste received in Year 1998 was 2,000 tonnes. In Year 2010, it is 2,600 tonne.

4.3 Licence

The tonnage is less than the 5,000 tonnes per annum above which a landfill requires a licence. However, an environment protection licence for the landfill was issued in 1997 to the Glen Innes Municipal Council because the site is within 250 m of a residential zone or dwelling (Table 1, EPA NSW 1996, p. 8) and therefore may have amenity and landfill gas impacts on residents.

The landfill is called the 'Glen Innes Waste Management Depot' on its Environment Protection Licence No. 5939 under Section 55 Protection of the Environment Operations Act 1997 archived 18 June 2009. It is a Class 1 solid waste landfill because its waste is ***'all solid waste including** putrescible wastes and other wastes approved by the EPA'* **(EPA NSW 1996, p. 9).**

4.4 Types of wastes

Condition L5.1 of the Licence states that the following types of wastes can be accepted.

Code	Waste	Description	Activity	Other Limits
NA	General Solid Waste (putrescible)			
NA	General Solid Waste (non-putrescible)	As defined in Scheduled 1 of the POEO Act, in force from time to time.		
NA	Asbestos Waste			
NA	Waste Tyres		Waste Disposal (application to land)	The total tonnage of waste disposed of at the premises must not exceed 4,000 tonnes in any reporting period.
NA	General Solid Waste	Wastes assessed as General Solid Waste which are also subject to general or specific immobilisation approvals which have been a restriction that may only be disposed of at waste disposal facilities which have currently operating leachate collection systems.		
NA		Any waste received on site that is below licensing thresholds in Schedule 1 of the POEO Act, as in force from time to time		NA

4.5 Recycled waste

Waste tonnage is minimised by recycling efforts. The State of Environment (SOE) Report (McKemey 2010) states

Recycling

Recycled materials are collected on behalf of Council by Glen Industries who also manage the Material Recovery Facility at the entrance to the Glen Innes Waste Management Depot. Council constructed the materials recovery facility in June 1995 and since then the recycling effort by the community has increased. From 1996 to 2008, the total quantity of materials that have been recycled has increased from 450.3 tonnes to 1461.34 tonnes, which is a 324% increase in recycling effort.

Materials recycled include paper, glass, plastic, aluminium, garden organics/vegetation, scrap metal, construction and demolition waste, steel and vehicle batteries. More than 5200 litre of oil has been recycled and countless numbers of tyres sent for recycling.

Green Waste

Currently green waste is separated and mulched. A complete cover of mulch is placed weekly on the compacted landfill to act as a cap. Council is a member of the Northern Tableland Waste Management Group and various methods of handling green waste are being addressed in an effort to utilise a cost effective regional method. The use of green waste as a capping material in landfill has the potential to passively oxidise methane within the landfill cap as it passes through a biologically active, oxygen rich layer of green waste. This is currently being viewed as significant in reducing greenhouse gas emissions (Glen Innes Severn Council 2009c).

Table 2: Recycled waste – Glen Innes Recycling Centre and Landfill

Material (unit)	*2005/06*	*2006/07*	*2007/08*	*2008/09*	*2009/10*
Paper (tonnes)	644	639	703.48	918.86	946.7
Glass (tonnes)	91	253	263.04	192.34	246.78
Plastic (tonnes)	20	43	87.49	40.15	65.46
Aluminium (tonnes)	4	8	0	9.34	10.01
Garden organics / vegetation (tonnes)	0	0	0	522.55	1158.81
Scrap metal (tonnes)	0	260	496.80	227.68	278.88
Construction & demolition (metres^3 or tonnes)	0	200 tonnes	2,500m^3	4,000 m^3	500 m^3
Vehicle batteries (tonnes)	31	45	0	0	5.83

(based on Table 20, McKemey 2010)

Table 2 indicates recycling quantities have increased over the years in paper, aluminium, green waste and construction and demolition waste, which is predominantly concrete. The concrete peak in Year 2008/09 was due to the construction of new retail infrastructure, for example, Woolworths and Big Mac outlets. There is an active program of encouraging waste minimisation. The community is encouraged to minimise the amount of waste generated to landfill by composting, mulching and recycling promoted by:

- Handing out of appropriate brochures at the landfill
- **Articles in Council's quarterly newsletter** and website, and
- A monthly section in Connecting with Your Council (Glen Innes Severn Council 2009c).

4.6 Northern Inland Regional Waste (NIRW) group initiatives

Glen Innes Severn Council is a member of the Northern Inland Regional Waste (NIRW) group.

NIRW is a voluntary local government networking group to specifically address waste management issues on a regional level. The group's membership consists of thirteen (13) Local Government Councils in the North West and New England regions of New South Wales, Australia. NIRW was formed in July 1998 and meets quarterly to discuss waste management issues and to organise regional initiatives. <http://www.nirw.org.au/index.html>

Council participates in the following NIRW programs:

- Annual chemical clean out campaign for old and left over chemicals from and around the home and farm. The program is aimed at reducing the risk of accidental poisoning and the inappropriate disposal of chemicals within the environment. The latest collection date was 10 August 2010 and the following types of wastes were accepted at the drop-off centre at the Council Works Depot, Lang Street:

Paint & paint related products	Pesticides, herbicides & poisons
Solvents & household cleaners	Motor fuels & fluids
Fire extinguishers	Pool chemicals
Acids & alkalis	Hobby chemicals
Smoke alarms	Fluoro Tubes

  The first 20 kg are free. Only rural and household quantities are accepted. Quantities over 50 kg need to be booked in. In 2007 this campaign collected a total 20,050 kg of rural and household hazardous waste from the NIRW area. Glen Innes collected 1,722kg.
- Regional Waste Art & Design Competition and Exhibition. This is an annual event. It celebrates the reuse and recycling of waste in our community through art, sculpture and graphic design. There are three sections: Primary School, Secondary School, and an Open/Community Section.
- Drum Muster is the National program that has been set up for the collection and recycling of cleaned, eligible, non returnable crop production and on-farm animal health chemical containers. People are required to clean their containers so they are free of any chemical residue and deliver them to either of three collection centres. The recycling facility in Rodgers Road receives containers from 8:30 am to 4:30 pm Monday to Friday. Collections are usually held in May and October at the Emmaville Landfill and Deepwater Landfills, but pre-booking with Council is necessary by phoning 6730 2350.
- E-Waste represents the electronic waste stream and includes items such as computers and peripherals, televisions, stereos and microwaves. The Armidale Dumaresq Council e-waste processing facility at the Long Swamp Rd waste facility is processing e-waste for the NIRW Member Council area.
- Anti-litter campaigns promote community awareness, knowledge and understanding of the littering issue and how it impacts the environment. Litter prevention methods and prosecution facts are also provided.
- Green waste mulching. Green waste (timber, garden and vegetation) is separated by Council at the Glen Innes Landfill. NIRW undertakes the tendering of green waste processing conducted on site at landfills for all Member Councils for a contract period of 2 years. This maximises green waste separation, provides the mulching service at a competitive price, and means that there is no longer a desire to burn green waste to conserve landfill air space. The mulch is currently used for landfill daily cover. Council plans to have the contractor break some of the green waste into finer particle sizes so a more saleable product is produced for local residents to purchase.
- Used oil recycling. NIRW coordinates the used oil recycling program. Council provides a waste-oil receptacle at the landfill for residents.

4.7 Illegal dumping

Council has an illegal dumping compliance team to handle cases of illegal dumping.

4.8 Landfill charges

A Council review in 2009 noted:

- **Council's landfill charges are significantly less than other Councils in the region.** (There is no charge for Glen Innes Severn Local Government Area (LGA) residents to dispose of clean fill, sorted domestic waste (with recyclables separated), green waste, and oil. Charges apply for unsorted domestic & commercial waste, dead animals, tyres and asbestos.)
- Council is not meeting the true cost of landfill, particularly in regard to achieving adequate financial reserves for rehabilitation and new landfill under the current waste funding and charging arrangements.

The Glen Innes Landfill fee structure for the previous and present financial years are as follows.

Description		2009/10 GST Inclusive	Proposed Fee 2010-11 (GST inclusive)
Domestic Waste - Sorted (Recyclables separated minimum of 1/3 recycling required)		Free	Free
Commercial quantities green waste, demolition waste concrete & bricks. * Arrangements may be made with Council for a monthly account.	Total Vehicle Weight (less tare weight of truck) per tonne	$5.50	$ 11.00
Commercial Waste - Sorted metal		Free	Free
Asbestos Waste - Glen Innes Waste Depot ONLY		$110.00	$115 /m^3
Garbage Bin Skips		$5.50	$11.00 per bin or as per commercial waste charge

For comparison purposes, a sample of Armidale Dumaresq Council charges for 2010/2011 is given below.

ARMIDALE DUMARESQ COUNCIL	FEES AND CHARGES 2010/2011	
Description of Rate, Fee or Charge	**Unit**	**Proposed Fee or Charge 2010/2011 Inclusive of GST**
Infrastructure		
Waste Services (General Fund)		
Solid Waste Services - cont.		
Waste Disposal Fees to Armidale Waste Transfer Station		
Asbestos Disposal	Per Tonne (minimum charge 0.5 Tonne)	303.00
Mixed Waste (sorted by customer at bins)		
Car/Sedan	Per load	7.20
Utility/Small trailer/Wagon	Per load	11.00
Large Trailer or Utility	Per Tonne	90.00
Trucks > 2 tonne	Per Tonne	90.00
Unsorted and/or contaminated mixed waste destined for landfill		
Car/Sedan	Per load	18.00
Utility/Small trailer/Wagon	Per load	26.00
Large Trailer or Utility	Per Tonne	180.00
Trucks > 2 tonne	Per Tonne	180.00

<www.armidale.nsw.gov.au>

4.9 Gatehouse, weighbridge, or drop off at bulk bins

Comparison of the Glen Innes Severn landfilling charges against Armidale Dumaresq Council charges illustrates that Glen Innes Severn Council is not obtaining full cost recovery to finance ongoing works at the landfill or to prepare for a new landfill if required. A manned gatehouse and weighbridge would allow gatehouse staff to accurately charge for incoming waste. Like at Moree, a demountable building as a gatehouse and an adjacent weighbridge is transferrable to a new landfill if required.

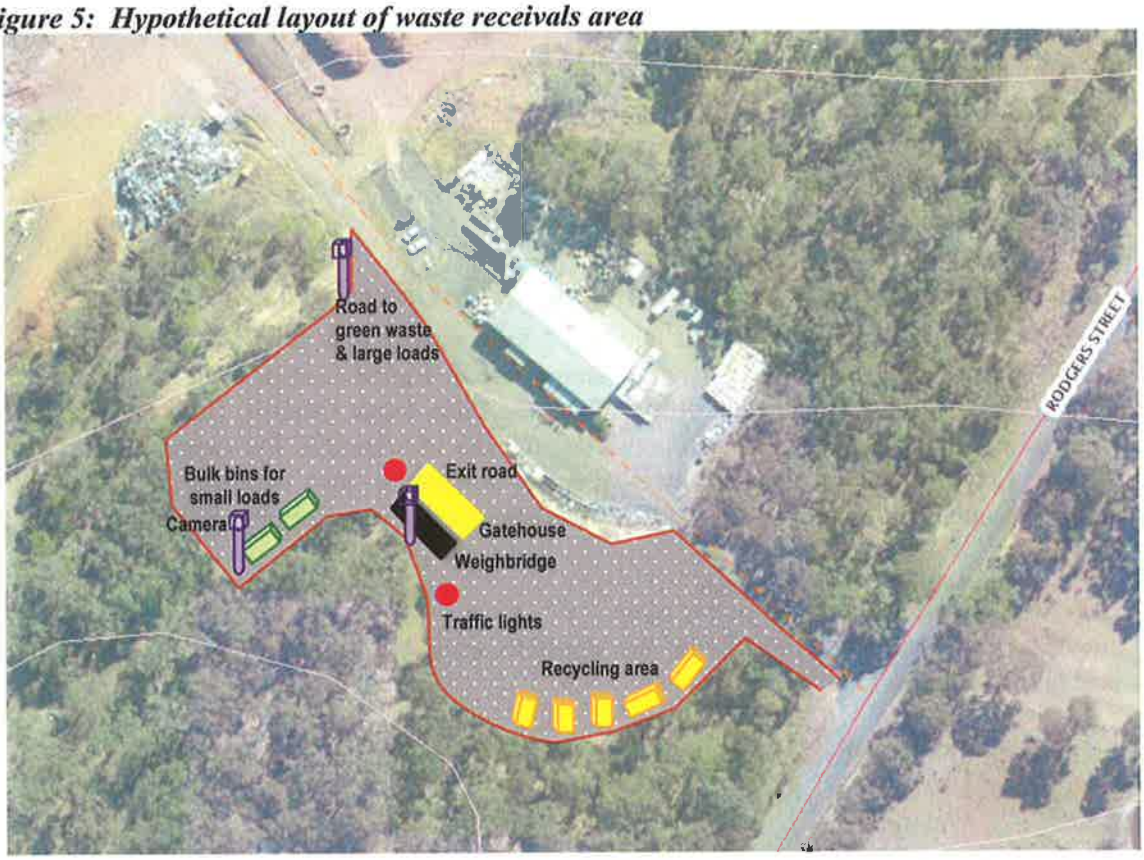
Closing the Blue Hills Road entry and widening the Rodgers Road entry to improve access and supervision is recommended.

A demountable gatehouse would provide reasonable working conditions for the gatehouse attendant. Its layout should allow the attendant to compute transactions without leaving air conditioned comfort. Gatehouse layouts at landfills for Armidale, Grafton and Gunnedah achieve this. High cameras at the Grafton Regional Landfill weighbridge allow inspections of load from within the gatehouse.

Drop off bulk bins within sight of the demountable gatehouse would allow better supervision of incoming loads so that inappropriate materials such as recyclables are not landfilled.

The above improvements will provide a conveniently located transfer station and processing facility. Its use can continue for decades even if a new landfill is located out of town. Figure 5 provides a hypothetical layout of the waste receivals area. Review of alternative logistics for waste receival areas at the following landfills is recommended: Armidale, Tamworth, Grafton, Moree, Gunnedah and Uralla. Advice from their hands-on staff will also be beneficial.

Figure 5: Hypothetical layout of waste receivals area



Base map from SIX © NSW Dept of Lands 2006, downloaded December 2010

4.10 Waste receival control

Council now has an employee permanently manning the entry to the Glen Innes Landfill to inspect loads and give directions to solid waste clients. This service reduces hazardous materials, promotes segregation of recyclable solid waste, and provides direction to clients to safeguard against occupational health and safety incidents. The recommendations in the preceding section about a gatehouse, weighbridge and bulk bin drop off for small loads would improve waste receival control.

4.11 Operating hours

Operating hours for the landfill and the recycling facility are provided on the Council website <www.gisc.nsw.gov.au>.

Glen Innes Waste Management Facility
Last modified: November 19, 2010 - 9:39 AM
Incorporates landfill & recycling centre
88 Rodgers Road, Glen Innes
Phone 02 6732 5919 (Glen Industries)
02 6730 2350 (Glen Innes Severn Council)
Hours of operation:
SUMMER HOURS 1 October - 30 April
Monday to Friday 8:30am to 5:00pm
Weekends & Public Holidays 10:30am to 4:30pm
WINTER HOURS - 1May to 30September
Monday to Friday 8:30am to 4:30pm
Weekends & Public Holidays 11:00am to 4:00pm

Closed: 12.20 pm - 1pm Daily
Closed: Christmas Day and Good Friday

Contact details
Director of Development and Environmental Services
council@gisc.nsw.gov.au

4.12 Compaction – track dozer versus steel-wheeled compactor

A compaction rate of 664 kg/m^3 was estimated from survey data for the Long Swamp Road Landfill, Armidale (1997-1998). This compaction rate is a good compaction rate for track-type dozers commonly used at rural landfills such as the Glen Innes Landfill. However, far greater compaction is possible, which in turn conserves the life of a landfill. For example, the Grafton Regional Landfill uses a Bomag steel-wheeled compactor that achieves a 1,000 kg/m^3 compaction rate. These compaction rates (refuse densities) are in keeping with those of Bolton 1995, p. 200:

Track-type dozers 535 to 653 kg/m^3.
Steel wheeled compactors 653 to 831 kg/m^3.

Compaction rates of even 1100 kg/m^3 are possible with daily compaction using heavy steel-wheeled compactors.

Three brands of steel-wheeled compactors are available in Australia: Caterpillar, Bomag, Tana (Photograph 2).

Photograph 2: A heavy, steel-wheeled Tana compactor with a Year 2005 price tag

G500

Weight: 50 tonnes
Height x Length x Width (m): 4.2 x 8.8 x 5
Engine: 403kW, 6 cylinder Caterpillar
Top speed each gear (km/h): 5, 7
Number of teeth/cutters: 442 (over 2 drums)
Blade movement (mm above/below ground level): 1,200/115
Cost: Approx $970,000
More info: Available from GCM Enviro on (02) 9457 9399

(inside**waste** JUNE/JULY 2005)

4.13 Compaction methods

Bolton (1995, pp. 199, 200) provides advice on compaction.

For best compaction with a track-type dozer, Bolton recommends an uphill slope, optimally 3H:1V, with 300 mm to 600 mm thick lifts. A compactor's effectiveness decreases quickly as the lift thickness increases.

For a steel-wheeled compactor, there is little benefit on working on a slope, so as flat a slope as possible is recommended. A steel-wheeled compactor can achieve up to a 50% greater compaction rate than a track-type dozer.

Three to five equipment passes is considered typical to achieve good compaction. Solid waste should not be placed on top of a previous 600 mm maximum lift until the previous lift has received a minimum of three compaction passes.

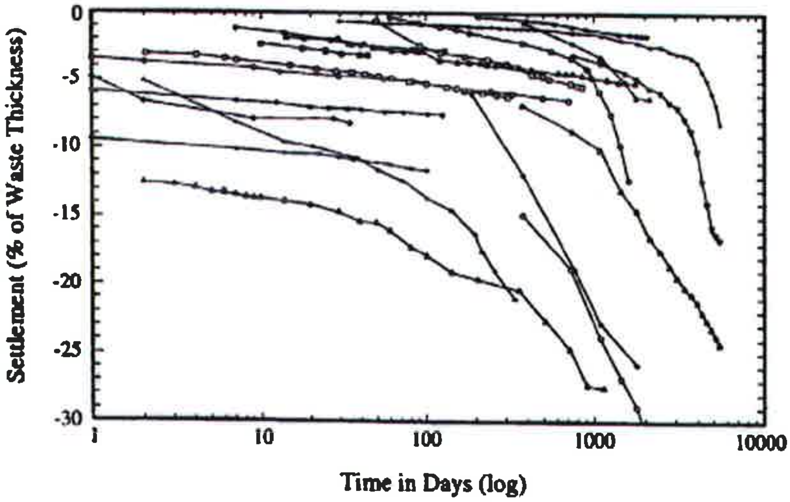
Photograph 3: Grafton Regional Landfill face November 2010

Note the front end loader starting to spread the waste just received so that the lift above the compacted solid waste will remain less than 600 mm (Photograph 3). A Bomag heavy steel-wheeled compactor is to the side of the face. The aim is to keep the face only 30 m wide.

4.14 Landfill settlement

Landfill subsidence also conserves landfill space at municipal solid waste landfills (MSW). The majority of final settlement occurs in the first year (Sharma and Lewis 1994, p. 579-583). **Koerner and Daniel's (1997, p. 20)** review found that up to 30% of height settlement extends beyond twenty years, but most occurs within three years (Figure 6).

Figure 6: Total settlement data from a number of MSW landfills



(Koerner & Daniel 1997, p. 20, after Edgar et al. 1990; Konig et al. 1996; Spikula 1996)

Koerner and Daniel are leading researchers and practitioners in landfill design. They recommend against the immediate final covering of MSW landfills with low permeable material such as clay.

> *Final covers for MSW landfills are almost always constructed immediately after the landfill cell is filled to capacity. The result is that a multi-layered, sophisticated, expensive cover is placed on a fundamentally unstable waste. Over time, the waste degrades and the cover deforms. Because differential settlement can be severe, the cover often has to be repaired.*
>
> *In our opinion, a different approach is more rational. We think that rather than constructing the engineered final cover immediately after filling a cell, it would be better, in many situations, to construct*

a temporary cover that allows controlled infiltration of water (and perhaps leachate infiltration). The temporary cover would be left in place 3 to 10 years, at which time much of the settlement would be complete. At that time, the final cover could be constructed. Because the foundation (underlying MSW) would be more stable, the long-term performance of the final cover would be improved. Current regulations, however, make this suggested practice illegal by requiring prompt construction of the final cover. We urge regulators and landfill owners to rethink the timing of final cover construction.

(Koerner and Daniel 1997, p. 219)

Reinhart and Townsend (1997: 131) also recommend postponement of final cover due to subsidence and explain that interim substitution with an intermediate cap (composed of more permeable soil) *'provides for limited infiltration of moisture, along with leachate recirculation, to maintain appropriate conditions for biodegradation of waste'.*

Pohland in Reinhart and Townsend, (1997, p.3) found that with leachate recirculation, landfill stabilisation time can be reduced from several decades to two to three years.

Although the EPA NSW (1996) Solid Waste Guidelines recommends capping with a more complex final cover including a 500 mm clay 'sealing layer' to be commenced within 30 days of landfill completion (EPA NSW 1996, p. 36), the guidelines are 'performance based'.

> Rather than prescribing actions, design specifications and standards, the EPA has selected a **performance-based** approach for these Guidelines to promote and achieve the best environmental outcomes. (EPA NSW, p.1)

This allows Council to request an alternative final cover system. Research findings such as that above can be used to argue the case for leaving only a seal-bearing layer for at least three years. In addition, biodegradation of waste should be encouraged not only to hasten settlement but also to reduce the long term risk of methane emissions and high concentrated leachate discharge. A more permeable cover allows the top substrate to remain oxygenated and reduces landfill methane contribution to the greenhouse effect.

- German studies of 'dry tomb' landfills found that the low permeable cover systems reduced moisture movement and inhibited or stopped landfill gas production (Kabbe et al. 1999).
- Kruempelbeck & Ehrig (1999, pp. 27-36) found that the estimated post-closure period of 30 – 50 years would be twice as long due to lack of biodegradation especially biodegradation of ammonium ions in leachate.
- There is now evidence that allowing methane to permeate through more permeable soil is likely to reduce methane as a greenhouse gas. Whalen, Reeburgh and Sandbeck (1990) conducted methane oxidation rate studies on topsoil above a landfill closed for seven years and covered with 1.5 to 3 metres of soil in the area of sample collection. Methane was being consumed in the soil by methane oxidising organisms. In one experiment, 31% of the methane was oxidised to carbon dioxide and the remaining 69% was incorporated into the biomass of the soil. No oxidation of methane was found in the top 0-3 cm horizon of a natural core (3% H_2O) but there was active oxidation of methane in the deeper soil zones (~7 to 13% H_2O). Methane oxidation to carbon dioxide therefore increases if moisture is allowed to permeate through a more permeable soil cover.
- Laboratory studies by Humer and Lechner (1999, pp. 403-410) proved that the microbial oxidation of methane in 600 mm deep, mature solid waste compost and sewage sludge is capable of entirely decomposing methane released from municipal solid waste landfills.

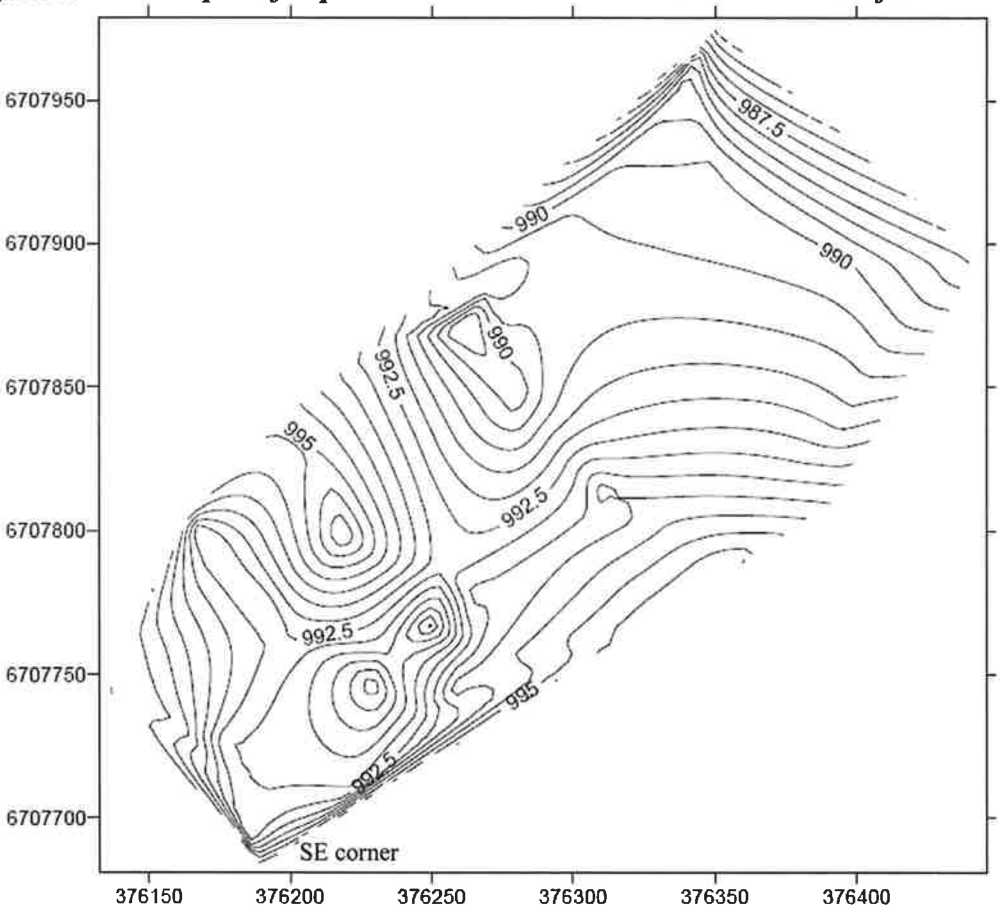
Therefore it is recommended that a seal-bearing layer ≥300 mm clayey soil (approximate thickness suitable for passage of a heavy vehicle such as a loaded dump truck) becomes the site maxim for traffic areas during the operations stage, and post closure for at least three years. The thinness of the seal bearing layer will allow some moisture ingress into shallow solid waste lifts, and will enhance biodegradation and settlement, conservatively saving at least 10% of the estimated remaining landfill air space.

4.15 Remaining landfill air space of Glen Innes Landfill

In September 2010, CodyHart conducted a simple survey at chosen spots across the landfill to obtain an estimate of the base levels of the landfill airspace yet to be filled. The surveyed relative levels based on a base mark of RL 1,000 m on a concrete ledge just outside the recycling facility are displayed on a satellite aerial copied from the NSW Department of Lands 2006, Spatial Information Exchange (SIX) <https://six.maps.nsw.gov.au>. The aerial is provided as Map 3 in Appendix A.

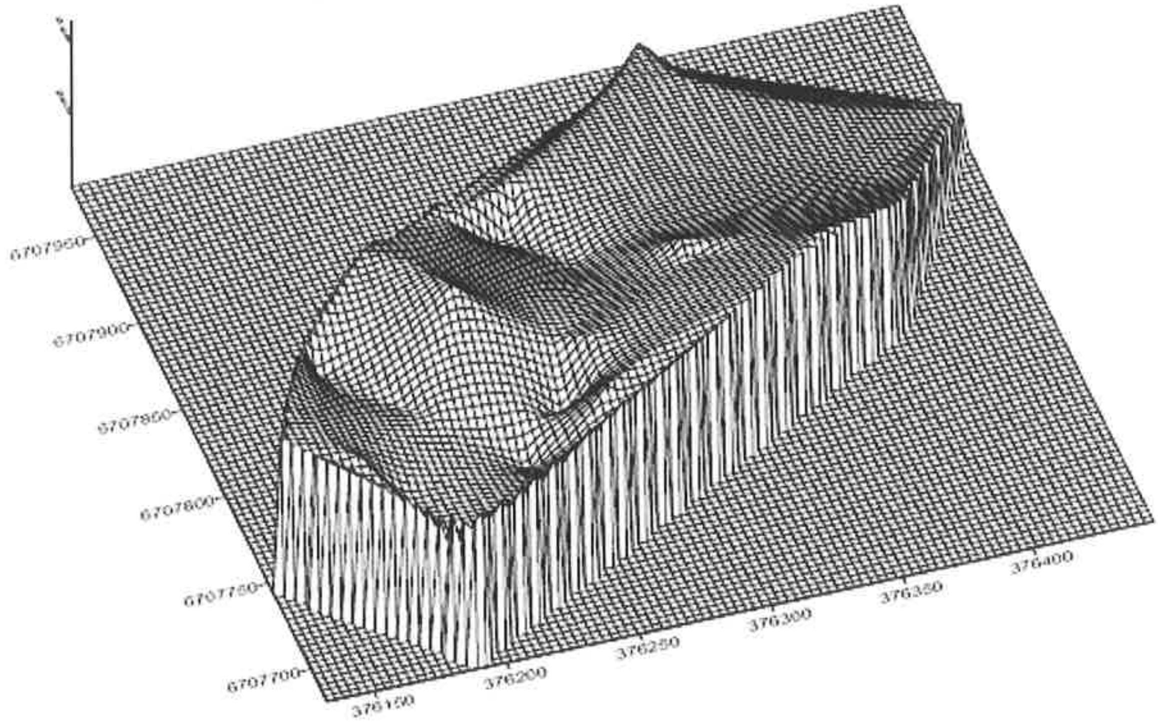
The northing, easting and RL of each survey point were input into the *Surfer* software package. A contour plot and a 3D wire plot were derived (Figures 7 & 8), oriented to be looking from the southeast corner of the landfill.

Figure 7: Contour plot of September 2010 waste levels - Glen Innes Landfill



The Easting 376200 is just below the southeast corner. Its RL is 996 m. Note the middle, western roadway entering the landfill at 992.5 m from Blue Hills Road and veering north to the current green waste stockpiles. The two southern 992.5 m levels denote roadways going down into the southern section of the landfill.

Figure 8: 3D wire plot September 2010 waste levels - Glen Innes Landfill

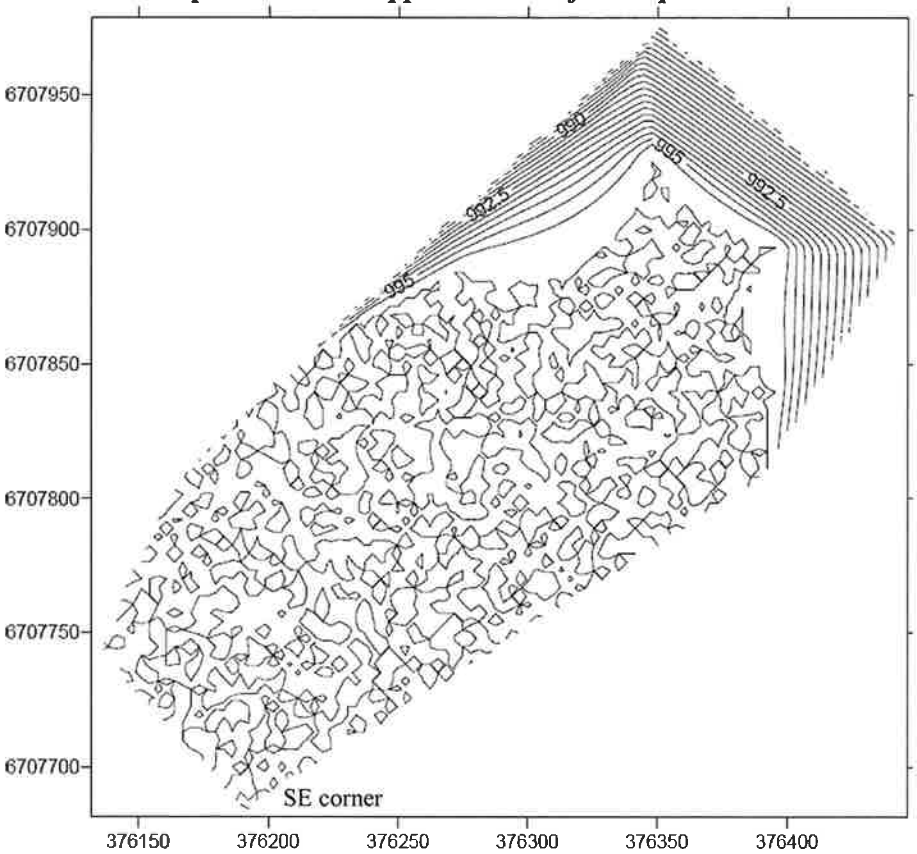


The 3D wire plot above gives a rough visual impression of the current top of the landfill gained from the limited number of survey points.

A pink dotted line on Map 3, Appendix A denotes a landfill level of RL 996 m, which is the current level of landfill waste in the southeast corner. This RL 996 m is extended across the top of the landfill airspace to denote what landfill airspace is still available for filling. The dotted pink line is indented in the north east, north and northwest to allow a 4(H):1(V) slope on these sides of the landfill. This is the steepest slope commonly accepted as being safe for movement of a tractor or slasher. The upper shape of the estimated landfill airspace remaining to be filled to a height of RL 996 m is therefore denoted by the pink dotted lines between points 45, 46, 47 and 48 and the dotted pink lines that go to the outside current base of the landfill at points 10, 11, 19 and 22.

The northing, easting and RL of these survey points were input into *Surfer*. A contour plot and a 3D wire plot were derived (Figures 9 & 10), oriented so that one is looking from the southeast corner of the landfill.

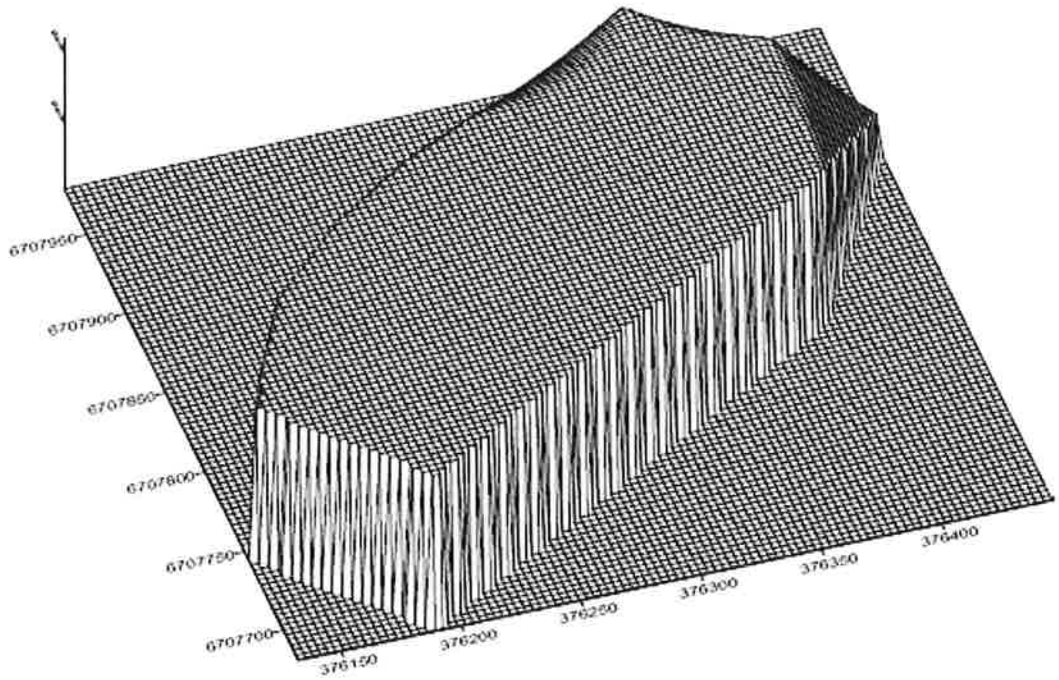
Figure 9: Contour plot estimated upper level landfill airspace RL 996 m - Glen Innes Landfill



The mosaic-like lines represent RL 996 m across the top of the landfill airspace.

Another way of looking at the future, achievable RL 996 m upper level of the landfill is through a 3D wire plot (Figure 9).

Figure 10: 3D wire plot upper level landfill airspace RL 996 m - Glen Innes Landfill



The space between the base of the remaining landfill airspace yet to be filled (the September 2010 landfill levels, Figures 7 & 8) and the upper estimated 996 m RL levels to finally be reached with solid waste (Figures 9 & 10) is a complex void. Its volume was estimated using the grid volume computation package in *Surfer*.

Total Volumes in cubic metres by:

Trapezoidal Rule:	139093.52095219
Simpson's Rule:	139106.21632814
Simpson's 3/8 Rule:	139094.68414072

(*Surfer* output)

Therefore, by filling the landfill as a single mass to this conservative level of RL 996 m, there is 139,000 m^3 of landfill airspace remaining to be filled.

4.16 Remaining landfill life based on three different compactors

From the remaining airspace volume above, we can estimate the remaining landfill life:

Estimates using 2,600 tonnes per year of solid waste + 400 tonnes per year of daily cover = 3,000 tonnes per year = 3,000,000 kg per year.

Track type dozer, say 550 kg/m^3	139,000 m^3 / [3,000,000 kg / 550] = 25 years
Smaller steel wheeled compactor, say 700 kg/m^3	139,000 m^3 / [3,000,000 kg / 700] = 32 years
Heavy steel wheeled compactor, say 1,000 kg/m^3	139,000 m^3 / [3,000,000 kg / 1,000] = 46 years

Being more precautionary let's say 4 M kg landfilled waste and daily cover

Track type dozer, say 550 kg/m^3	139,000 m^3 / [4,000,000 kg / 550] = 19 years
Smaller steel wheeled compactor, say 700 kg/m^3	139,000 m^3 / [4,000,000 kg / 700] = 24 years
Heavy steel wheeled compactor, say 1,000 kg/m^3	139,000 m^3 / [4,000,000 kg / 1,000] = 35 years

In summary, using precautionary figures, filling to RL 996 m with a track dozer, the landfill will last 19 more years. However, using a heavy, steel wheeled compactor, the Glen Innes Landfill will last 35 more years.

Therefor, the Glen Innes Landfill life will be extended by 16 years if a heavy, steel wheeled compactor is purchased. A brand new, fifty tonne, steel wheeled compactor costs ~$1M to $1.2M.

4.17 Landfill establishment cost saving

The BDA Group in 2009 conducted a study of '*The full cost of landfill disposal in Australia*' for the Federal Government Department of the Environment, Water, Heritage and the Arts.

Small landfills were categorised as accepting <10,000 tonnes /year with their assumed annual disposal at 5,000 tonnes/year. Glen Innes Landfill is therefore categorized as a small landfill. The costs per tonne are higher for a small landfill than for medium and large landfills as a result of fixed costs components (BDA Group 2009, p 12). The breakdown of estimated small landfill costs per tonne was as follows:

Table 3: Full costs of landfilling – small landfill <10,000 tonnes per year

Type of cost	Small	Medium	Large
a) Land	$5	$3	$2
b) Approvals / site development	$10	$6	$4
c) Best practice liner	$13	$8	$5
d) Leachate collection	$6	$4	$3
e) Gas recovery	$6	$4	$3
f) Amenity management	$1	$1	$1
g) Operations	$34	$20	$14
h) Capping & remediation	$10	$6	$4
i) Post-closure maintenance	$15	$9	$6
Total	*$100*	*$60*	*$40*

Source: BDA estimates (BDA Group 2010, p. 46)

If the current Glen Innes Landfill is managed as a single mass to last for at least an extra 16 years due to the use of a heavy, steel wheeled compactor in comparison to a track type dozer, the landfill establishment costs foregone are at least $4.08 M computed as follows:

Let's say the new landfill site will last for another 100 years. The total landfill cost for a similar population as present is estimated at 3,000 tonnes per annum x 100 years x $100 per tonne = $30,000,000. The landfill establishment cost is $40 per tonne [a) to e) Table 3], that is, 40% of $30,000,000 = $12,000,000.

If 16 years (16%) of the new landfill life is saved by buying a heavy, steel-wheeled compactor for the current Glen Innes Landfill, then the savings are at least 16% of $30 M = $4.8 M. Deduct the cost of the compactor and the savings are $4.8 M - $1.2 M = $3.6 M. (If the waste and cover annual tonnage per year remains at 3,000 tonnes/year, then the savings will be $6.3 M.) Add on another 10% to the years for the expected settlement of the solid waste, and the savings range is between $4.08 M and $6.93 M.

5. DISCHARGES OF POLLUTANTS TO WATER

This section outlines Council initiatives already undertaken and those proposed to meet the water pollution prevention environmental goals set out in the *Environmental Guidelines: Solid Waste Landfills* (1996, p. 4), that is, prevent pollution of water by leachate, detect water pollution, and remediate water pollution. The proposed initiatives will be attained by managing the landfill as a single mass but with localised surface water controls.

5.1 Prevent pollution of water by leachate

Even though a leachate barrier and collection system was not required by the NSW EPA in the 1990s when the southern section of the landfill was constructed, a one metre thick clay liner was compacted into the base of the cell, and a leachate sump and pump and three dam treatment system installed.

The northern section, the older section of the landfill, does not have a leachate collection system.

Geophysical surveys, a study of groundwater infiltration into the landfill, a study of quarry dam pump out, groundwater monitoring, and surface water monitoring have not alerted to any problems arising.

5.1.1 Geophysical surveys

Geophysical resistivity surveys were conducted in Year 2003.

> *The surveys were designed to examine the possibility of leachate exfiltration to the groundwater via any major fracture zones within the underlying rock and also infiltration of groundwater to the current waste cell. The surveys also attempted to determine the extent, direction and depth of any existing leachate migration pathways, or zones where these might occur in the future. This information could assist in choosing the optimum placement of any additional groundwater monitoring bores, cut-off drains or other groundwater treatment works, if required.* (Bennett 2003, p. 1)

Bennett (2003) found no indication of leachate discharge into groundwater surrounding the landfill site. Although there are areas of relatively low resistivity to the north of the landfill, the values are not low enough to indicate leachate contamination. Instead, the lowest resistivities indicate possible groundwater pathways. The same can be said for a resistivity profile assessed just south of the landfill bund wall that borders the current landfill and the quarry.

5.1.2 Risk assessment of groundwater infiltration into the landfill

The Bennett (2003) resistivity surveys were part of the work conducted in Year 2003 to meet a licence requirement for a study and options report for groundwater infiltration into the current cell of the Glen Innes Landfill. The requirement was as follows:

> ***U1 Study and Options Report - Groundwater Infiltration into Landfill***
>
> *U1.1 The licensee is currently non-compliant with clause O5.2 of the licence which specifies that the leachate collection system must be installed above the groundwater table. The licensee has estimated that approximately 7kL/day of groundwater is collected in the leachate sump. The licensee must undertake a study that identifies environmental risks and management options for groundwater infiltration into the operating landfill. The study and report must:*
>
> 1. *Quantify and describe the existing groundwater infiltration problem including:*
>   a) *estimated volume of waste within the groundwater;*
>   b) *assessment of leachate quality and variation as a result of groundwater infiltration;*
>   c) *current operational procedures of pumping out groundwater - such as time between pumping using automatic levels controls and pre-set levels;*
>   d) *volume and levels of groundwater collected prior to pumping.*
> 2. *Identify environmental risks associated with groundwater infiltration and potential leachate exfiltration into groundwater from the landfill.*
> 3. *Identify options for improved management of groundwater during the operating phase of the landfill - including operation and capital options (if feasible).*
> 4. *Identify implications and options for management of groundwater infiltration during landfill closure stage.*

Major findings of the study by Hart (2003) advised by Ralf Stoeckeler, Director of Works and Infrastructure, Glen Innes Municipal Council were as follows:

U1.1 Introduction

The landfill leachate collection sump is installed above the confined groundwater levels of the confined aquifer below the landfill. Water table definitions only apply to unconfined aquifers and so cannot be applied to the Glen Innes Landfill. Piezometric pressure is forcing groundwater upwards into the current cell of the Glen Innes Landfill.

1 a) The estimated maximum volume of combined waste, leachate and groundwater, before leachate pump cut-in, is ~468.75 m^3. Given voids in the compacted waste filled by the leachate and groundwater mixture, the actual volume of waste in the leachate/groundwater

mixture was estimated at 66% of 468.75 m^3 = 309.38 m^3 (based on a compaction rate of 664 kg/ m^3 and that there is 1,000 kg of water/m^3).

1 b) Groundwater dilution of leachate improves the concentration quality of the leachate because quality indicators such as total nitrogen and electrical conductivity are about halved in concentration. However, this does not improve the loading and so the same loading has to be treated in the leachate ponds and by irrigation onto the old landfill.

1 c) The leachate pump operates on a two float system. When the water level in the sump rises to approximately 2 m over the pump, a switch activates the pump which will run until the water level drops to the low level which is just above the pump inlet. The pump then switches off until the water level rises to the 2m level again.

Council has a spare pump at the workshop in the case of a malfunction. The old pump can be pulled out and replaced immediately with the standby pump to allow the malfunctioned pump to be sent away for repair. To assist Council in monitoring the pump condition, a flashing red warning light has been installed at the site. The light is activated automatically if the water level in the sump rises 1 m above the normal maximum water level. This warning light has proven to be effective and has alerted staff (and on 2 occasions members of the public) to the fact that the pump has stopped operating and remedial action was able to be taken immediately.

As an added precaution, the electricity meter box with the circuit breakers for the pump has been locked to prevent unauthorised persons switching the pump off.

1 d) An estimate of the maximum depth of solely groundwater near the sump base is 0.36 m. The estimated maximum volume of groundwater available prior to pumping when the waste is saturated with rainwater is 16.4 kL/day; and when conditions are dry, a minimal volume of 3.71 kl/day is available. These estimates were in keeping with the groundwater seepage noted on the quarry floor (Photograph 4).

Photograph 4: Groundwater seepage (foreground) in quarry, June 2001

A review of leachate pump volumes in a high rainfall period 6/11/2001 to 3/01/2002 found that 20% of the total rainfall collected in the landfill cell catchment, would not have become leachate if the landfill design is modified:

- to reduce the catchment area; and
- to reduce infiltration into non-active sections of the landfill by some intermediate clay covering, and spreading or irrigating collected rainwater on clay or sandy soils in as large an area as possible to allow evaporation.

However, such conclusions should also consider the faster biodegradation of "wet" "bioreactor" landfills as supported by the Department of Environment UK (1995:213). Waste stabilisation quickens and leachate quality improves in a wet, bioreactor type landfill, reducing the post-closure care time for a landfill.

2. Environmental risks associated with groundwater infiltration and potential leachate exfiltration into groundwater from the landfill were identified using the approach outlined in Risk management standard AS/NZS 4360:1999 (Standards Australia, Standards New Zealand 1999).
. Environmental hazards that may become a reality were outlined:
   a) Groundwater contamination of the quarry to the south may occur if there is insufficient head on groundwater that infiltrates upwards into the cell.
   b) Groundwater contamination may also occur if the leachate/groundwater levels in the landfill cell rise and new pathways are found to groundwater via higher access routes.
   c) Surface water contamination may occur if leachate/groundwater being pumped into the leachate treatment ponds exceed their capacity.
   d) Extra subsidence and methane production around the leachate sump may occur if there is too great a volume of leachate/groundwater surrounding the sump.

3. Options for improved management of groundwater during the landfill operating phase were devised by analysing the environmental risks listed above using the approach recommended in AS/NZS 4360:1999. Areas detailed for management attention were as follows.
   a) Installation of two more monitoring wells in the Commons area to the north of the old landfill to more closely monitor groundwater moving under the landfill and then under the Commons area. (These wells were installed in Year 2004.)
   b) There would be less need for groundwater monitoring of the Wilga Street wells when new wells are installed in the Commons area. (Groundwater monitoring ceased in the Wilga Street wells in December 2003.)
   c) The groundwater level status quo should be maintained. Pump out of the quarry sedimentation dam should continue to be undertaken only when the dam is at a high level so that the groundwater levels under the current cell remain relatively constant and are not lowered. Lowering the groundwater levels upgradient of the current cell is likely to increase the chance of leachate seepage into underlying groundwater pathways. [A management plan has been devised (Hart 2009) and has been implemented.]
   d) Undertaking quarterly readings of leachate pump electricity usage will assist in noting any undue increases in leachate/groundwater volume. (Part of this LEMP.)
   e) It may be worthwhile to review the current landfill filling plan to see if there are any areas that can be contoured and intermediate covered to allow greater surface retention of rainwater to promote evaporation, or diversion away from the current cell if at all possible. (Part of this LEMP.)

4. Groundwater infiltration management post closure.
   The current leachate pump is handling the present leachate pump-out efficiently. In the study of wet period pump-out there was a maximum 31 kL/day of combined leachate/groundwater pumped out. The pump capacity is 7.2 kL/hour so the system copes well. Despite greater potential leachate volumes as the waste volume increases, intermediate and final cover will reduce surface water ingress and leachate generation. The current leachate pump may therefore be effective post closure and it is likely that it would need to

be kept operational for many years post closure. A thirty-year post closure maintenance and monitoring period is often mentioned in the literature.

The contours of the current cell floor before waste deposition (Appendix A, Map 2) indicate that the cell was contoured to fall to the current sump. Unless groundwater contamination is found in the new wells in the town commons area, there appears to be no need to install another groundwater/leachate sump if groundwater monitoring validates that the present pump continues to be adequate. If groundwater contamination is found, a possibility is another geophysical survey across the intermediate or final covered areas of the southern section of the landfill to note areas where groundwater/leachate is pooling and at which another sump is likely to be worthwhile. (Due to the open status of the southern section of the landfill and the paucity of continuous soil cover material to place geophysical spikes along a continuous line, it was not possible to run geophysical lines across the southern section of the landfill in the May 2003 survey.) However, it needs to be noted that drilling through rubbish is not an easy task.

Even when groundwater/leachate volumes decrease post closure and only minimal leachate pumping is necessary, groundwater monitoring would need to continue to see if lack of pump-out affects groundwater quality. The period of continued groundwater monitoring post closure and installation of a final cover should have a hydrogeological basis, for example, it may be based on the average linear velocity of groundwater movement under the site and distance between the landfill and downgradient wells.

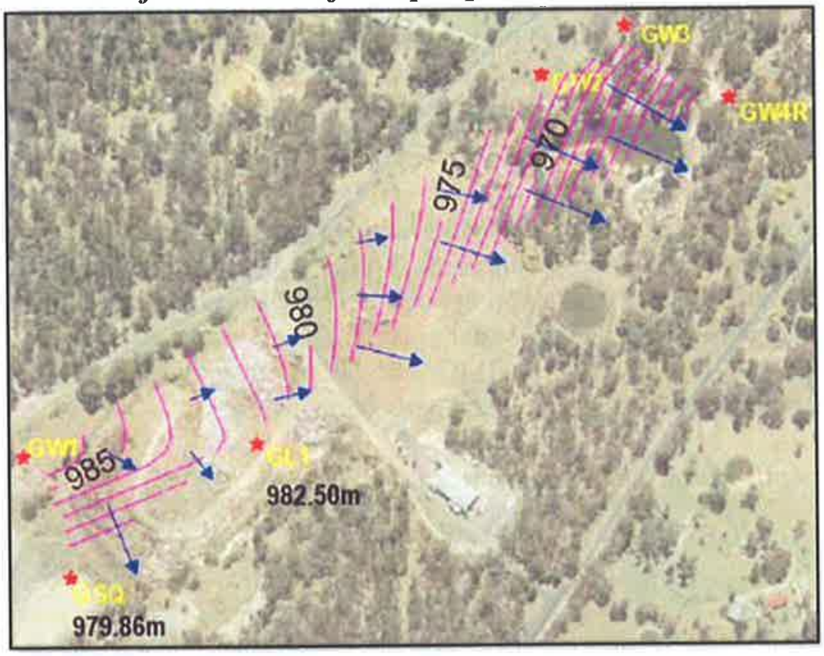
5.1.3 Quarry sedimentation dam pump out study

As a result of the risk assessment study, the maximum pump out of the quarry sedimentation dam was determined as the join between the two large concrete pipes supporting the pump shed. This is at 981.86 m RL based on a 1,000 m base mark on the concrete just outside the recycling facility – far higher than that shown on Photograph 5.

Photograph 5: Base of quarry sedimentation dam Year 2001

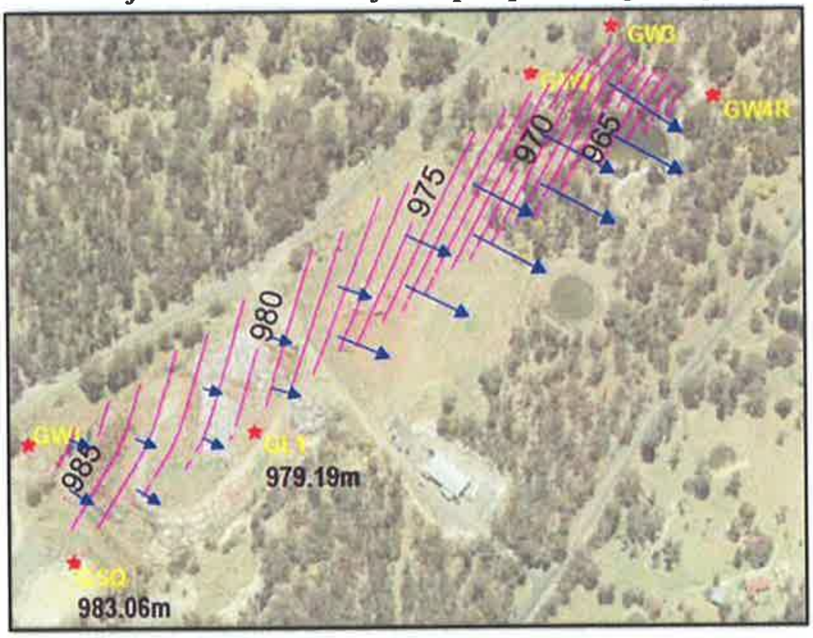
This maximum pump out to 981.86 m RL is to reduce hydraulic inducement of leachate flow from the landfill southwards under the landfill/quarry bund wall towards the quarry. Figure 11 shows that groundwater/leachate flow direction is more towards the quarry if the leachate sump (GL1) is not working and rises to 982.5 m, and the quarry dam at the same time has been pumped out to a low level 979.86 m, i.e., 0.4 m above the dam base.

Figure 11: Groundwater flow direction if GL1 pump not working, GSQ dam too low



It was therefore recommended by Hart (2009) that the quarry base is partially in-filled to allow vehicular access to the southern end of the dam and at the same time to reduce the level of pump-out required. The long term objective is to pump out to half way down the top concrete pipe of the pump standpipe (Figure 12), thus further reducing the hydraulic pressure risk of landfill leachate ingression into the quarry dam.

Figure 12: Groundwater flow direction best if GL1 pump working & higher water level at GSQ



It is also notable that pump out should not be for at least five days after heavy rainfall events and that the suspended solids 30 mg/L sample should be used as a guide for pump out.

5.2 Detect water pollution

All current surface water, leachate, and groundwater sampling points are shown on Figure 13.

5.2.1 Leachate

Concentrated leachate is sampled in the leachate sump (GL1) quarterly, and the treated leachate six monthly from the final dam (GL2) of the three leachate treatment dams. Results to date show that the treatment dams are treating the leachate well, and that the final water is suitable for irrigation on the old northern section of the landfill.

5.2.2 Surface water

The quarry sedimentation dam (GSQ) is being sampled quarterly to review if the water quality is suitable for pump out to the ephemeral stream. To date, suspended solids is the major concern. The water quality at surface water sampling point GS2 is being sampled six monthly, preferably when flowing, to review its surface water quality against the Australian freshwater aquatic ecosystem guidelines (ANZECC & ARMCANZ 2000). It is a degraded stream due to the considerable number of car bodies and metal parts buried within it.

Figure 13: Sampling locations – Glen Innes Landfill

Base map from SIX (Spatial Information Exchange) © NSW Dept of Lands 2006, downloaded 1 Oct 2010

5.2.3 Groundwater

Surface water and groundwater interact. The contours shown on Figures 11 and 12 apply to water levels for the quarry sedimentation dam, the leachate sump and the groundwater wells.

Three groundwater wells (GW1-GW3) are monitored quarterly and one (GW4R) six-monthly where groundwater flow rate is slower. Well depths from the top of the internal PVC casings are respectively 62.5 m, 12.62 m, 22.90 m, and 25.08 m. Screens to allow groundwater ingress are at the base of the wells.

Groundwater monitoring has been conducted since Year 2001. No landfill leachate ingress into the groundwater has been detected. The one metre clay liner under the southern portion of the landfill, and the clays downgradient of the landfill, are therefore attenuating and preventing leakage of landfill leachate.

5.3 Remediate water pollution

There is downgradient land space available to remediate water pollution if it occurs.

5.4 Surface water runoff control

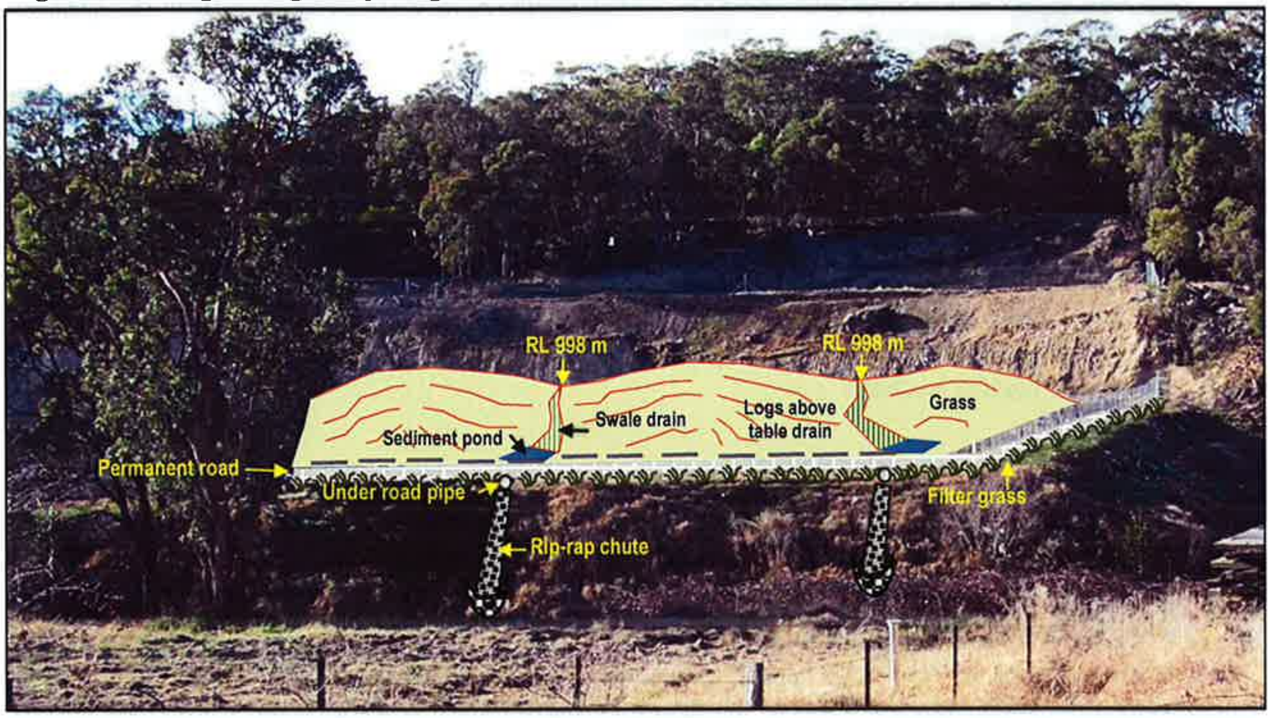
Currently most surface water runoff, except runoff from the entry road from Blue Hills Road, is captured by the leachate sump at the centre of the southern section of the landfill, or runs off directly into the three dam leachate/surface water treatment system, from which it is irrigated back onto the northern end of the landfill.

As the landfill increases in height, surface water runoff control will be necessary over partially disturbed areas. The ephemeral stream that flows on the western side of the landfill will be protected by restricting the size of landfill cells and current faces, and by creating and maintaining grassed slopes and other filtration measures such as sediment ponds. Landfill leachate volume per unit of solid waste will be reduced and the capacity of the current leachate / surface water treatment ponds will be conserved.

It is proposed that imminent filling concentrate on shaping the southern end of the landfill and work progressively northwards in a manner that suits operations. Sediment runoff control will be accomplished by shaping the landfill so that surface water runoff drains into localised swale drains and sediment ponds (Figure 14).

The reason for the proposed westward drainage is that connection between the cliff face and solid waste on the eastern side of the landfill may be jeopardised by seepage from drainage pathways. A slippage may occur and present an occupational health and safety hazard. Review of the catch drain at the top of the cliff and lining it with low permeable material is important for keeping the cliff face stable.

Figure 14: Progressing landfilling with sediment controls



The southwest corner post ground level (GL) is currently RL 995.654 m. This is the benchmark for planning slopes for surface water runoff. The RL 998 m level on the cliff side of the landfill (Figure 14) is the level that allows for good site drainage and fits in with the estimate of the total landfill lasting for at least another 35 years if a heavy, steel wheeled compactor is used. Attaining that level would be better managed by compacting the waste in 600 mm lifts to attain a total height of approximately 2 metres before moving on to a new cell. If the inlet to the sediment ponds is RL 996 m, a 1% fall along a swale drain would be attained from a height of RL 996.7 m against the cliff face. Perhaps this is the first goal when concentrating on landfilling the southern section of the landfill. In the meantime, other areas of waste can be covered with mulch.

Drainage from the tipping pad should be towards the solid waste. Bolton (1995, pp. 182-195) provides details on pushing solid waste and cell operations.

As the southern end of the landfill increases in height, swale drains can be formed and the areas grassed. Grass should provide at least 70% and preferably 90% cover before runoff is routed into the sediment ponds. Before then, the surface water should be allowed to soak into the ground and follow its present path of seeping towards the leachate sump.

However, the swale drains will be infilled later and other forms of top drainage such as more rip-rap chutes or HDPE flex drains (Bolton 1995, p. 158) will need to be set up to channel the surface water runoff to the sediment ponds. This flatter top profile will provide a platform for green waste management when the current main road access in Blue Hills Road is closed for landfilling.

Recommended design keystones for landfilling progression are as follows:

Stage 1. Before proceeding, consult with a geotechnical engineer re slope stabilities including that of the southern bund, the eastern cliff face, and the western bund of the northern section of the landfill.

Stage 2. Install three small, eastern sediment ponds and a permanent road along the eastern and southern boundaries of the southern section of landfill.

Stage 3. Install two landfill gas passive vents - as discussed in Section 6.2.

Stage 4. Fill the southern end of the landfill with solid waste to create fall to the most southern sediment pond. The top of the swale drain should be at least RL 996.7 m to allow for a 1% fall to a sediment pond, and the waste on either side of the swale drain should be higher than RL 996.7 m with a fall of at least 1% to the swale drain.

Stage 5. Continue landfilling in the southern section of the landfill to complete the swale drain falls to the other two sediment ponds.

Stage 6. Research, design and construct the new wastes receival area. See Section 4.9 and Figure 5 for some ideas.

Stage 7. Re-engineer the Blue Hills Road entry. Break up the bitumen on the lower section of the internal road entering off Blue Hills Road so that it will not act as a channel for landfill leachate. Construct and key in a batter wall that will join up the western batter walls of the southern and northern sections of the landfill. Construct a drainage trench to direct the leachate from this section towards the landfill sump. The specifications for this area should be devised by a geotechnical engineer. Start filling this area with solid waste.

Stage 8. Fill in southern section swale drains with solid waste to create a top platform for green waste according to space required. Have at least a 1% slope on the top platform to drain surface water runoff to high slope drains which fall to the sediment ponds: rip-rap chute drains, or drop down HDPE flex drains (Photograph 6), or ½ corrugated circular drains. The side slopes and top area should be covered with intermediate cover (≥ 300 mm thick clay, compacted sufficient for loaded dump trucks and compacted lightly). Add topsoil and seed to the side slopes (maybe Japanese millet or oats for initial, quick cover) and attain a good, permanent grass coverage. Do the same to top areas which will not be used for green waste processing.

Photograph 6: Drains to dissipate flow on high slopes – HDPE flex & riprap chute drain

(Landcom 2006)

Stage 9. Create a clay batter on top of the northern slope of the northern section of the landfill to contain solid waste and key it in. Fill this area with solid waste so that the slope rises at 4H:1V. This is a safe slope for a slasher. Cover the side slopes with at least 150 mm of topsoil and sow with grass. Ensure that initial runoff from this area is drained to the current leachate/surface water treatment dams. Continue landfilling in this area until the RL 996 m level is reached at a 4H:1V slope.

Stage 10. Work out the starting height for the continuation of the permanent road on the northern section of the site so that it has at least a 1% slope southwards. A table drain on the inside of this road should drain to a new sediment pond located as shown on Figure 28, Section 5.4.3. This permanent road may run around the edge of the whole northern section of the landfill.

Final stages. Continue placing a clay batter on the outside edges of the northern section of the landfil before landfilling in small cells. The landfill may go above the RL 996 m level, but side slopes of 4H:1V are recommended as a safety level for slashing. When landfilling is complete at the site, it may be used as a transfer station and green waste processing yard. These possibilities should be kept in mind when planning final landfill progression.

The following sections give further design details for Stages 2, 4 and 10.

5.4.1 Stage 2: Three sediment ponds and permanent road

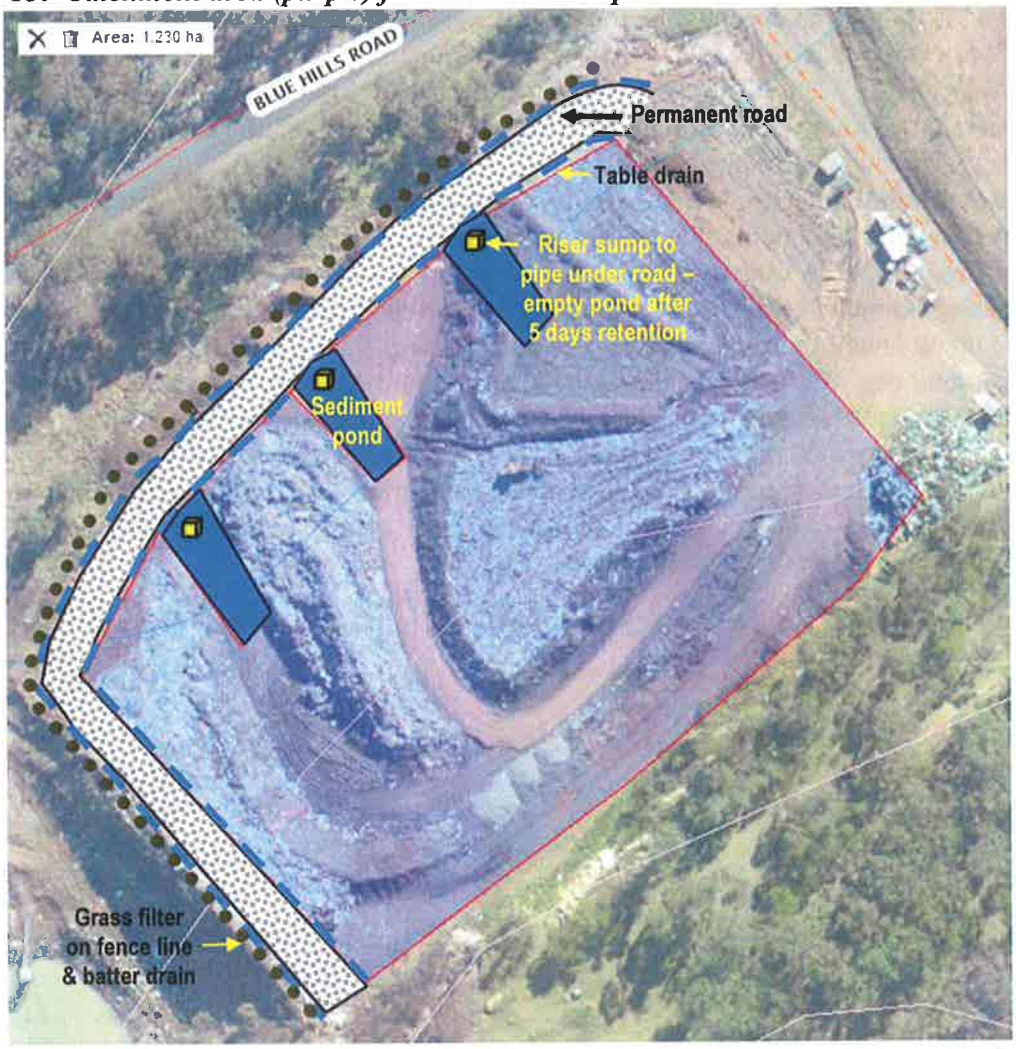
Currently surface water runoff from the southern section of the landfill, except runoff from the entry road from Blue Hills Road, is captured by the leachate sump located in the centre of the southern section of the landfill. (Runoff from the northern section flows directly into the three dam leachate/surface water treatment system. The treated water is pumped from the final dam and spray irrigated over the northern end of the landfill.) However, as the landfill expands, it would reduce leachate and conserve the current pond volume if rainwater runoff from disturbed areas is diverted to extra sediment ponds. Three sediment ponds are recommended for the southern section of the landfill (Figure 15).

Construct the sediment ponds on the southern section of the landfill before the solid waste levels become too high – but do not route runoff water to them until swale drains have been formed and grassed to provide at least 70% and preferably 90% coverage.

Make sure solid waste in the sediment pond locations is well compacted and settled prior to pond installation.

Size of the sediment ponds is calculated for the worst case scenario of dispersive soils (Group D soils with high runoff) with no grass cover and slow to settle sediment (Type F and say five days to settle) – a worst case scenario, as recommended in *'Managing Urban Stormwater: Soils and Construction, Volume 2B Waste landfills'* prepared by the Department of Environment and Climate Change (DECC) NSW (2008a). However, the grassed slopes and swale drains as depicted in Figure 14 will reduce sediment entrainment in the surface runoff water considerably.

Figure 15: Catchment area (purple) for three sediment ponds



The overall catchment area for the three sediment ponds is 1.23 hectares (purple shaded area, Figure 15). Each of the three sediment ponds will therefore collect runoff water from 0.41 ha. Using this runoff area and the formula from *Managing Urban Stormwater: Soils and Construction Volume 1* (NSW Govt 2006, p. 6-22) for sediment laden runoff water, the total basin volume is computed as follows:

Basin volume = settling zone volume + sediment storage zone volume

Settling Zone Volume

V = 10 x Cv x A x Ry-%ile, x-day (m^3)

where:

10 is a unit conversion factor; Cv is a volumetric runoff coefficient, defined as that portion of rainfall that runs off as stormwater over the X day period [5 day rainfall depth for Tenterfield at 90% percentile for landfills = 47.4 mm (NSW Govt 2006, p. 6-24). For Group D soils of design rainfall depth 41-50 mm the C_v = 0.69 NSW Govt 2006, p. F-4)]; A = total catchment area (ha); and R is the x-day total rainfall depth (mm) that is not exceeded in y percent of rainfall events (Tenterfield data NSW Govt 2006, p. 6-24).

For Glen Innes settling zone volume of one sediment pond in southern section of landfill

V= 10 x 0.69 x 0.41 hectare x 47.4 mm = 134 m^3

Basin dimensions for a 0.6 m settling depth

Surface area = 134 m^3 /6 x 10 = 223 m^2

Let L = 3W, therefore W = 8.6 m and L = 25.9 m (make W = 8.5 m; L = 26 m)

Sediment storage zone volume = 50% of the settling zone volume

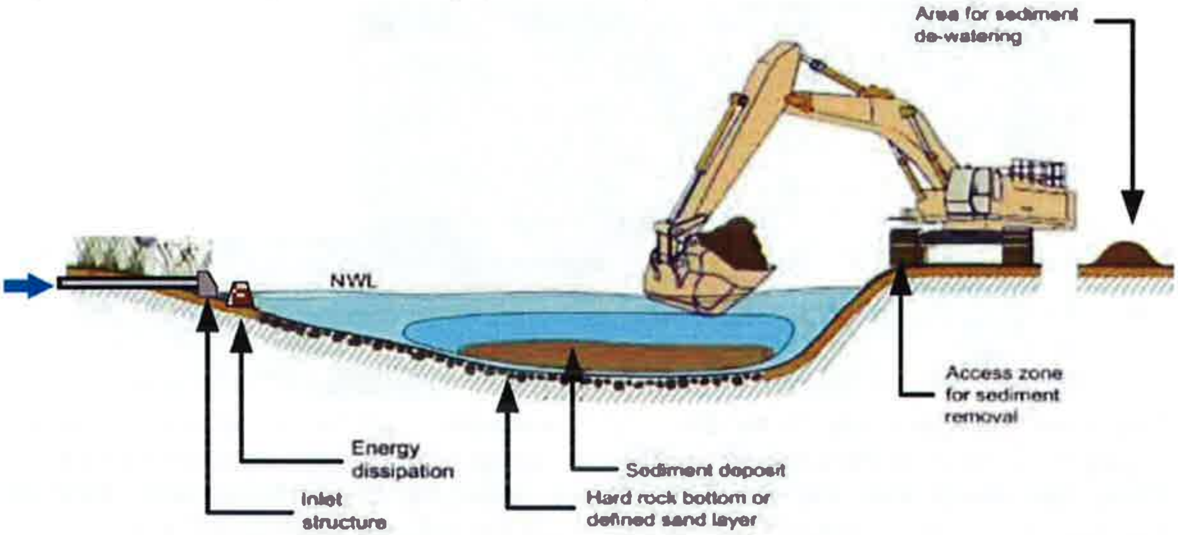
= 67 m^3 [At a surface area of around 223 m^2 (not allowing the effects of the sloping sides), the sediment storage depth will be slightly deeper than 0.3 m.]

Total basin volume = 134 m^3 + 67 m^3 = 201 m^3

Sediment ponds specification – southern section of landfill

- Spend extra time compacting the south-western side of the landfill to attain a base height for the sediment ponds of RL 992.75 m. The inlet drain pipe will be at RL 996 m.
- ~8.6 m W x 25.9 L x 2.25 m D (1.5 m water depth + 0.75 m freeboard), total volume 201 m^3
- General guidelines for a sediment pond/basin on solid ground are given by Landcom (2006). A copy is provided in Appendix B, Page 1.
- Adapt the design for emplacement on very well compacted solid waste – 600 mm compacted clay base, overlain internally with low permeable material such as Geofabrics Australasia Pty Ltd *Elcoseal*, then 300 mm protective clay and finally rocks that define the bottom if desilting is required (Figure 16). Down-slope rock reinforcement assists (Figure 17).
- The upper level of the sediment storage zone (0.3 m) should be identified with a mark on a permanent peg. When this level is reached, the sediment should be removed with a bobcat or front end loader (Figure 16). The design should be amenable to entry of heavy equipment. Dosing with gypsum may be necessary if the water has not settled after 5 days.
- Water is decanted from the basin after the sediment has settled (Use check valve on end of tube inserted in close ended PVC pipe with upper slots. This allows decanting of clearer water from the top of the water column).

Figure 16: Sediment pond decanting of sediment - if worst case scenario occurs



(JSCWSC 2009)

Figure 17: Down-slope rock reinforcement

(BCC 2006)

- A sump outlet using light weight HDPE pipe (rather than the concrete sump in Figure 18) should be higher than the sediment storage zone – say 0.9 m from the base of the pond and connected to a concrete pipe ~ 325 mm in diameter that runs under the permanent road to the riprap chute drain. A culvert above the riprap chute drain will stabilise the pipe and riprap drain (Figure 19).

Figure 18: Substitute 0.9 m high HDPE pipe for sump, convert later to bioretention basin

(GCCC 2007)

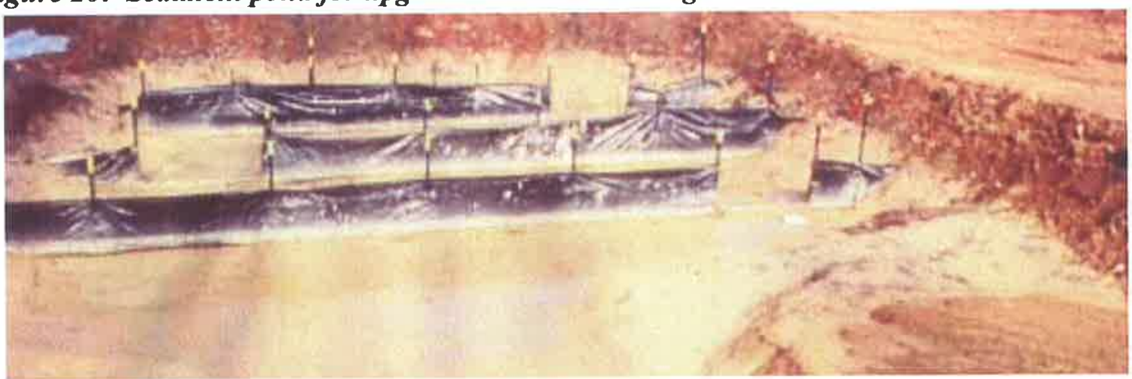
Figure 19: Culvert at end of under road drain and above riprap drain

(BCC 2001)

- The aim is to convert the sediment pond to a bioretention basin (Figure 18) once grassing of the upgradient swale drains is complete.

A bioretention basin (Figure 18) gives a better impression than a sediment pond (Figure 20), but at least 70% permanent grass cover upstream is needed before conversion to a bioretention basin.

Figure 20: Sediment pond for upgradient areas with no grass cover



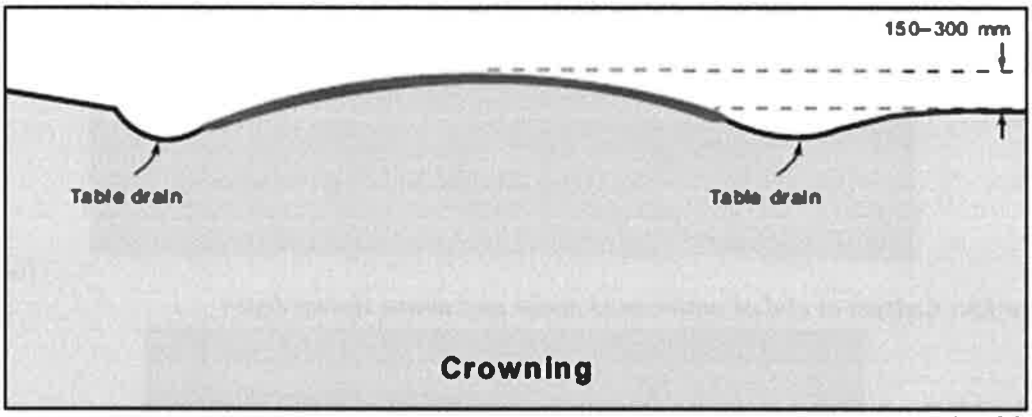
(BCC 2001, front cover)

Permanent road specification – southern section of landfill

A good quality, permanent road on the perimeter of the landfill is necessary as a fire trail and for all weather access to the landfill.

- Width - at least 6 metres.
- Final height at least RL 996.75 m
- Camber the permanent road to a table drain / batter drain on either side (Figure 21).
- Table drains. Internal drain - ~ 2 metres wide, 0.6 m deep, and all flowing to a sediment pond. Runoff flow can be dissipated in the steeper, southern table drain with intermittent, bundles of rocks that form small check dams, or even cover the whole base, and shallow **rooted (≤20 cm) grass/plants**. When grass cover is at least 70% and sediment control is good, the internal table drains may be converted to swale drains and simply slashed. External table/batter drain ~1 metre wide with a small grass hedge on the fence line, and 0.1 m deep at the lowest point.
- Underlay the drains on the internal side with 600 mm of clay and internally with low permeability material such as Geofabrics Australasia Pty Ltd *Elcoseal.*

Figure 21: Centre crown the permanent road to table drains on either side



(DECC 2008b)

- Road – ensure solid waste has been compacted over a period of time before laying say 300 mm compacted clay base, then geofabric and road base or *Tensar* or *Ecocell* (Figure 22). Alternatively, the specification in Appendix B, page 4 may be used.

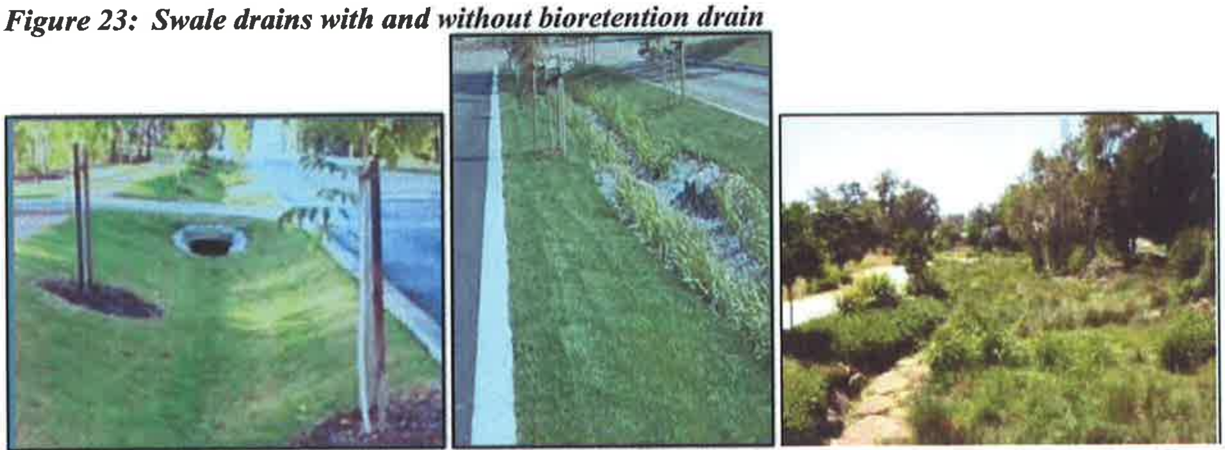
Figure 22: Geofabric and lateral control material to stabilise non-bitumen roads

(Geofabrics Australasia Pty Ltd 2010)

5.4.2 Stage 4: Swale drains

Fill the southern end of the landfill with solid waste to create fall to the most southern sediment pond. The top of the swale drain should be at least RL 996.7 m to allow for a 1% fall to a sediment pond, and the waste on either side of the swale drain should be higher than RL 996.7 m with a fall of at least 1% to the swale drain. Swale drain examples are provided in Figure 23.

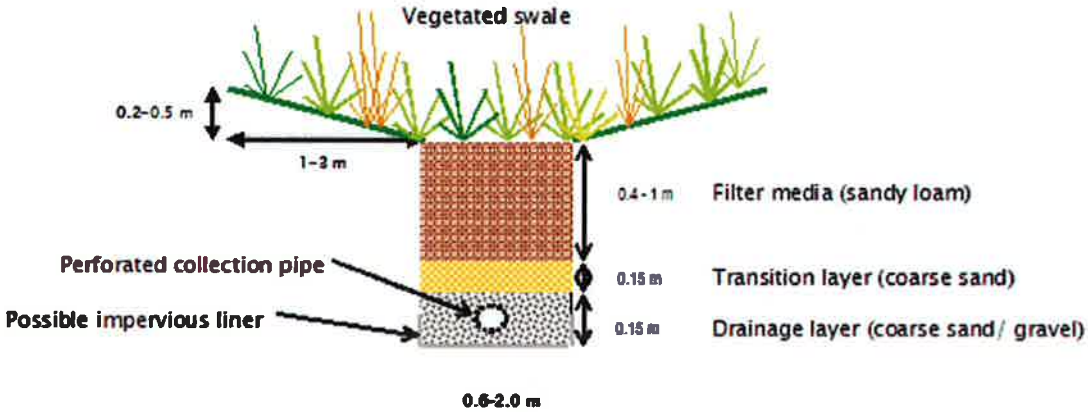
Figure 23: Swale drains with and without bioretention drain



(JSCWSC 2009)

In urban environments bioretention drains often have a perforated collection pipe at the base and high permeability material to encourage soaking into the surrounding media (Figure 24). The opposite is required at the landfill. A low permeable material such as compacted clay is required at the base to prevent infiltration into the landfill. Due to clogging potential at a landfill of the bioretention trench, the perforated collection pipe is not advised, but thin layers of filter material above compacted clay in the base of the swale drain, such as coarse sand or sandy loam, would act as a filter media - if thought warranted.

Figure 24: Typical swale drain with a bioretention drain



(GCCC 2007)

Filter fences slow the flow, are noted for their easy erection, and can be promptly installed in troublesome erosion areas (Figure 25). A detailed specification for installation of filter fences and ideas on using turf strips to limit runoff are provided in Appendix B, pages 2 and 3 from Landcom (2006). Track walked slopes allow grass seeds to lodge better (Figure 26).

Figure 25: Filter fences and swale drain

(GCCC 2007)

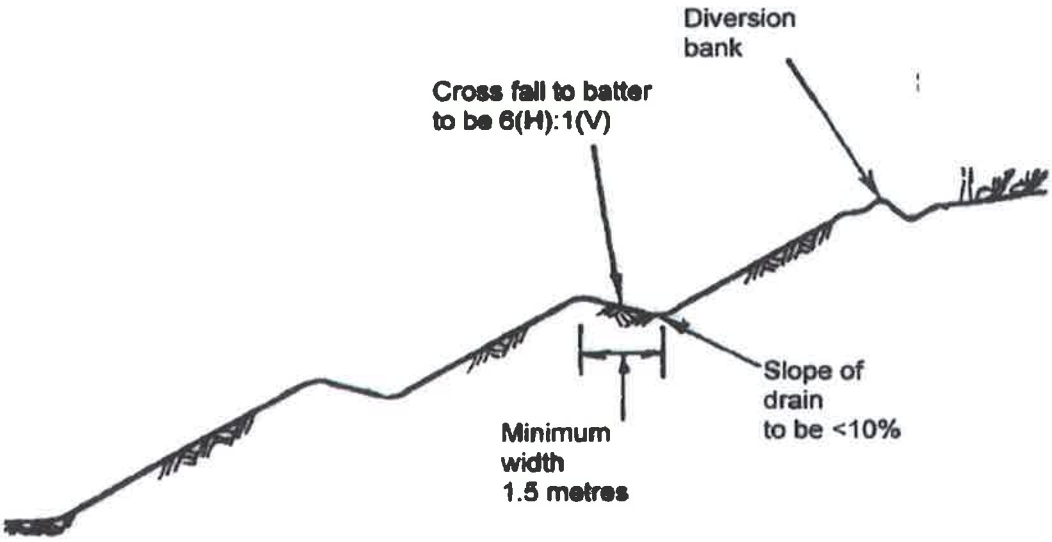
Figure 26: Track walked slopes allow seeds to lodge

(Landcom 2006)

Maximum slope length

Maximum recommended slope length on highly erodible soil is 80 metres (NSW Govt 2004, p. 4-3). Meanders in the swale drain, and mid-slope berms perpendicular to the fall on the slopes leading to the swale drains are recommended (Figure 27).

Figure 27: Berm drains slow flow on long slopes



(Landcom 2006)

Swale drain specification

- Slope swale drain from high in the east, to low in the west, across the landfill. The east to west distance across the southern end of the landfill is 70 metres. Let's say the height of the sediment pond inlets are RL 996 m. For an initial 1% fall, the height of the top of the swale drain at the cliff is ~RL 996.7 m; for a 2% fall the height at the cliff is ~RL 997.4 m; and for a 3% fall the height is ~RL 998 m at the cliff (Figure 14).

Notes: A 3% slope is 33.3H:1V where 3% = (1/33.3) x 100. A 3 % minimum slope is the guideline for the top of a landfill (NSW EPA 1996). The recommended longitudinal slope for best operation of a swale is between 1% and 4%.

- Create a couple of meanders, and groups of rocks in the base of the swale to slow the flow.
- Cover the slopes and swale drains with intermediate cover (≥ 300 mm thick clay, compacted sufficient for loaded dump trucks and compacted lightly). Spread topsoil to a minimum depth of 150 mm for turf species and 300 mm for groundcovers. Council may wish to create its own compost to spread as topsoil from its green waste and sales yard manure. A four page brochure on *'How to compost on farm'* is found at <http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/166476/compost-on-farm.pdf>. Abby is happy to provide personal advice.

  Abby Jenkins
  Soils Advisory Officer Wollongbar
  1243 Bruxner Highway, Wollongbar NSW 2477
  Ph: 02 6626 1200
  Fax: 02 6628 1744
  abigail.jenkins@dpi.nsw.gov.au
- Roughen the surface parallel to the contour by track walking up and down the slope with a dozer. This will support seed embedment. (Figure 26)
- Fine surface mulching can improve germination and grass establishment while protecting the soil surface.
- Do not plant trees. This causes long-term rainwater ingress into the landfill thus creating further leachate.
- Use filter fences before grass has been sown and while it is getting established. (Figure 25)
- Discuss perennial grasses to grow on the slopes, and plants for the base of the swale with the Glen Innes Agricultural Research and Advisory Station which specialises in pasture research for dry highland conditions. Groundcover plant species for swales that once established can tolerate dry conditions are detailed on the Gold Coast City Council website (www.goldcoast.qld.gov.au/.../section_13_13_selections_for_WSUD_systems. pdf) and may be used for initial ideas. However, it also needs to be kept in mind that the grasses and plants chosen need a shallow root system, less than 20 centimetres below the surface, to avoid die off caused by landfill gases. Oats and Japanese millet may also be used for initial soil binding.
- October to November sowing is the most ideal. For successful establishment and healthy growth, the following initial watering routine is recommended.

Week 1-2	3 visits/ week
Week 3-6	2 visits / week
Weeks 7-12	1 visit / week
- Slashing the turf will assist its growth and create a first class landfill.

5.4.3 Stage 10: Sediment pond northern end of the landfill

After ascertaining the starting height and slope of the permanent road on the landfill's southern section, install the permanent road. In the northwest corner extend a pipe from the road's internal table drain under the road and then have a rip-rap chute to a sediment pond located as shown on Figure 28.

Figure 28: Northern sedimentation pond size and location

There is likely to be natural clay in the location of the northern sediment pond, so less clay will be needed than for the sediment ponds in the southern section of the landfill. Although the surface area is larger, the depth specifications and maintenance measures are similar to those for the southern sediment ponds provided in Section 5.4.1.

Let's say that half the northern section of the landfill (~1 hectare) will be initially disturbed and need erosion and sediment control measures.

Using the formula from *Managing Urban Stormwater: Soils and Construction Volume 1* (NSW Govt 2006, p. 6-22):

Basin volume = settling zone volume + sediment storage zone volume

Settling Zone Volume

V = 10 x Cv x A x Ry-%ile, x-day (m^3)

where:

10 is a unit conversion factor; Cv is a volumetric runoff coefficient, defined as that portion of rainfall that runs off as stormwater over the X day period [5 day rainfall depth for Tenterfield at 90% percentile for landfills = 47.4 mm (NSW Govt 2006, p. 6-24). For Group D soils of design rainfall depth 41-50 mm the C_v = 0.69 NSW Govt 2006, p. F-4)]; A = total catchment area (ha); and R is the x-day total rainfall depth (mm) that is not exceeded in y percent of rainfall events (Tenterfield data NSW Govt 2006, p. 6-24).

For Glen Innes settling zone volume

V= 10 x 0.69 x 1 hectare x 47.4 mm = 327.06 m^3

Basin dimensions for a 0.6 m settling depth

Surface area = 327.06 m^3 /6 x 10 = 545.1 m^2

Let L = 3W, therefore W = 13.5 and L = 40.5 m

Sediment storage zone volume = 50% of the settling zone volume

= 163.53 m^3 [At a surface area of around 545 m^2 (not allowing the effects of the sloping sides), the sediment storage depth will be slightly deeper than 0.3 m.]

Total basin volume = 327.06 m^3 + 163.53 m^3 = 490.59 m^3

Dimensions: ~13.5 m W x 40.5 m L x 2.25 m D (1.5 m water depth + 0.75 m freeboard), total volume 490.59 m^3

6. EMISSIONS OF POLLUTANTS TO THE ATMOSPHERE

Methane is the gas of concern found amongst the many hundreds of gases that constitute landfill gas. It is a colourless, odourless gas that is flammable and explosive.

Landfilled solid waste decomposes in the absence of oxygen and results in the production of methane (CH_4), a major greenhouse gas. Methane emissions do not occur until the solid waste is approximately three months old when conditions become anaerobic (without oxygen). It has less greenhouse effect once converted to carbon dioxide (CO_2), a process that takes about 8 years in the atmosphere. This breakdown process speed ups in the anaerobic atmosphere in a landfill, and the CH_4 often completely oxygenates to CO_2 when allowed to filter through cover soil and mulch aided by the microbes that this cover contains.

The practice of covering temporarily completed cells with green waste mulch at the Glen Innes Landfill should continue because it assists methane oxidation.

6.1 Methane monitoring and remediation

Methane monitoring is conducted quarterly across the surface of the landfill, at the base of southern bund wall and inside and outside the site buildings. Some methane has been detected at irrigation points on the northern section of the landfill and alongside the leachate sump. The emission points are remediated promptly with soil cover in which the methane converts to carbon dioxide.

6.2 Passive venting of landfill gas

A passive vent is a vent that has no mechanical workings, such as a blower or a pump, to pull the landfill gas out. Advective flow is the major transport for gas migration out of the landfill. There is a pressure difference inside and outside of the landfill, causing the gas to move with the pressure gradient. Diffusion within the landfill causes the gases to move from an area of high concentration, to an area of lower concentration, thus drawing the gas towards the passive vent.

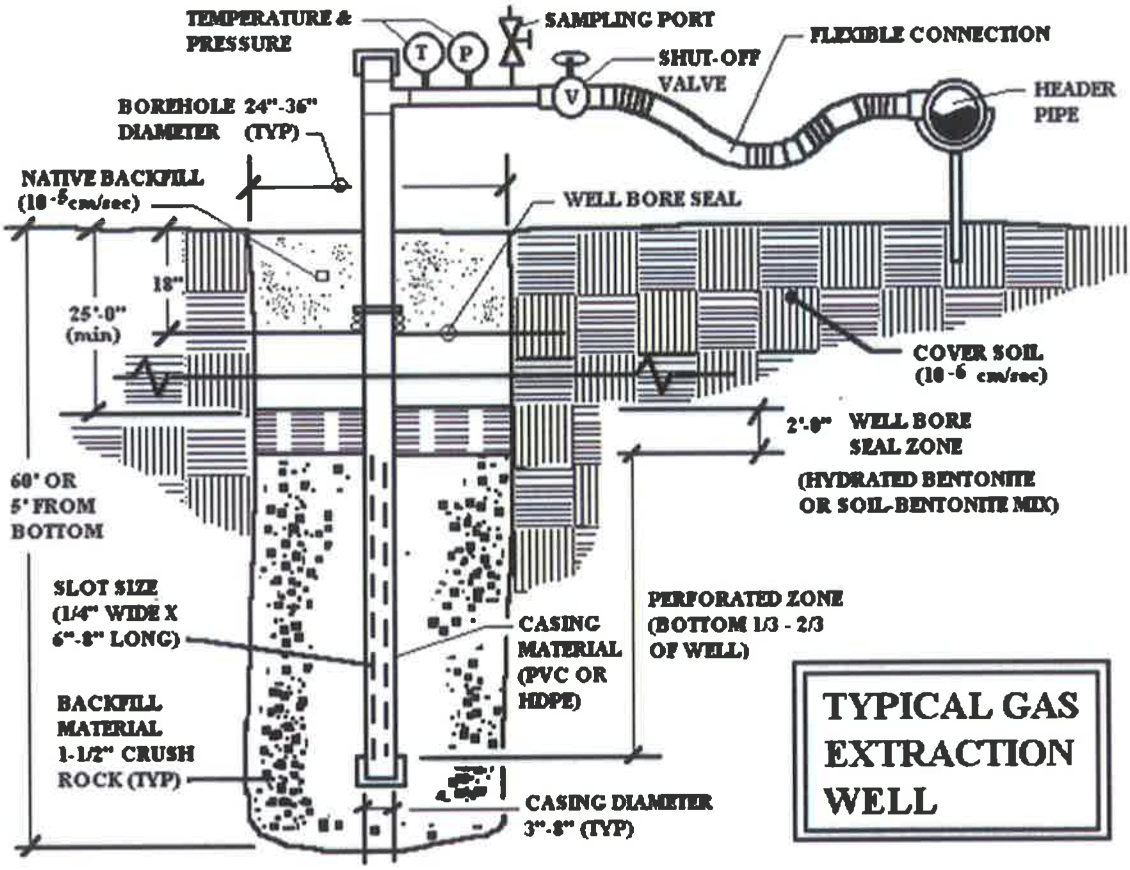
The Glen Innes Landfill leachate sump and the road base surrounding act as a passive landfill gas vent. The depth of solid waste surrounding the sump in Year 2010 is approximately 12 metres, and the solid waste depth tapers to a few metres on the western side of the southern section of the landfill.

Two types of passive venting are commonly used: vertical wells or trenches. Vertical wells are surrounded by permeable media such as gravel and are often placed in the deeper sections of landfills (Figures 29, 30, 31). Passive trenches are also filled with gravel and are commonly placed on the perimeter of a landfill. Both vertical wells and trenches should be above landfill water level. The main reason for the trench design is to cut off any lateral migration of gas from the landfill.

Two vertical wells with 800 mm casing and 900 mm diameter surrounding gravel pack are recommended. A 6 metre long slotted pipe should suffice at the base. Place them in the deepest sections of the landfill, to the north and south of the sump, for example, in the low road to the south of the sump and in a low section of the current entry road before landfilling further.

Passive venting trenches (Figure 32) upgradient of the internal table drains of the permanent western road, and alongside the eastern boundary of the landfill are recommended.

Figure 29: Passive landfill gas vent – similar construction to a gas extraction well



(Calrecycle 2006)

Well piping is typically Sch 80 PVC or SDR 11 HDPE to provide a strong material for resisting pipe failure from landfill settlement. Pipe perforations or slots (Figure 30) should begin approximately 6 to 7 meters below the landfill surface to inhibit air infiltration. Greater gas emissions are obtained with a wider borehole and casing. The road base currently used around the leachate sump would probably suffice for the backfill material. A possible structure is a geonet rolled into a circle and held together with cable ties, and supported by some surrounding roadbase to hold the structure upright. This will leave gas infiltration voids. The passive vent in front of the compactor in Photograph 2, page 15, is not wide enough to be fully effective.

Figure 30: Slotted gas extraction pipe

(Calrecycle 2006)

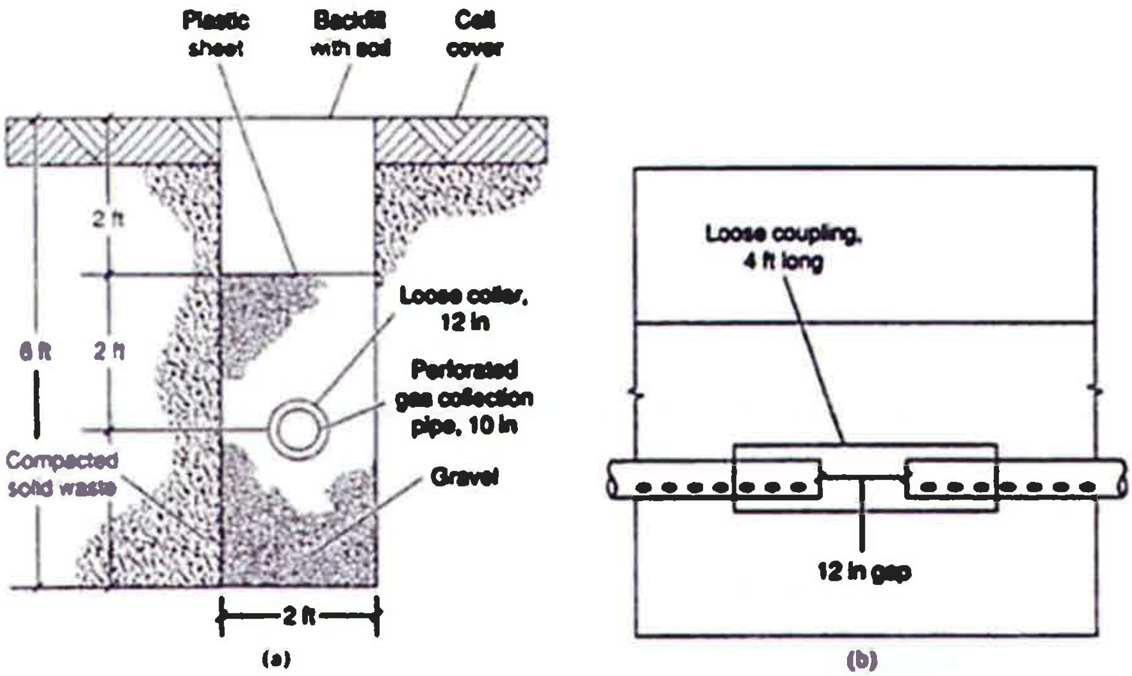
A variety of head designs may be considered (Figure 31). Number 2 has vertical biofilters connected to the header pipe (Morales 2006) to oxidise methane to carbon dioxide. The final one has whirly head extractors at the top of the pole to keep the gas higher than people that may be nearby.

Figure 31: Head designs for passive vents

((Calrecycle 2006) (Morales 2006) (Martin Geotech UK)

The horizontal collecting pipes in Figure 32 need to be connected to vertical venting pipes similar to those in Figure 31.

Figure 32: Passive vent trench design



(Keith & Tchobanoglous 2002)

Placement of geotextile within the trench before gravel placement will stabilise the trench and optimise gas flow. The plastic sheet in Figure 32 is a geomembrane. Placing geomembrane on the side of the trench closest to the outside of the landfill will further restrain lateral gas movement towards neighbouring buildings.

Some rules of thumb for passive venting in the literature are as follows:

- One vent for 7500 m^3 of solid waste

- Vents need to be spaced not more than 20 to 30 metres apart. Typically, wells are spaced no farther apart than three times the depth of the waste with a maximum acceptable spacing of 100 metres.
- The oxidation process can be enhanced by the maintenance of the capping system to prevent it from cracking and the addition of mulched green waste material above the low permeability liner.
- Passive venting is best for less than 1 million tonnes of solid waste. Above this quantity utilisation of landfill gas for electricity generation is viable – as long as the waste is ≥10 metres deep and there is more than 100 mm of annual rain.

7. LAND MANAGEMENT AND CONSERVATION

Sections 4, 5 and 6 of this LEMP concern:
- Landfill structure and operations
- Discharges of pollutants to water, and
- Emissions of pollutants to the atmosphere.

The methods presented for dealing with these issues were devised with land management and conservation in mind.

Council will interpret the methods detailed in the preceding sections within resource limits to implement best management landfill practices and so:
- Assure quality of incoming waste
- Record wastes received
- Minimise landfill space used
- Maximise recycling
- Remediate for beneficial use post closure

8. PREVENTION OF HAZARD AND LOSS OF AMENITY

Council has implemented the following practices to prevent hazard and loss and amenity:
1. Prevent unauthorised entry. Council has recently fenced the total landfill section of the Lot.
2. Prevent degradation of local amenity. Council enforces 'Cover your load' requirements. The solid waste is covered with green waste to limit odours, dust, vermin, weeds and litter. Implementation of the design plans detailed in this LEMP will improve local amenity.
3. Prevent noise pollution. Landfilling noise is limited to operating hours. Waste recyclers such as the metal recycling and green waste mulching contractors are mindful of noise legislation.
4. Adequate fire fighting capacity. Town water is only available at the recycling facility. However, the site is only three kilometres from the Glen Innes Fire Station which has two fire fighting units and is staffed by an officer of the NSW Fire Brigade and voluntary staff. Roads on the landfill itself are suitable for fire engine access.
5. Staff training. Council has appointed a full time person responsible for landfill management. He attends solid waste training courses and NIRW meetings. All landfill plant operators are trained and are now being instructed in methods of landfill operation based on Bolton (1995). Some recycling centre staff have completed studies for a waste management certificate. Qualified environmental monitoring contractors conduct environmental monitoring quarterly.

9. GEOTECHNICAL REVIEW

The recommended Stage 1 of Section 5.4 *Surface water runoff control* was consultation with a geotechnical engineer re slope stabilities.

Suggested items on the geotechnical review agenda are as follows:

- Stability of the southern bund as the landfill goes higher
- Stability of the eastern cliff face and suitable material for a catch drain above the cliff
- Stability of the western bund of the northern section of the landfill as the landfill goes higher
- Piping the quarry sedimentation dam water to downgradient of the landfill
- Stability of the quarry walls
- Stability of the sediment ponds proposed for the southern section of the landfill
- Specifications of a bund wall to key in and close off the present Blue Hills Road entry to the landfill for landfilling, and a trench system to direct leachate to the leachate sump
- Route for underground pipes to allow leachate irrigation onto the southern section of the landfill once the northern section becomes an active landfill again

10. CONCLUSION

This LEMP updates environmental management for the Glen Innes Landfill.

Major findings presented are as follows:

1. A geotechnical review of landfill slope stability is recommended.
2. Landfill capacity will be maximised by joining the southern and northern sections of the landfill into a single mass.
3. If a heavy, steel wheeled compactor is used, the single mass landfill will last another 35 years, an extra 16 years in comparison to track type compaction.
4. The extra 16 years benefit from managing the present Glen Innes Landfill as a single mass and using a heavy, steel wheeled compactor will save in the order of \$4.08 M to \$6.93 M – after the cost of a brand new heavy, steel wheeled compactor has been subtracted.
5. A new entry via Rodgers Road specifically for the landfill that incorporates a gatehouse, recycling and small waste load drop off is recommended as a means of better screening solid waste.
6. Similar charges to Armidale Dumaresq Council charges are recommended to encourage waste sorting and increase recycling rates.
7. Further sediment controls are recommended as the landfill progresses in height. It is best to manage the landfill as both a landfill and park land using waster sensitive urban design.
8. Continued use of green waste mulch to cover solid waste, and installation of passive landfill gas vents and trenches are recommended to reduce landfill and neighbourhood risks.

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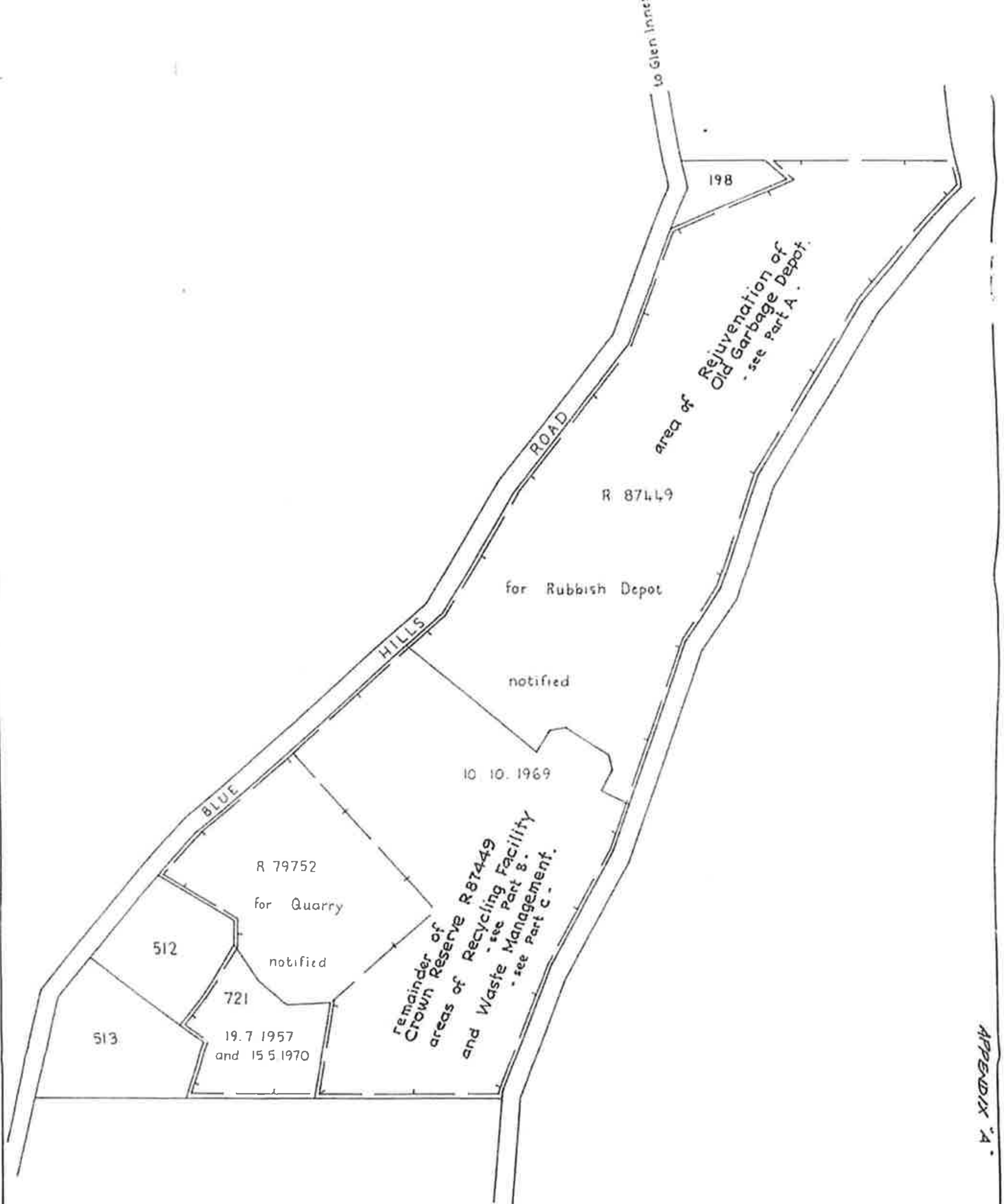
APPENDIX A - Maps



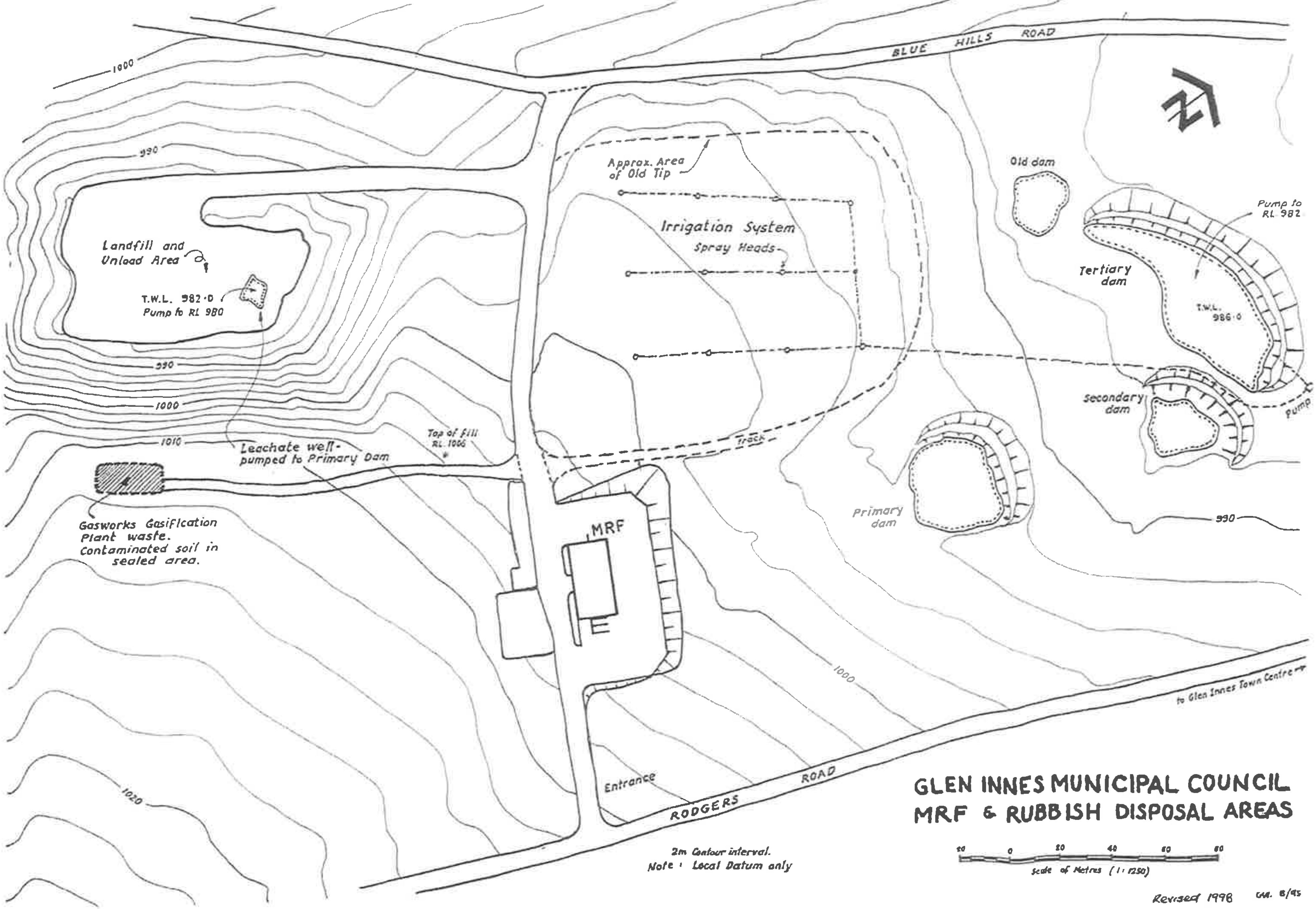
DEPARTMENT OF LANDS N.S.W.
CROWN LANDS OFFICE
PARISH GLEN INNES FILE No. AE 82 H 21
COUNTY GOUGH
LAND DISTRICT GLEN INNES

0	10	20	30	40	50	60	70	80	Table of mm

Diagram Showing

Reserves 79752 and 87449

APPENDIX "C"

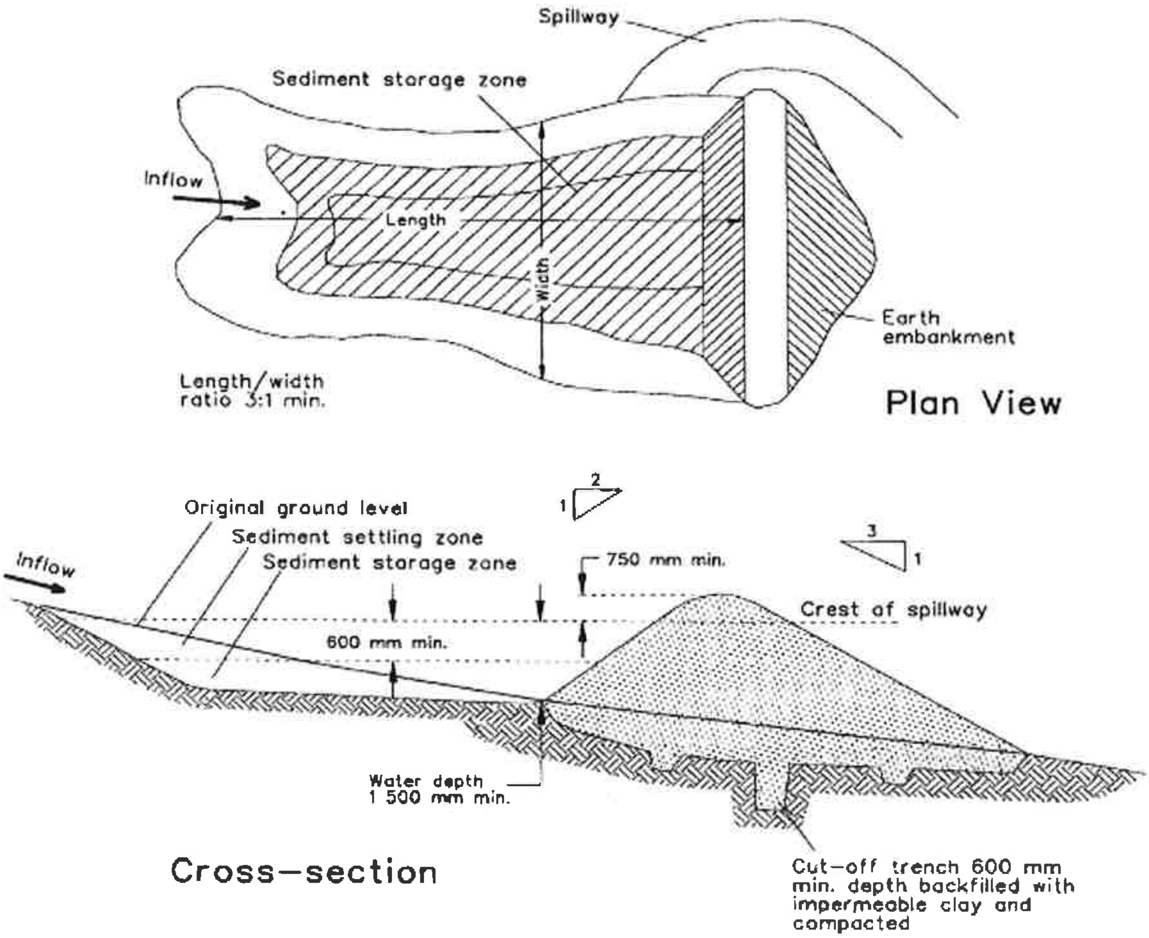


GLEN INNES MUNICIPAL COUNCIL
MRF & RUBBISH DISPOSAL AREAS

Revised 1998 GH. 8/95

N
RLs surveyed Sept 2010
Base mark 1,000 m outside MRF
Extrapolated RLs
From site observations Sept 2010
(Aerial photograph earlier)
First fill level
996.00 m
10 984.715
9 988.78
47 996.00
48 996.00
11 988.20
8 991.392
15 988.981
16 992.042
28 989.100
14 989.821
17 995.159
29 989.921
23 995.082
12 991.635
31 994.459
18 994.944
43 991.994
30 993.484
39 996.582
7 993.584
38 992.677
13 994.195
995.376
21
2 995.99
995.154
42
44 991.994
37 989.742
26 993.677
40 992.594
3 998.861
1 1000.00
20 991.334
996.00
46
19 995.654
24 991.742
32 992.677
25 989.573
41 994.954
27 994.439
33 992.439
4 1003.227
36 992.002
5 1003.797
34 992.0397
992.002
35
996.002 22
45
6 1004.372
Scale 1:1,993

APPENDIX B – Sediment Control Measures



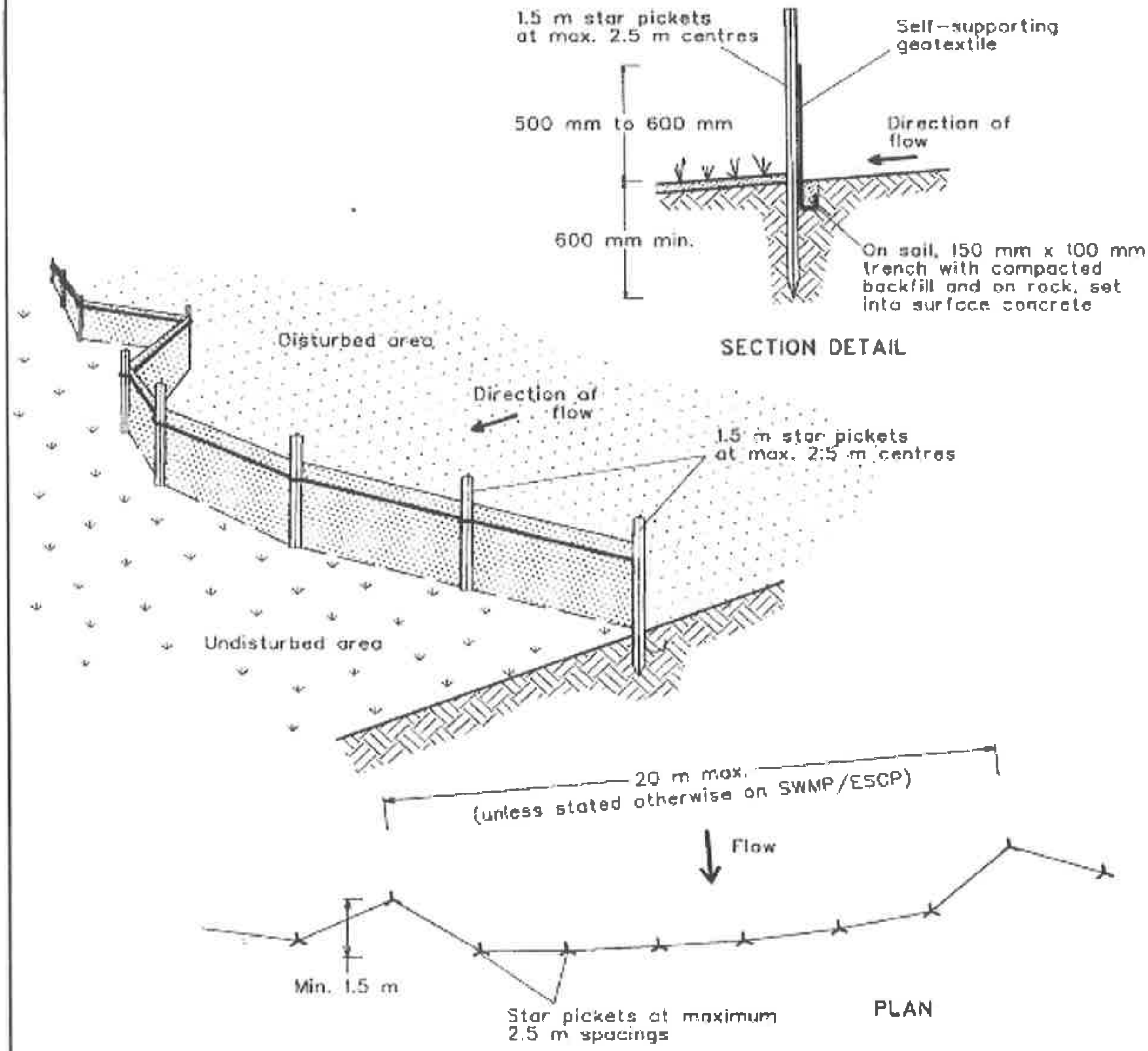
Construction Notes

1. Remove all vegetation and topsoil from under the dam wall and from within the storage area.
2. Construct a cut-off trench 500 mm deep and 1,200 mm wide along the centreline of the embankment extending to a point on the gully wall level with the riser crest.
3. Maintain the trench free of water and recompact the materials with equipment as specified in the SWMP to 95 per cent Standard Proctor Density.
4. Select fill following the SWMP that is free of roots, wood, rock, large stone or foreign material.
5. Prepare the site under the embankment by ripping to at least 100 mm to help bond compacted fill to the existing substrate.
6. Spread the fill in 100 mm to 150 mm layers and compact it at optimum moisture content following the SWMP.
7. Construct the emergency spillway.
8. Rehabilitate the structure following the SWMP.

EARTH BASIN - WET

(APPLIES TO 'TYPE D' AND 'TYPE F' SOILS ONLY)

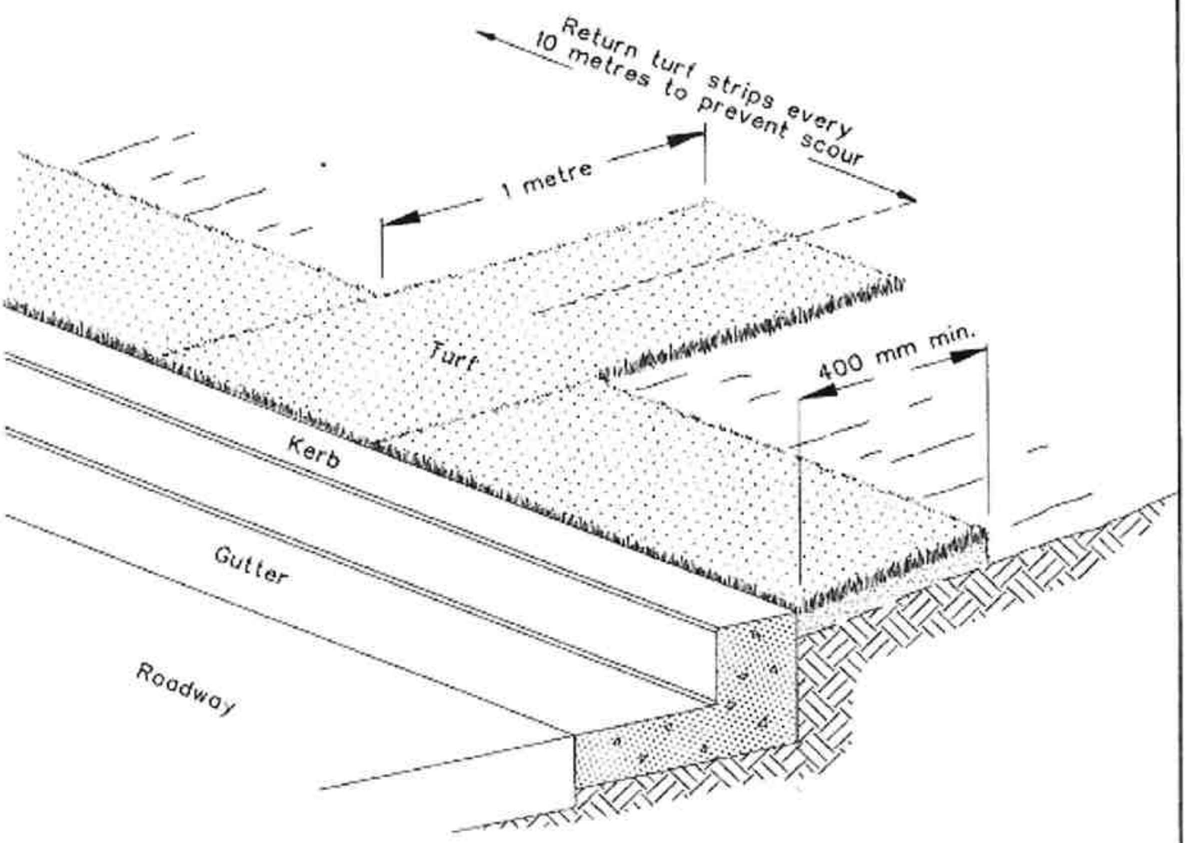
SD 6-4



Construction Notes

1. Construct sediment fences as close as possible to being parallel to the contours of the site, but with small returns as shown in the drawing to limit the catchment area of any one section. The catchment area should be small enough to limit water flow if concentrated at one point to 50 litres per second in the design storm event, usually the 10-year event.
2. Cut a 150-mm deep trench along the upslope line of the fence for the bottom of the fabric to be entrenched.
3. Drive 1.5 metre long star pickets into ground at 2.5 metre intervals (max) at the downslope edge of the trench. Ensure any star pickets are fitted with safety caps.
4. Fix self-supporting geotextile to the upslope side of the posts ensuring it goes to the base of the trench. Fix the geotextile with wire ties or as recommended by the manufacturer. Only use geotextile specifically produced for sediment fencing. The use of shade cloth for this purpose is not satisfactory.
5. Join sections of fabric at a support post with a 150-mm overlap.
6. Backfill the trench over the base of the fabric and compact it thoroughly over the geotextile.

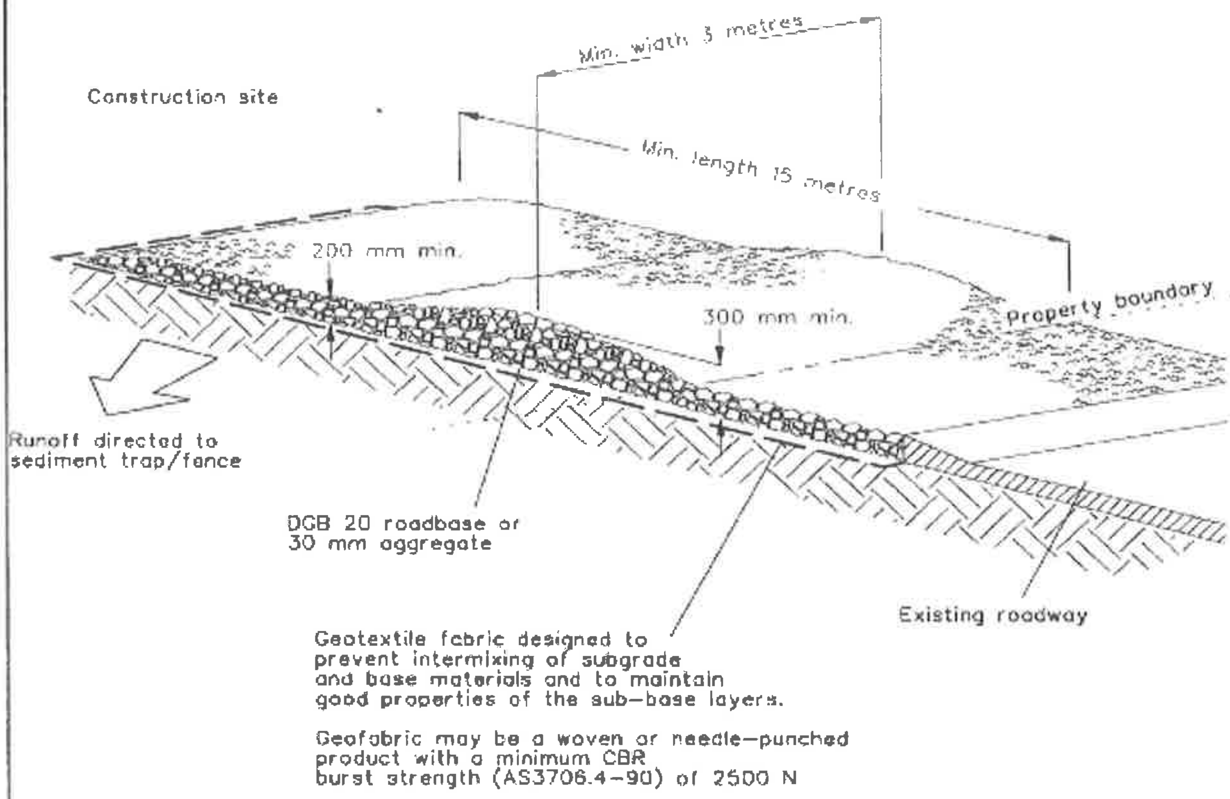
SEDIMENT FENCE **SD 6-8**



Construction Notes

1. Install a 400-mm minimum wide roll of turf on the footpath next to the kerb and at the same level as the top of the kerb.
2. Lay 1.4 metre long turf strips normal to the kerb every 10 metres.
3. Rehabilitate disturbed soil behind the turf strip following the ESCP/SWMP

KERBSIDE TURF STRIP **SD 6-13**



Construction Notes

1. Strip the topsoil, level the site and compact the subgrade.
2. Cover the area with needle-punched geotextile.
3. Construct a 200-mm thick pad over the geotextile using road base or 30-mm aggregate.
4. Ensure the structure is at least 15 metres long or to building alignment and at least 3 metres wide.
5. Where a sediment fence joins onto the stabilised access, construct a hump in the stabilised access to divert water to the sediment fence

STABILISED SITE ACCESS **SD 6-14**