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Shire of Northam

Report for Northam Town Site

Environmental Planning - Northam Town Pool

January 2012

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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1. Introduction

The townsite of Northam is situated on the Avon River. Stream flow in the Avon River is determined by seasonal rainfall, evaporation patterns and weather events. As a general rule, flow in the main channel of the Avon River commences in the autumn and continues through to mid-summer. During the hot and dry summer months (typically December – February) the Avon River dries into a series of isolated pools.

One of the key features of the Avon River at the Northam townsite is the ‘Town Pool’ which was created through the construction of a weir in 1907 at the northern end of the pool (Seal 1995). Water depth in the pool is controlled by the weir.

There are several known water quality issues associated with the pool and a number of existing and proposed strategies have been identified to attempt to make the river a greater focus for future development as well as a sustainable water body all year round.

Historical flood management practices (river training scheme), and historic and current land use practices (clearing of land for agriculture, agricultural landuse practices, stormwater management) have mobilised sediment and salt and contributed nutrients and other contaminants to the river system and its river pools.

Sediment accumulation is a key issue for many of the river pools of the Avon River, and the Northam Town Pool is no exception. The accumulation of sediment has contributed to a reduction in the depth of the pool and an increase in the nutrient loading, leading to shallow, eutrophic conditions that provide a favourable habitat for the growth of aquatic weeds as well as regular algal blooms.

The ongoing water quality issues within the Northam Town Pool have impacted on the recreational amenity of the pool during the summer months, and have also contributed to declining ecosystem values.

This study reviewed the considerable volume of literature relating to the management of the Avon River and its river pools. The report collates existing data and strategies associated with the aim of developing a longer term solution or management strategies to minimise the ongoing issues associated with the pool.

1.1 Report objectives and methodology

The objectives of this study are to:

- Identify existing strategies and options for the improvement of the Northam town pool, and to review these and any additional strategies in the context of long term improvement of the Town Pool.
- Review existing water quality, flows and drainage information for the Avon River at the Northam Town Pool, and the Northam townsite.
- Investigate options for long term improvement in the water quality of the Town Pool.
- Assessment and review of the identified strategies and options.
- Stakeholder review of the strategies and options and identification of a recommended approach.
- Costing of the stakeholder recommended approach.
- Reporting of the outcomes of the investigation.

2. Drainage within Northam townsite

A desktop review of the existing drainage for the Northam townsite was conducted through assessment of available drainage data, existing reports and discussions with the Shire of Northam drainage consultant, David Porter from Porter Engineering.

The available drainage for the Northam townsite is presented in Figure 1. At the time of reporting the Shire of Northam were still in the process of identifying all drainage infrastructure within the townsite (D. Porter, pers. comm.) however published information for various drainage catchments in the Northam townsite is summarised below.

2.1 Northam townsite – general drainage

The Northam townsite is located on clay soils with very limited opportunity for infiltration of stormwater runoff. As a result stormwater runoff is primarily transferred via overland flowpaths using the road network.

There is a limited underground drainage network near the town centre, and some creeklines that occur within the townsite have been modified for drainage purposes. The townsite drainage network transfers stormwater towards the Avon and Mortlock River system.

The Hard Infrastructure Audit completed for the Northam townsite by McDowall Affleck (draft 2012) identified the Northam Weir as having a high tailwater, which may contribute to flooding of Minson Avenue for 1 in 5 year ARI rainfall events. The Infrastructure review recommends a drainage audit, hydrologic assessment and development of drainage strategy for the whole Northam townsite.

2.1.1 Victoria Oval drainage network

JDSi Consulting Engineers (2009) undertook a desktop analysis of the existing drainage network upstream of Victoria Oval to allow development of drainage criteria for the future subdivision of land and to prepare a design to replace the existing open drain between Throssell Street and Wellington Street with a realigned piped drainage system. The report identifies existing culvert information where available (Section 5.8), describes open drainage and catchment sizes.

The option to replace the existing open drain between Throssell Street and Wellington Street was investigated due to the likelihood that Throssell Street will become a major road. The existing culverts at Throssell Street are undersized and result in frequent overtopping of the road. Increasing the culvert capacity is constrained by the location of the Perth-Kalgoorlie pipeline and therefore the option of a piped drainage alignment was considered. Raising the level of the road is identified as the preferred option. Other options identified included the construction of a compensating basin to restrict the flow through the culverts. It is recommended that additional storages also be constructed within new development upstream of Throssell Street to maintain flows at pre-development rates. The report notes that if the open drain is realigned and replaced with a piped section the piped drainage will have capacity to control minor events, however in extreme rainfall events stormwater will bypass the pipe system and surface water flow will occur. It is recommended that the Council consider providing a flowpath with capacity to cater for surface runoff within the pipeline alignment.

2.1.2 King Creek Catchment

Wheatbelt NRM (2011a) undertook modelling of the existing and proposed stormwater runoff for the King Creek catchment. The report identifies catchment areas for existing urban, proposed subdivision and agricultural catchments, and uses culvert dimensions identified by JDSi (2009) and confirmed during a site visit.

2.1.3 Minson Street Catchment

Wheatbelt NRM (2011d) identify that stormwater currently discharges from the Minson Avenue outfall via culverts under Peel Terrace. The culvert outlets discharge downstream of the Northam Weir, and therefore stormwater from this catchment is not discharged directly to the Northam Town Pool. Low flow stormwater events are directed from the Minson Avenue outfall to the Swan Enclosure, a 2,500 m^2 artificial wetland managed by the Shire of Northam. The specific details of the pipe network upstream of the Minson Avenue outfall are unknown (Wheatbelt NRM 2011d).

1:20,000 (at A3)

0 100 200 400 600 800 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LEGEND

- Department of Water Gauging Station 615062
- Well
- Culvert
- Drainage
- Rivers
- Cadastre

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Revision	0
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Northam Location Map

Figure 1

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239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: Shire of Northam: Department of Water Gauging Station 615062 - 20111108, Well - 20111108, Culvert - 20111108, Drainage - 20111108, Rivers - 20111108; Landgate: Cadastre - LGATE-082 - 20111108, Northam Nov 2010 Mosaic - 20111108. Created by: jrutherford

3. Hydrology of the Northam Town Pool

3.1 Northam Town Pool

The Northam Town Pool is an artificial pool formed on the Avon River through construction of the Northam Weir. The weir was initially constructed in 1901, and was repaired or upgraded a number of times (1907, 1945, 1946, 1955, 1957 and 1975) according to a timeline for the Town Pool by Gutteridge Haskins & Davey (1992). The height of the weir crest constructed in 1975 was 145.98 mAHD (Gutteridge Haskins & Davey 1992).

The Northam Town Pool is generally considered to comprise the main section of the pool between the weir and the bridge at Newcastle Road. This section of the pool comprises the large open water section of the pool and stretches for a distance of approximately 1.35 km and is approximately 120 m wide at its widest point (Waterways Commission 1995).

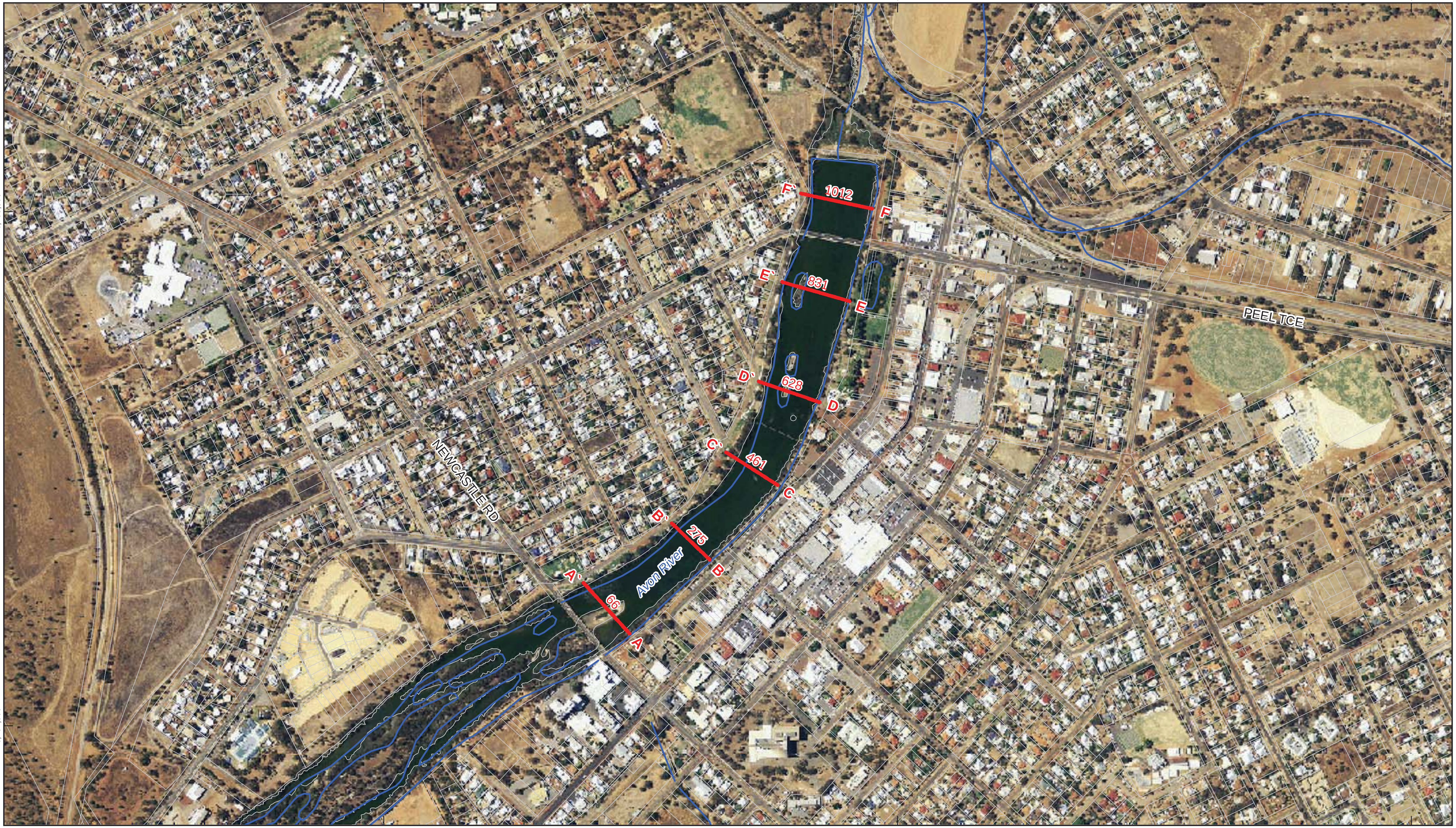
The total pool also includes the braided section upstream to the riffle at Burlong Pool, comprising the length of river that is inundated once water ceases to flow over the weir at Northam. This section of river extends over an extra 3.7 km at reduced width (30 – 50m, P. Weatherly pers comm.).

The Shire of Northam commissioned RMS Surveys to complete a topographic survey of the Northam Town Pool between Newcastle Street Bridge and the crest of the Northam weir. Key topographic data from the survey completed in April 2011 include:

- The weir height varies between 145.87 mAHD and 146.02 mAHD.
- The lower edge of the riparian bank of the pool is approximately 145 mAHD.
- The deepest part of the pool follows the section identified as the natural river course, and is the area dredged during the most recent dredging of the pool in 2000 (D. Cummins, DoW, pers. comm.). This section of the pool is generally < 144 mAHD with two low points:
  - Low of 143.57 mAHD in the section of pool between the Peel Terrace Bridge and the weir.
  - Low of 143.53 mAHD between pedestrian bridge and the Newcastle Street Bridge.

Appendix A shows the 2011 survey of the Northam Town Pool, as well as typical cross-sections of the Northam Town pool. The locations of the typical cross-sections from the 2011 survey are shown in Figure 2. Included in Appendix A is the pool survey completed by Paul Kraft & Associates that preceded the dredging of the pool in 2000. Comparison of the two surveys shows higher pool bed levels in the 2000 survey than the 2011 survey in many parts of the pool. The 2011 survey data indicates that siltation of the pool over the last decade has not resulted in pool bed levels that were present during the last dredging project of the pool in 2000.

The Northam Town Pool has three existing islands within the main section of the pool. Based on the Northam Town Pool Sediment Management Plan (Waterways Commission 1995) one of the islands was naturally formed and the remaining two are artificially created from the sediment within the pool. The naturally formed island is considered stable, while the two artificial islands are in various states of degradation.



1: 10,000 (at A4)

0 40 80 160 240 320 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

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LEGEND

- Northam Town Pool Cross Sections (Meters upstream of Newcastle Road)
- Rivers
- Cadastre

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Northam Town Pool Cross Sections

Figure 2

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Data source: Shire of Northam: Rivers - 20111108; Landgate: Cadastre - LGATE-082 - 20111108, Northam Nov 2010 Mosaic - 20111108, Roads - 20111102; GHD: Cross sections - 20120112. Created by: jrutherford

3.2 Stream flow at Northam Weir

Table 1 displays the seasonality and high variability of streamflow within the Avon River at the Northam Weir gauging station over 30 years (1977 to 2011).

Table 1 Water flow statistics for the Northam Weir (615062) for the period 1977 - 2011

Statistic	Water Year Apr-Mar (GL)	Wet Season Apr-Oct (GL)	Dry Season Nov-Mar (GL)
Mean	124.5	109.2	12.2
Median	88.2	80.8	1.5
Historic Maximum	512.4	506.5	231.4
90th percentile	273.7	231.2	10.1
75th percentile	152.9	128.4	3.4
50th percentile	88.2	80.8	1.5
25th percentile	54.6	45.6	0.14
10th percentile	23.3	21.1	0.07
5th percentile	21.0	18.4	0.05
Historic Minimum	17.8	9.6	0.02

3.3 Water Quality at Northam Weir

Water quality data from the DoW gauging station at the Northam Weir (615062) was analysed for the period 1973 to 2010 to provide an indication of the annual fluctuations in water quality within the Northam Town Pool (Table 2, Table 3 and Table 4). Water quality statistics for the gauging station at Spencer Brook (615028), which is approximately 8.5 km upstream of the Northam Town Pool, have also been summarised to provide an indication of the water quality upstream of the Northam Town Pool (Table 5).

The water quality targets from the DoW Avon River Catchment Water Quality and Nutrient Monitoring Programs for 2006 to 2008 of 1.0 mg/L for total nitrogen (TN) and 0.1 mg/L for total phosphorus (TP) are used to analyse the nutrient quality of the water in the Northam Town Pool.

The TP concentration was below the target of 0.1 mg/L for more than 90% of the samples, where the median TP concentration for the entire sampling period was 0.03 mg/L. The TN concentration exceeded the target of 1 mg/L for over 70% of the samples, where the median TN concentration for the entire sampling period was 1.2 mg/L.

Table 2 Total nitrogen concentration (mg/L) at Northam Weir (gauge 615062)

Year	Minimum	Maximum	Median	90 Percentile	10 Percentile	Number of samples
1994	1.20	1.85	1.58	1.70	1.21	9
1995	0.96	10.11	1.24	2.61	1.01	24
1996	3.52	3.52	3.52	3.52	3.52	1
1997	0.90	1.59	1.00	1.35	0.95	6
1998	0.78	2.38	1.01	1.80	0.85	6
1999	0.85	2.92	1.20	2.90	0.99	10
2000	0.82	2.90	1.40	2.28	0.86	15
2001	0.86	3.40	1.00	2.56	0.86	5
2002	0.65	1.60	0.78	1.23	0.69	6
2003	0.77	2.50	1.30	2.02	0.82	5
2004	0.79	1.90	0.92	1.53	0.81	5
2005	0.92	1.80	1.10	1.52	0.95	5
2006	0.73	2.60	1.20	2.20	0.80	20
2007	0.87	3.50	1.30	2.42	1.12	13
2008	0.82	2.10	1.00	1.92	0.95	19
2009	0.90	4.20	1.25	3.39	0.92	10
2010	0.95	2.70	1.65	2.50	0.96	6

Table 3 Total phosphorus concentration (mg/L) at Northam Weir (gauge 615062)

Year	Minimum	Maximum	Median	90 Percentile	10 Percentile	Number of samples
1994	0.00	0.13	0.05	0.08	0.03	11
1995	0.02	1.55	0.05	0.15	0.02	26
1996	0.14	0.14	0.14	0.14	0.14	1
1997	0.02	0.07	0.04	0.06	0.03	6
1998	0.02	0.08	0.03	0.06	0.03	6
1999	0.01	0.21	0.03	0.14	0.02	10
2000	0.01	0.14	0.02	0.06	0.01	15
2001	0.02	0.07	0.04	0.06	0.02	5
2002	0.01	0.10	0.05	0.09	0.02	6
2003	0.01	0.04	0.03	0.04	0.02	6
2004	0.02	0.09	0.03	0.07	0.02	5
2005	0.00	0.03	0.02	0.03	0.00	5
2006	0.00	0.18	0.03	0.09	0.01	20
2007	0.02	0.09	0.03	0.05	0.02	13
2008	0.02	0.07	0.02	0.05	0.02	19
2009	0.01	0.36	0.02	0.19	0.01	10
2010	0.02	0.10	0.06	0.09	0.02	6

Table 4 Water quality summary key parameters at Northam Weir (615062) over sampling period 1973 to 2010

Parameter	Minimum	Maximum	Median	90th Percentile	10th Percentile	Number of samples
Metals						
Al (tot) (mg/L)	0	0.62	0.30	0.61	0.12	5
Fe (tot) (mg/L)	0.05	0.57	0.19	0.46	0.09	14
Mn (tot) (mg/L)	0	0.12	0.05	0.09	0.002	14
Physical Characteristics						
Alkalinity (tot) (CaCO3) (mg/L)	38	243	98	189	41	23
pH	6.3	9.9	8.1	8.7	7.2	660
Cond uncomp (lab) (uS/cm)	1300	28700	13500	17700	7155	1708
Non-metals						
K (tot) (mg/L)	6.0	34.1	12.0	28.0	8.0	21
Mg (sol) (mg/L)	50.0	830.0	273.0	518.2	68.9	24
Na (sol) (mg/L)	324	4600	1625	3009	439.2	24
Ca (sol) (mg/L)	26	192	103	182	36	24
Cl (sol) (mg/L)	604	8687	5186	6900	2441	413
SiO2 (sol react) (mg/L)	2.0	13.0	9.0	12.0	2.7	22
SO4 (tot) (mg/L)	75	485	192	453	82	17
NO3 (sol) (mg/L)	1.0	17.0	4.0	16.4	1.6	17
Nutrients						
N (tot) {TN, pTN} (mg/L)	0.65	10.11	1.20	2.54	0.86	167
NH3-N/NH4-N (sol) (mg/L)	0.00	1.24	0.02	0.22	0.00	82
P (tot) {TP, pTP} (mg/L)	0.00	1.55	0.03	0.09	0.01	172

Table 5 **Water quality summary key parameters at Spencers Brook (615028) over sampling period 1973 to 2010**

Parameter	Minimum	Maximum	Median	90th Percentile	10th Percentile	Number of samples
Metals						
Al (tot) (mg/L)	0.00	0.20	0.04	0.17	0.01	3
Fe (tot) (mg/L)	0.04	0.28	0.26	0.28	0.08	3
Mn (tot) (mg/L)	0.03	0.36	0.06	0.30	0.04	3
Physical Characteristics						
Alkalinity (tot) (CaCO3) (mg/L)	19	60	40	56	24	2
pH	6.70	8.22	7.66	7.97	7.07	17
Cond uncomp (lab) (uS/cm)	2650	13400	9450	12122	3460	10
Non-metals						
Mg (sol) (mg/L)	190	478	390	461	241	4
Na (sol) (mg/L)	1000	2420	2000	2354	1240	4
Ca (sol) (mg/L)	68	136	120	131	84	4
Cl (sol) (mg/L)	2300	5480	4200	5186	2780	4
Nutrients						
N (tot) {TN, pTN} (mg/L)	0.53	4.79	0.80	1.60	0.53	11
NH3-N/NH4-N (sol) (mg/L)	0.00	0.12	0.02	0.09	0.01	4
P (tot) {TP, pTP} (mg/L)	0.00	0.05	0.02	0.03	0.01	11

4. MUSIC Modelling

4.1 Previous studies

Wheatbelt NRM (2011) conducted stormwater nutrient modelling using MUSIC V4 (Model for Urban Stormwater Improvement Conceptualisation) software for the Northam Townsite to provide an indication of the gross contribution of nutrients from the current development at Northam to the Avon River, and also provide an estimate the expected increase in nutrient loading resulting from new and planned subdivision within the townsite. Modelling was conducted at the daily time-step for 44 sub-catchments within the Northam townsite, and simulated over a 10-year period from 1999 to 2009. Due to limited monitoring data, the water quality model was uncalibrated. Snapshot sampling for a range of stormwater contaminants (nutrients, metals and hydrocarbons) was conducted at Northam, York and Toodyay as part of this study during 2010 and 2011, to provide input parameters for the water quality modelling. This data was compared to data collected in the Avon Arc Pools and available data for similar urban catchments within the Avon Arc towns.

The MUSIC modelling results presented in Wheatbelt NRM (2011) and a summary of the flow and nutrient monitoring data conducted by the DoW at the Northam Weir are presented in Table 6. The modelling results indicate that the current Northam townsite contributes approximately 7% of TP and 2% of TN to the total nutrient loads at the Northam Weir. The results also indicates that future proposed development within the Northam townsite will increase the TP discharge by 102%, the TN discharge by 35% and the TSS load by 74%. The modelling assumed that the proposed development occurs up to the maximum allowable housing density, as identified within the current local planning schemes.

Table 7 presents a breakdown of the model results from Wheatbelt NRM (2011) showing the key areas which contribute to the majority of increased nutrient and sediment discharges, as a result of the planned development.

Table 6 Modelled current and projected annual stormwater and nutrient volumes (adapted from Table 3 in Wheatbelt NRM (2011))

Parameter	Northam townsite current	Northam townsite projected	Projected increase	Avon River at Northam Weir
Flow (ML)	1,293	1,829	41%	127,000
Total Phosphorus (kg)	250	455	102%	3,400
Total Nitrogen (kg)	2,990	4,050	35%	134,050
Total Suspended Sediment (t)	173	301	74%	-

Table 7 **Modelled increase in stormwater flow and contaminants, as a proportion of the total increase from the planned development (adapted from Table 4 in Wheatbelt NRM (2011))**

Catchment	Flow	TSS	TP	TN
Hatton St	13%	15%	11%	12%
Morrell St	5%	5%	3%	4%
King Creek	24%	24%	22%	21%
CBD	0%	0%	2%	-1%
Woodley Farm	15%	16%	14%	15%
Golf Course	6%	7%	9%	8%
Western Residential	8%	9%	8%	8%
Sth – Special Residential	16%	14%	13%	19%
Nth – Special Residential	8%	9%	14%	8%
Other	3%	2%	5%	5%

5. Literature Review

There have been several studies and investigations in the Avon catchment that relate to the water quality issues within the Town Pool. The key studies that have been reviewed and summarised include:

- Northam Town Pool, Amelioration of silting, Progress report for Town of Northam (Gutteridge Haskins & Davey 1992).
- Northam Town Pool Sediment Management Plan (Waterways Commission 1995).
- Avon River Management Authority, Avon River Survey 1996, Volume 5 Avon River Pool Survey (Jim Davies & Associates 1997).
- River Recovery Plan Section 6 – Northam (Water and Rivers Commission and Avon River Manamgement Authority 1999).
- Avon River Catchment Water Quality and Nutrient Monitoring Program for 2006 (Department of Water 2007).
- Assessment of the status of river pools in the Avon catchment (Department of Water 2007).
- Review of the Economic Viability of Sediment Extraction from the Avon River Pools (Advanced Choice Economics and Viv Read & Associates 2007).
- Desktop analysis Northam Townsite Drainage Strategy (JDSi 2009).
- Avon River Catchment Water Quality and Nutrient Monitoring Program for 2007 (Department of Water 2009).
- Avon River Catchment Water Quality and Nutrient Monitoring Program for 2008 (Department of Water 2009).
- Preliminary Hydrology Assessment – Childlow Street Subdivision Northam (Wheatbelt NRM 2011).
- King Creek Catchment Hydrologic Assessment (Wheatbelt NRM 2011).
- Hydrologic Assessment – Minson Avenue Catchment (Wheatbelt NRM 2011).
- Background Paper – Stormwater Quality (Wheatbelt NRM 2011).
- Proposal for reinvigorating the town pool of Northam (Davey 2011).

5.1 Northam Town Pool, Amelioration of silting, Progress report for Town of Northam (Gutteridge Haskins & Davey 1992)

The Northam Town Council commissioned Gutteridge Haskins & Davey to provide advice regarding the siltation of the Northam Town Pool. The progress report provided the following detail:

- A time scale of the modification of the Avon River indicating the rate of sedimentation and degradation of the river.
- Identification of the major constituents of the sediments in the Northam Town Pool and major pools above Northam.
- Identification of the source of the sediments.

- Collation of physical data relating to the catchment and river channel to allow the channel to be modelled.

According to the timeline within the progress report the weir was initially constructed in 1901, and was repaired or upgraded a number of times (1907, 1945, 1946, 1955, 1957 and 1975). The height of the weir crest constructed in 1975 was 145.98 mAHD. The timeline also provides a history of river channel works and dredging within the Town Pool.

The progress report provides a literature review of the effects of river training, including various types of channel adjustment. The review notes that perennial rivers may adjust more quickly to river training, and that the discontinuous nature of flow in ephemeral rivers may delay morphologic adjustment and prolong recovery. The progress report gives an overview of the major river pools, and a sediment survey conducted in 1977 revealed a range of sediment size fractions from fine to coarse.

The report notes that it is important to identify the source of the sediment to properly direct efforts to reduce pool siltation. If the sediment was found to originate in the channel bed the report concludes that catchment rehabilitation works may not have short term impacts on siltation. Possible ways of reducing sediment inflow to the Northam Town Pool identified within the progress report include:

- Construction of sediment traps upstream of the pool.
- Revegetation of the river channel in the upstream reach.

The report recommended the following:

- Avon River upstream of Northam be resurveyed at the same location to determine changes.
- Flow modelling of the Avon River be performed to assess the change in flood levels.
- Sediment transport modelling be performed for the Avon River between Muresk and Northam Town Pool.
- Resurvey of the Northam Town Pool at the same sections to allow estimation of the rate and volume of sedimentation.
- Methods of dredging be further investigated, with dredging only performed once the outcomes of various management options have been considered.

5.2 Northam Town Pool Sediment Management Plan (Waterways Commission 1995)

The Northam Town Pool Sediment Management Plan (Waterways Commission 1995) identifies a number of strategies to address sediment problems within the Town Pool. In addition the document also considers strategies to address water quality and habitat. The purpose of the plan was to assist the Northam Town Council at the time to make informed decisions regarding the management of the Northam Town Pool, through provision of a recommended works outline. The management plan gives a chronological timeline of events for the Northam Town Pool from 1907 to 1995, as well an overview of the pool environment.

Four major management issues and strategies were identified including:

- Sediment deposition (short and long term).
- Increasing nutrient levels and subsequent degradation of water quality.

- Decreasing wildlife habitat.
- Decreasing aesthetic appeal.

For each of these key issues the management plan outlines the objectives, potential outcomes, management options and the preferred strategy as outlined in Table 8. In addition to an outline and preliminary costings for works, the plan also identifies key environmental considerations and approvals. The Waterways Commission identify dredging of the pool as the preferred option for alleviating immediate sediment problems, however note that the longer term sedimentation issues within the wider catchment need to be addressed.

Table 8 Key issues and preferred management strategies for the Northam Town Pool

Issue	Objectives	Potential outcomes	Management options	Strategy
Sediment deposition – short term	To increase water depth in the pool during summer	◗ Protection of one of the few remaining viable refuge areas for waterbirds ◗ A more aesthetic pool environment ◗ Maintenance of a major attraction for Northam	◗ Do nothing ◗ Increase the height of the weir to retain water in the pool during summer ◗ Add sluice gates to retain more water at the end of summer ◗ Dredge a channel along the natural river course ◗ Dredge the entire pool ◗ Add make up water to the pool in summer	The management options were evaluated against a suite of environmental and other criteria. The preferred strategy was: ◗ Increase the depth of the Northam Town Pool by dredging
Sediment deposition – long term	To prevent further sedimentation of the pool in the future	◗ As above ◗ Reduction in ongoing maintenance required for the pool	◗ Further research into sedimentation processes ◗ Removing sediment at strategic locations ◗ Revegetation to trap sediment ◗ Remodelling the river to its natural state	◗ Undertake an annual survey of the Northam Town Pool to provide information about level of sediment accumulation within the pool ◗ Investigate options to undertake ongoing maintenance dredging of the pool ◗ Install a sediment trap upstream of Northam Town Pool at Burlong Pool ◗ Support research to determine appropriate ways to reduce sediment movement within the Avon River
Water quality	To improve water quality in the pool	◗ Reduced health risk ◗ Protection of valuable waterbird habitat ◗ More pleasant pool environment ◗ Improved opportunities for recreation	Sediment removal will provide slight relief by removing nutrient rich sediments. Long term management dependent on detailed well structured water quality management program comprising: ◗ Water quality monitoring to assess effectiveness of removing sediments ◗ Identification of all nutrient and other pollutant sources to the	Develop a water quality management program in conjunction with Avon River Management Authority aimed at improving water quality in the Northam Town Pool

Issue	Objectives	Potential outcomes	Management options	Strategy
			pool ◗ Development of management strategies to eliminate or reduce sources of pollution to the pool ◗ Implementation of management strategies ◗ Continued water quality monitoring to observe changes in water quality and to assess the effectiveness of water quality strategies	
Waterbird habitat	To improve waterbird habitat around the pool	◗ Protection of the white swan colony ◗ Maintenance of refuge and habitat for native birdlife	◗ Rehabilitation of existing islands ◗ Artificial island construction	Rehabilitation of existing islands: ◗ Stabilise existing islands within the Northam Town Pool and adjacent foreshore areas ◗ Ensure access to birdlife in stabilisation designs ◗ Request Waterways Commission to prepare plans and to supervise stabilisation works Artificial island construction ◗ Trial construction of floating artificial rafts as breeding sites for the white swan colony ◗ Should artificial rafts be unsuccessful consider long term construction of additional islands ◗ Construct an island on the sand bank downstream of the Avon Bridge
Aesthetics				Addressing the above considered to improve the aesthetics of the Northam Town Pool

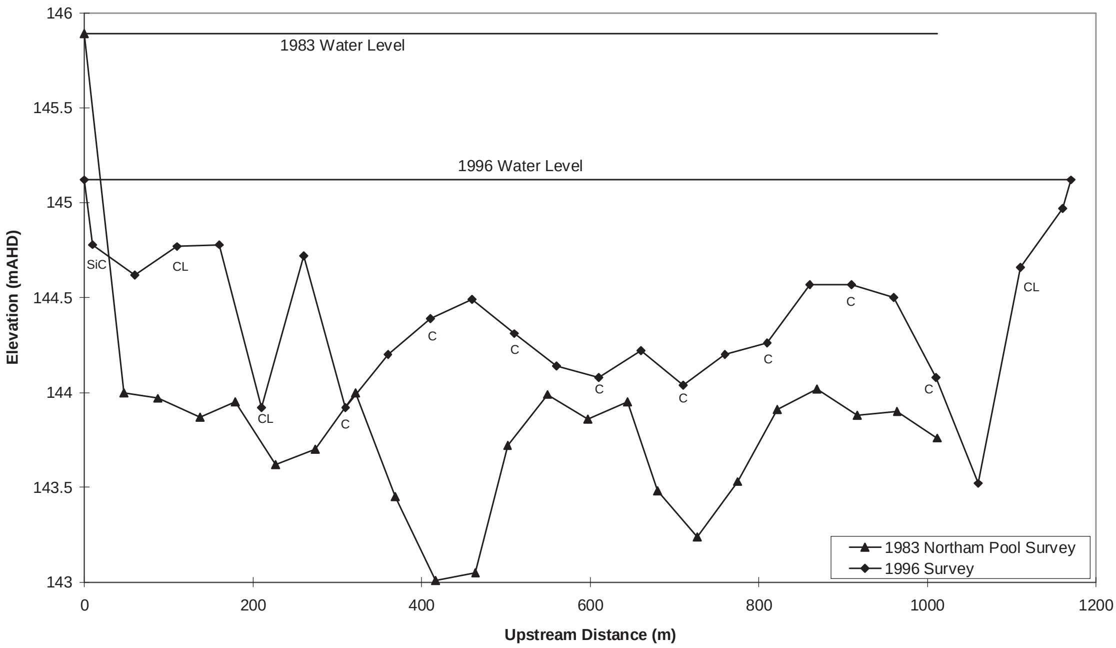
5.3 Avon River Management Authority, Avon River Survey 1996, Volume 5 Avon River Pool Survey (Jim Davies & Associates 1997)

JDA conducted a study of the channels and pools within the Avon River between Yenyening Lakes in the east and the National Park in the west.

The Pool is located in the centre of Northam, and is bounded by the Northam Weir and the Newcastle Road bridge. A detailed survey of the Northam Pool was conducted in 1984, which involved 20 cross sections at 50 m intervals between the weir and the Newcastle Road bridge. The pool is just over 1 km in length, with an average depth of 1 m based on measurements taken in 1996. Water is retained in the pool during the summer months by the weir.

The bed sediment of the pool is predominantly silt/clay with a higher sand content closer to the sand bars. Total phosphorus in the water varies from 0.10 mg/L to 0.17 mg/L, and there is a high nutrient content in the sediments which expected from clay/organic matter. Algal blooms are common in the Town Pool, especially during the summer months when the flushing is reduced.

Figure 3 Northam Pool Bed Elevation (JDA 1997)



A survey of the condition of the Avon River pools was conducted in May and June 1996. The survey results for the two transects for the Northam Town Pool are summarised below:

- Vegetation condition: The left and right bank shows no areas of significant erosion. Accretion is occurring across much of the main channel width. The accreting bedforms may be bed dunes forming stable bars, or erosion bar features on the channel margins or within the centre of the main channel now stabilised and accreting. As well as grasses and ground cover, this river section has significant regeneration of overstorey species within the main channel.
- Tree species: *Eucalyptus rudis, Melaleuca rhaphiophylla* and *Casurina obesa*, have been identified along the river pool banks.
- Regeneration: No regeneration.
- Bank stability: The banks were identified as stable.
- Sediment: Predominantly silt and clay (>60% content) with higher sand content near weir and upstream of Newcastle Road Bridge.

5.4 River Recovery Plan: Section 6 – Northam (Water and Rivers Commission 1999)

- Presents a vision for a healthy and sustainable management of the river system for the Avon River by 2020.

- The River Recovery Plan (RRP) covers river section 6: lies between Spencer Brook Bridge and Northman Town Weir, and focuses on strategies which can be achieved at a local level to improve the ecological condition and amenity value of the river.
- The Avon River has become degraded primarily from the impact two key human activities: clearance of woodland for agriculture which has mobilised the salt from the soil, and dredging the river bed to abate flood heights which has mobilised the coarse river-bed sediments.
- At the local level there is much that can be done to improve the ecological condition and amenity value of the river.
- Northam Town Pool – potential to be Northam's greatest asset or liability.
- There are considerable water quality management issues for the Northam Pool including the threat of sediment infill, eutrophication, excessive seagrass, Sago Pond Weed (Coleogeton and Lamprothamnium) growth and algal blooms (From RRP Section 6).
- Five key issues presented:
    1. River discovery and appreciation – to encourage and facilitate the local community understanding, appreciation and enjoyment of the natural qualities of the river.
        - Pools – to re-create pools, where appropriate along the river in order that they may again contribute to the natural form and character of the river and be used for recreation.
        - Burlong pool sediment trap - strategy in place to trap and remove sediments from Burlong Pool, which allows for a contractor to remove a fixed amount of sediment each year from two sand traps located upstream and downstream of the pool. This strategy aims to restrict sediment flow into the Northam Town Pool
        - Northam Town Pool – strategy is in place to increase the water depth of the pool during summer, improve water quality within the pool, improve waterbird habitat around the pool and improve the overall aesthetics of the pool.
            - Monitor sediment accumulation in Northam Town Pool (NTP) and take further action to minimise sediment input as necessary (Priority: high, timing: ongoing)
            - Continue the program of sediment trapping and removal at Burlong Pool as long as is required to maintain the amenity value of the site as a water-based recreation area (Priority: high, timing: ongoing)
            - Estimate sediment fluxes at Burlong Pool (Priority: high, timing: ongoing)
            - Continue surveying the profile of the river between NTP and Northam town boundary (Priority: medium, timing: ongoing)
    2. River repair – To repair the ecological damage associated with the river training, catchment vegetation clearance and other damaging activities. The key strategic actions identified relating to river repair included:
        - Foreshore revegetation.
        - Instream stabilisation, including stabilisation of old islands and creation of new islands.

- Sediment management through construction of riffles, preparation of a sediment management strategy.
- Restriction of stock access.
- Eradication of weeds.

3. Natural events – Increase community knowledge regarding the impacts from flooding and fire.
4. River pollution – Identification of pollution sources was identified as a strategic objective for the town pool.
    - Stormwater – the plan identifies that there are no restrictions on the types of material and substances that enter the river through the stormwater outlets. The nominated strategic action was the preparation of a municipal stormwater management programme which applies best management practice to existing and new stormwater drainage systems.
    - Industrial wastewater – the plan identifies that point source pollutants from industrial sources can enter the river through the stormwater system. The nominated strategic actions were to seek licensing of point sources under the Environmental Protection Act, and to encourage landowners to implement best management practices.
    - Septic wastewater – the majority of Northam town identified connected to septic tanks or leach drains which have high potential to leach nutrients to groundwater. Strategic actions were to encourage ongoing conversion to in-fill sewerage, and to investigate alternative treatment units where a sewerage system is not appropriate.
    - Agricultural wastewater – the contribution of the catchment to the water quality issues of the Avon River in Northam were identified. The nominated strategic actions included management planning for tributaries of the Avon River upstream of Northam, and best management practices.
    - Accidental spillage – management of accidental spillage identified as an important measure to prevent river pollution. Strategic actions to prevent pollution events were to work in collaboration with designated authorities.
5. Strategic planning – the importance of strategic planning was identified within the plan, particularly the importance of appropriate foreshore planning. This was predominantly in regard to land use planning within the 1:100 floodplain, acquisition of foreshore land for public ownership, and where foreshore land is privately owned ensuring appropriate management. Key priority of strategic planning documents is to maintain the quality of the Northam Town pool.

- The river training scheme and excessive clearance of vegetation in the catchment has had a deleterious effect on the river environment through direct loss of foreshore and river channel vegetation causing erosion of banks and beds and sedimentation of pools.
- The quantity and mobility of sediment in the river has increased significantly since major vegetation clearance in the catchment and the river training scheme.

- Stabilisation of river bed sediments and the creation of new islands and channels would help reduce the problem. However, the forces of the river system (flow) may reduce the effectiveness of stabilisation schemes.
- Ultimately, work should be undertaken towards creating a balance between a new system of braided channels and pools, and a channel system capable of moving water downstream at an acceptable rate under flood conditions. Define an optimum balance between sediment trapping and stabilisation and flow efficiency and effectiveness.
- Stormwater generally discharges to the river at stormwater outlets on the margins of the river, where these discharge points are usually open ends of drainage pipes. Currently, there is no restriction on the types of material and substances which enter the river through the stormwater outlets.

5.5 Assessment of the status of river pools in the Avon catchment (Department of Water 2007)

The Department of Water (2007) investigated 42 locally significant pools on the Avon River, including the Northam Town Pool, to develop broad criteria to prioritise the rehabilitation of the pools on the Avon River. The Northam Town Pool was identified as one of 10 pools within the Avon River where river recovery management plans have been prepared and/or recovery work has been undertaken to restore the pools to as near their natural state as possible.

Management options for restoring the Avon River pools to as near their natural state as possible include:

- Sediment extraction – removal and disposal of sediments from the pools by dredging or long reach excavation, to help restore the depth of the pool to help maintain aquatic habitats during the summer months.
- Sediment control – install sediment traps (riffles and snags) to help stabilise unconsolidated channel sediment by reducing the velocity of flow, forcing sediment deposition, and trapping sediment upstream of the structure.
- Revegetation – construction of vegetative buffer strips along the foreshore to slow runoff and stop the transport of suspended sediment into the river. Incorporating in-stream vegetation into the pools can slow water flow, prevent bank erosion and detain soil and sediment while providing a valuable habitat for fauna.
- Fencing – Construct fences on both sides on the river and river pools to restrict stock access to the river and help protect the existing riparian vegetation and revegetated areas which will assist in trapping sediments.
- Monitoring and maintenance – Conduct ongoing monitoring (water quality, fauna surveys, pool survey, revegetation assessment) and maintenance (weed control, repairing constructed riffles, extracting sediment from the pools) to help evaluate and maintain the success of the recovery projects.

5.6 Avon River Catchment Water Quality and Nutrient Monitoring Programs for 2006, 2007 and 2008 (Department of Water)

The Department of Water have conducted snap-shot sampling along the Avon River over 2006 to 2008 to establish baseline data for future reference to determine if the water quality of the Avon River catchment is being maintained, improved or deteriorating. The chemical and physical water quality parameters sampled during the Avon River basin water quality program were total nitrogen (TN), total phosphorus (TP), total dissolved salts (TDS), total suspended solids (TSS), pH and flow information (where it could be obtained).

Sampling was conducted at 17 gauging sites along the Avon River, including gauge 615062 at the Northam Weir, and samples were collected fortnightly, when the river was flowing at the gauging stations (flow usually began in April and continued at most sites until December or early January).

The TN and TP results are compared to the Avon Catchment Council target for Walyunga of 1.0 mg/L of TN and 0.1 mg/L TP, which is based on the targets set in the Environmental Protection Policy for the Swan and Canning Rivers (1997). All parameters are classified according to the Statewide river water quality assessment (Department of Water 2004), except for TDS which are compared to a classification table in Stream salinity status and trends in south-west Western Australia (Department of Environment, 2005).

Table 9 Classifications used for total nitrogen and total phosphorus (Department of Water 2004)

Classification	Total nitrogen (mg/L)	Total phosphorus (mg/L)
Low	< 0.75	< 0.02
Moderate	0.75 – 1.2	0.02 – 0.08
High	1.2 – 2.0	0.08 – 0.2
Very High	> 2.0	> 0.2

Table 10 Classifications used for total dissolved salts (Mayer, Ruprecht & Bari, 2005)

Classification	Total dissolved salts (mg/L)
Fresh	< 500
Marginal	500 – 1000
Brackish	1000 – 5000
Saline	5000 – 10000
Highly saline	10000 – 35000
Brine	> 35000

Table 11 Classifications used for pH (Department of Water 2004)

Classification	pH
Acidic	< 6.5
Neutral	6.5 – 8.0
Alkaline	> 8.0

Table 12 Classifications used for total suspended solids (Department of Water 2004)

Classification	Total suspended solids (mg/L)
Low	< 5
Moderate	5 – 10
High	10 – 25
Very High	> 25

Table 13 Classifications used for dissolved oxygen (Department of Water 2004)

Classification	pH
Low	< 8
Oxygenated	8 – 12
Hyperoxic	> 12

Table 14 Median (and range) water quality readings (mg/L) for Northam Weir – Avon River (615062)

Parameter	2006	2007	2008	Comment
TN	0.990 (0.8 – 1.6)	1.400 (0.87 – 3.5)	1.1 (0.82 – 2.1)	Moderate to very high, some recordings above target of 1.0 mg/L
TP	0.023 (0.005 – 0.049)	0.033 (0.017 – 0.085)	0.025 (0.015 – 0.072)	Low to moderate below target of 0.1 mg/L
TDS	10326 (8505 – 16839)	7407 (6032 – 13360)	8799 (3583 – 12630)	Brackish to highly saline
TSS	3 (1 – 5)	5.5 (1 – 22)	1.0 (<1 – 25)	Low to High
pH	8.8 (8.4 – 9)	8.3 (7.98 – 8.79)	8.4 (7.70 – 9.88)	Neutral to alkaline
DO	11.6	10.1 (7.88 – 13.2)	11.0 (8.8 – 17.0)	Oxygenated to hyperoxic

The key recommendations for the Avon River catchment include:

- Continue regular monitoring of the water quality within the Avon basin and publishing of the data and undertake additional sampling during major rainfall and flow events in summer to assess the effects on water quality.
- Implement river recovery plans to improve the water quality of the Avon River catchment, such as revegetation of riparian and other areas of the catchment, water management to decrease erosion, fencing of waterways and riparian zones and implementation of best management practices for agriculture.

5.7 Review of the Economic Viability of Sediment Extraction from the Avon River Pools (Advanced Choice Economics and Viv Read & Associates 2007)

Advanced Choice Economics and Viv Read & Associates (2007) conducted a review of the economic viability of sediment extraction from the Avon River pools for the Department of Water and the Swan River Trust in response to sedimentation being identified as a significant threat to the Avon River Pools in the Avon NRM Strategy (ACC 2005). Many of the major Avon River pools have become filled with sediment as a result of alteration to the river channel from the river training scheme during the 1950s to 1970s to reduce the flood risk, as well as erosion from agricultural catchments.

This study was conducted to evaluate the most cost effective method for the government to remove sediment and conduct ongoing maintenance of the sediment deposition within the Avon Rive pools.

The sediment volume for the major river pools was estimated from the 1996 river pool survey (JDA 1997), and the total available sediment deposits in 26 major river pools is estimated as 2,065,000 m^3. Northam Town Pool is estimated to have a sediment volume of 230,000 m^3, where approximately 70% of the pool is filled with sediment, and the sediment is predominantly silt and clay. Table 15 summarises the opportunities and constraints for harvesting sediment from the river pools along the Avon River presented in the study, and the site specific opportunities and constraints for the Northam Town Pool. Although the Northam Town Pool has available land for stockpiling the sediments and road access to the pool, the sediment has a relatively high proportion of silty clay sands, which is not considered a marketable resource. Consequently, harvesting sediments from the Northam Town Pool was not considered economically viable, and Northam Town Pool was not included in the benefit cost analysis.

Table 15 Opportunities and constraints for the feasibility of removing and selling sediment from river pools in the Avon River

Opportunities	Constraints	Northam Town Pool
Environmental: Removing sediment from the pools improves the environmental condition of the pools.	Stockpiling: availability of adjacent land for stockpiling sediment.	Stockpiling: public land is available adjacent to the pool for stockpiling sediment.
Social: increased visual amenity of the river pools.	Roads: road access to river pools is limited, and in some cases, roads will have to be constructed. At some pools the sediment will need to be transported across a rail road to reach the main road.	Road access: Existing road access to the pool is good, and no additional railway crossings are required.
Quality: the coarse sand sediments provide good quality fill for buildings as it is free draining and resistant to white-ants.	Water levels: Dredging equipment may be required to remove sediment in pools where there is water.	Water levels: due to water being in the pool, it is likely that dredging equipment is required.
Cost: Access to the sediments could be potentially free of government costs, and high demand for the product from building industry.	Transport: Transport costs will be incurred to transport the sediment to the market.	Transport: It is approximately 97 km from Northam Town pool to the Perth CBD along the main roads.
	Quantity and quality: the quantity and quality of coarse sand sediment varies significantly across pools.	Quantity and quality: Northam Town Pool is estimated to have a sediment volume of 230,000 m^3, and the sediment is predominantly silt and clay.

The study found that there is a strong interest for the extraction of marketable sand sediment, and the average travel distance from the pools to Perth is 100 km, which is considered within acceptable transport distance for major extractive industries. Only pools which had a high proportion of coarse sand sediments were considered, which included: Yangedine, Gwambygine, Cold Harbour, Mt Hardy, 3-Mile, Mearse, Jangeling, Burlong, Egoline, Katrine, Millard, Deepdale, Jimperding and Long.

5.8 Northam Townsite Drainage Study (JDSi 2009)

JDSi Consulting Engineers (2009) conducted a desktop analysis of the existing drainage network upstream of Victorian Oval, to determine the drainage criteria for future subdivisions within the catchment. The study identified the sub-catchments upstream of Victorian Oval and determined the design flows and any constraints within the existing and proposed pipe alignments and capacity.

All road crossings within the King Creek catchment are culvert crossings, and the sizes were estimated by the Shire of Northam from a site investigation:

- Throssell St: Consists of 2 × 300 mm diameter and 2× 375 mm diameter concrete pipes.
- Burnside Avenue: Consists of two 1800 mm wide × 1200 mm deep box culverts.
- Chidlow Street: Consists of two 1800 mm wide × 1200 mm deep box culverts.
- Duke St: Consists of three 2100 mm wide × 1500 mm deep box culverts.

Table 16 presents the theoretical capacities at key locations along the King Creek Drain and estimated 10 year ARI and 100 year ARI design flow capacities, where the design flow rates were estimated using the Rational Formula. Based on the analysis, all locations have capacity to accommodate for the 10 year ARI event, except for the Throssell St culverts which are severely undersized and a section along Burnside Avenue to Chidlow drain.

Table 16 Theoretical capacity and estimated design flows at locations along the King Creek drain for 10 year ARI and 100 year ARI events (adapted from the table in section 4.5 of JDSi, 2009)

Location	Capacity (m^3/s)	Q10 flow (m^3/s)	Q100 flow (m^3/s)
Throssell St culverts	0.6	6.56	13.61
Throssell to Burnside drain	28.01	7.65	15.78
Burnside Avenue culverts	11.0	7.65	15.78
Burnside to Chidlow drain	6.29	7.68	15.87
Chidlow St culverts	9.0	7.68	15.87
Chidlow to Duke drain	20.99	7.98	16.48
Duke Street culverts	19.5	7.98	16.48
Duke to Wellington drain	20.62	8.15	16.97

5.9 Biological Survey of the Northam Town pool – Macroinvertebrates (Strehlow 2009)

This study reports the results of a biological survey of the macroinvertebrate and fish fauna present in the Northam Town Pool to determine the general health of the pool. The town pool was divided into five sections (S1: below weir, S2: immediately above weir, S3:Town Pool, S4: Town Pool, S5: braided section upstream), and sampled for macroinvertebrates, macrophyte biomass, benthic microbial community and water quality in July 2008, October 2008, January 2009 and April 2009.

The macroinvertabrate community of the Northam Town Pool was found to be characteristic of a disturbed, salinised system. A total of 23 families were recorded with the abundance, richness and composition varying between sections and seasons.

The report identifies that dense stands of the following macrophytes occurred during late winter-early autumn including, with the highest biomass in mid-April/spring: *Coleogeton pectinatus, Lamprothamniun* sp. and *Ruppia* sp.. In addition to the macrophytes and macroalgae the pool had a high biomass of nuisance filamentous algae which occurred thoughout the year.

Strehlow (2009) identified that management of the Town Pool is challenging as the pool is part of the larger Avon River system and is affected by activities in the upper catchment. The report recommended that a guiding vision linked to management goals and priorities be identified for the Northam Town Pool to form the basis of future management decisions and priorities. It was noted that prevention of regime shifts should be include in this vision.

The following key recommendations were identified:

- Management – successful management of the natural systems is based on well defined management aims, including defining primary management aims. A number of management aims were identified to prevent additional disturbances and improve the ecological function including:
  - Maintain and restore hydrological regimes.
  - Identify sources of nutrient inputs and implement mitigation strategies.
  - Reduce nutrient inputs to the pool.
  - Protect and expand remaining fringing vegetation.
  - Eradicate introduced species.
  - Implement rehabilitation programs.
  - Maintain physio-chemical variables at or below those of the ANZECC trigger values.
- Catchment scale strategies – secondary salinisation, eutrophication and changes to the flow regime are the key threatening processes to the Northam Town Pool and all three occur at the catchment scale, requiring management at the catchment scale.
- On-ground strategies – a number of measures are recommended to maximise biodiversity and ecological health of the Northam Town Pool:
  - Identification of sources of nutrients.
  - Modification of existing drains.
  - Construction of nutrient retention wetlands.
  - Revegetation of shallow shore with native reeds and sedges.
  - Encourage the growth of submerged mavrophytes.

- – Revegetation of the riparian zone.
  - – Flushing the pool by opening the weir.
  - – Re-establishment of upstream river braiding.
  - – Institution of environmental education programmes and community awareness.
  - – Reduction of garbage in pool.
  - – Management of bird numbers.
- Future research and monitoring – further understanding is required of the following key parameters:
  - – Dissolved oxygen – little information on the diurnal and seasonal changes in DO levels. Important to reducing cause of low DO levels.
  - – Sediments – the nutrient, heavy metal and pesticide load within the sediment store is unknown, and presence of acid sulfate soils also not confirmed.
  - – Long-necked tortoise – health and reproductive status unknown.
  - – Routine monitoring – addition of Chl a to routine DoW monitoring.
  - – Routine monitoring of fish and invertebrate fauna – ideally twice a year, minimum of once a year.
  - – Monitoring effectiveness of implemented management measures.

5.10 Nutrient management for the Avon River Basin; a toolkit for managing nutrient loss to the environment from a range of land uses (Department of Water 2010)

The toolkit undertaken as an Avon Catchment Council project, and was prepared by Viv Read and Associates and published by the Department of Water. The toolkit provides land managers with ways to limit nutrient loss from a variety of land uses and to restore the environmental values of waterways in the Avon River Basin. The toolkit applies to point and diffuse sources of nutrients, including wastewater treatment plants, abbatoirs, intensive animal industries, landfill sites, small-scale and broadacre farming, and rural towns. The toolkit sets the challenge to those who live and work in the Avon River Basin to contribute 'their bit' towards cleaner water in the Avon and Swan river systems for a healthier and sustainable future.

The general nutrient management guidance and potential solutions identified within the toolkit were based on an extensive review of nutrient management practices.

The toolkit is based upon four key steps:

1. Assessing the risk.
2. Evaluating the management options.
3. Implementing the chosen management option.
4. Monitoring the response.

For each of the point and diffuse sources of nutrients identified above the toolkit provides examples of nutrient management options and strategies that may be implemented by the land manager.

Of particular relevance to the Northam townsite are the recommended management options and strategies for local government and town communities, which include:

- Construct detention basins or nutrient stripping wetlands for management of stormwater.

- Restore fringing zone vegetation for waterways and wetlands.
- Develop Nutrient and Irrigation Management Plans for large-scale recreational facilities.
- Adopt water sensitive urban design (WSUD) principles and practices for urban development.
- Adopt land use planning decisions which will achieve the following:
  - restriction of development in the floodplain and waterlogged areas.
  - recognition of land capability constraints (for example, soil type and landform), the potential for nutrient loss to the environment and appropriate management of this risk.
- Require light industry to develop and implement contingency plans to prevent or manage unplanned off-site discharges.
- Monitor water quality of receiving waters where Shire facilities may be impacting on nutrient levels, to assess the impact of management practices and make changes where necessary.
- Support state government agencies by promoting local community awareness and information about nutrient management and environmental impacts.

5.11 Background Paper – Stormwater Quality (Wheatbelt NRM 2011)

Wheatbelt NRM (2011) conducted stormwater nutrient modelling using MUSIC V4 software for the Northam Townsite to provide an indication of the gross contribution of nutrients from the current development at Northam to the Avon River. This is discussed further in Section 4.

The results provide an estimate the expected increase in nutrient loading resulting from new and planned subdivision within the townsite. Modelling was conducted at the daily time-step for 44 sub-catchments within the Northam townsite, and simulated over a 10-year period from 1999 to 2009. Due to limited monitoring data, the water quality model was uncalibrated. Limited snapshot sampling was undertaken of stormwater drainage.

The study recommended that nutrient abatement infrastructure should be implemented within new subdivisions to reduce the stormwater contaminant discharge from the town and to protect the downstream Northam Town Pool and other assets from future degradation.

Key points from the report:

- River pools within the Avon Arc reported as eutrophic or contain nutrient rich sediments.
- Increases in contaminants within stormwater runoff from increased residential density and development of commercial and industrial estates.
- Daily time step nutrient and flow modelling for 1999 – 2009 MUSIC stormwater modelling was undertaken for 44 subcatchments within Northam to provide an indication of the gross contribution of nutrients from Northam to the Avon River. Modelling results indicate that stormwater from the Town of Northam contributes approximately 7.3% and 2.2% of total discharge at Northam Weir for TP and TN respectively.
- Modelling results indicate that new and planned subdivisions (new developments identified within local planning schemes) likely to result in 102% increase in TP, a 35% increase in TN and a 74% increase in TSS if no nutrient abatement strategies are undertaken (limit the increase of contaminants within stormwater discharge from Northam to protect the downstream environmental assets).

- Study presented information on the expected impact that the proposed development may have on downstream environments and infrastructure to help inform policy and planning decisions regarding the current and future development within Northam.
- Excessive amounts of nutrients (N and P) can promote rapid growth of aquatic plants (toxic and non-toxic algae). Excessive aquatic growth can result in anoxic conditions.
- Effective removal of nutrients can often be achieved by settling out the silt and clay particles, to which the nutrients attach. It is considered likely that the majority of particulate matter containing nutrients currently settle out in river pools downstream of the Avon River, resulting in them containing nutrient rich sediments and eutrophic conditions.
- River pools and riparian vegetation provide primary habitats supporting various ecosystems, provide drought refuge for wildlife and performing important roles in the cycling of nutrients and other contaminants.
- There are considerable water quality management issues for the Northam Pool including the threat of sediment infill, eutrophication, excessive seagrass, Sago Pond Weed (Coleogeton and Lamprothamnium) growth and algal blooms (From RRP Section 6).
- There are five Avon River Pools located within the Shire of Northam, where four are considered to be of environmental and/or social value. The pools have considerable water quality issues; the key issues include sediment infill, excessive nutrients and algal growth.
- The key threatening processes to the Avon River pools include: grazing of the river and tributaries (reduced in recent years from fencing of river); erosion of the river beds and banks, especially within tributaries resulting in sediment deposits in river pools; nutrient enrichment and organic matter resulting in eutrophication; general water quality pollution including metals, hydrocarbons and nutrients associated with fertilisers.
- Most significant threats to the river pools are considered to be sedimentation and nutrient enrichment generated from local catchments that discharge directly, or immediately upstream of the river pools.
- Stormwater from the Northam townsite discharges directly into the Northam Pool, carrying pollutants to the pool including suspended sediments, hydrocarbons, nutrients and dissolved metals, where eutrophication of the Northam Pool is considered to be a direct consequence of nutrient rich stormwater discharge from the Northam townsite.
- Average annual flow at the Northam Weir is estimated to be 127 GL, containing 3.4 tonnes of TP and 143 tonnes of TN, based on flow and nutrient modelling by the Department of Water.
- Monitoring of nutrient and metal concentrations at Northam has been undertaken over the period 1998 to 2009 by the Department of Water.
- Recommended that implementation of nutrient abatement infrastructure within new sub-divisions is considered critical to limiting stormwater contaminant discharge from the town and protecting downstream environmental assets from further degradation.
- Includes nutrient sampling data, and MUSIC modelling results.

5.12 Preliminary Hydrology Assessment – Chidlow Street Subdivision Northam (Wheatbelt NRM 2011)

Wheatbelt NRM (2011) conducted a preliminary hydrology assessment of the Hatton St outfall subcatchment (approximately 344 ha) which is located within the Northam townsite and discharges to the Avon River upstream of the weir. The Hatton St catchment consists of predominantly agricultural land (299 ha) existing urban development (42.5 ha), the Chidlow St subdivision (9.5 ha) and proposed future subdivisions south of Throssell St (62.5 ha).

The study conducted MUSIC V4 modelling to assess the potential hydrologic impact of the proposed subdivisions on peak flows and water quality within the Hatton St outfall catchment. Results from a number of modelling scenarios were presented, including modelling the current conditions, and the proposed developments with and without detention basins.

The hydraulic modelling results indicated that flow attenuation structures, such as detention basins, are required within the proposed subdivisions to ensure that the downstream pre-development peak flows are maintained. The detention basins will act to attenuate peak flows only, and are likely to have limited impact on the water quality discharging from the proposed subdivisions.

The water quality modelling results are presented in Table 17. The results indicated that the Chidlow St subdivision would increase the nutrient discharge from the Hatton Creek Catchment by 4% to 6%, and the proposed development upstream of Throssell St would increase the nutrient discharge from the Hatton Creek Catchment by 12% to 18%. The study recommended that additional purpose built nutrient reduction infrastructure is implemented within future subdivision developments to maintain water quality discharging from the Hatton St catchment.

Table 17 Summary of the water quality monitoring results for the annual discharge from Hatton St catchment (adapted from Table 6 –Wheatbelt NRM, 2011)

Parameter	Predevelopment	Chidlow St Subdivision		Future development (upstream of Throssell St)	
	Total	Total	Increase	Total	Increase
Flow (ML)	276	285	3.3%	332	14%
TSS (kg)	42,000	44,563	6.1%	52,800	20%
TP (kg)	89.7	95	5.9%	118	24%
TN (kg)	763	791	3.7%	898	15%

5.13 King Creek Catchment Hydrologic Assessment (Wheatbelt NRM 2011)

Wheatbelt NRM (2011) conducted hydrologic and water quality modelling (using MUSIC V4) of the King Creek catchment to assess the potential changes to peak flows and nutrient loads from a planned subdivision located immediately upstream of Throssell Road. The King Creek catchment (435 ha) discharges to the Avon River upstream of the Northam weir, and consists predominantly of agricultural land (274.5 ha) and a mix of developed urban (64.75 ha) and subdivisions (96.3 ha).

Hydraulic modelling was undertaken (using HEC-RAS modelling software) to assess the flow capacity of the current stormwater infrastructure and MUSIC modelling was conducted to assess the current and potential peak flows and nutrient loads. Modelled scenarios included the current conditions, the proposed development conditions and the likely impact of potential flow and nutrient reducing infrastructure including detention dams, biofiltration basins and vegetated swales.

Detention dams are used to temporarily contain stormwater discharge from upstream in the catchment, allowing the flows to discharge through a pipe of a spillway at a known discharge rate to reduce peak flows associated with short duration and high intensity rainfall. Three detention dams were included in the analysis, where two were located upstream of the proposed subdivision with an assumed capacity of 10,000 kL, and one located downstream of subdivision and upstream of Throssell St with a capacity of 15,000 kL.

Biofiltration basins are typically landscaped depressions or shallow basins used to filter pollutants form stormwater runoff prior to discharge to the natural environment. Biofiltration basins are typically sized between 1 to 3% of the impervious surface area of the catchment. Four biofiltration basins were included in the analysis within the planned subdivision, with the total area of the biofiltration basins of approximately 1 ha.

Vegetated swales are effective in removing suspended sediment and reducing nutrient discharge and moderating peak flows. A 450 m vegetated swale was included in the analysis located downstream of Throssell St.

The modelling results indicated that the proposed development within the King Creek catchment will result in increased peak flows and nutrient discharge to the Avon River. Hydrologic modelling indicated that the proposed development would result in a 40% increase in the 1:10 ARI peak flow and a 10% to 15% increase in the 1:100 ARI peak flows, where the flow capacity of the existing stormwater conveyance infrastructure is exceeded on average 1:10 to 1:20 years. The analysis indicated that detention basins are effective in reducing peak flows for shorter duration rainfall events.

The water quality modelling results are presented in Table 18. Water quality modelling indicated that the proposed development is likely to increase TSS and nutrient discharge within stormwater by 75% and 220% respectively. Implementation of stormwater treatment infrastructure, including biofiltration basins and vegetated swales, is likely to reduce the TSS and nutrients by 30% and 45% respectively, over that likely to occur if assuming no stormwater treatment infrastructure is implemented. This study concluded that due to the nature of the development, it will be difficult to maintain pre-development water quality conditions.

Table 18 Modelled nutrient loads for the 1 yr – 1 hr storm event at Throssell St crossing (adapted from Table 10 –Wheatbelt NRM 2011)

	Pre-development	Post-development	Treatment
Flow (ML)	1.62	5.29	4.49
TSS (kg)	45.4	745.2	151.0
TP (kg)	0.05	2.39	0.70
TN (kg)	2.26	14.90	8.71

5.14 Hydrologic Assessment – Minson Avenue Catchment (Wheatbelt NRM 2011)

Wheatbelt NRM (2011) conducted hydrologic and water quality modelling (using MUSIC V4) of the Minson Avenue catchment to assess the potential options for improving the water quality of the stormwater generated from the Minson Ave outfall catchment, prior to discharge to the Avon River via culverts under Peel Tce downstream of the Northam Weir pool. Stormwater from the Minson Ave catchment discharges to a 2500 m^2 artificial wetland (Swan Enclosure) located within Minson Park, immediately upstream of Peel Tce, which provides a stormwater quality management function for low flows discharging from the Minson Ave outfall. The total subcatchment area of the Minson Ave outfall located upstream of the Swan Enclosure is 33.05 ha.

Surface water quality treatment scenarios of a number of treatment options including a biofiltration basin, a vegetated swale and a settling pond were modelled using MUSIC to provide an indication of the likely water quality improvement which can be achieved. The modelling results from this study, presented in Table 19,provides an indication of the likely reductions in various parameters which can be achieved with different treatment mechanisms. The analysis indicated that a biofiltration basin is likely to be most effective in reducing stormwater pollutants, with a 90% reduction in the TSS and reduction in TP and TN by 60% to 70%. However, the physical topographical constraints and overall constructions cost are likely to limit the feasibility of the incorporating a biofiltration basin into the existing development. The study recommended that a settling pond in series with a vegetated swale should be constructed, as this system can achieve similar water quality improvements to the biofiltration basin, and it is not constrained by topographic constraints.

The study indicated that the current practice of discharging stormwater into the Swan Enclosure prior to discharge to the Avon River provides some water quality improvements. However, it is recommended the operating guidelines and procedures of the Swan Enclosure be revised to determine opportunities to achieve the most effective water quality management outcomes.

Table 19 Modelled effectiveness (percentage reductions) of alternative stormwater management options (adapted from Table 7 –Wheatbelt NRM 2011)

	Biofiltration basin	Swale	Swale and pond	Pond only
Flow	20%	0%	5%	5%
TSS	90%	53%	68%	35%
TP	70%	39%	57%	34%
TN	62%	29%	45%	26%

5.15 Proposal for Reinvigorating the town pool of Northam (Davey 2011)

Bob Davey from Bob Davey Real Estate prepared a proposal for the reinvigorating the Northam Town Pool for the Shire of Northam (2011). The key recommendations from this proposal include:

- **Maintain pool water level**: Augment the summer water levels in the pool with a suitable source of groundwater, especially for years when summer storms do not occur. Investigations should be conducted into a potential groundwater source such as underground streams, or groundwater in the

Bert Hawk Oval area. A pumping system should be designed to access the groundwater, with the possibility of discharging the water in a fountain within the pool.

- **Redirect Sewer**: Redirect the sewer line under the river bed, at a location between the current location and the railway bridge.
- **Redirect North Burlong (Stage 1)**: Redirected the river at North Burlong to slow the water flow to increase the rate of sediment deposit, before entering the town pool.
- **Silt traps:** Install silt traps between the Newcastle Bridge and Charles Street to help trap sediments, and also act to build-up a retaining wall to maintain water in the pool during the summer months. The community could help to dredge the silt traps.
- **Dam wall:** Reconstruct the top of the dam wall to provide a structure which regulates the flow of water and incorporated relief valves for managing flood events.
- **Aeration of water:** Incorporate aeration devices into the Town Pool, such as paddle boats, fountains (currently 4 fountains in the pool) windmills and solar aeration units.
- **Island:** Construct a small island in the pool located in front of the new weir to increase the water movements in this stagnant part of the pool.

5.16 Summary table

A summary of the management strategies from the literature review is provided in Table 20.

Table 20 Summary table of recommended strategic actions from review of literature

Issue	Strategic actions	Implementation
River Recovery Plan Section 6 – Northam (Water and Rivers Commission and Avon River Management Authority, 1999)		
Restore River Pools To re-create pools, where appropriate, along the river in order that they may once again contribute to the natural form and character of the river and may be used for recreation.	Northam Town Pool – strategy is in place to increase the water depth of the pool during summer, improve water quality within the pool, improve waterbird habitat around the pool and improve the overall aesthetics of the pool. Monitor sediment accumulation in Northam Town Pool (NTP) and take further action to minimise sediment input as necessary (high priority, ongoing). Continue the program of sediment trapping and removal at Burlong Pool as long as is required to maintain the amenity value of the site as a water-based recreation area (Priority: high, timing: ongoing). Estimate sediment fluxes at Burlong Pool (Priority: high, timing: ongoing). Continue surveying the profile of the river between NTP and Northam town boundary (Priority: medium, timing: ongoing).	
Foreshore revegetation Revegetate areas of the river foreshore based on their need and suitability for revegetation.	Prepare detailed, site-specific planting/seeding schedules for designated revegetation sites, linked to foreshore fencing, in-stream sediment stabilisation and site-specific weed eradication where appropriate.	Priority: high, timing: short
Recreational use Encourage appropriate river and recreational activities at strategically located and suitably managed sites.	Determine and designate alternative sites for horse riding and motor bike riding. Monitor river recreational use. Close inappropriate vehicle access to the river and foreshore and the river reserve, allow vehicle access at recreational sites.	Priority: high, timing: short/ongoing.
In-stream stabilisation Restrict sediment movement by stabilising river bed sediments, where appropriate.	Prepare, and implement site-specific sediment stabilisation works focusing at designated sediment stabilisation sites. In general, those site include: • Old islands (stabilising islands). • New islands (sediment deposition islands). • Sediment slugs. • Scour areas (river margins).	

Issue	Strategic actions	Implementation
Sediment management Sustainably limit sediment movement along the river.	Undertake a survey of the river section to identify appropriate locations for construction of river riffles. Prepare a sediment management strategy in association with any pool re-creation strategy.	Priority: high Timing: Medium to long
Stock access Restrict stock access to the Avon River.	Undertake fencing of the river foreshore with specific fencing goals, and advise relevant landowners along the river section the reasons for the move to restrict stock access to the river.	Priority: high Timing: short
Rubbish disposal Enforce the notion of the river as a 'rubbish-free zone'.	Remove rubbish from sites where it has been accumulated and undertake a community education program which discourages the disposal of rubbish in the river.	Priority: high Timing: short / medium
Flooding Increase the communities understanding of the impacts of flooding and the need for action to minimise the risks and damage associated with flooding.	Determine and implement best management strategies for use and management of land in the 1:100 year floodplain.	Priority: High Timing: Medium
Stormwater Apply best practice stormwater management for all new developments and to the existing stormwater management system, where possible, to minimise the amount of pollutants entering the river through the stormwater drainage network.	Encourage and facilitate preparation of municipal stormwater management programme which applies best management practice to existing and new stormwater drainage systems	Priority: high Timing: short
Industrial wastewater Minimise the input of pollutants to the river from industrial sources.	Seek licensing of point sources of pollutant to the river, under the Environmental Protection Act, where appropriate Encourage and facilitate those responsible for pollutant sources, which are not prescribed premises, to determine and implement best management practice strategies to minimise pollutant inputs to the river. Moderately	Priority: high Timing: ongoing
King Creek Catchment Hydrologic Assessment (Wheatbelt NRM 2011)		

Issue	Strategic actions	Implementation
Flood management Manage the increase in peak flows within the King Creek catchment from a planned subdivision located immediately upstream of Throssell Road. The King Creek catchment discharges to the Avon River upstream of the Northam Weir.	Construction of three detention basins (two upstream of the proposed development and one downstream of the subdivision) is recommended to reduce the peak flows.	Decisions regarding the location and size of the detention structures will require more detailed analysis of the costs and benefits associated with construction.
Nutrient management Manage the increase nutrient load within the King Creek catchment from a planned subdivision located immediately upstream of Throssell Road.	This study concluded that due to the nature of the development, it will be difficult to maintain pre-development water quality conditions. The study recommended the implementation of stormwater treatment infrastructure, including biofiltration basins and vegetated swales, which is likely to reduce the suspended sediment and nutrients by 30% and 45% respectively, over that likely to occur if assuming no stormwater treatment infrastructure is implemented.	
Hydrologic Assessment – Minson Avenue Catchment (Wheatbelt NRM 2011)		
Nutrient management Investigate potential options for improving the water quality of the stormwater generated from the Minson Ave outfall catchment, prior to discharge to the Avon River downstream of the Northam Weir pool. The stormwater currently passes through an artificial wetland which functions as a swan enclosure, before to discharging to the Avon River	The study recommended constructing a settling pond in series with a vegetated swale to reduce the nutrient and sediment loads prior to discharging into the Avon River. It is recommended the operating guidelines and procedures of the Swan Enclosure be revised to determine opportunities to achieve the most effective water quality management outcomes.	
Preliminary Hydrology Assessment – Childlow Street Subdivision Northam (Wheatbelt NRM 2011)		

Issue	Strategic actions	Implementation
Flood management Manage the increase in peak flows within the Hatton St outfall catchment from future proposed development. Hatton St catchment discharges to the Avon River upstream of the Northam Weir.	Flow attenuation structures, such as detention basins, are should be constructed within the proposed subdivisions to ensure that the downstream pre-development peak flows are maintained.	
Nutrient Management Manage the increase in the nutrient load within the Hatton St outfall catchment from future proposed development.	The study recommended that additional purpose built nutrient reduction infrastructure is implemented within future subdivision developments to maintain water quality discharging from the Hatton St catchment.	
Avon River Catchment Water Quality and Nutrient Monitoring Program for 2006, 2007 and 2008 (Department of Water)		
Water quality monitoring Monitor the water quality within the Avon River.	Continue regular monitoring of the water quality within the Avon basin and publishing of the data and undertake additional sampling during major rainfall and flow events in summer to assess the effects on water quality	
Assessment of the status of river pools in the Avon catchment (Department of Water 2007)		
River Pool Recovery Implement management programs to try and restore the Avon River pools to their natural state.	Implement management options including sediment extraction, sediment controls (riffles and snags), revegetation (along the banks and in-stream islands), fencing and monitoring and maintenance programs to restore river pools to their natural state.	
Proposal for reinvigorating the town pool of Northam (Davey 2011)		
Maintain pool water level	Augment the summer water levels in the pool with a suitable source of groundwater, especially for years when summer storms do not occur. Investigations should be conducted into a potential groundwater source such as underground streams, or groundwater in the Bert Hawk Oval area. A pumping system should be designed to access the groundwater, with the possibility of discharging the water in a fountain within the pool.	

Issue	Strategic actions	Implementation
Redirect Sewer	Redirect the sewer line under the river bed, at a location between the current location and the railway bridge.	
Redirect North Burlong (Stage 1)	Redirected the river at North Burlong to slow the water flow to increase the rate of sediment deposit, before entering the town pool.	
Silt traps	Install silt traps between the Newcastle Bridge and Charles Street to help trap sediments, and also act to build-up a retaining wall to maintain water in the pool during the summer months. The community could help to dredge the silt traps.	
Regulate flow	Reconstruct the top of the dam wall to provide a structure which regulates the flow of water and incorporated relief valves for managing flood events. Construct a small island in the pool located in front of the new weir to increase the water movements in this stagnant part of the pool.	
Aeration of water	Incorporate aeration devices into the Town Pool, such as paddle boats, fountains (currently 4 fountains in the pool) windmills and solar aeration units.	

6. Review of legislation

This section presents a review of the current legislation that is applicable to the Northam Town Pool.

6.1 Rights in Water Irrigation Act 1914

The Avon River is a Proclaimed Surface Water Area under the *Rights in Water Irrigation Act 1914*. Under the terms of this classification any interference with water from a watercourse or wetland within the catchment is prohibited. As such any proposals for subdivision/development which interfere with a water course, wetland or groundwater are required to be referred to the Department of Water for comment.

6.2 Shire of Northam Local Planning Strategy (2004)

The Shire of Northam Local Planning Strategy (2004) notes that the management and protection of the Avon River rests with the Department of Water (then Department of Environment).

6.3 Statewide Policy No. 5 Environmental Water Provisions Policy for Western Australia

Statewide Policy No. 5 Environmental Water Provisions Policy for Western Australia (Water and Rivers Commission 2000) outlines the approach to be followed to determine how water will be provided to protect ecological values when allocating the rights to use water in Western Australia. The policy also lists the guiding principles to be followed when making such decisions and outlines a water allocation planning framework in which these principles are to be applied.

6.4 Environmental Protection Act

Point sources of pollution may be licensed under the Environmental Protection Act.

6.5 Aboriginal Heritage Act 1972

Aboriginal sites are protected under the Aboriginal Heritage Act 1972 and should not be disturbed within consent from the Western Australian Department of Indigenous Affairs and Western Australian Office of Native Title.

The whole of the Avon River is recognised as a registered Aboriginal Site (DIA 3536 Swan River, including DIA 15979 Avon River).

Any disturbance or restoration works for the Northam Town Pool or the Avon River will require full consultation with the appropriate Aboriginal communities prior to any disturbance, and all relevant approvals.

7. Stakeholder engagement and site visit

GHD conducted a site visit to the Northam Town Pool on the 11 November 2011 and met with a number of key stakeholders from the Shire of Northam, Wheatbelt Development Commission, Avon Environmental Society, Department of Water, Porter Consulting Engineers, Wheatbelt NRM Avon Community Development Foundation, Toodyay Friends of the River, York River Group as well as local business representatives.

The purpose of the meeting was to identify key community concerns as well as opportunities for the Northam Town Pool and also to discuss a range of strategies and options that may assist in improving the environmental and aesthetic quality of the pool.

Key concerns that were addressed primarily related to the loss of amenity of the Northam Town Pool during the mid to late summer period, attributed largely to the occurrence of offensive odours, stagnant water and decline in water level.

The benefit of identifying a *desired outcome* for the town pool was recognised by the stakeholders present at the meeting. This is important as it will assist in the identification of the potential options for improving the pool. Desired outcomes for the pool identified by the stakeholders included:

- Long term environmental improvement.
- Desire to have the pool 'full' year round.
- Reduction in offensive odours during summer.
- No impact on downstream communities.
- Recognition of the need to balance aesthetic (people) values and environmental values in identifying potential options.

Minutes from the stakeholder consultation meeting are provided in Appendix B.

The site visit included a brief review of the existing residential and town drainage and the DoW gauging station, and the southern bank of the Northam Town Pool was traversed between the Peel Terrace and Burlong Pool. Features of the Northam Town Pool are shown in Table 21

Table 21 Northam Town Pool features

Plate 1: Northam Weir

Plate 2: Poor water quality in the pool shallows upstream of Northam Weir

Plate 3: Aquatic plants along the edge of the pool

Plate 4: Facing downstream from Newcastle Road bridge

Plate 5: Drainage inflow to the Northam Town Pool upstream of Newcastle Road bridge

Plate 6: Drainage inflow to the Northam Town Pool upstream of Newcastle Road bridge

Plate 7: Drainage inflow between the Newcastle Road bridge and the Railway bridge

Plate 8: Drainage inflow between the Newcastle Road bridge and the Railway bridge

8. Review of management strategies and options

The stakeholder consultation identified the following desirable outcomes for the Northam Town Pool:

- Improvement in the aesthetics of the town pool during summer through an increase in water level and reduction in odour
- Long term improvement in the water quality from an environmental perspective
- Any improvement strategies implemented should have no detrimental impact on downstream communities

Strategies and options that may achieve the desirable outcomes for the Northam Town Pool have been identified through the review of available literature (Section 2, summarised in Table 20) and through stakeholder engagement (Section 7).

A brief overview of the identified strategies and options is given below along with an assessment against the criteria in Table 22.

Table 22 Broad assessment criteria

Criteria	Description
Effectiveness	This criteria is based on a desktop assessment of the perceived effectiveness of the strategy/option in achieving the desired outcomes for the pool. In evaluating this criteria each strategy/option was assessed as being implemented independent of other strategies/options.
Implementation	This criteria is based on a desktop assessment of the perceived ease of implementation of the strategy/option. In evaluating the ease of implementation other considerations such as potential site constraints and requirements for additional information to further endorse the strategy/option were considered.
Cost	The evaluation of the cost comprised an estimate of the capital cost and ongoing life cycle costs including maintenance requirements for comparative purposes only.

8.1 Management plan for Northam Town Pool

The development of a management plan for the Northam Town Pool will provide clear management objectives for the pool, and enable a coordinated approach to achieve the objectives.

A management plan should include:

- Objectives for management of the Northam Town Pool.
- Baseline characterisation of the Northam Town Pool.
- Monitoring and evaluation of the management plan to monitor the success of implemented strategies and options.
- Reporting and review structure.

The Waterways Commission developed the Northam Town Pool Sediment Management Plan in 1995. This management plan identifies a number of strategies to address sediment problems within the Town Pool, and also identifies a suite of additional strategies to address the overall environmental and aesthetic quality of the pool. A management plan for the Northam Town Pool would likely comprise an update of the existing document with more recent information and consideration of additional management strategies.

In identifying the objectives or priorities for management of the Northam Town Pool consultation will need to be undertaken with the wider community and relevant stakeholders. While stakeholder consultation has been undertaken for the purposes of this project more extensive consultation should be undertaken to fully develop overarching management objectives for the Town Pool.

Effectiveness

- While not resulting in direct improvement in water quality of the Northam Town Pool a management plan will enable a coordinated approach and establish objectives for management.

Implementation

- Development of a management plan will require liaison with relevant stakeholders to identify agreed management objectives for the Northam Town Pool.
- The management plan should provide an update of the existing environment (baseline condition) of the Northam Town Pool so that implemented management strategies and options can be evaluated through comparison to the baseline condition.

Cost

- The cost of a management plan will be dependent on the required supporting investigations (water quality, sediment store etc).

8.2 Water quality monitoring

The Northam Town Pool is currently monitored as part of the snapshot water quality monitoring program for the Avon River. The snapshot monitoring program has recognised many of the water quality issues relating to the Northam Town Pool within the context of the wider water quality issues of the Avon River. In order to quantify the source contribution of nutrient, contaminant and sediment load, and to establish the baseline water quality of the Northam Town Pool a targeted water quality monitoring program is required.

This information is considered vital to inform the ongoing management of the pool, and to monitor the impact of the strategies and options implemented to improve the water quality in the Town Pool. A targeted monitoring program will also enable monitoring of the water quality for a series of additional contaminants in order to assess the suitability of the water for recreational contact, which was noted by some stakeholders as a desirable outcome for the Town Pool, and to assess for other contaminants not previously monitored.

The Department of Water has prepared a guideline entitled *Water quality monitoring program design* (DoW 2009) which notes that monitoring is the “consistent, regular, long-term gathering of data” and that everything else is a sampling event or series of sampling events.

Key monitoring periods are recommended to include:

- Late spring surface water flows prior to the cease to flow and isolation of the pool.
- Throughout the summer and autumn isolated pool phase.
- Several stormwater runoff events throughout the year.

Key monitoring sites are recommended to include:

- The upstream and downstream extents of the pool.
- 3 or 4 sites along the length of the pool with samples collected near to the surface and at depth.
- Stormwater drains that flow directly into the town pool.

Effectiveness

- A targeted monitoring program will provide important information about the nutrient, contaminant and sediment load of the Town Pool which will help to determine the most appropriate management strategies to address the existing water quality issues.
- A targeted monitoring program will provide baseline water quality data on the existing nutrient, contaminant and sediment load of the Town Pool which will be important in order to assess the effectiveness of the management strategies implemented to improve the water quality of the pool.

Implementation

- Water quality monitoring is currently undertaken within the Avon Arc catchment. Implementation of an additional water quality monitoring program targeted at the Northam Town Pool will therefore not be an onerous undertaking.
- Require additional staffing resources.

Cost

- Monitoring of the town pool will require small capital expense on an ongoing basis (moderate expense overall).
- Capital expense related to a targeted monitoring program will predominantly relate to staffing resources (development of monitoring program, monitoring, analysis and reporting) and disbursement costs (travel, equipment and laboratory).

8.3 Sediment control

The high sediment load in the Avon River has been identified as ongoing water quality issue and is also responsible for filling of numerous pools along the river. The River Training Scheme and agricultural practices within the catchment are key issues that have resulted in a high suspended sediment load in the river.

Early studies identified that the sediments within Northam town pool were medium to coarse sands indicating transport by medium to high energy conditions (Pearce, 1987; Southwell, 1990). More recently a report prepared for DoW and SRT (ACE and Viv Read & Associates 2007) identified the Northam Town Pool as being 70% filled with sediments, primarily of silty clay origin. This was based on the earlier river pool survey by JDA (1997) Coarser sediment generally deposited upstream from the Northam Town Pool in the Burlong Pool.

8.3.1 Dredging of Town Pool

A review of constructed wetlands in the south west region of Western Australia (ENV 2008) identified sediment and sludge removal as a management measure for constructed wetlands with ongoing nuisance algal issues. Dredging of the sediment from the Town Pool will remove a source of nutrients from the water column as well as increase the depth of the pool, potentially resulting in both water quality and aesthetic improvements.

Timelines of works carried out at the Northam Town Pool (Gutteridge Haskins & Davey 1992, Waterways Commission 1995) identify that dredging occurred in the following years: 1914, 1952/53, 1954/56 (~36,000 m^3), and 1975 (partial excavation). The most recent dredging project was completed in 2000 resulting in the removal of 50,000 m^3 (DoW 2007a). Subsequent testing of the stockpiled sediment revealed there may be potential acid sulfate soils within the dredge spoil (see Appendix B).

The Northam Town Pool Sediment Management Plan (Waterways Commission 1995) notes that the limited sediment sampling conducted in 1995 revealed that sediment nutrient levels (TN and TP) were in the low to moderate range, and pesticide and heavy metals in two samples were very low. This limited sediment sampling is not considered sufficient to inform a dredging program. A complete sediment analysis of the Town Pool is required to inform any future dredging program particularly given concerns regarding potential heavy metal and pesticide contamination, as well as the unknown sediment nutrient load and exposure of acid sulfate soils (Strehlow 2009).

The DoW Water Note 38 *Management of sediment in pools of the Avon River system* (DoW 2009) identifies that the following should be undertaken prior to any sediment extraction from the Avon River:

- Preparation of a pool management plan.
- Obtain licenses, permits and approvals where necessary. For example a Rights in Water and Irrigation Act 1914 (WA) permit may be required to disturb bed and banks.
- Undertake testing of sediment quality to identify nutrients, potential acid sulfate soils or other contaminants that may require special handling and disposal precautions.
- Further advice should be sought from DoW.

Effectiveness

- Dredging of the town pool will likely result in a short term decline in water quality (i.e. algal bloom) in response to disturbance of the sediment nutrient store.
- Further short term deterioration in pool water quality may occur due to suspension of heavy metals and pesticides, and exposure of acid sulfate soils.
- Dredging of the Town Pool in isolation of other management strategies or improvements option will likely result in a medium term improvement in water quality.
- Dredging of the Town Pool will result in long term benefits if implemented with other management strategies aimed at reducing the sediment load to the Town Pool, or through ongoing dredging operations.

Implementation

- Previous testing of dredge spoil identified acid sulfate soils (ASS).

- Implementation of any future dredging of the Northam Town Pool should be undertaken following the advice outlined in the DoW Water Note 38 *Management of sediment in pools of the Avon River system* (DoW 2009).
- Will require an assessment of the Northam Town Pool sediment volume and sediment quality (contaminants, nutrients and ASS) in order to quantify the volume of sediment to be removed, potential disposal requirements and contingency management plans should ASS or contaminants be released from the sediment store.
- Clearances will be required to undertake any dredging works (bed and banks permit, Aboriginal Heritage clearance).
- Disposal at authorised location will be required if sediments are identified as ASS.

Cost

- Dredging of the pool will require considerable capital expense.
- Recent estimates for dredging costs are $17 per tonne (with on-site sediment disposal) based on DoW's sediment removal project in 2007 and 2008 (DoW 2009).
- Additional capital costs may include:
  - Assessment study of the sediment volume and quality (including ASS).
  - Disposal costs at a licensed facility if required.

8.3.2 Management of Burlong Pool

Management of the sedimentation of Burlong Pool has been used as an ongoing management strategy to minimise further sedimentation of the Northam Town Pool. Extraction of sediment from the Burlong Pool is generally conducted on an annual basis. This sediment extraction is a commercial operation to remove in the order of 10,000 m^3 of coarse sediment per year.

Effectiveness

- Ongoing extraction of sediment from the Burlong Pool under the current commercial arrangements is recognised as acting as a natural sediment trap for the Northam Town Pool by helping to trap coarse sediment upstream.

Implementation

- The current dredging licence is due for renewal in 2012. It is recommended that the licence be reviewed prior to reissue to ensure that it is operated to achieve full benefit to the Northam Town Pool.
- Implementation should continue under a commercial arrangement.

Cost

- Sediment removal of Burlong Pool is a commercial operation.

8.3.3 Installation of sediment traps upstream of the town pool

Sediment traps work to slow down the river flow to enable suspended sediment to drop out of the water column. Sediment traps are generally most effective on coarser sediment, and not on fine sediment which is the key sedimentation issue in the Northam Town Pool. Local knowledge suggests that there are a couple of small pools located between the main section of the Northam Town Pool and Burlong Pool that may be excavated to act as natural sediment traps (M. Revell, DoW, pers. comm.).

Effectiveness

- Excavation of existing small pools between Northam Town Pool and Burlong Pool and/or installaition of a sediment trap upstream of the Northam Town Pool should be considered to reduce the coarse sediment load.
- Sediment traps unlikely to be effective under high flow conditions that likely carry the silty clay sediment load found in the Northam Town Pool.
- Will require frequent, ongoing maintenance to be effective in reducing sediment load to the town pool.

Implementation

- Sediment will need to have a disposal location identified.
- Testing of sediment may be required if contaminants are suspected.

Cost

- Capital cost of the sediment trap likely to be small.
- Ongoing maintenance costs to remove sediment from the trap,
- Ongoing disposal costs through identification of a suitable disposal location, or potential disposal at an authorised location.

8.4 Maintenance of pool water level

Maintenance of the water level within the Northam Town Pool was identified as a key desirable outcome amongst stakeholders (Section 7), and will lead to improved aesthetic and environmental values for this important asset to Northam and the region.

The water level within the Northam Town Pool is observed to decline during the mid to late summer period. The observed decline in water level is estimated at 300 mm. This decline is less than the high evaporation rate over the summer period (~ 1 metre), which may indicate that a local groundwater source (Jessup Terrace aquifer) may partially maintain the water level of the pool during summer (P. Weatherly pers. comm.).

Considering the dimensions of the Northam Town Pool (Section 3.1), the estimated replacement volume of water to maintain a water level depth of 1 m throughout the summer period in the main section of the pool is in the order of 30 – 50 ML of water. Including the upstream braided section the volume of water required to maintain the Northam Town Pool to the weir height is in the order of 50 – 80 ML.

Three water sources have been identified as providing a potential source of water to top-up the Northam Town Pool during the mid to late summer period and these are discussed in Sections 8.4.1 to 8.4.3 below.

It is important to note that artificial supplementation of water levels is generally supported by the DoW where the effects of a drying climate or over-abstraction of groundwater for consumptive purposes has resulted in the degradation of environmentally significant wetlands. The DoW note in the *Stormwater Management Manual for Western Australia* that artificial maintenance of permanent water bodies during the dry season by topping up with groundwater is an inefficient use of water resources, and has the potential to cause further water quality problems. The DoW have advised (D. Cummins, pers. comm.) that a proposal to supplement the Northam Town Pool using groundwater would be assessed through a groundwater licence application. The DoW would provide detail on the level of assessment required in response to the groundwater licence application, with consideration of the water quality, impacts on groundwater hydrology and other factors. Preliminary assessment of the proposal may be obtained through meeting with the appropriate DoW personnel to discuss the proposal.

8.4.1 Source - Groundwater

The Environmental Water Flow Requirements (GHD 2009) report prepared for the then Avon Catchment Council identified that the Avon River pools that retained high water levels and good water quality throughout the summer drought and isolated pool phase were believed to be maintained by groundwater discharge as either seeps or upwelling zones.

A desktop review was completed to identify and characterise key low salinity groundwater resources within the Avon River Basin for the Avon Catchment Council (GHD 2006).

This report identified two major low salinity groundwater resources within the Avon River Basin:

- Beverly to Westdale palaeochannel – comprising a large single palaeochannel system associated with the Avon River with significant groundwater resources below 5000 mg/L.
- Meckering sandplain - Deeply buried unconnected sand sheets running from northern Dowerin to west of Meckering, east of Goomalling – aquifers in the order of 1 km^2 scale.

Other than these two major aquifers the remaining groundwater sources are relatively small groundwater resources as fractured rock aquifers or sandplain aquifers associated with yellow sands. These resources are typically limited in capacity and yield (GHD 2006).

Effectiveness

- The effectiveness of maintaining the Northam Town Pool water levels using a groundwater resource will rely on the identification of a sustainable groundwater source of suitable water quality.
- Groundwater source will need to have low salinity and nutrient levels.
- If a suitable quality groundwater source is identified the supplementation of the pool water levels will likely lead to improvement of the water quality and pool aesthetics through dilution of the salinity and nutrient concentration of the pool. The increased pool depth will also reduce the growth of weed within the pool, which is favoured by shallower conditions.

Implementation

- Existing knowledge of the hydrogeology within the Northam area is poor and therefore implementation of this strategy relies upon the identification of a sustainable groundwater source of suitable water quality through hydrogeological investigations.
- Anecdotal evidence suggests that the water level in the Town Pool declines by 0.3 m in summer when evapotranspiration is estimated at 1 m. An estimated volume of between 50 ML to 80 ML will be required to maintain water levels at the weir height throughout late summer and autumn.
- Clearances will likely be required to add an alternate water source to the pool (Bed and Banks permit, Aboriginal Heritage clearance).

Cost

- Hydrogeological investigations will require considerable expense with no certainty of finding a suitable groundwater resource (personnel, exploration drilling costs, pumping tests, laboratory tests).
- Additional capital expense will occur to install infrastructure to pump or truck the water to the pool over the required period on an annual basis.

8.4.2 Source - Recycled wastewater

The Water Corporation operate a wastewater treatment plant at Northam downstream of the Town Pool. Treated wastewater is currently discharged to the Avon River downstream of the Northam townsite. While it is noted that the existing treated wastewater effluent is allocated for irrigation use, the projected growth in the Northam townsite population will result in additional effluent volume.

The Northam Wastewater Treatment Plant (WWTP) is located approximately 3 km north-west of the Northam town centre. The Northam WWTP uses primary and secondary treatment to treat up to 1,500 kL per day (DEC 2010). The treated effluent is discharged via a pumping to the Shire reuse pond or via an infiltration channel to the Avon River. The existing water quality of the Northam WWTP treated effluent for the period 2002-2009 is outlined in (Table 23).

Table 23 Northam WWTP effluent quality (DEC 2010)

Treated effluent quality	Mean	Min	Median	Max	90th percentile
Ammonia (mg/L)	32.3	9.6	34	65	41.7
BOD (mg/L)	13.3	<5	10	45	30
pH	7.3	4.9	7.3	8.8	7.8
Presumptive Thermo-tolerant Coliforms (cfu/100mL)	755	10	250	>10,000	1,960
Suspended Solids (mg/L)	45	5	20	530	80
Total dissolved solids (mg/L)	1,225	1,150	1,250	1,250	1,250
Total nitrogen (TN) (mg/L)	40.9	22	40.5	110	48.7
Total phosphorous (TP) (mg/L)	1.2	0.1	0.8	12	2.3

The treated effluent is likely to be treated to a suitable standard for recreational purposes following the installation of a UV disinfection trial in 2010 (DEC 2010). To meet the environmental water quality requirements of the Town Pool, the nutrient concentration of the effluent will need to be reduced substantially, in particular TN which had an observed minimum concentration of 22 mg/L (Table 23). On this basis the Northam WWTP will require a major upgrade in order to achieve treated effluent water quality of a suitable standard for discharge to the Northam Town Pool.

Effectiveness

- Provided that treated wastewater can be reliably treated to a quality that is suitable for environmental and public health the use of treated wastewater will provide a long term water source.

Implementation

- The treated wastewater will require additional treatment to meet environmental, health and recreational guidelines for discharge into the town pool.
- Environmental and health risk assessments studies will need to be completed.
- The Shire of Northam currently reuse the treated effluent water as an alternate water source for irrigation purposes. Implementation of this option will require much of the available volume of treated effluent to meet the required 50 ML to 80 ML to maintain water levels in the pool during the summer period.
- Will require considerable upgrade to the existing WWTP to achieve acceptable nutrient levels for discharge to the pool.
- Clearances will likely be required to add an alternate water source to the pool (Bed and Banks permit, Aboriginal Heritage clearance).
- Need to consider transport and storage of treated wastewater prior to discharge into the pool.

Cost

- Treatment of wastewater to a suitable quality will require upgrading of the Northam WWTP which will be a considerable capital expense. An indicative cost for similar WWTP upgrades is of the order of $20 m to treat 2 ML per day.
- Additional ongoing costs will be incurred through maintenance, storage, transport, monitoring of effluent quality, and monitoring of the pool.

8.4.3 Source – Stored stormwater

Stormwater runoff from the townsite has been identified as a potential water source to retain, store and use during the summer period to maintain the water level within the Northam Town Pool.

Utilisation of stormwater to supplement the Northam Town Pool will require acquisition of a suitable site for either an excavated and lined basin or storage tanks. The detention basins proposed for the King Creek catchment are designed to detain flows, reducing the peak flows associated with short duration, high intensity rainfall events (NRM 2011a, and are therefore not suitable for long term storage of stormwater runoff.

Stormwater runoff from existing and proposed urban development may be directed from the drainage system into constructed basin/tanks for later use to supplement the water level in the Town Pool. The DoW (2009) note that the Shire of Northam operate an existing 37 ML reservoir at Wundowie, which stores treated wastewater and stormwater runoff from the town.

It is important to note that stormwater runoff potentially contains high nutrient and sediment load. Water stored in an open basin may also evapo-concentrate nutrient concentrations (M. Giraudo, pers. comm.), and poor water quality may result in management issues within the storage, particularly given the potentially long storage period. The potential for high nutrient concentrations will likely require treatment prior to discharge to the Northam Town Pool. If an open basin is considered then further consideration needs to be given to minimising the creation of a mosquito breeding habitat.

Effectiveness

- Large storage area will be required in addition to the proposed detention basins identified for future urban development areas (ie. Kings Creek detention basins).
- Stormwater runoff potentially contains high nutrient and sediment load and may require pre-treatment if intended to be stored and used to supplement summer water levels in the Northam Town Pool.

Implementation

- Will require acquisition of additional land in addition to the detention basins required for stormwater management.
- Will need to consider design factors to reduce water quality issues such as algal blooms, in particular water quality, residence time and light.
- Will need to consider design factors to minimise the creation of mosquito breeding habitat.

Cost

- The reservoir at Wundowie was constructed through a co-investment project between the Water Corporation and the Commonwealth government. The Community Water Grants Scheme contributed $121,000 towards the cost of expanding and lining the reservoir.
- The Shire of Northam has indicated that earthworks associated with the reservoir at Wundowie cost between \$5.30 - \$5.90/m^3. Lining of an excavated basin is an additional \$20/m^2 (C. Hunt pers. comm.).

8.5 Increase weir height

Raising the height of the weir to increase the volume of the Northam Town Pool was identified as a potential strategy to improve the recreational value of the pool, while also potentially reducing the occurrence of poor water quality towards the end of summer. This strategy was previously employed for the Northam Town Pool by the Public Works Department (Gutteridge Haskins & Davey 1992). Public Works Department files note that the weir crest was raised by sandbags from 1967 until 1974 from spring until the end of summer to conserve a greater lake volume through summer.

Effectiveness

- Larger volume of water may improve the recreational amenity of the pool throughout the summer period.
- Increasing the depth of the pool may delay the occurrence of algal blooms and hypoxic conditions.

Implementation

- Increasing the height of the weir will increase the length of the river pool beyond its current extent, flooding the existing islands and the braided section of the river upstream of the Newcastle Road bridge which will impact the ecology of the river. Ecological studies will likely be required to support this option.

- If a permanent increase in weir height was to be implemented this may impact on the existing drainage of the Northam town centre and drainage studies will be required to identify the influence of the water level in the pool on the drainage infrastructure.
- A permanent increase in the weir height would need to consider potential flood impacts and contingencies.

Cost

- Drainage infrastructure and flood studies for the Northam town centre.
- Capital works for any upgrade of the Northam Weir will need to consider the relocation of the sewer pipes that run along the existing weir.

8.6 Stormwater management

The existing stormwater infrastructure within the Northam townsite comprises traditional drainage systems designed for maximum collection and conveyance of stormwater to the Avon River and in many cases the Northam Town Pool. As the key infrastructure and asset owner and land-use planning decision making authority the Shire of Northam plays the key role in the management of stormwater within the Northam townsite.

Numerous reports have previously identified the need to implement improvements to the management of stormwater within the townsites of the Avon catchment (Strehlow 2009, Wheatbelt NRM 2011a, b).

As noted by Wheatbelt NRM (2011a), the implementation of nutrient abatement infrastructure within new subdivisions is considered critical to limiting increases in stormwater contaminant discharge from the Town of Northam. Implementation of best management practice to the management of stormwater in existing and proposed urban, semi-rural and industrial development will assist to minimise the amount of pollutants entering the Avon River, specifically the Northam Town Pool, and the Mortlock River through the stormwater drainage network.

8.6.1 Development of stormwater guidelines

The Stormwater Management Manual for Western Australia (DoW 2004-2007) was developed to achieve multiple outcomes from stormwater management in Western Australia. In addition to the traditional objective of flood protection the Stormwater Management Manual identifies additional outcomes including stormwater reuse, water quality management and protection of ecosystems. While primarily implemented within the Perth metropolitan region, the drainage design and stormwater treatment measures identified within the document are applicable to regional Western Australian centres.

Effectiveness

- Review of the stormwater management options presented within the Stormwater Management Manual for Western Australia, as well as alternative stormwater management options, will help to identify those options and strategies that are suitable to the local conditions within the Northam townsite.
- Development of stormwater guidelines for the Shire of Northam.
- Following identification of suitable stormwater management options for Northam these may be implemented by other local towns leading to cumulative reduction in sediment and nutrient loads from the town centres on the Avon River.

Implementation

- Implementation of this option would include a review of the existing drainage systems and their management to identify and prioritise:
  - Sources of pollution.
  - Opportunities to prevent pollution from these sources.
  - Opportunities for inclusion of stormwater treatment measures in existing drainage systems.
  - Strategic planning of future urban development and drainage requirements to minimise adverse environmental impacts.

Cost

- Drainage review study and identification of appropriate drainage designs for future urban development and stormwater treatment measures to retrofit any existing drainage within the townsite.

8.6.2 Stormwater infrastructure

Retrofitting existing infrastructure and setting new design guidelines for future urban and industrial development will assist in reducing peak flows, nutrients and sediment into the Avon River and Northam Town Pool, and also the Mortlock River. The stormwater infrastructure that is recommended to be implemented within the existing and proposed development within the Northam townsite and other townsites in the Avon Arc includes (Strehlow 2009, DoW 2010, Wheatbelt NRM 2011):

- Implementation of detention dams in upstream catchments to reduce peak flow.
- Swales and biofiltration basins to promote nutrient uptake and sedimentation.
- Redirection of existing drains discharging into the Town Pool into a nutrient retention pond prior to discharge to the Northam Town Pool.
- Vegetation of stormwater drains to improve nutrient uptake, slow flows and promote sedimentation.

Effectiveness

- Retrofitting of existing stormwater infrastructure and implementation of best management practice stormwater infrastructure identified as suitable for future development within the Northam townsite (Section 8.6.1) will lead to reduced nutrient and sediment discharge directly into the Northam Town Pool.

Implementation

- Retrofitting of existing stormwater infrastructure is likely to be challenging in some areas as there are considerable gaps in the data for the Northam townsite drainage. In addition it has been noted that there is limited space for retrofitting or provision of a nutrient retention wetland for the drainage on the northern side of the pool.
- Implementation of the best management practise stormwater drainage design for future urban and industrial developments will require a change in the planning process requiring developers to submit a water management strategy or plan to identify proposed stormwater drainage infrastructure within the proposed development. This will require that some land within the future development areas is set aside for stormwater management. This will bring future development in Northam in line with existing development in other regional centres around Western Australia such as Broome,

Kununurra, Geraldton etc that have started to implement Better Urban Water Management (WAPC 2008) using stormwater design suitable to the particular region.

Cost

- Costs associated with retrofitting of existing stormwater infrastructure will be dependent on the selected stormwater upgrade.
- Implementation of best management practice stormwater for future development within the Northam townsite will initially be at the developers expense with costs passed onto to landowners.

8.7 Aeration

Aerators improve the circulation of water in their immediate surrounds and can help to reduce the occurrence of algal blooms by introducing oxygen rich water to lower layers preventing stratification or stagnation of the water column (ENV 2008).

ENV (2008) reviewed management strategies implemented throughout the Perth metropolitan region to reduce water quality issues within constructed wetlands. The review identified that artificial aeration was the most common management measure implemented to control algal blooms (ENV 2008) and this technique was successfully implemented when used in conjunction with other management strategies.

Strehlow (2009) notes that there is a perception that aeration of the pool will fix water quality issues of the Northam Town Pool, and notes the importance of reducing the cause of low dissolved oxygen levels (i.e high nutrient and sediment load) instead of just relieving the symptoms.

Aerators are currently operated within the Northam Town Pool, however are limited to the section of pool near the Swinging Bridge and the Northam Visitor Centre. There are five aerators installed in this section of the pool however at the time of the site visit only one aerator was in operation. The aerators are only capable of aerating the water in the immediate vicinity of the aerators. The large size of the Northam Town Pool will require that larger aerators are distributed throughout the pool to improve circulation of the water.

Plate 9: Aeration unit in operation in the Northam Town Pool

Effectiveness

- Aeration in isolation will not improve water quality of the Northam Town Pool however may lead to a reduction in water quality issues in immediate vicinity of the aerator.

Implementation

- The Shire of Northam currently operates five aerators in the Northam Town Pool in the open water section outside the Northam Visitor Centre.
- Review of aeration units to identify appropriately sized aeration units to improve water circulation within the open water section of the Northam Town Pool.

Cost

- Capital costs of aeration units will vary depending on type of unit (submerged or fountain type). Example cost include aerators installed in Lake Joondalup are reported to have cost $30,000 (ENV 2008).
- Ongoing power and maintenance costs.

8.8 Oxygenation

The water quality issues that occur during summer and autumn in the Northam Town Pool are of a similar nature to those experienced in the upper portions of the Swan and Canning River Estuary, and in the Canning River upstream of the Kent Street weir. The upper portions of the Swan and Canning River Estuary are known to experience hypoxic conditions which have been observed to facilitate sediment release of nutrients (Douglas et al. 1997) and heavy metals. The Kent Street Weir Pool is identified as having poor water quality and algal blooms in response to oxygen depletion of sediment layers releasing nutrients into the water column (Swan River Trust 2011a). Oxygen depletion may also occur following the death of algal blooms or aquatic weeds, through bacterial decomposition of the organic matter depleting oxygen along the bottom of the pool. Oxygen depletion of the Kent Street Weir Pool is also noted to result in fish kills and loss of biodiversity, unpleasant odours and loss of recreational values (Swan River Trust 2011b).

As a result of these ongoing issues with hypoxia, the Swan River Trust implemented the enhanced delivery of oxygen to the water column through oxygenation. The first plant was installed in the upper Canning River in 1997. Several other plants have since been implemented at numerous sites.

The benefits of oxygenating a 2.3 km stretch of the Canning River, upstream of the Kent Street Weir Pool, are noted to include:

- Provision of habitat for aquatic organisms through adequate dissolved oxygen levels.
- Enhanced nitrogen removal through the natural processes of nitrification (the formation of oxidised nitrogen) and denitrification (the formation of nitrogen gas).
- Increased phosphorus retention in sediments through binding with iron under aerobic conditions, making it unavailable for algal growth.
- Reduced stored organic matter by acceleration of aerobic breakdown of organic carbon.
- Odour reduction.
- Reduction in nutrients available for algal growth.

Effectiveness

- Oxygenation of the water column has been found to be successful at treating the symptoms of oxygen depletion (i.e. nutrient and heavy metal release from sediment) within the upper portions of the Swan and Canning River Estuary, including the Kent Street Weir Pool which is similar to the Northam Town Pool.
- This management option will likely have success in alleviating the symptoms of poor water quality in the Town Pool.
- If implemented in isolation this option will not reduce the sedimentation of the Town Pool and may be required to be operational for longer periods should further water quality degradation occur.

Implementation

- The Swan River Trust has undertaken extensive research into the options for oxygenation and therefore the technology is relatively well understood.
- A suitable site will need to be identified for the siting of the oxygenation plant.
- Environmental approvals are likely to be required to enable disturbance of the bed and banks of the Northam Town Pool.
- Aboriginal Heritage may be required.

Cost

The Swan River Trust have provided the following indicative costs for an oxygenation plant delivering up to 20 kg/hr:

- Capital costs: Approximately $1.2 m over two years (includes planning, approvals and construction).
- Ongoing operational costs (half of MoU):
  - Wages $45K
  - Monitoring $8K
  - Maintenance $43K
  - Oxygen $13K
  - Electricity $12K

8.9 Floating wetland

Floating wetlands have been implemented for water quality improvement purposes within water bodies worldwide. These structures may comprise both biodegradable and more permanent floating designs, and feature wetland vegetation on floating pontoons or similar floating craft.

The vegetation uptake the nutrients within the water body they are installed within, and may be harvested to maintain the nutrient uptake efficiency of the system. These structures work by providing a dense planting of nutrient stripping wetland vegetation within the water body, rather than planted at the edges of the water body. The wetland vegetation uptake nutrients and the roots provide a large surface area for biofilms which also consume the nutrients nitrogen and phosphorus, and provide a food source to micro-invertebrates and other aquatic fauna.

The Shire of Northam have implemented a small scale floating island project within the Northam Town Pool following receipt of a grant for water quality improvement of the pool.

Plate 10 and 11: Floating wetland being installed within the Northam Town Pool (Photo: Bernie Masters)

Effectiveness

- Floating wetlands have been found to be an effective means of increasing the uptake of nutrients from water bodies by providing a dense planting of wetland vegetation.
- May be installed as one large system or a number of smaller systems to increase the spatial coverage of the pool, and target different areas.
- Provide additional habitat benefit to the pool ecosystem.
- Can be designed to have a natural rather than constructed appearance at vegetation maturity.

Implementation

- The size of floating wetland that is required to achieve ongoing improvement to the pool water quality is unknown. In email correspondence to the Shire of Northam Bernie Masters from Floating Islands Australasia (FIA) notes that the Northam Town Pool contains 43 kg of Phosphorus and 500 kg of Nitrogen, requiring nearly 30 m^2 of floating wetland to remove most of the P and 167 m^2 to remove most of the N.
- May require a number of floating wetlands to have a measurable impact on the pool water quality.
- Maintenance required to maintain the effectiveness of the system in nutrient removal.
- Generally floating wetlands are installed in closed water bodies, whereas the Northam Town Pool is located within a river system that experiences high winter flows. Flows may damage the integrity of the floating wetlands.
- Nutrient loading of the town pool will need to be quantified.

Cost

- The Shire of Northam have made an initial capital outlay of $6,500 for a floating wetland approximately 30 m^2 in size from FIA Technology Pty Ltd. The cost of vegetation and installation costs are additional to this purchase cost. This size wetland was estimated to treat TP in the Northam Town Pool.

- FIA Technology Pty Ltd identified that a larger floating wetland to uptake TN in the Northam Town Pool would need to be approximately 167 m^2 at a capital cost of $38,000. The cost of vegetation and installation are additional to this purchase cost.
- Additional maintenance costs will include bird netting at an estimated cost of $25/$m^2$, and additional seedlings to replace those that do not survive.

8.10 Island rehabilitation and construction

The islands within the Northam Town Pool (Section 3.1 are considered to be important features to improve the habitat value and also the aesthetic value of the pool. The two artificially created islands require rehabilitation to stabilise and provide additional vegetation, as a result of erosion and degradation by waterbird populations. Construction of additional islands will need to consider the flow characteristics within the Northam Town Pool to ensure their longevity and reduce the potential for erosion.

Strehlow (2009) notes that while construction of further islands would enhance the aesthetic value of the pool it will also provide additional waterbird breeding habitat and therefore contribute to the eutrophication of the pool.

Plate 12 and 13: Existing islands within the Northam Town Pool

Effectiveness

- The islands within the Northam Town Pool are not considered to provide a direct improvement to the water quality of the pool, and may be detrimental through provision of increased waterbird habitat and therefore increased nutrient contribution to the pool.
- The islands are considered to have an aesthetic value for the Northam Town Pool.

Implementation

- Rehabilitation of existing islands may include stabilisation and revegetation.
- Construction of new islands needs to consider the preferential flow paths within the pool to minimise the potential for erosion.

Cost

- Primary costs for rehabilitation will be incurred through manual labour and vegetation costs.
- Primary costs for rehabilitation will be incurred through sediment source costs, manual labour and vegetation costs.

8.11 Management of waterbirds

Management of the waterbird population of the Northam Town Pool is likely to be a difficult management strategy to implement due to conflicting community views. Some aspects of the community view the bird populations as a tourist attraction, however introduced and feral bird populations compete with native species for resources and breeding space (Strehlow 2009). Furthermore while the nutrient contribution of introduced bird species to the nutrient loading in the Northam Town Pool has not been quantified it is considered to be a significant contributor of ammonia (Strehlow 2009).

Management of introduced bird populations should include the discouragement of feeding birds of the Northam Town Pool. The South East Regional Centre for Urban Landcare identify that bread fed to birds contains 1 to 2 grams of phosphorus and contributes to the nutrient load of the water bodies.

Effectiveness

- Management of the bird population around Northam Town Pool will have small but cumulative impact on the nutrient load of the pool.

Implementation

- Limited resource requirements.

Cost

- Capital outlay in the form of signage and advertising.

8.12 Catchment management

Many of the key water quality issues within the Northam Town Pool, including high nutrient and sediment loads, changes to the flow regime and high salinity are contributed by processes that occur at the catchment scale and are therefore difficult to manage at the local Northam townsite scale. Management of the Northam Town Pool is therefore a challenge as the pool is part of the larger Avon Arc catchment and is affected by activities in the catchment upstream of Northam (Strehlow 2009). Key catchment management actions that can help to reduce the flow of nutrients an sediment to the Avon River and the Northam Town Pool include:

- Revegetation of the riparian zone.
- Restricting stock access by fencing.
- Stabilisation of bed and banks.
- Slowing stormwater runoff from agricultural lands using contour banks.

Effectiveness

- The effectiveness of catchment management for improving the water quality and aesthetic value of the Northam Town Pool will rely on all land managers from individuals to local government and State

Government agencies acting to reduce the impact of their activities on the Avon River system and ultimately the Northam Town Pool, as well as downstream environments.

Implementation

- Successful implementation of catchment management as a tool to improve the quality of the Northam Town Pool will require the cooperative effort of the numerous stakeholders who hold a vested interest in the pool including local government, upstream local government, State Government, government agencies, community catchment groups and private landholders.

Cost

- Management at the catchment scale will require considerable ongoing funding for capital works for individual projects, as well as ongoing maintenance and monitoring.

8.13 Summary

The management strategies and options in Section 8of the Environmental Planning – Northam Town pool report were assessed against the criteria outlined in Table 22. Coded criteria were identified for the assessment criteria for the purposes of comparing the various strategies and options (Table 24).

Table 25 provides a summary of the management strategies using the colour coding for comparison purposes.

Table 24 Summary coding of assessment criteria

Effectiveness	Implementation difficulty	Cost
Limited	Very Hard	Very High
Moderate	Hard	High
High	Moderate	Medium
Very High	Low	Low

Table 25 Summary of management strategies

Option	Effectiveness	Implementation difficulty	Cost	Long term requirements
Management plan for Northam Town Pool	Moderate	Low	Low	Ongoing monitoring, reporting and review.
Water quality monitoring	Moderate	Low	Low	Develop monitoring program. Collect, analyse and publish data.

Option	Effectiveness	Implementation difficulty	Cost	Long term requirements
Dredging of Northam Town Pool	Moderate	Hard	High	Preparation of a dredging management plan. Testing of sediment quality. Potential requirement to dispose of ASS/contaminated sediment. Monitoring pool water quality during operations.
Trap and remove sediment from Northam Town Pool	Moderate	Moderate	Medium	Install traps dredge silt traps. Dispose of silt/sediments. Ongoing maintenance.
Trap and remove sediments from upstream river pools (i.e. Burlong Pool)	High	Low	Low	Dredging and disposal of silt/sediments - contractor
In-stream stabilisation to stabilise river bed sediment	High	Moderate	Medium	Ongoing maintenance.
Restore/revegetate bank vegetation	Moderate	Low	Low	Plant vegetation Maintain/water vegetation
Maintain summer water level in the Northam Town Pool by augmenting with external water source - Groundwater	Moderate	Very Hard	High	Identification of a sustainable water resource of suitable water quality. Ongoing pumping cost. Maintenance of the pump.
Maintain summer water level in the Northam Town Pool by augmenting with external water source - Recycled wastewater	Moderate	Very Hard	Very High	Major upgrades of WWTP to achieve water quality. Ongoing pumping cost. Maintenance of the pump.

Option	Effectiveness	Implementation difficulty	Cost	Long term requirements
Maintain summer water level in the Northam Town Pool by augmenting with external water source – Stormwater storage	Moderate	Very Hard	Very High	Acquisition of land for water storage in excess of stormwater drainage requirements. Water quality treatment may be required to achieve suitable water quality. Ongoing pumping cost. Maintenance of the pump.
Develop stormwater management guidelines for Northam	Moderate	Low	Low	Review of best management stormwater practices for WA to identify most suitable options for Northam. Implemented and updated by Shire of Northam and DoW
Apply best practise stormwater management for all new developments within the Northam Townsite	High	Moderate	Medium	Construct structures – developer Maintain structures – developer and Shire of Northam
Retrofit existing stormwater management systems with best management practises within the Northam Townsite	High	Hard	High	Construct structures – Shire of Northam Maintain structures – Shire of Northam
Aeration of water in Northam Town Pool	Moderate	Low	High	Install aeration device Maintain device Power costs
Oxygenation	High	Hard	Very High	Acquisition of land for oxygenation plant. Monitoring. Ongoing maintenance - contractor. Power costs.
Floating wetland	Moderate	Low	Medium	Ongoing maintenance.
Island rehabilitation and construction	Limited	Moderate	Low	Ongoing maintenance.

Option	Effectiveness	Implementation difficulty	Cost	Long term requirements
Management of waterbirds	Moderate	Hard	Low	Maintenance of signage and educational materials.
Catchment management - including agricultural and rural townsite	High	Hard	Very High	Ongoing engagement and liaison with Shires and catchment groups located upstream.

9. Recommendations and way forward

It is important to note that all of the management strategies and options discussed in Section 8 have some aspect of annual management and maintenance and none are one-off solutions to the water quality and aesthetic issues that occur within the Northam Town Pool. While implementation of some of the management strategies and options in isolation may result in short term improvements to the system these strategies and options may only treat the symptoms of the water quality issues, and not result in long term improvement to the Town Pool.

The complexity of the environment of the Northam Town Pool and the Avon catchment requires implementation of an integrated approach that addresses the management of the system as a whole rather than treatment of the symptoms of poor catchment management.

9.1 Recommendations

9.1.1 Adaptive management approach

It is recommended that an adaptive management approach is implemented which is supported by ongoing, targeted monitoring of the Northam Town Pool and its inflows. The adaptive management approach and supporting monitoring program should be outlined within a management plan for the Northam Town Pool that updates the Northam Town Pool Sediment Management Plan (Waterways Commission 1995). This document will outline the management objectives for the Northam Town Pool and will be subject to ongoing review as identified by the management body that will implement the plan.

The management plan will identify the suite of management strategies and options that will be implemented as funding is made available. These should be detailed within the management plan and reviewed, reported against and updated as needed.

These management strategies and options will include those that are proven to have long term water quality benefits, are based on sound knowledge of the existing environment and pose minimal environmental risk to the ecology of the Northam Town Pool, and any downstream environments.

Management strategies and options that should be considered for future implementation to achieve long term water quality improvement of the Northam Town Pool are listed below.

1. Management strategies that have proven success in reducing sediment and nutrient loads within the local environment and in other aquatic environments worldwide. These include:
   - Stormwater management within urban and industrial regions to reduce peak flows, allowing suspended sediment to settle out of water, and rehabilitation of drainage lines to promote biological uptake of nutrients and other contaminants (Section 8.6).
   - Catchment management strategies including revegetation and fencing of riparian zones to reduce sediment in runoff and prevent erosion (Section 8.12).
   - Installation and maintenance of sediment traps to reduce sediment loads (Section 8.3.2, 8.3.3).

2. Management options that have shown some success in improving the water quality of water bodies experiencing similar issues as the Northam Town Pool (stagnant water during summer, algal blooms). These include:
   – Aeration on a scale appropriate to the water body in question (Section 8.7).
   – Floating wetlands on a scale appropriate to the water body in question (Section 8.9).
3. Other management options that may increase the aesthetic amenity and environmental habitat of the Northam Town Pool, however will have limited to no water quality improvement. These include:
   – Island rehabilitation or construction (Section 8.10).

It is important to note that the success of an adaptive management approach will require a commitment to invest in the long term management of the Northam Town Pool. Also as noted within the report *Nutrient management for the Avon River Basin: a toolkit for managing nutrient loss to the environment from a range of land uses* (DoW 2010, Section 5.10) it is a challenge to all those who live and work in the Avon River Basin to contribute 'their bit' towards cleaner water in the Avon and Swan river systems for a healthier and sustainable future.

9.1.2 Dredging of sediment

In addition to the adaptive management approach it is recommended that the option to dredge sediment from the Town Pool be further considered following discussions with the Department of Water. The Town Pool has a substantial dredging history and provided the dredging operations are managed appropriately this will contribute to improved water quality in the pool.

Ongoing dredging of Burlong Pool is also recommended to maintain its function as a natural sediment trap for the Northam Town Pool. The current dredging licence is due for renewal in 2012. It is recommended that the licence be reviewed prior to reissue to ensure that it is operated to achieve full benefit to the Northam Town Pool.

9.1.3 Supplementation of summer water levels

It is recommended that the management option of supplementing the summer water level in the Northam Town Pool, an option preferred by many in the stakeholder group, be subject to a feasibility study to support implementation. The identified alternate water source options have significant capital costs to implement, and pose significant environmental risk to the pool and therefore it is recommended that a feasibility study is undertaken to provide certainty in one option prior to the Shire of Northam investing further funds.

9.2 Recommended approach

A key outcome of the stakeholder engagement process was the identification of the desired outcomes for the Northam Town Pool (Section 7). Of the desired outcomes the two measurable improvements included:

- Long term environmental improvement.
- Desire to have the pool "full" year round.

To achieve long term environmental improvement of the Northam Town Pool a range of the identified strategies and options, both at the local and greater catchment scale, have been identified. In contrast to achieve the desired outcome for the Northam Town Pool to be "full" year round can only be achieved through supplementation of water levels with an alternate water source.

On this basis the following approach is recommended:

1. Develop/update management plan for the Northam Town Pool.
2. Monitoring of the Northam Town Pool, its inflows and outflow.
3. Implement selected water quality improvement options at the local and catchment scale.
4. Discuss dredging of Town Pool with Department of Water.
5. Feasibility study to investigate alternate water source options to maintain summer water level.

9.2.1 Costs

Capital costs for the recommended nutrient management strategy and options are summarised in Table 26. The costs identified are indicative capital costs, based on commercial rates that have been developed for the purposes of comparing the various management strategies and options. Costs are primarily commercial rates, with the exception of catchment management activities such as rehabilitation and revegetation activities.

The accuracy of the estimates is not expected to be better than approximately ± 30% for the items described in this report. Detailed review and design is recommended for more accurate budget setting purposes. In particular the costs for stormwater management structures will be largely determined by the sizing of the structure and particular site characteristics.

The operating costs have not been prepared for this stage of the work. The indicative capital costs are exclusive of GST, and do not consider design, administration, ASS field-testing, monitoring, or ongoing maintenance costs.

The indicative capital costs were estimated with reference to the Stormwater Management Manual for Western Australia (DoW 2007), the Music Users Guide (CRCCH 2005), additional information regarding rates from refereed sources including the Department of Water (2009), The Department of Environment's River Restoration – how much does it cost? (Appendix C) and Rawlinsons Australian Construction Handbook (Rawlhouse Publishing Ed 29 2011).

Table 26 Recommended approach and indicative capital costs

Staging	Overarching management strategy	Sub-strategy	Description	Indicative capital cost
1.	Management plan		Update the Northam Town Pool Sediment Management Plan to reflect the current status of the pool, objectives for management, proposed management strategies and monitoring and review program.	$20,000-$30,000

Staging	Overarching management strategy	Sub-strategy	Description	Indicative capital cost
2.	Monitoring of the Northam Town Pool		Water quality monitoring of the Northam Town Pool, its inflows and outflow. The monitoring program will identify the current status of the pool and will enable monitoring of success of implemented strategies.	~$35,000 annual monitoring. Based on laboratory disbursement costs, analysis and reporting. Lab costs include quarterly monitoring for comprehensive suite of analytes, 3 event based stormwater sampling and 3 summer sampling events for reduced suite of analytes. No personnel costs included as local resource required for event based sampling.
3.	Implement selected water quality improvement options at the local and catchment scale	Stormwater management guidelines	Preparation of stormwater management guidelines suitable for future, and retrofitting of existing, urban and industrial sites within the Northam townsite and other townsites in the Avon Arc region.	$25,000 - $40,000
		Stormwater infrastructure – new development	Implement best management practice stormwater infrastructure for new urban and industrial developments.	Dependent on the size and type of stormwater infrastructure. Key costs associated with extent of earthworks and size and extent of vegetation. See Appendix D for indicative costs. Costs borne by developer.
		Stormwater infrastructure – retrofitting	Retrofit existing drainage infrastructure following best management practice.	Dependent on the size and type of stormwater infrastructure. Key costs associated with extent of earthworks and size and extent of vegetation. See Appendix D for indicative costs.
		Sediment management - Dredging	Undertake dredging of the Northam Town Pool.	~$680,000 Based on DoW (2009) rate of $17/tonne assuming onsite disposal, and removal of 20,000 m^3 with density of ~2.00 kg/L. Note: Cost of dredging management plan, monitoring, treatment of ASS and soil disposal (if required) not included.

Staging	Overarching management strategy	Sub-strategy	Description	Indicative capital cost
		Sediment management – Dredging Burlong Pool	Review existing dredging licence for Burlong Pool and reissue for tender.	NA Commercial operation for contractor.
		Sediment management – installation of sediment traps	Install sediment traps at locations upstream of the Northam Town Pool that are easily accessible for ongoing maintenance.	\$45.60 m^{-3} based on excavation to 1.5 m in heavy soil (Rawlinsons 2011). Note: Ongoing maintenance costs.
		Upgrade floating island		FIA Technology Pty Ltd identified that a larger floating wetland to uptake TN in the Northam Town Pool would need to be approximately 167 m^2 at a capital cost of \$38,000. The cost of vegetation and installation are additional to this purchase cost. Additional maintenance costs will include bird netting at an estimated cost of \$25/m2, and additional seedlings to replace those that do not survive.
		Ongoing catchment management projects	Rehabilitation of river riparian zone. Fencing of river sections.	Costs for site preparation and fencing works are drawn from DoE (2006) (see Appendix C). <u>Revegetation</u> Costs determined by site and plant selection – see DoE (2006) (Appendix C)for estimate of plant and material costs. <u>Site preparation</u> \$1,525 ha <u>Fencing</u> \$3,214 / km fencing for 7 line ringlock fence

Staging	Overarching management strategy	Sub-strategy	Description	Indicative capital cost
4	Feasibility study			$30,000-$50,000 Indicative costs only for a desktop options assessment incorporating: - Conceptualisation of likely schemes. - Preliminary water balances. - Preliminary risk assessment. - Indicative schedule of timing and costs.

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Wheatbelt NRM (2011d) *Hydrologic Assessment – Minson Avenue Catchment*, Shire of Northam, Wheatbelt NRM, Northam, Western Australia, June 2011

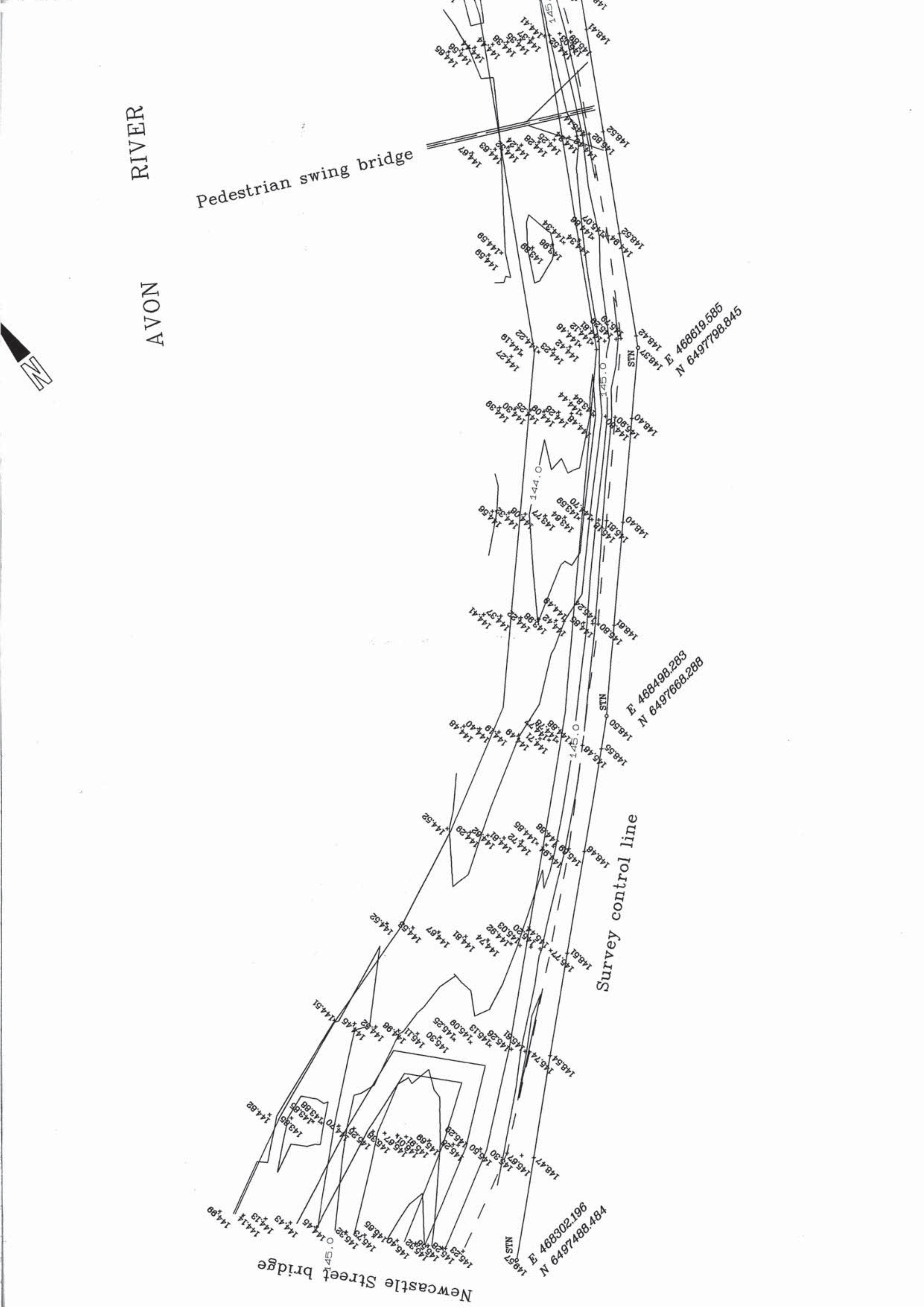
Appendix A

Northam Town Pool

Pool survey and cross-sections

June 2000 Survey

Paul Kraft & Associates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AVON
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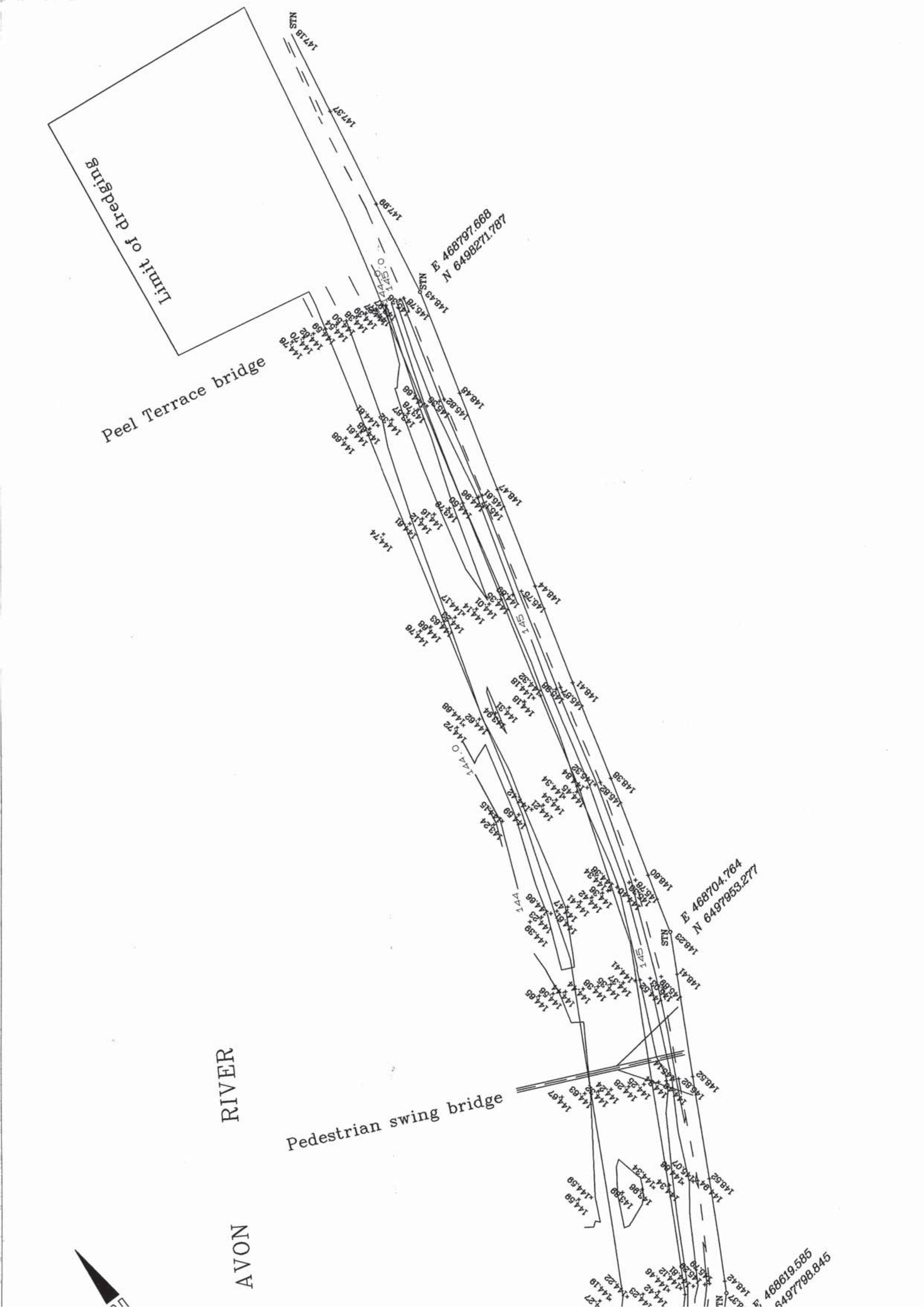
STN
E 468498.283
N 6497668.288
Survey control line
STN
E 468302.196
N 6497488.484
Newcastle Street bridge


Limit of dredging
STN
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N 6498271.787
Peel Terrace bridge
E 468704.764
N 6497953.277
RIVER
AVON
Pedestrian swing bridge
E 468619.585

AUL KRAFT & ASSOCIATES
PO BOX 428
NORTHAM WA 6401
Phone: 9574 2690 Fax: 9574 2991

rveyor: ppk

Date: June, 2000

SOUNDINGS JUNE 2000
FOR
AVON RIVER, NORTHAM

Figs 2-6
River survey for Dredging

No.	Date	By	Amendments

Files:

Field Books:

Approved:

FEATURE SURVEY

AVON RIVER, NORTHAM

CLIENT: TOWN OF NORTHAM

Scale 1:1500

Sheet 1 of 1 S

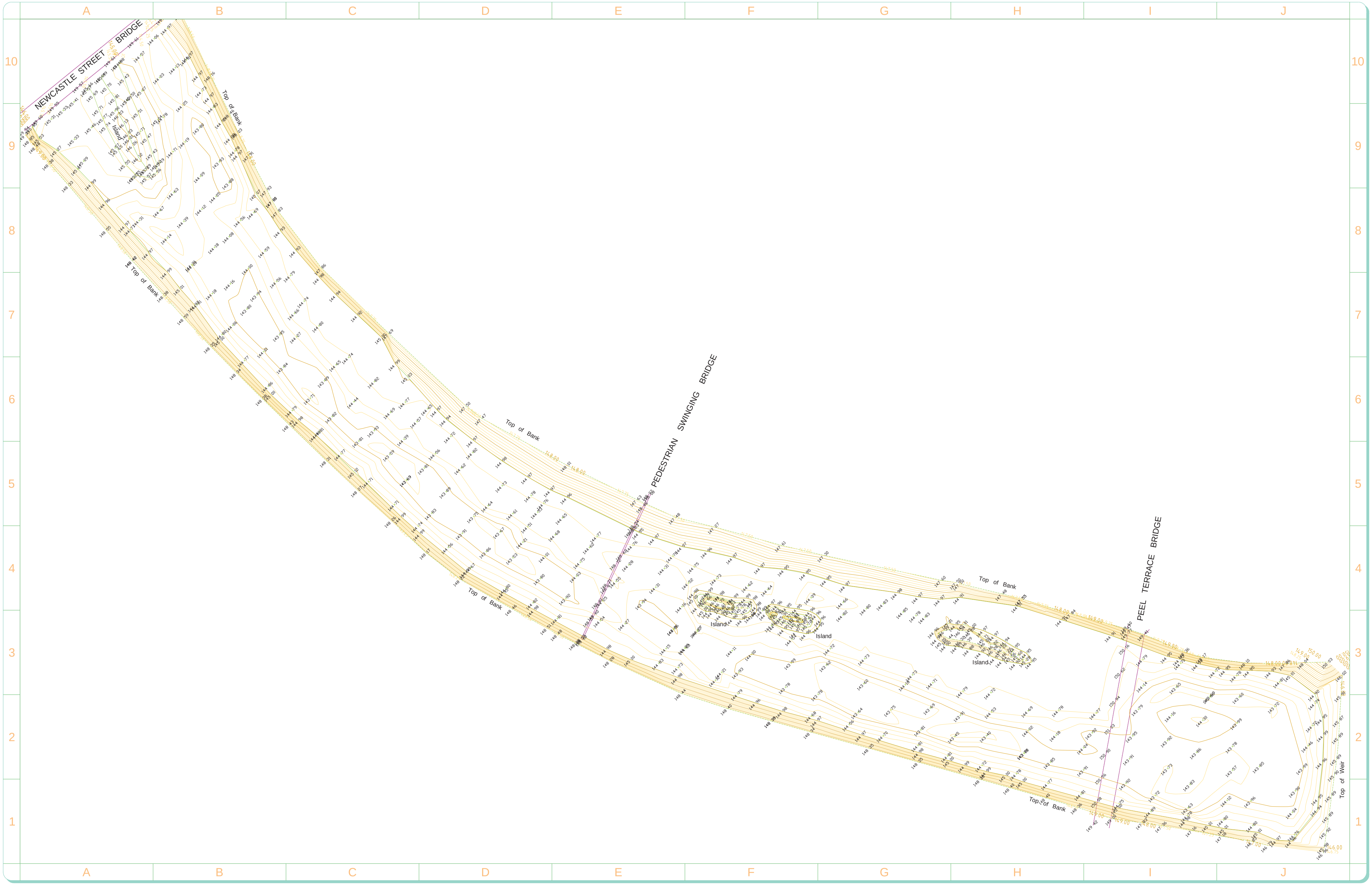
Datum for Levels:

Drawing N

30/00.01

April 2011 Survey

RMSurveys



RMSurveys LICENSED SURVEYORS
SUBDIVISIONS • STRATA TITLES • LAND INFORMATION
GPS SURVEYS • GEODETIC SURVEY AND COMPUTING
ENGINEERING & CONSTRUCTION SETOUT
PO Box 832
Willetton WA 6955
Phone: (08) 9457 7900
Fax: (08) 9457 7922
email: rmsurvey@rmsurveys.com.au

SCALE 1:1250

ALL DISTANCES ARE IN METRES

ORIGINAL DRAWING SIZE A1

Rev	Description	Drawn	Chckd	Appvd	Date
0	Initial Issue.	AC	SL	GR	6/05/11

Surveyor	SL	Vertical Datum	AHD
Survey Date	28/04/11	Horizontal Datum	MGA 50
Data Source	LISCAD9	Job No.	NORTH-AVON

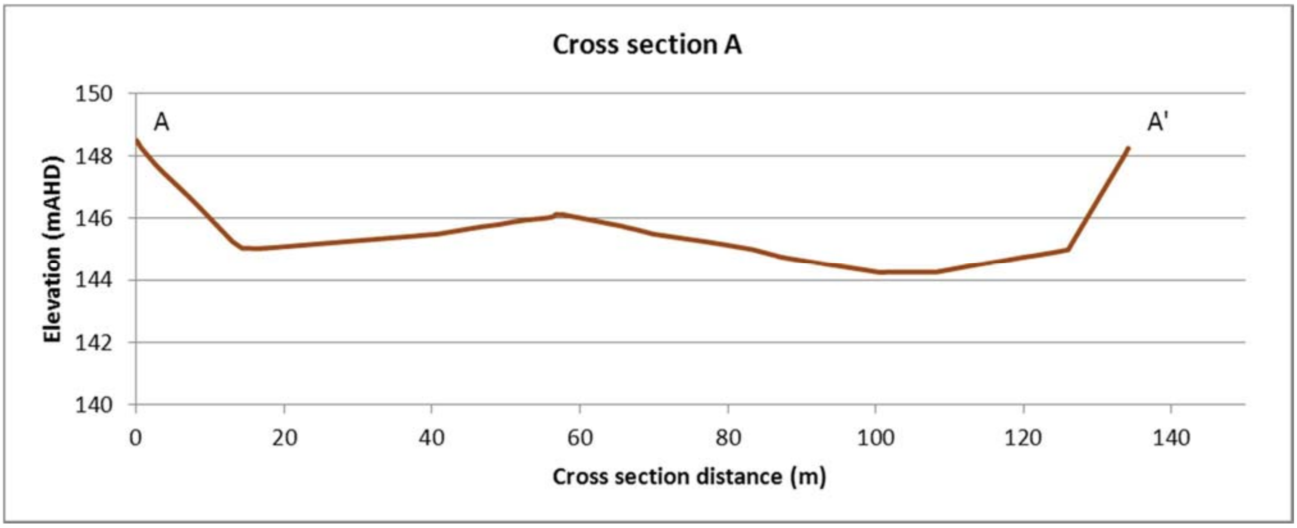
FEATURE AND CONTOUR SURVEY
Town River Pool
Avon River
Northam

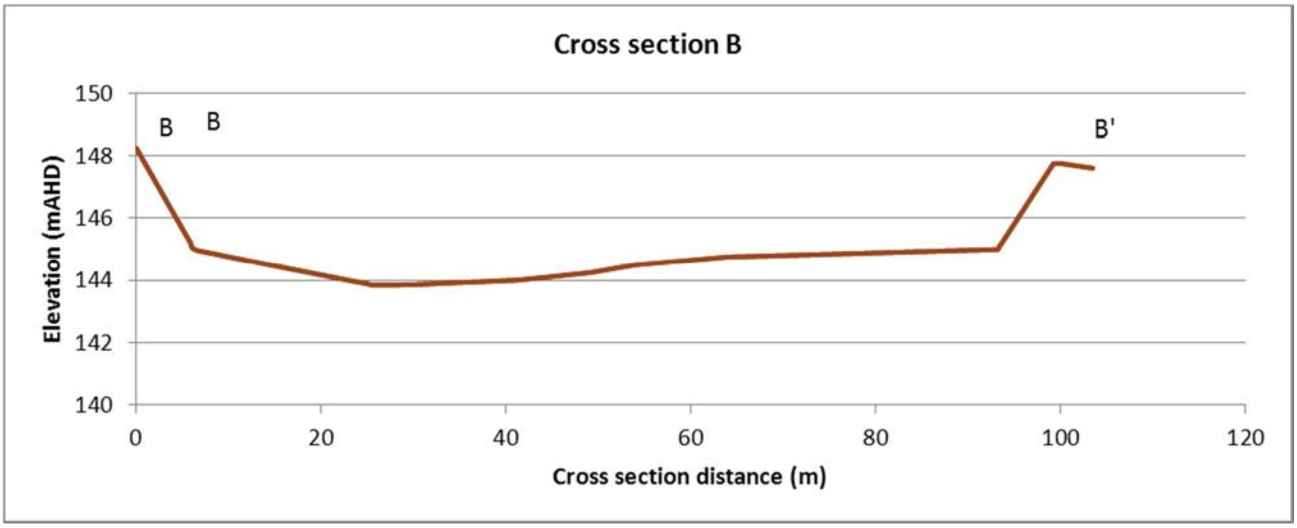
Client: Shire of Northam

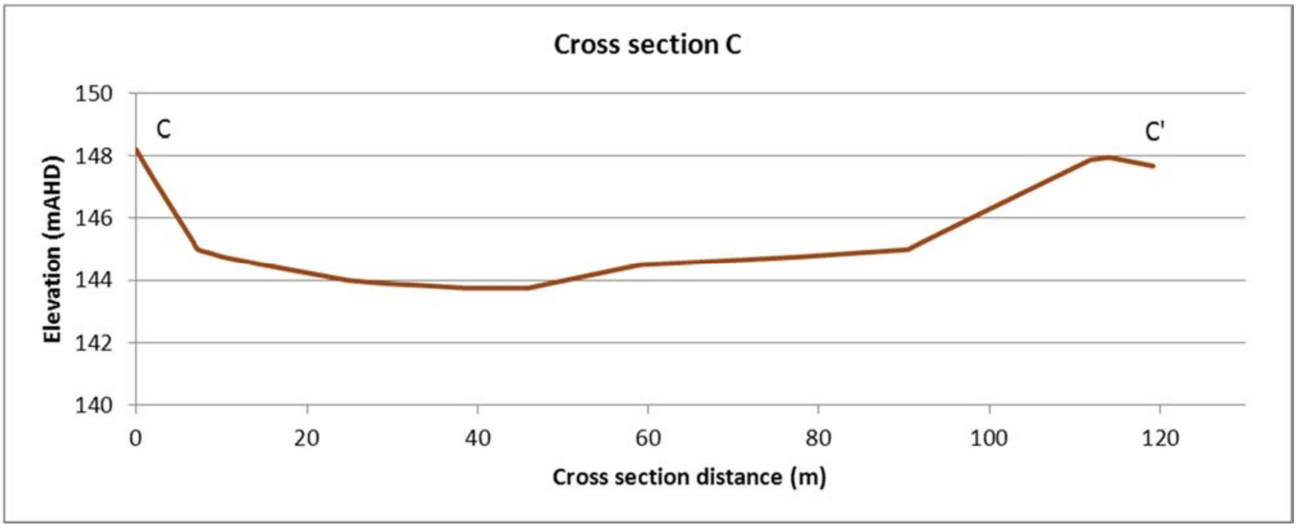
Drawing No.: NORTH-AVON-01 | Revision: 0 | Sheet: 1 | Of: 1

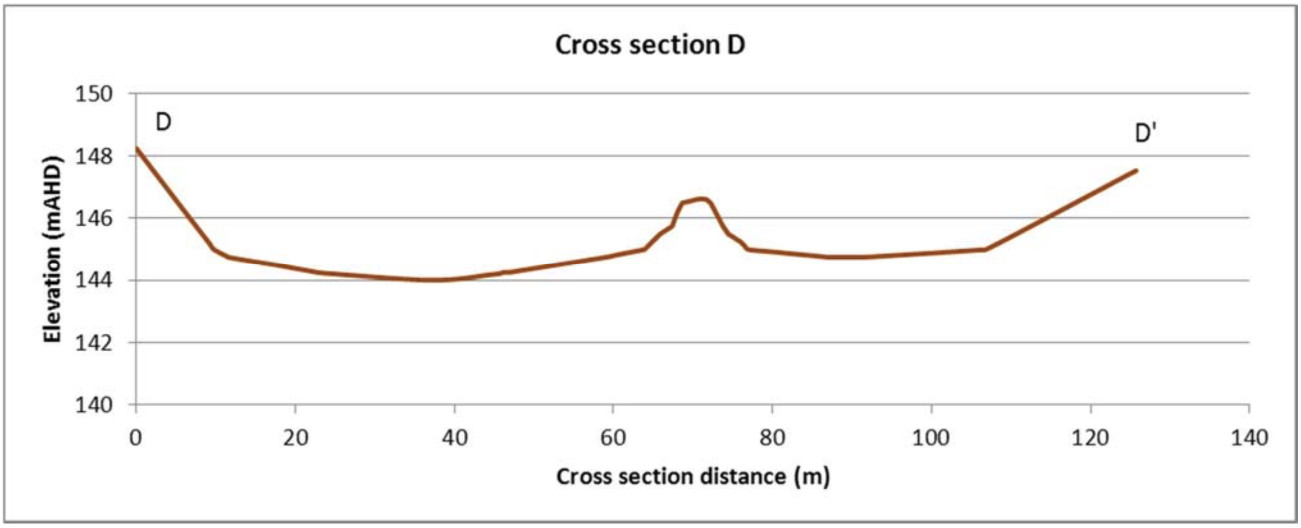
Northam Town Pool Cross-sections 2011 (from survey by RMSurveys)

Refer Figure 2 for location








Cross section D
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144
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140
D
D'
Elevation (mAHD)
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20
40
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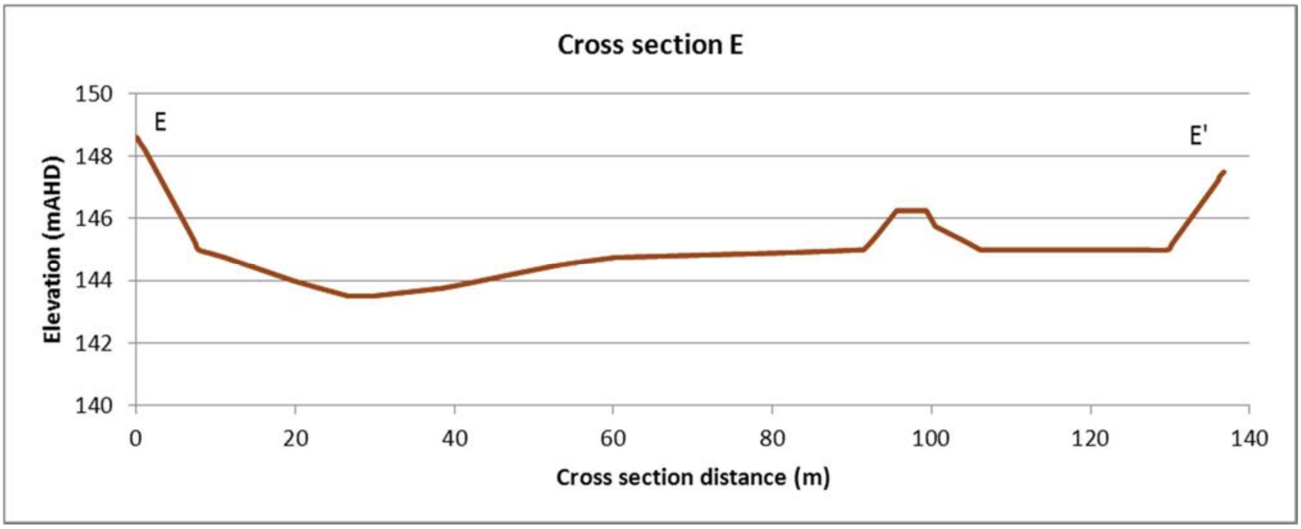
100
120
140
Cross section distance (m)


Cross section E
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Elevation (mAHD)
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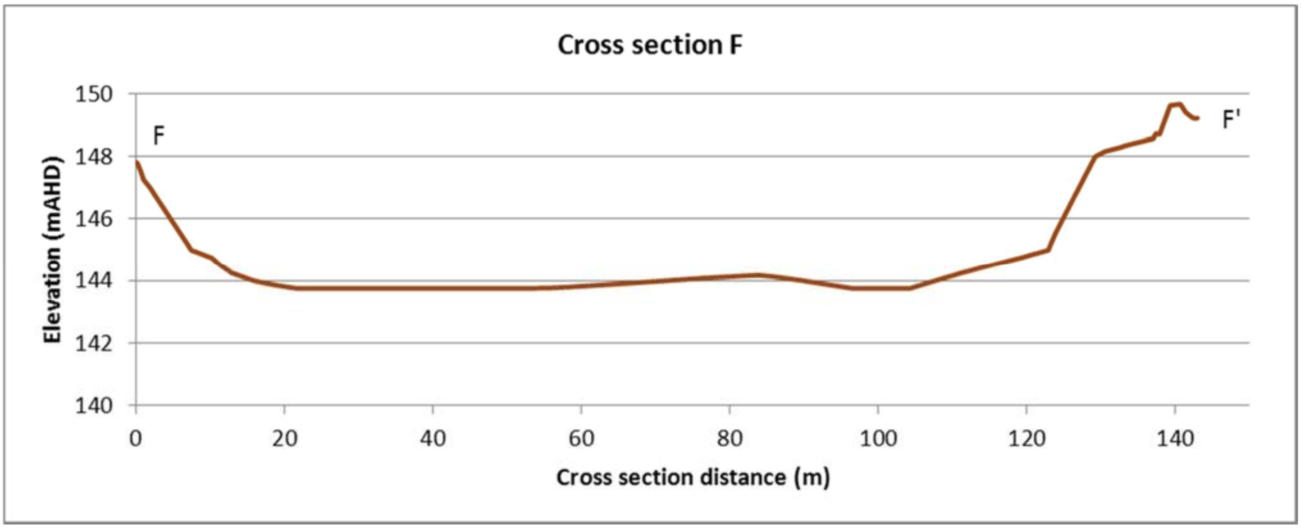
Cross section distance (m)


Cross section F
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Elevation (mAHD)
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Cross section distance (m)

Appendix B

Stakeholder engagement

Minutes from stakeholder meeting

![GHD logo]

Minutes

24 November 2011

Project	Northam SuperTowns Environmental Planning	From	Kelsey Hunt
Subject	Stakeholder meeting and site vist notes	Tel	61 8 6222 8222
Venue/Date/Time	Northam Visitor Centre 11/11/2011	Job No	61/27628
Copies to	All attendees and Name (Company)		
Attendees	William Baston (WB) (Shire of Northam) Steve Pollard (SP) (Shire of Northam) David Porter (DP) (Porter Consulting Engineers) Grant Arthur (GA) (Wheatbelt Development Commission) Bob Davey (BD) (Bob Davey Real Estate) Paul Tomlinson (PT) (Avon Community Development Foundation) Cec McConnell (CM) (Thinkscape) Natarsha Woods (NW) (Wheatbelt NRM) Kerry Horan (KH) (Wheatbelt NRM) Peter Weatherly (PW) (Avon Valley Environmental Society) Desrae Clarke (DC) (Toodyay Friends of the River) Wayne Clarke (WC) (Toodyay Friends of the River) Don Cummins (DC) (Department of Water) Greg Warburton (GW) (Toodyay Friends of the River) Kelsey Hunt (GHD)	Apologies	Mark Cugley (Swan River trust) Cecily Howell (Avon River Conservation Society)

Minutes

Will Baston – Background to SuperTowns

Will Baston gave a brief background and introduction to set the scene for the stakeholder rmeeting. Key points included:

- GAP Analysis in Northam revealed need to provide increased and consolidated office accommodation, focus on development of hard and community infrastructure, develop a plan that address housing density concern, with a focus on environmental planning

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T 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

- Environmental planning – the importance of the river was highlighted in the Community Groups forum on Tuesday at the Recreation Centre.

David Porter – Overview of Stormwater Infrastructure

David Porter gave an overview of the existing stormwater drainage infrastructure within the Northam townsite. Key points included:

- Key priority for stormwater infrastructure in the Northam townsite has been on conveyance of stormwater flows
- Updates to storm water drainage have been occurring and need to continue
- Levee banks constructed to reduce flooding of lower parts of town adjacent to river, old infrastructure issues with the town built outwards from the banks of the river
- There are pump station backflow issues from Minson Avenue due to capacity constraints which leads to flooding on occasions.
- Manifold drain that discharges to Swan Enclosure discharges downstream of the weir.
- There is uncertainty as to the drainage catchment that contributes to the manifold drain.
- Shire is currently trying to identify all drainage infrastructure within the townsite.
- King Creek catchment modified to improve the flow rate/conveyance however no water quality improvements were installed.
- The northern shore of the river still has uncontrolled discharge and haphazard drainage directly into the river. There is uncertainty as to whether there is adequate space to enable retrofitting of the existing drainage infrastructure.

Don Cummins – Department of Water perspective

- Pool is vested with Regional Development and Lands.
- Primary concerns with any management options from a regulatory perspective relate to requirement for Bed and Banks permits.
- Stakeholder involvement in this process is the provision of information.
- Issues associated with previous dredging included the release of ASS (Brad Degans assessment of sediment) and also heritage issues with disturbance of the river bed. These will need to be considered in any future dredging plans.

Minutes

General Stakeholder Discussion

A number of key issues and observations relating to the Northam town pool were discussed by the meeting participants. These included:

- Acknowledgement of the variety of stakeholder views of ways to improve the pool (GA).
- Stakeholders need clarity of the order of importance and magnitude of improvement that various options present (GA).
- The river is an Aboriginal Heritage site.
- York has previously focussed on flood conveyance however are moving towards water quality improvements.
- A catchment wide approach is required; potentially avoidance of direct discharge into the waterway is required?
- Burlong Pool is a natural sediment trap and is an important aspect to consider for ongoing management of the town pool.
- The River Training Scheme of the 1950s had a negative impact on the river and its pools and any future actions should not repeat this.
- Key issue of summer eutrophication and smell, with the lower the water level the worse the smell gets.
- Overarching desire to enhance amenity value of the pool through an increase in summer water levels.
- Annual evaporation of the area is 1 metre and yet the water level only falls by 300mm indicating that there is seepage from somewhere. Jessup Terrace aquifer may be naturally feeding the river.
- Flood events are an important tool in managing the nutrient and sediment load of the pool through flushing effects (CM).
- The pool is important from an Indigenous perspective, and should be used to its full potential. The Avon's integrity needs to be maintained due to its connection to the Swan River (KH).
- It was noted that the last comprehensive River Recovery Plan was completed in 1997 however there has been a dramatic shift in weather patterns in the last decade. Update on the current status of the nutrient loads and flows during this period would be of interest. Also an estimate of the impact of the proportion/significance of the nutrient discharge from the urban area now and in 20 years with a 20,000+ increase in population (CM).
- The vegetation with the town pool is unique to inland river systems and serves as a nursery to fish. This needs to be considered in the event of dredging or other bed disturbing activities

(PW).

The advantage and disadvantages of development of further business along the river banks was discussed including:

- Desire to address the prospect of further riverside development.
- It was mentioned that it isn't forward looking to develop along the river shoreline - many towns and cities that have done this are regretting it nowadays.
- It was stated that the Visitor Centre has increased the flooding risk to the Northam townsite through putting holes in levee banks.
- Noted that a set a regulations and conditions will be required for this type of development to occur, if it is pursued at all.
- Stated that the 1 in 5 year flood floods Minson Avenue.

General comments and discussion relating to options for improving the town pool included:

- Hydrogeological investigation will be required to support the option of **artificially supplementing the pool water levels during summer**. Any investigation needs to consider the water source, water quality and the potential downstream impacts.
- Successful improvement of the pool water quality will require **engagement with neighbouring Shires** (PT).
- The **weir could be raised or lowered** – perhaps sluice gates could be installed or potential for water to be pumped from elsewhere? Wells are located west of Mills Bridge however uncertainty regarding the water quality and quantity (PT). Increase in weir height has the potential to increase the sediment load within the pool (CM).
- Benefits of **floating wetlands** were discussed in the context of nutrient stripping wetlands/ponds at nursery. It was noted that the vegetation need to be removed/harvested once they have grown otherwise they die and release nutrients back into the system. Floating wetlands were identified as currently being employed within the Northam town pool however the dimensions of the wetlands were not identified.
- **Dredging of sediment** was discussed with regards to the benefits of removing the nutrient laden sediment. Short term impacts of algal blooms and issue of sediment disposal also noted. Identified as a short term solution. Other issues include potential acid sulphate soils when the soils are exposed – Brad Degans undertook analysis of the previously dredged sediment.
- **Planning guidelines for future development** were raised as a tool to reduce the sediment

and nutrient in runoff from the town as a longer term option. Installation of rainwater tanks to reduce summer peak flows also raised, particularly with potential for increasing storms as a result of climate change.

- **Catchment management** through reduction in input of sediment from upstream catchment identified as a management tool to improve the pool (WC). Management needs to be undertaken at a regional level in order to contribute environmental improvements (GW). Concerns raised over the associated impacts of deep drainage with regard to salinity and ASS (WC).
- **Islands** within the town pool are observed to improve the habitat value of the town pool (PW). More islands may be installed however consideration needs to be given to the predominant flowpaths in order to ensure their resistance to erosion.
- **Aerating units** were identified to have limited impact in their current form.

*The benefits of having a **desired outcome**/objective for the town pool was recognised by the stakeholders present at the meeting. Desired outcomes for the pool included:*

- Long term environmental improvement.
- Desire to have the pool ‘full’ year round.
- No impact on downstream communities.
- Reduction in smell during summer.
- Recognised the need to balance people values and environmental values in looking at potential options.

The general conclusions regarding the issues, potential options and stakeholder desires for Northam town pool included:

- The amenity value of the pool to the Northam town and the Avon region is important. There is historical significance with maintaining the amenity of the pool – sense of place. Maintenance of the pool water level to improve the amenity of the pool while also providing an environmental outcome through improved habitat for wildlife will be positive outcome.
- Any options that are investigated should not impact on downstream communities.
- River is only a small section of the river and any options need to consider the whole river.
- Many options considered will require regular maintenance. There is a need to consider what is affordable, and also identify those options that are out of reach that may be implemented later.

Minutes

- Northam town drainage needs to be considered within the context of whole of catchment management.
- The options for ongoing management of the pool will require a combination of short and long term actions and strategies.

Kelsey Hunt
Environmental Scientist

Appendix C

River Restoration – how much does it cost?

Department of Environment (2006)

River Restoration - how much does it cost? Plus some rehabilitation and construction tips

Introduction

Western Australia's waterways are amongst our most precious natural resources. They are an integral part of the environment and it is imperative that we look after them. River restoration presents us with the opportunity to ensure that actions that are detrimental to our rivers and streams are halted and allows us to repair some or all of the damage.

The restoration of riparian land is an increasingly popular activity in Western Australia. River restoration is needed to maintain habitat, control erosion and improve water quality. A secondary benefit of river restoration is an improvement of the aesthetics and natural beauty of the river.

While embarking on any river/stream restoration it is important to keep in mind that small reaches of a river do not function in isolation. They are intimately linked with the entire river as well as the surrounding terrestrial communities and the catchment. For a river/stream restoration project to be successful, it needs to operate in conjunction with catchment management, i.e. nutrient management, soil conservation, remnant bushland protection, ecological corridors, weed control and other activities.

This document provides a simple breakdown of the costs of river restoration activities. It is intended to assist in the costing of items such as employment, labour, technical advice, materials and equipment. More detailed information on River Restoration and Waterways Management can be found in the Department of Environment River Restoration Manual, Water Notes and Water Facts.

The figures and calculations contained in this document are a guide only, based on estimates for the year 2004 and do not include GST. They do not take into account numerous site-specific factors that are unique to each river/stream restoration project. In order to calculate an accurate cost estimate for your restoration project, you will need to obtain pricing for materials and machinery hire from your local suppliers and contractors. The value of the labour costs has been given an approximate dollar figure, however labour to plant seedlings and construct fences is generally in-kind or voluntary. These labour estimates may be useful in preparing funding applications that require matching contributions.

Please ensure appropriate approvals are obtained from relevant state and local government authorities prior to commencing any restoration works.

Levels of river restoration

There are varying levels of river restoration, depending on the amount of restoration work required, your objectives, resources and time frame. In deciding on the amount of river restoration work required or desired, the following factors should be considered:

- What is the condition of the waterway?
- What are your objectives and resources?
- Are you being strategic?

Waterway condition

For instance, if the waterway is in relatively good condition, it may only need a small amount of work, such as fencing, some revegetation and minor weed control, to restore biodiversity and improve river health. If it is in moderate condition, with some eroded or sediment filled sections and abundant weeds, and you want to restore it as extensively as possible, this will require more work and resources such as engineering works to stabilise erosion, revegetation, and weed control. A Department of Environment Rivercare Officer can help you determine the condition of your waterway and how much effort is required to restore biodiversity and improve river health. You should also refer to the planning and management section of the Department of Environment River Restoration Manual for information on how to assess foreshore condition.

Objectives and resources

Consider what you want the waterway to look like and how much time and money you have and/or want to invest. Depending on your resources, and the nature of the waterway, three basic levels of restoration could be undertaken.

1.Extensive restoration of a river ecosystem involves including a riparian buffer (defined using biophysical criteria[1]). At this level, one kilometre of river channel would require 12 hectares of revegetation and needs to accommodate a wide range of under, middle, and overstorey species. The main aim of this level of restoration is to increase biodiversity and re-establish natural riverine environments. A canopy cover of at least 50% should be a long-term target, because riparian shade can substantially reduce water temperatures, the benefits of which (eg. increased dissolved oxygen levels) can be "exported" downstream resulting in improvements in receiving aquatic systems.

2. A more moderate level of restoration involves rehabilitation of a river ecosystem to increase bank stability and partially improve biodiversity value and water quality. The riparian buffer is usually not as extensively revegetated as above, with one kilometre of river channel requiring about two to six hectares of revegetation, the majority of which will be comprised mostly of overstorey and shrub species.

3. Partial or limited levels of restoration may involve works to control a single point of erosion, or just fencing without revegetation, the construction of stock crossings or the mere addition of logs to increase habitat diversity. The aim of this level of restoration is to improve water quality marginally, mainly by reducing erosion. Any revegetation of the riparian zone is usually limited to overstorey species or sedge and rush planting along the bank only. This level of restoration is reserved for waterways that have little to no biodiversity value and essentially serve as drainage lines.

A fourth level may be simply fencing a riparian zone that is in excellent condition to prevent it from degradation.

Allocating resources to monitoring and maintenance of any restoration activity is essential to its success. You should not consider undertaking any level of restoration without anticipating the need for post-restoration monitoring and maintenance. See Water Note WN 28 Monitoring and evaluating river restoration works.

Strategic restoration

The level or degree to which a river is restored should also be considered strategically. It is better to first expend resources on the protection and rehabilitation of waterways that are currently in good condition, and prevent them deteriorating, than trying to improve waterways that are already severely degraded, requiring the injection of extensive resources. If the waterway is in a thoroughly degraded state, having little or no biodiversity value and is essentially serving as a drainage line, then expending large amounts of resources in rehabilitating it may not be the most sensible course of action. In this case, limiting the restoration works to fencing from stock and some basic erosion control such as placement of large woody debris may be enough to give the system the chance to recover some waterway health. In rural areas, preventing stock access is often all that is needed to encourage

[1] Biophysical criteria are the physical and biological features that are associated with, or are influenced by a waterway, such as vegetation, hydrology, soil type, erosion, geology and habitat. The extent of a riparian zone and therefore the extent of a suitable buffer is determined using these criteria. See River Restoration Manual Chapter RR 16 Determining Foreshore Reserves or Water Note WN 23 Determining Foreshore Reserves for more information.

natural regeneration of riparian vegetation, thus reducing the need to put resources into buying plants and labour to plant them, along with weed control and site preparation.

Fencing

Fencing to protect revegetation and other restoration work is a necessary pre-requisite for most riparian rehabilitation projects. In rural areas, fencing is most important because it protects riparian vegetation from the effects of livestock grazing and trampling. Fences also serve to keep stock away from areas of a river or stream that are susceptible to erosion. In urban areas, fences serve to prevent human activity from encroaching upon the riparian zone.

The location of fences along waterways is also important. Ideally the location should be determined using the biophysical criteria, i.e. the fence should protect the entire extent of the riparian zone and its vegetation. More information on fencing can be found in Water Note WN18 Livestock Management: fence location and grazing control and Water Note WN19 Flood proofing fencing for waterways.

Because the construction of fencing involves expensive materials and considerable effort, it is imperative that the correct type of fence is chosen. For some projects it may be advisable to fence the most valuable reaches and highly impacted areas as a priority. Sometimes a single strand of electric wire can be effective in keeping cattle out of a river or creek. In general, 7-line ringlock fencing is adequate to keep all stock out of riparian areas. Five-line ringlock or hinged joint fencing can be used for sheep, and 6-line ringlock or hinged joint is sufficient for cattle. It is important that the fence be of substantial construction. A life expectancy of at least 50 years should be considered.

Table 1 lists the some of the main components involved in fence construction. The prices given are simply a guide and will vary marginally around the State. Prices were taken from the 2004 Farm Budget Guide produced by the Department of Agriculture and further details can be found at http://budget.farmonline.com.au/index.asp

Table 1. Material and operating costs for fence construction. Prices are GST exclusive unless stated.

MATERIALS	COST (2004)	LABOUR AND EQUIPMENT	COST (2004)
Droppers (81.5 cm galvanized, pack of 50)	$59.45	**Fence construction** (2 people x 10 hours x $20/hr)	$400/km
Steel posts (1.65m)	$5.70 ea.	**Contract fence construction**	$2000 - $2500/km
Steel posts (1.80m)	$6.01 ea.	**Post-hole digger** (2 man petrol)	$85/day
Treated pine posts (1.8m)	$8.04 ea.		
5 line ringlock (200m roll)	$180 ea.		
6 line ringlock (200m roll)	$197 ea.		
7 line ringlock (200m roll)	$207 ea.		
5 line hinged joint (200m roll)	$115 ea.		
6 line hinged joint (200m roll)	$138 ea.		
7 line hinged joint (200m roll)	$169 ea.		
Plain wire (500m roll)	$90 ea.		
Galvanised Barbed wire (400m roll)	$79 ea.		
Wire Strainer	$75 ea.		
Field gates (1.13m x 3.6m)	$122 ea.		
Tie wires (320m)	$18 ea.		
Insulated posts (Fibreglass 1.5m)	$4.40		
Insulators (200/km)	$0.85-$1.65		

	ea.
Electric fencing wire (HTHG strong wire, 1500m)	$105 ea.
Battery powered energiser (12 volt 2km)	$155 ea.
Mains powered energiser (240 volt 15km)	$177 ea.
Rabbit netting	$2 480/km

Other aspects to consider

- Various other pieces of equipment including axes, crowbars, gloves and long-handled shovels are required during fence construction. Most landowners will already possess these items or they can be borrowed from local Shires. Regional Department of Environment Offices may also be able to loan equipment.
- Gates are part of fences and are required for machinery access for fire fighting, firebreak construction, spraying for weed control etc. At least two gates per kilometre of fence may be needed in some areas.
- In hilly terrain where fences follow meandering contour lines, there will be an increased number of strainers. In contrast, it is possible to cut corners along some reaches of the river to reduce the number of strainers required.
- A third barb on the top line of the ringlock and possibly a fourth on the bottom line may be required. Rabbit netting, while expensive, could be considered for protection of valuable remnant vegetation and new plantings.
- Contract fence construction should be considered with a multi-strand electrified fence to ensure it is done safely. This is not necessary for simple, single or double wire fences.
- You may be able to receive varying degrees of assistance with the cost of fencing. For example, the Natural Heritage Trust will provide up to the reasonable full cost of fencing where the area is or will be protected for biodiversity conservation in perpetuity by a binding covenant on title; up to $2000 per kilometre where the area to be fenced will be under a voluntary management agreement or fixed term covenant for at least 10 years; or up to $600 per kilometre for all other purposes (except standard boundary fencing which is not subsidised),
- Flood proofing fencing may also need to be considered. See Water Note WN19 Flood proofing fencing for waterways.

Table 2 provides an example of the cost of the construction of two different types of fencing, ringlock and electric, calculated on a per kilometre basis. All prices were taken from the 2004 Farm Budget Guide produced by the Department of Agriculture and further details can be found at http://budget.farmonline.com.au/index.asp

Table 2. Example of different fencing costs - total cost calculation per kilometre.

TOTAL COST / KM FOR 7-LINE RINGLOCK FENCE		**TOTAL COST / KM FOR ELECTRIFIED FENCE (6 WIRES)**	
Item	**Cost (2004)**	**Item**	**Cost (2004)**
Posts (1.65m) x 100	$570	**Posts** x 50	$220
7-line ringlock (200m roll) x 5	$1035	**Electric wire** (1500m roll) x 4	$420
Strainer/strut assembly x 10	$750	**Strainers** x 2	$150
Barbed wire (700m roll) x 2.5	$197.50	**Insulators** x 200	$170 - $330

Gates x 2	$244	**Droppers** x 100	$118.90
Tie wire (320 m) x 3.125	$56.25	**Contractor for construction**	$2000
Labour	$361.20		
TOTAL	**$3,214 / km**	**TOTAL**	**$3,078.9 - $3238.9 / km**

Riffle construction

Before European settlement, most Western Australian rivers had a complex of pool-riffle sequences that added to the diversity of habitats in a stream. Most of these rivers and streams have been altered in some way through our use or neglect and this has generally had a negative effect on biodiversity. There is however, a creative technique available to restore habitat complexity and thus restore biodiversity. This technique is the construction of artificial riffles. Riffles are also constructed to prevent streambed incision and subsequent bank collapse, and in some cases, to bring about sedimentation and thus raise bed level. In this way floodplain connection can be restored through raising water levels. See RR 10 Stream stabilisation, for more information on riffle construction and design.

The extent of riffle restoration in streams and rivers depends on the degree of degradation, the goals of the restoration project and involves the rough analysis of what might have been there previously. Some projects might also involve the simultaneous excavation of pools that have silted up over time. Riffle size will depend on the size and flow characteristics of the river or stream in question, available manpower and equipment, natural materials present at the site, economic constraints, and the desired life span of the structure.

Total construction cost, including materials, machinery hire costs, consultant fees and labour, for a major riffle sequence (for example, four riffles of approximately 6 meters stream span by 3 metres in width) is estimated at $16,000 - $18,000 / km. When this figure is added to the cost of fencing, revegetation, site preparation and maintenance, and erosion control measures, the cost of extensive river restoration becomes relatively expensive. However, it is important to put the cost of riffle construction into perspective. Water Corporation concrete drop structures are approximately 10 times more expensive to construct than riffles, typically costing in the order of $35,000 each or $120,000 / km.

Table 3 breaks down some of the main costs involved in riffle construction and other soft engineering works. Most prices were taken from the 2004 Farm Budget Guide produced by the Department of Agriculture and further details can be found at http://budget.farmonline.com.au/index.asp

Table 3. Material and earth moving costs involved in riffle and crossing construction and other works. Most equipment hire can incur a transport fee of $3.50/km.

MATERIALS	COST (2004)	LABOUR AND EQUIPMENT	COST (2004)
Rock	$50/m^3	**Bobcat**	$65/hr
Concrete	$20/m^3	**Backhoe**	$70/hr
Bollards (pine 100-125mm x 1.8 m)	$10.97	**Large excavator** (30t)	$144/hr
Star pickets	$8	**Small excavator** (22t)	$110/hr
Anti-erosion netting 2.1m x 25m Jute 2.4m x 50m BIOMAC	 $145.60 $336	**Mobilisation fee** (involved in excavator hire, applicable with short-term hire only)	$45/hr (this price is highly variable)
Pins 150 (box 500)	$125	**Tip truck** (8t)	$70/hr

Logs (There would be an additional cost of harvesting and transport).	$ 10-20/tonne for residue timber	**Roller** (1 man, walk behind, petrol powered)	$125/day
		Grader	$90/hr
		Tractor	$80/hr
		Site supervisor/coordinator	$26/hr
		Specialist labour	$26/hr
		General labour	$20/hr
		Ute hire	$46/day
		Monitoring	$960/yr

If the purpose of constructing artificial riffles and pools is specifically to increase habitat diversity they must be designed carefully to be effective, with attention to the needs of resident and desired species and consideration of the prevailing physical factors in a particular river or stream. See River Restoration Manual Chapter RR 10 Stream stabilisation, for more information on riffle construction and design.

Other aspects to consider

- Prices for rock are linked to local availability and transport distance. Generally rock spoil is purchased by the truckload (10 m^3). Rock requirements will vary for each site depending on the nature of the river channel base (i.e. sand, clay, rock, etc).
- Rock can often be collected free of charge, from a paddock or mining company, but a transport charge may still apply.
- Logs and residue timber (branches/tree stumps etc…) can be purchased for around $10-20/tonne. High quality timber logs are in high demand for saw milling and can be very expensive.
- Logs can often be sourced for free from Local Government, Main Roads and developers. However it is important not to remove too much natural debris from around the restoration site. Logs with natural holes can provide homes and habitat for native fauna.
- Bought rock is usually obtained from a quarry. It is also very important that your rock supplier understands the importance of rock size in riffle construction. It is sometimes necessary to hand pick rock in order to ensure the correct size, which involves further labour costs. These are all factors that need to be considered when calculating the total cost of on-ground works.
- A small riffle will generally take between 7 - 10 m^3 of rock, while a major riffle sequence will require at least 4 times this amount.
- The labour required for 50 m of stream channel is approximately 2 people for 20 hours. It is important to have good site supervision because ease of working and the methods used will affect the overall cost.
- Operating costs are reduced if rock stockpiles are established on both sides of the creek, in a location central to the extent of the site works.
- Riffles need to be notched into the bed and bank, which requires an excavator. The rest of the work placing the rock can be done with a front-end loader, bobcat or tractor.
- A project supervisor should therefore be onsite at all times as contractors using earth moving and shaping equipment need precise direction when excavating streambeds. This is to ensure the correct amount of earth is shifted or removed. Costs can be reduced if landowners provide earth-moving equipment.
- The ideal size for a typical creek or small river varies according to stream power, and its important to calculate this to ensure rocks won't move in large flows (See River Restoration Manual Chapter RR9 Stream Channel Analysis, pg 28).
- On smaller creeks where access is difficult or riparian vegetation may be damaged by machinery, hand placement of rocks may be considered.

Stock crossings

When stock are reliant on a stream as their only source of water, it is inevitable that there will be significant damage caused by the concentration of their activity along fragile stream/river bank environments causing loss of riparian vegetation, habitat and erosion. Problems due to stock access are readily addressed by excluding stock by fencing and/or by providing off-stream livestock watering points. Costs of off-stream watering points include pumping systems, such as solar pumps, reticulation and troughs, may be more than repaid through increased production. More information can be found in Water Note WN6 Livestock management: construction of livestock crossings, and Water Note WN7 Livestock management: watering points and pumps.

Table 4 estimates the cost of a rock-lined livestock crossing, including materials, labour and equipment.

Table 4. Estimate of the cost to construct a stock crossing.

MATERIALS, LABOUR AND EQUIPMENT	COST (2004)
Rock (10m^3)	$500
Concrete (10m^3)	$200
4 hours large excavator hire (including mobilisation fee of $250)	$826
Labour (2 people @ $20/hr for 6 hours)	$240
Site survey and design	$900
Site supervision	$312
TOTAL	**$2978**

Erosion control

River Restoration Manual Chapter RR10 Stream Stabilisation, provides information on erosion control techniques. Man-made structures may be required in specific areas where simple revegetation will not be sufficient to prevent erosion. Management options for bank erosion could involve relatively simple strategies, such as anti-erosion matting, or heavy structural measures such as rock lining or installation of bollards. In the usual sense of bank stabilisation and protective works, project costs are directly related to the safety margin required of the bank (Abernethy & Rutherfurd 1999). Rebattering with wood bollards or rock lining of a 50 metre erosion hot spot, including construction materials, machinery hire, site supervision and labour, is approximately $5000.

Other soft engineering works might include the addition of low impact paths to manage access to recreation areas. Skill is needed in directing the contractor to give the works a 'natural' feel. A consultant can offer direction in planning of engineering works to ensure a more ‘natural’ design or site supervision to guide machine operators.

Large woody debris

Large woody debris (LWD) is an important structural and functional component of stream ecosystems. In-stream debris, such as logs and large branches provide hard surfaces for attachment and growth of aquatic plants and invertebrates. They also establish habitat conditions of fundamental importance for maintenance of fish populations and also provide a range of flow conditions including ponding.

LWD can consist of a wide range of types and sizes including logs, coarse roots, and smaller branches. As well as creating habitats, the inclusion of LWD in pools and along the banks of rivers and streams also results in decreased erosion and sedimentation, as well as improving natural aesthetics. See Water Note WN9 The value of Large Woody Debris (Snags) and Water Note WN13 The management and replacement of large woody debris in waterways, for more information on the use of LWD.

The addition of LWD to pools and other strategic positions along a river is estimated at $27,000 / km. This figure was established using costing from on-ground works that have taken place around Western Australia over the last two to three years. Main costs are for timber (approximately *80 logs @ $1,500*) and log retrieval and placement ($12,000, including chainsaw and tractor hire and general labour). It is important to remember that this is an estimate only. In some cases, particularly near woodland areas, logs may be readily available; therefore cost for materials is dramatically reduced. Logs may need to be cut to specific sizes, making it necessary to hire a chainsaw ($90/day or $400/day with operator). A tractor will be required to move heavy logs to correct positions.

Simple realignment of on-site logs to optimise flow and prevent bank and channel erosion is estimated at $2,400/km. (This cost includes 2 people x 20 hours @ $20/hr and 20 hours machinery hire at $70/hr).

Site preparation and weed control

River Restoration Manual Chapter RR4 Revegetation: Revegetating riparian zones in south-west Western Australia and Water Note WN 24 Riparian zone revegetation in the Avon catchment *Riparian zone revegetation in the Avon catchment* provide more information on site preparation. More information on weeds and weed control can be found in Water notes WN1 Wetlands and weeds, WN15 Weeds in waterways, WN22 Herbicide use in wetlands and WN25 The *effects and management of deciduous trees on waterways*.

Site preparation requirements will vary with soil type and degree of degradation. For example, preparation of a site with a high gravel/rock component may require a small excavator to loosen the area to be planted. For grassed areas, a backhoe might be used to scarify the area before revegetation commences. In some cases, where the land to be planted is compacted (perhaps due to stock or vehicle access), ripping and mounding of the site will be necessary before revegetation can begin. Ripping and mounding loosens and aerates the upper layer of the soil to allow better drainage and easier root penetration. A word of caution - ensure ripping and mounding of the soil does not take place in the floodway, but rather in the floodplain, to avoid the soil washing away. It also needs to be carried out at right angles to the main direction of water flow (either instream flow or surface runoff).

The cost of ripping/mounding is obviously dependent on the size of the land area involved, which is directly related to the level of restoration. For example, extensive restoration requires a minimum riparian buffer of 30-60 metres on either side of the river or stream (or to the extent of the biophysical criteria, whichever distance is greater). This represents a land area of 3-6 hectares either side of the river over a 1 km stretch, or 6-12 hectares in total.

Weed infestation of riparian habitats can severely restrict establishment and growth of desirable indigenous plants. An appropriate weed control program is recommended as part of any riparian rehabilitation program. Weed control measures can include physical or chemical intervention and should be applied on an on-going basis, especially for 18-24 months post planting. Weed control requirements should diminish with the progressive establishment of indigenous riparian communities. The use of weed control matting is recommended to provide some weed suppression, help retain moisture and provide some bank stabilisation until plant roots take hold. Table 5 provides a breakdown of the costs of site preparation and weed control.

Table 5. Material and operating costs for site preparation, weed control and maintenance (costs do not include GST.)

MATERIALS	COST (2004)	LABOUR AND EQUIPMENT	COST (2004)
Glyphosate (360g/L) Normally 2L/ha is sufficient	*$19.60/L*	**Ripping**	$130/hr
Simazine	$11.44/kg	**Mounding**	$50/hr
Fusilade	$77/L	**Weed control specialist**	$400/day
Weed control matting (2.1m x 25m)	$145.60 ea.	**Mulcher**	$95/hr
		Chipper (75 mm petrol)	$142/day
		Grasshopper control	$200/ha
		Chainsaw and operator	$400/day/ha
		Brushcutter	$45/day
		General labour	$20/hr
		Small excavator	$110/hr
		Backhoe	$70/hr
		Spray units	$17/day

Other aspects to consider

- It may be possible to use borrowed Council equipment for weeding and various site maintenance activities. This equipment might include gloves, wheelbarrows, spades, rakes, brush cutters, trailer to cart weeds away, etc.
- Weeds should be pulled by hand wherever possible. Weeds that cannot be hand pulled such as typha and couch should be slashed and sprayed 2-3 times a year following peak growing times, mainly spring and summer. Please seek advice from a Rivercare Officer before undertaking weed control activities. In some areas, such as the Avon, weed pulling is generally not recommended as it causes soil disturbance and brings new weed seeds to the surface.
- Spraying is recommended when volunteers can't keep up with the scale of infestation. Ideally, herbicide knockdown in early winter using a surfactant free, Glyphosate based herbicide (with low aquatic toxicity), should be the preferred option. A specialist operator may be needed to spray weeds when stronger chemicals are required.

NB: The use of herbicides needs very careful consideration close to waterways, and as they can be quite toxic should be undertaken by a competent contractor. Sometimes the label does not permit use near waterways. Be sure to comply with the manufacturers instructions when applying herbicide.

- Studies of past weed control programs show Glyphosate and Simazine to be most effective for the majority of weed species. Veldt grass is best controlled with Fusilade. In most cases 2 L/ha of herbicide is adequate. Roundup Biactive® has been shown to have reduced toxicity to aquatic fauna and is preferable to other herbicides for use near waterways.
- In rural areas, controlled grazing for brief periods, one or two years after revegetation may be appropriate to manage weed growth.

Table 6 provides an estimate of the cost per hectare for site preparation, including weed control and ripping/mounding. The total cost caters for a combination of physical removal of weeds by volunteers and spraying, as this is a common weed control strategy for many restoration projects.

Table 6. Site preparation – approximate cost per hectare (costs do not include GST).

MATERIALS, LABOUR AND EQUIPMENT	COST ($ per ha) (2004)
Herbicide (Glyphosate or Simazine @ 2L/ha)	$40/ha
Spraying (weed control specialist @ 2ha/day)	$200/ha
Ripping (1ha/hr)	$50/ha
Mounding (1ha/hr)	$50/ha
Brushcutter hire	$45/ha
General labour (4 people x 6 hours x $20/hr)	$480
Weed control matting (1000m^2/ha @ $2.78/m^2) [Does not usually apply for C grade restoration]	$2780/ha
TOTAL	**$1,525/ha**

Revegetation - planting

The main objectives for revegetation are usually erosion control, biodiversity enhancement and water quality improvement. The cost of revegetation varies depending on the scale of the project, species of trees, shrubs or rushes/sedges planted as well as planting density. It will also depend on the type of plant community to be restored. Whatever the community type, a variety of species combinations will ensure diversity and reduce the risk of losing the majority of plantings to pests, disease or drought.

The planning process before undertaking any revegetation should include the compilation of a list of native plant species suitable for the particular area. Plants for riparian revegetation should be locally indigenous, either propagated from seed found near the area or species that are naturally found living in the area. The key to the successful recruitment of plants in a sustainable, low maintenance riparian area is awareness of appropriate species and their preferred niche across the riparian zone and adjacent upland. There is a need to choose plants that will offer best bank stabilisation and that will develop sufficiently, not only to generate initial shading and supply of hard leafed organic matter, but also continue to supply woody debris to the waterbody in the long term.

Rushes and sedges are an important part of a riparian revegetation species list. They are often found at the land-water interface and play an important role in stabilising banks, providing food and habitat, aerating sediment, and filtering and binding pollutants and nutrients. Examples include *Juncus kraussii* (Shore Rush), *Carex appressa* (Tall Sedge) and *Baumea articulata* (Jointed Twig Rush). As a general rule, rushes and sedges should be planted at 6-9 plants/m2. Each species should be planted in single species groups to avoid competition losses. Establishment of sedges and rushes is most successful in permanently wet or moist areas during peak growth times (spring and summer). Conditions that are ideal for sedge establishment include gently sloping banks, hard and sandy substrate, and protection from wind and wave action. More information on revegetation can be found in River Restoration Manual Chapters RR 8 Using rushes and sedges in revegetation of wetland areas in the south west of WA, RR 5 Revegetation: case studies from south-west Western Australia and RR 4 Revegetation: revegetating riparian zones in south-west Western Australia. The publications; *Riparian Plants of the Avon Catchment*, Water Note WN 24 Riparian zone revegetation in the Avon catchment, Water Note 31 WN 31 Revegetating with native grasses in the Avon Catchment and Water Note WN 32 Establishing samphires in the Avon Catchment may also help with revegetation information in riparian areas of the Avon River Basin.

The cost of seedlings will vary depending on their stage of growth, their availability and ease and method of propagation. Collecting your own seed or growing seedlings in community nurseries could reduce costs. Table 7 offers a guide to prices.

Table 7. Itemised costings for revegetation (costs do not include GST).

MATERIALS	COST (2004)	LABOUR AND EQUIPMENT	COST (2004)
Seedlings - large (70mm pot) - prices will vary depending on quality, quantity - i.e. bulk buying - and species)	$1.40-$1.70 ea.	**Tree planting machine**	$80/day
Seedlings - small - prices will vary depending on quality, quantity - i.e. bulk buying - and species)	$0.40-$0.60 ea.	**Revegetation consultant**	$90-120/hr
Mature plants	$2-$12 ea.	**Seedling planting**	$0.50 ea.
Rushes/Sedges	$0.55 (cell) - $11.00 (1m strip)	**Tree planting** (eucalypts)	$1.40 ea.
Tissue cultured rushes / sedges	$1.10 (cell) $12.10 (1m strip).	**Direct seeding** (excluding seed)	From $350/ha
Mulch (bulk order only)	$40/m^3		
Tree guards (pack 100)	$24.25.		
Bamboo stakes (pack 1000)	$63.90		
Jarrah stakes	$0.86 ea.		
Seed (for direct seeding)	$300/Kg		

Other aspects to consider

- Further costs relating to packaging/handling and freight will also need to be considered. Packaging/handling charges vary marginally between suppliers and freight costs will depend on distance between the supplier and the project.
- A cubic metre of mulch spread 15cm deep on the ground will cover an area of approximately 10m^2.
- Soft plastic tree guards provide some protection for seedlings from grazing and are most useful in creating a humidifying effect that supports seedling growth and suppresses some weeds. They are more durable and affordable than the hard plastic tree guards. Each tree guard requires 3-4 stakes. Prices of tree stakes vary with size and type, as well as the quantity ordered.

Revegetation - Direct seeding

In most riparian revegetation situations seedlings are preferable, however direct seeding offers a less expensive alternative. The price of seed will depend on species selected for revegetation. *Acacia* and *Melaleuca* species are generally the least expensive, while seed for *Hakea* and *Grevillea* species can be as high as $6800/Kg. Seed for most *Banksia* species is also relatively expensive. In a seed mix for direct seeding however, it is usually adequate to contain only 5-10% of one or a combination of the more expensive varieties.

Most seed mixes used in restoration/revegetation works are around the $300/Kg mark, comprising 60-70% middle stratum species (shrubs 40cm-2m in height), 15-20% annuals and herbs, and 15-20% trees. Seed prices can be subject to change due to seasonal availability. Table 8 provides a guide for seed prices for the more common species of native flora. The provision of free seed provenance information is standard practice for most seed supply companies.

Table 8. Seed prices for main native flora varieties (does not include GST).

VARIETY	PRICE RANGE	AVERAGE PRICE
Acacia (Wattle Trees and Shrubs)	$83 – $880 / Kg	**$285/ Kg**
Casuarina/Allocasuarina (She-oaks)	$187- $396 / Kg	**$285 / Kg**
Banksia	$39 - $132 / 1000 seeds	**$82 / 1000 seeds**
Grevillea	$7 - $80 / 25g	**$30/ 25g**
Hakea	$8.25 - $170 / 25g	**$52 / 25g**
Eucalyptus	$149 - $2,420 / Kg	**$280 / Kg**
Dryandra	$77 - $171 / 1000 seeds	**$112 / 1000 seeds**
Melaleuca (Honeymyrtles)	$182 - $1089 / Kg	**$383 / Kg**
Callistemon/Calothamnus (Bottlebrushes)	$237 - $2,090 / Kg	**$458 / Kg**
Atriplex (Saltbush)	$77 - $160 / Kg	**$102 / Kg**

Other aspects to consider

- The spread-rate for direct seeding can be anywhere between 2 Kg and 5 Kg of seed per hectare, depending in the extent of revegetation.
- Spread rate will be decreased when direct seeding is done in conjunction with seedling planting. For instance for extensive restoration, you will need 5kg/ha of seed if undertaking 100% direct seeding, but only 2kg/ha if combining 50% seedlings (1200/ha) and 50% seed (allow 1200 seedlings/ha in this case). For a more moderate level of restoration, 3 kg of seed per hectare would be needed if undertaking 100% direct seeding, but only 1kg/ha if combining 50% seedlings (600/ha) and 50% seed (allow 600 seedlings/ha in this case).
- The aim in restoration is to try to replicate the structure and floristics of an area. Complete restoration to a pre-disturbed state is very expensive, not to mention virtually impossible. Initially, keep the seed mix simple and choose species that are easily germinated. You can increase the number of species as you become more familiar with local plant communities and after observation of what succeeded and what didn't.
- Seeking advice from a Department of Environment Rivercare Officer or a revegetation consultant is recommended, especially for large-scale projects, to ensure that appropriate foreshore and in-stream species are selected and planting density is adequate. A consultant can also help establish a herbarium to catalogue local flora or supervise seed collection.

Consultants

The majority of river restoration projects depend upon the involvement of volunteers and private landowners, with limited or no technical training. In order to design the best revegetation solution or the most appropriate riffle structure, it is necessary to understand the relationship between the river system and its catchment as well as the existing river processes. Understanding the broader context is more likely to result in a successful restoration project that is self-sustaining in the longer term. For example, failure to allow for the dominant river processes that control channel size and shape may mean that structural measures (riffles, riprap etc) are more likely to require costly maintenance.

For this reason, many restoration projects include a consultancy component. For example, a taxonomic specialist may be required to conduct a baseline aquatic fauna survey for future monitoring purposes. Similarly, a botanist may be employed to conduct a flora survey of existing native plant communities to ensure complementary species are chosen for revegetation. The cost of this type of consultancy can be upwards of $600 a day. Department of Environment Rivercare Officers can also be contacted at your nearest regional office for assistance, at no cost.

Aboriginal heritage

Groups will also need to investigate the Aboriginal significance of their restoration site before undertaking any works. Consultation with Aboriginal groups may require payment, which can vary in each situation. See Water Note WN30 Safeguarding Aboriginal heritage and contact the Department of Indigenous Affairs for more advice.

Other activities

There are various other costs involved in any rehabilitation program. These include costs for:

- **On-going maintenance** (especially weed control).

Monitoring and Evaluation (materials and labour). For example, operating cost of monitoring water quality is estimated at 4 hours per month for each landowner @ $20/hr. (water testing kits $310 each; piezometers $150 each). Make sure the monitoring and evaluation of the restoration activities is relevant to what you had hoped to achieve. (eg monitoring water quality would not be the most appropriate method if you want to see if the biodiversity of the riparian zone has increased!). More information on monitoring and evaluation can be found in Water Note WN 28 Monitoring and evaluating river restoration works and *Protection, Regeneration, Revegetation - Evaluation. A guide to planning and designing a monitoring and evaluation program for native vegetation management projects*. Department of Conservation and Land Management, Perth.

- Report production ($18/copy).
- Signage ($1000 ea.).
- Communications (phone and stationery).
- Travel ($0.83/km for car travel).

Costings Case Study – Restoration of Harvey River at River Road, Harvey.

By Jesse Steele, Rivercare Officer, Peel Harvey Catchment Council.

The Harvey River Restoration Taskforce Inc. was established in 2001 to ensure that the Harvey River Basin's water resources and ecological values, which may be lost or degraded due to the Harvey Dam redevelopment, are regenerated elsewhere in the Basin.

This project commenced early in 2004 and involved restoration of approximately 1km (3.7 Ha) of the Harvey River along River Road.
River restoration at this site included:

- removal of noxious weeds including Giant Reed, Blackberry, Morning Glory (*Ipomoea indica*) and Bridal Creeper,
- construction of two in-stream rock-riffle structures,
- installation of Large Woody Debris,
- revegetation
- and promotion of the area as a river restoration demonstration site.

The following table outlines the costs associated with the project.

Table 9. Costs associated with a River Restoration Project on the Harvey River conducted over 2004/2005.

MATERIALS AND EQUIPMENT		UNIT PRICE	QUANTITY	COST (PRE – GST)
Seedlings	Sedges	$0.95 ea	1090	$1,035
	Seedlings	$0.4 ea	5400	$2,160
	Seedlings	$0.35 ea	2100	$735
	Seedling delivery		1	$100
Earthworks	Excavator hire			
	Mobilisation and demobilisation of excavator (~80km total)	$600	1	$600
	Bank battering at selected nodes for bank restoration and excavator entry	$90/hr	6 hrs	$540
	Riffle construction	$110/hr	16 hrs	$1,440
	LWD placement	$110/hr	3 hrs	$270
	Bobcat hire – shifting rocks	$60/hr	25 hrs	$1650
Riffle Materials and Surveying	Surveying costs	By quote	2 days	$2,955
	Rock supply and delivery (~60km total)	$32 m^3	90 m^3	$2,880
Spraying & Planting Preparation	Burning of site		1 day	$2,000
	Slashing and ripping of entry point site	$85/hr	5 hrs (~2 Ha)	$425
	Initial spray of entry point site	$85/hr	2 hrs	$170
	Broad spray (project area)	$85/hr	13 hrs	$1,150
	Spring weed control, spot spray around seedlings	$55/hr	33 hrs	$1,815
Additional Materials	Jute matting and steel pegs	$90 per roll	8 rolls (2 sites)	$1,300
	Tree guards	$0.5 ea	5000	$2,610
	Delivery of tree guards and matting		8m^3 (180kg)	$620
	Mulch	In-kind		
	Delivery of mulch (~150km total)	26m^3$	240m^3	$6,300
	Spreading mulch at entry point	$60/hr	16 hrs (240m^3)	$1,050
	Design of sign	By quote		$450
	Sign writing (2400 x 1200)	By quote		$850
Tree Felling	Flame tree removal and poisoning, mulching of trees trunks		~20 large trees	$5,000
Community Support	Green Corp, local landowners and Curtin university students helped with spraying, planting and removal of Giant weed.	In kind	800 hours	
		Total Cost		**$38,100**

The HRRT Rivercare Officer developed an action plan and timeline for the restoration, which was given to surrounding landholders. A detailed project map was developed that outlined the approximate area (Ha) of the restoration zones and the predominant weeds.

Access to the site was severely limited due to dense infestations of Giant Reed and Blackberry. The area had little native vegetation, with no native understorey. Previous attempts to cut weeds with brush-cutters had failed and previously cut areas had again become overgrown with Giant Reed. Therefore, it was decided that the site should be burnt prior to restoration.

The majority of weed biomass was removed during the burn, allowing increased access to the site. Giant Reed was sprayed once regrowth reached 0.5 of a metre and a total of two further herbicide applications were applied. The remainder of the Giant Reed not killed by the above method was cut and then wiped with herbicide by a local Green Corp Team. All Giant Reed material was stacked on the floodplain and burnt. The site was again sprayed in late May in preparation for planting.

Approximately 20 large flame trees were removed using a tree lopper. The stumps were injected with herbicide; however stumps were left in the bank to reduce erosion.

Restoration areas where divided into 3 zones; the submergent and emergent zone which includes the low and high water marks, the damp to ephemeral zone which is sometimes damp but often dry, and the upland zone which was originally the river floodplain but due to upstream water regulation now only receives water through precipitation. The area of each zone in Hectares was mapped using a GIS system. The number of seedlings for each zone was calculated using the following densities:

Zone	Seedling per Ha
Submergent – emergent	10,000 (predominantly rushes and sedges)
Damp – ephemeral	5,000
Uplands	2,000

Riffles were constructed to improve in-stream habitat and utilise in-stream flows, which are restricted due to upstream water regulation. By creating pool-riffle sequences a larger amount of water is retained in the river and new habitats, including permanent pools are created. The riffles provide fast, flowing aerated habitats and help to back-flood an area. This creates pools, which provide shelter and breeding areas.

Riffle locations and rock estimates were developed through surveying completed by the Department of Environment. The Department of Environment assisted in developing a brief for the surveying contractor who constructed a detailed longitudinal river profile. The longitudinal profile was used to calculate the extent of ‘back-flooding’ with a corresponding riffle height.

Due to the steep banks along the river, the excavator created an entry ramp and ‘pad’, which the machine sat on and from which the riffle was built. A bobcat was used to push rocks down the bank near the ‘pad’ so the excavator did not have to continually move up and down the bank and create unnecessary erosion. The ramp used by the excavator was backfilled, re-contoured and covered with jute matting to reduce erosion. Banks at the second riffle site were also battered and covered with jute matting. Large Woody Debris was placed around each of the riffles, but was limited to approximately 10 large pieces as existing large trees restricted movement of the excavator.

As the site was to be a river restoration demonstration site an ‘entry point’ was constructed. The entry point was a large upland area adjacent to River Road. The entry point was devoid of any native vegetation. It was first slashed and then sprayed to remove weeds. A small zone next to the road was used as a parking bay, it was levelled using a bobcat and then lined with limestone and gravel. A sign was placed at the head of the parking area.

The donate mulch was spread using a bobcat. Seedlings were planted in late June and tree guards were placed around all seedlings to enable spot spraying in spring.

This project had a lot of community input and support. The local fire brigade conducted the initial burn. A Green Corp team worked on this project for three weeks, removing Giant Reed, placing weed matting, planting and installing tree guards. Local landholders helped completed around 50% of spraying work. Additional removal of Giant Reed was completed through three community work days and 2 Curtin University Student Volunteer weekends.

Figure 1. Surveying the riffle site at River Road. *(Photo Jesse Steele)*

Figure 2. Conducting the controlled burn at River Road. *(Photo Jesse Steele)*

Figure 3. Construction of the riffle. *(Photo Jesse Steele)*

Figure 4. Placing geotextile fabric on the restoration site. *(Photo Jesse Steele)*

The project was initially greeted by cynicism as a previous attempt to restore this section of the river in 1995 failed spectacularly. The site would not normally be chosen for a restoration project because of its heavily degraded state. However, the site represented one of the few areas around Harvey where local landholders were trying to control weeds. By building on this local resource it is hoped that the project will be sustainable in the long-term. Ongoing control of Giant Reed, Blackberry and Bridal Creeper is required.

Although the project in only recently established it has already generated interest from local Shire Councillors who are seeking river restoration ideas for the Harvey Townsite Tourist Precinct located upstream on the Harvey River.

More information

Contact the Department of Environment to find out how to contact a Rivercare Officer to assist with your river restoration project.

Water Notes and the River Restoration Manual provide more information on fencing, construction of livestock crossings, revegetation, weed control, stream stabilisation techniques and other river restoration activities.

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Appendix D

Stormwater management manual for Western Australia – indicative stormwater infrastructure costs

Department of Water (2004-2007)

<table>
<tr><th>Stormwater infrastructure</th><th>Reference costs</th><th>Notes on costs</th><th>Key considerations</th></tr>
<tr><td>Vegetated swale</td><td>• $4.50/m^2 of hydromulched swale
• $15-$20/m^2 of vegetated swale</td><td>Dollar values are in 2003 Australian dollars</td><td rowspan="5">Earthworks
• Cost will be variable depending on existing topography and varying subsurface conditions
• Costs will also vary depending on whether installed within new development or implemented as a retrofit of an existing drainage system

Vegetation
• Early ordering of tubestock to minimise costs and ensure availabity of specific species
• Planting should be undertaken in Autumn to reduce maintenance costs associated with watering

Land
• Constructed wetlands have a high land take compared to other BMPs such as bioretention systems</td></tr>
<tr><td>Bioretention system - swale</td><td>$100/m - $410/m</td><td>Dollar values are in 2003/2004 Australian dollars</td></tr>
<tr><td>Bioretention system - basin</td><td>• $125-$150/m^2 (>100 m^2 area)
• $225-$275/m^2 (<100 m^2 area)</td><td>Dollar values are in 2004 Australian dollars</td></tr>
<tr><td>Detention basin</td><td>• $2,000/ha of catchment
• $30,000/ML of basin volume
• $60,000/ha of basin area</td><td>Dollar values are in 2001 to 2005 Australian dollars depending on original source.</td></tr>
<tr><td>Constructed wetland</td><td>$500,000 - $750,000/ha</td><td>Dollar values are in 2002 Australian dollars</td></tr>
</table>

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