MAITLAND
CITY COUNCIL

Drainage

Asset Management Plan

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1. EXECUTIVE SUMMARY

What Council Provides

Council provides a drainage network to enable the conveyance of stormwater to the downstream destination while considering the safety of the community and the protection of property.

Asset Category	Quantity
Conduits and Culverts	280.8km
Pits	11355
Headwalls	660
Floodgates	33
Detention Basins	71
Gross Pollutant Traps	50

What does it Cost?

There are two key indicators of cost to provide the drainage asset management service.

- The life cycle cost being the average cost over the life cycle of the asset, and
- The total maintenance and capital renewal expenditure required to deliver existing service levels in the next 10 years covered by Council's long term financial plan.

The total maintenance and capital renewal expenditure required to provide the drainage network the in the next 15 years is estimated at $1.1M.

Plans for the Future

Council plans to operate and maintain the drainage network to achieve the following strategic objectives.

1. Ensure the drainage network is maintained at a safe and functional standard as set out in this asset management plan.
2. Ensure the drainage network meets the demand of future growth as set out in this asset management plan.
3. Keep up to date with current best practice management techniques.

Measuring our Performance

Quality

Drainage assets will be maintained in a reasonably usable condition. Defects found or reported that are outside our service standard will be repaired. See our maintenance response service levels for details of defect prioritisation and response time.

Function

The intent is that an appropriate drainage network is maintained in partnership with other levels of government and stakeholders to provide an adequate and safe drainage network.

Drainage asset attributes will be maintained at a safe level and associated signage and equipment be provided as needed to ensure public safety. We need to ensure current and future demands are met.

Safety

We inspect all WSUD assets regularly. Pit and pipe networks have defects identified during rain events where there are failures. Works are prioritised and defects are repaired in accordance with our risk management plan to ensure they are safe.

The Next Steps

The actions resulting from this asset management plan are:

- Continue formal inspections
- Continue to prioritise maintenance and capital works in accordance with the risk management plan
- Undertake asset inventory of floodgates and open channels

2. INTRODUCTION

2.1 Background

This asset management plan demonstrates responsive management of assets (and services provided from assets), compliance with regulatory requirements, and to communicate funding required to provide the required levels of service.

The asset management plan is to be read with the following associated planning documents:

Maitland 2021 Community Strategic Plan 2011

Maitland Delivery Program 2011

Asset Management Policy 2011

Asset Management Strategy 2011

This asset management plan covers the infrastructure assets identified in Table 2.1.

Table 2.1. Assets covered by this Plan

Asset category	Quantity	Replacement Value ($M)
Conduits and Culverts	280.8km	$69.48M
Pits	11355	$14.52M
Headwalls	660	$0.59M
Floodgates	33	$0.40M
Detention Basins	71	$19.19M
Gross Pollutant Traps	50	$4.77M
TOTAL		**$108.77M**

Key stakeholders in the preparation and implementation of this asset management plan are:

Community	User safety, Work requests & Satisfaction
Assets & Infrastructure Planning	Planning / Design & Control
City Works & Services	Provision of Services
Developers	Compliance and Contribution

2.2 Goals and Objectives of Asset Management

The Council exists to provide services to its community. Some of these services are provided by infrastructure assets. Council has acquired infrastructure assets by 'purchase', by contract, construction by council staff and by donation of assets constructed by developers and others to meet increased levels of service.

Council's goal in managing infrastructure assets is to meet the required level of service in the most cost effective manner for present and future consumers. The key elements of infrastructure asset management are:

- Taking a life cycle approach,
- Developing cost-effective management strategies for the long term,
- Providing a defined level of service and monitoring performance,
- Understanding and meeting the demands of growth through demand management and infrastructure investment,
- Managing risks associated with asset failures,
- Sustainable use of physical resources,
- Continuous improvement in asset management practices.[1]

2.3 Plan Framework

Key elements of the plan are

- Levels of service – specifies the services and levels of service to be provided by council.
- Future demand – how this will impact on future service delivery and how this is to be met.
- Life cycle management – how Council will manage its existing and future assets to provide the required services
- Financial summary – what funds are required to provide the required services.
- Asset management practices
- Monitoring – how the plan will be monitored to ensure it is meeting Council's objectives.
- Asset management improvement plan

A road map for preparing an asset management plan is shown below.

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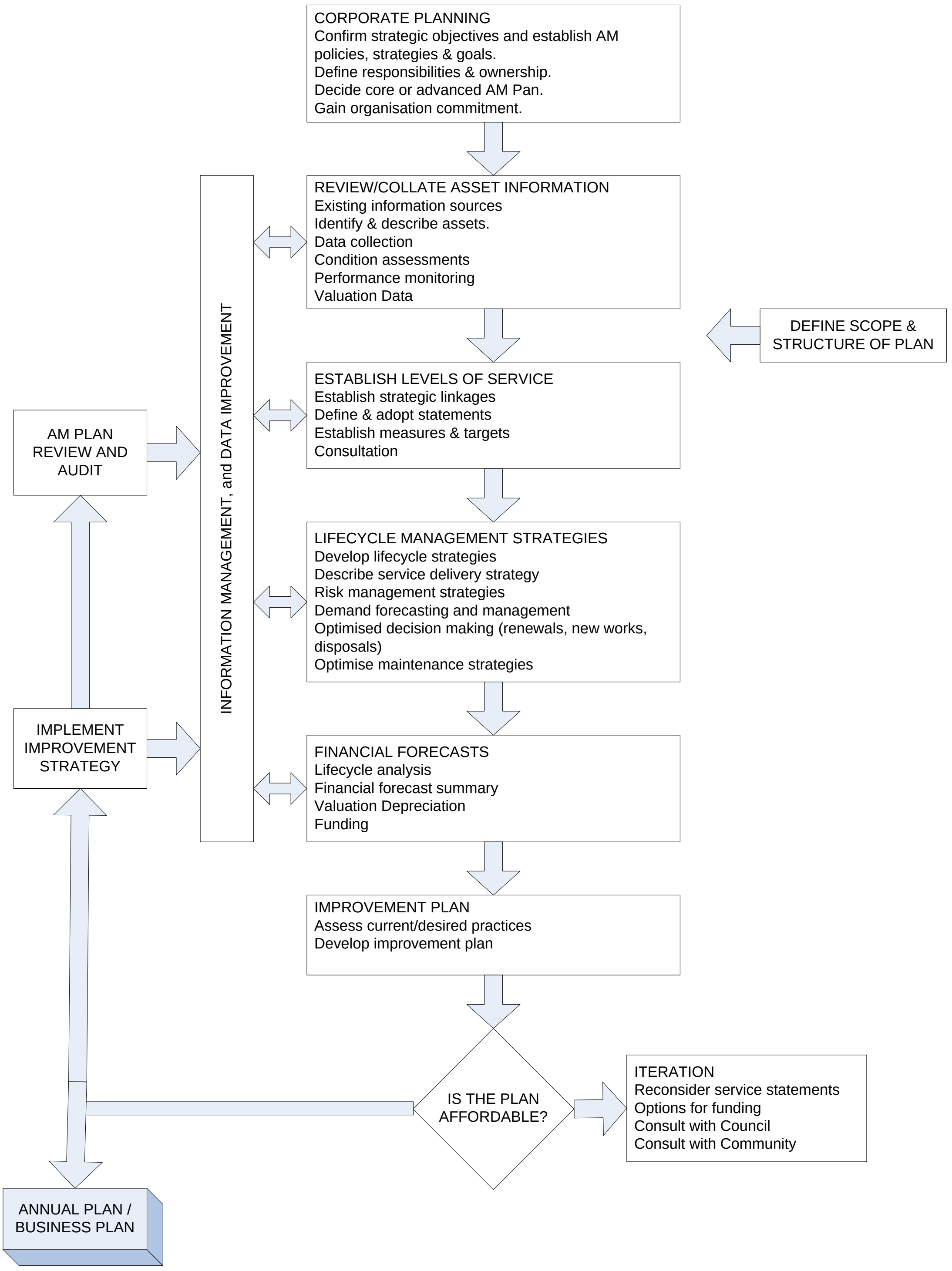
[1] IIMM 2006 Sec 1.1.3, p 1.3

Road Map for preparing an Asset Management Plan

Source: IIMM Fig 1.5.1, p 1.11



2.4 Core and Advanced Asset Management

This asset management plan is prepared as a ‘core’ asset management plan in accordance with the International Infrastructure Management Manual. It is prepared to meet minimum legislative and organisational requirements for sustainable service delivery and long term financial planning and reporting. Core asset management is a ‘top down’ approach where analysis is applied at the ‘system’ or ‘network’ level.

Future revisions of this asset management plan will move towards ‘advanced’ asset management using a ‘bottom up’ approach for gathering asset information for individual assets to support the optimisation of activities and programs to meet agreed service levels. The ground work for this upgrade has begun.

3. LEVELS OF SERVICE

3.1 Customer Research and Expectations

The community expect that the drainage system is maintained and operated to a level that localised flooding is minimised and the environment is protected. This reinforces the need for GPTs and other such devices to increase the quality of stormwater released to downstream water systems. This community expectation has been determined from the number and information provided by customer service requests.

3.2 Legislative Requirements

Council has to meet many legislative requirements including Australian and State legislation and State regulations. These include:

Table 3.2. Legislative Requirements

Legislation	Requirement
Local Government Act 1993	Sets out role, purpose, responsibilities and powers of local governments including the preparation of a long term financial plan supported by asset management plans for sustainable service delivery.
Protection of the Environment Operations Act 1997	Ensure the protection of the environment through Design and Construction practices.
Fisheries Management Act 1994	Ensure that fish passage is not impeded and preserve and conserve key fish habitats and threatened communities.
Threatened Species Conservation Act 1995	Ensure conservation of biological diversity, key habitat and ecologically sustainable development.
Native Vegetation Conservation Act 1997	Ensure conservation and management of native vegetation.
Water Management Act 2000	Maintain creeks and other natural waterways to ensure flow isn’t impeded and the systems are as free as possible of weed species.

3.3 Current Levels of Service

Council has defined service levels in three ways.

Community Levels of Service relate to how the community receives the service in terms of safety, quality, quantity, reliability, responsiveness, cost/efficiency and legislative compliance.

Environmental levels of service relate to the quantity of stormwater received by downstream natural water systems, as well as the speed at which this water is discharged.

Supporting the community service levels are operational or technical measures of performance developed to ensure that the minimum community levels of service are met. These technical measures relate to service criteria such as:

Service Criteria	Technical measures may relate to
Quality	Functionality of drainage systems
Quantity	Adequate size of drainage systems
Safety	Number of injury accidents
Environmental	Quality of water draining to wetlands

Performance measures for service levels include information gathered during inspections by asset and operational staff, community feedback, condition rating and the amount of works completed.

The level of service of drainage assets is provided in a cost-effective manner, ensuring that the needs of the community are met city wide. A prioritisation process is undertaken, using the risk management process outlined later, to manage the high number of customer requests and works identified during inspections. The prioritisation process ensures high priority works are undertaken in a timely fashion and low priority works are undertaken when resources permit.

4. FUTURE DEMAND

4.1 Demand Forecast

Factors affecting demand include population change, changes in demographics, seasonal factors, environmental obligations, consumer preferences and expectations, economic factors, agricultural practices, environmental awareness, etc.

Demand factor trends and impacts on service delivery are summarised in Table 4.1.

Table 4.1. Demand Factors, Projections and Impact on Services

Demand factor	Present position	Projection
Population	2001 Census – 53,803	2026 – 96,000
Demographics	Commercial – 71.76%	
	Industrial – 26.47%	
	Rural – 1.77%	

4.2 Changes in Technology

Technology changes are forecast to affect the delivery of services covered by this plan in the following areas.

Table 4.2. Changes in Technology and Forecast effect on Service Delivery

Technology Change	Effect on Service Delivery
New or improved Water Sensitive Urban Design (WSUD) devices	Different maintenance practices and equipment required to maintain and achieve environmental outcomes / Correct device choice for particular area to achieve water quality outcomes.

4.3 Demand Management Plan

Demand for new services will be managed through a combination of managing existing assets, upgrading of existing assets and providing new assets to meet demand and demand management.

4.4 New Assets from Growth

The new assets required to meet growth will be acquired from land developments and constructed by Council. The new asset values are summarised in Table 4.4.

Table 4.4. New Assets from Growth – 2008/9

Asset Category	Quantity	Cost
Pits	77	$114,257
Headwalls	9	$8,010
Ponds	1	$438,240
Pipes	1.9km	$379,673

Acquiring these new assets commits council to fund ongoing operations and maintenance costs for the period that the service provided from the assets is required. These future costs are identified and considered in developing forecasts of future operating and maintenance costs.

5. LIFECYCLE MANAGEMENT PLAN

The lifecycle management plan details how Council plans to manage and operate the assets at the agreed levels of service (defined in section 3) while optimising life cycle costs.

5.1 Background Data

The data on drainage assets is stored in a GIS based system which is updated as new development areas and capital or maintenance works are installed. The data can be output into a database to allow the information to be reported on. Pit and pipe sizes, lengths, inverts, date of installation is recorded. Similar data is recorded for the other drainage asset categories.

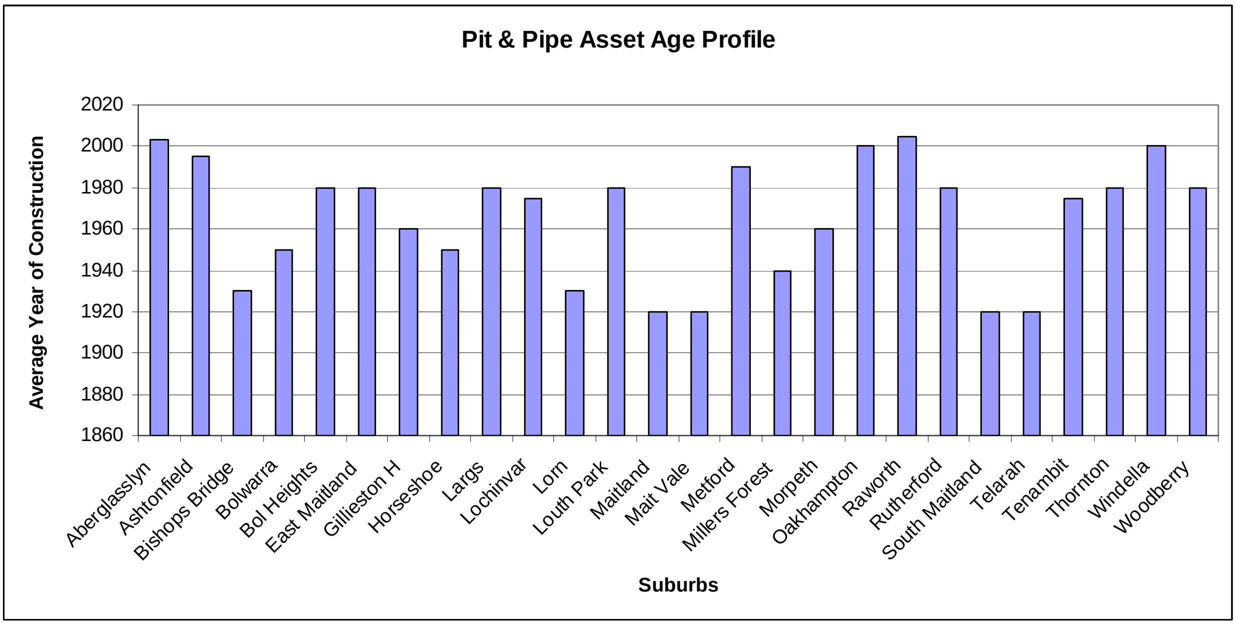
5.1.1 Physical parameters

The assets covered by this asset management plan are shown below.

Asset Category	Quantity
Conduits and Culverts	280.8km
Pits	11355
Headwalls	660
Floodgates	33
Detention Basins	71
Gross Pollutant Traps	50

The age profile of Council's assets is shown below.

Fig1. Asset Age Profile



The average age takes into account the amount of pipe and pits constructed at different times and these have been averaged to find the average year of construction for pit and pipe systems in each suburb of Maitland's LGA.

The WSUD devices throughout the LGA are up to 15 years old, with the majority of the ponds and GPTs constructed after 2000.

5.1.2 Asset capacity and performance

Council's services are generally provided to meet design standards where these are available.

Locations where deficiencies in service performance are known are detailed in Table 5.1.2.

Table 5.1.2. Known Service Performance Deficiencies

Site	Project/works Description	Estimate
90 Aberglasslyn Rd, Rutherford	4 x pipes replaced	$20,000
Rockleigh Street, Thornton	Continue SW pipes 30m	$8,000
Brooks Street, Telarah	Install pipe system to replace/assist existing from Dee Street to south of Capper	$150,000
Woodlands Drive, Thornton	Headwall at property boundary (no36) connected to 3x 375mm for 15m to a 1200x2400 sag pit. Connect this with 675mm pipe to 900x900 pit adjacent the others in low point, this then connects to existing headwall with 675mm pipe under Woodlands Drive	$160,000
Currawong Close, Thornton	Replace no10 and 11 driveway with 450x900 box culverts, Install 2x 900mm pits downstream of the cul de sac and 35m of 600mm pipe to connect them	$65,000
Woodlands Drive, Thornton	Upgrade piped system adjacent 17 Woodlands Drive, as in Woodlands Estate Stormwater Study	$40,000
Bligh Street, Telarah	Install drainage line as identified in Telarah Catchment Study	$175,000
Church Street, Maitland	Upgrade drainage system from no29 to outlet off Stillsbury Lane	$300,000
Woodlands Drive, Thornton	Upgrade piped system adjacent 30 Woodlands Drive, as in Woodlands Estate Stormwater Study	$155,000
Honeyeater Place, Thornton	Upgrade piped system downstream of Honeyeater Place, as in Woodlands Estate Stormwater Study	$160,000
Reflection Drive, Louth Park	Erosion Control and Rehabilitation behind no87	$100,000
South Street, Telarah	Upgrade of pipe system to natural channel from Kerrie Close	$250,000
Thornbill Grove, Thornton	Upgrade drainage system in Thornbill Grove, as in Woodlands Estate Stormwater Study	$200,000
Bent Street, Maitland	Upgrade drainage in Bent Street and Fry Street from Grant Street to Athel D'Ombrain Drive	$250,000
Thomas Coke Dr, Thornton	Construct GPT at end of Catchment	$200,000
Capper Street, Telarah	Install pipe system to replace/assist existing from Parkes to Brooks Street	$75,000

The above service deficiencies were identified from our asset register and development investigation areas.

5.1.3 Asset condition

The condition of Council's assets in the above areas identified as having service performance deficiencies require capital expenditure over a number of years to bring the assets up to Council's current required level of service. Additionally, capital and maintenance expenditure is required in more recently developed areas to ensure the assets do not fall to an unacceptable level.

Drainage assets have a condition rating related to their age based deterioration.

Condition is measured using a 1 – 5 rating system.[2]

Rating	**Description of Condition**
5	Only planned maintenance required.
4	Minor maintenance required plus planned maintenance.
3	Significant maintenance required.
2	Significant renewal/upgrade required.
1	Unserviceable.

Overall, the asset condition of the Drainage network in Maitland is 3, being of average condition with significant maintenance required. This being the average means that there are drainage systems with conditions rating from 1 through to 5. Overall, 70% of the drainage network has a rating of 3 to 5, and 30% of the network has a rating of 1 to 2. The target standard for the drainage network is to have 85% at 3-5 and 15% at 1-2.

5.1.4 Asset valuations

The value of assets as in 2009 covered by this asset management plan is summarised below. Assets were last revalued for the development of this plan.

Current Replacement Cost	$108.77 M
Depreciable Amount	$108.77M
Depreciated Replacement Cost	$95.56M
Annual Depreciation Expense	$0.98M

Council's sustainability reporting reports the rate of annual asset consumption and compares this to asset renewal and asset upgrade and expansion.

The average rate of asset consumption is 0.65%. This is due to static structures such as pits, pipes and GPTs having a life of 200 years, and devices such as ponds having a life of 50 years or up to 100 years with adequate maintenance and renewal.

A summary of the asset depreciation without maintenance or capital expenditure and the asset rejuvenation with capital and maintenance expenditure over the next 50 years is shown below.

Fig 2. Forecast expenditure and depreciation of Drainage Assets

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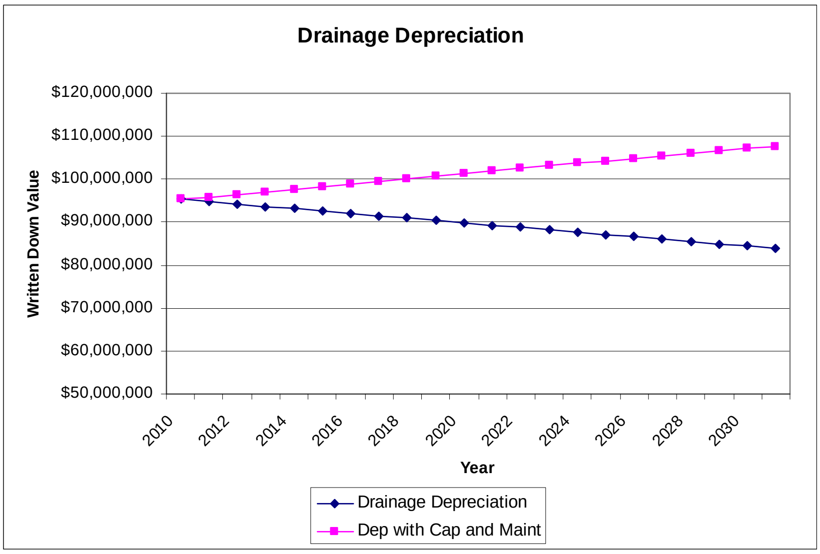
[2] IIMM 2006, Appendix B, p B:1-3 ('cyclic' modified to 'planned')



5.2 Risk Management Plan

An assessment of risks associated with service delivery from infrastructure assets has identified critical risks to Council. The risk assessment process identifies credible risks, the likelihood of the risk event occurring, the consequences should the event occur, develops a risk rating, evaluates the risk and develops a risk treatment plan for non-acceptable risks.

See Council's Road Risk Management Procedure for risk assessment.

5.3 Routine Maintenance Plan

Routine maintenance is the regular on-going work that is necessary to keep assets operating, including instances where portions of the asset fail and need immediate repair to make the asset operational again.

5.3.1 Maintenance plan

Maintenance includes reactive, planned and cyclic maintenance work activities.

Reactive maintenance is unplanned repair work carried out in response to service requests and management/supervisory directions.

Planned maintenance is repair work that is identified and managed through Council's Civil Maintenance Delivery Program (MDP). MDP activities include inspection, assessing the condition against failure/breakdown experience, prioritising, scheduling, actioning the work and reporting what was done to develop a maintenance history and improve maintenance and service delivery performance.

Cyclic maintenance is the replacement of higher value components/sub-components of assets that is undertaken on a regular cycle including the cleaning of GPTs and desilting of outlet pipes from WSUD devices. This work generally falls in the maintenance expenditure.

Maintenance expenditure trends are shown in Table 5.3.1

Table 5.3.1. Maintenance Expenditure Trends

Year	**Maintenance Expenditure**		
	Reactive	**Planned**	**Cyclic**
2005/06	$300,000	$200,000	$100,000
2006/07	$200,000	$240,000	$60,000
2007/08	$100,000	$240,000	$186,300
2008/09	$100,000	$240,000	$192,500

Planned maintenance work has increased and will continue to increase in the next financial year due to the implementation of the Civil Maintenance Delivery Program and the implementation of this Asset Management Plan.

Maintenance expenditure levels are considered to be inadequate to meet required service levels. Future revision of this asset management plan will include linking required maintenance expenditures with required service levels.

Assessment and prioritisation of reactive maintenance is undertaken by Council staff using experience and judgement.

5.3.2 Standards and specifications

Maintenance work is carried out in accordance with the following Standards and Specifications.

Relevant Australian Standards for construction eg. Pipe Systems.

Maitland City Council Manual of Engineering Standards

5.3.3 Summary of future maintenance expenditures

Future maintenance expenditure is forecast as below. Note that all costs are shown in current 2009/10 dollar values.

A cost per year of $154,500 for WSUD devices and up to $495,500 for other drainage types was derived from the cyclic and planned maintenance of WSUD devices, and the trend for cost of reactive and planned work of pit and pipe systems throughout the LGA in previous years. This will require a total maintenance budget of $650,000 per annum.

Deferred maintenance, ie works that are identified for maintenance and unable to be funded are to be included in the risk assessment process in the infrastructure risk management plan. The prioritisation of drainage maintenance works can mean that some jobs are delayed according to Council's risk management plan, however the ideal amount to spend of maintenance works is above. Spending money of maintenance can mean that deterioration of assets is slowed or delayed and therefore capital works are reduced.

Maintenance is funded from Council's operating budget and grants where available. This is further discussed in Section 6.2.

5.4 Renewal/Replacement Plan

Renewal expenditure is major work which does not increase the asset's design capacity but restores, rehabilitates, replaces or renews an existing asset to its original service potential. Work over and above restoring an asset to original service potential is upgrade/expansion or new works expenditure.

5.4.1 Renewal plan

Assets requiring renewal are identified from estimates of remaining life obtained from the asset register worksheets on the *'Planned Expenditure template'*. Candidate proposals are inspected to verify accuracy of remaining life estimate and to develop a preliminary renewal estimate. Verified proposals are ranked by priority and available funds and scheduled in future works programmes. The priority ranking criteria is detailed in Table 5.4.1.

Table 5.4.1 Renewal Priority Ranking Criteria

Criteria	**Weighting**
Fit for purpose – water volumes	25%
Safety	50%
Maintenance requirements	15%
Environmental impact	10%
Total	100%

Renewal will be undertaken using 'low-cost' renewal methods where practical. The aim of 'low-cost' renewals is to restore the service potential or future economic benefits of the asset by renewing the assets at a cost less than replacement cost.

5.4.2 Renewal standards

Renewal work is carried out in carried out in accordance with a number of Standards and Specifications, and MCC Manual of Engineering Standards.

5.4.3 Summary of future renewal expenditure

Projected future renewal expenditures are forecast to increase over time as the asset stock ages. The costs however are interlinked with capital replacement and maintenance. For WSUD devices, renewal is interlinked with maintenance as the renewal of a pond is the cleaning and dredging of silt and sediment. For pit and pipe systems, renewal is either maintenance as with repair of pipe slippage or capital as with replacement of sections of broken pipe. Therefore, the costs are shown above in maintenance expenditure and below with capital expenditure. Overall, renewal is expected to be approximately 40% of overall maintenance and capital costs, based on the upgrade needs for areas below standard as identified earlier.

5.5 Creation/Acquisition/Upgrade Plan

New works are those works that create a new asset that did not previously exist, or works which upgrade or improve an existing asset beyond its existing capacity. They may result from growth, social or environmental needs. Assets may also be acquired at no cost to the Council from land development. These assets from growth are considered in Section 4.4.

5.5.1 Selection criteria

New assets and upgrade/expansion of existing assets are identified from various sources such as councillor or community requests, proposals identified by strategic plans or partnerships with other organisations. Candidate proposals are inspected to verify need and to develop a preliminary renewal estimate. Verified proposals are ranked by priority and available funds and scheduled in future works programmes. The priority ranking criteria is detailed below.

Table 5.5.1 New Assets Priority Ranking Criteria

Criteria	Weighting
Development Requirements / Contributions	50%
Age	25%
Condition	25%

5.5.2 Standards and specifications

Standards and specifications for new assets and for upgrade/expansion of existing assets are the same as those for renewal shown in Section 5.4.2.

5.6 Disposal Plan

Disposal includes any activity associated with disposal of a decommissioned asset including sale, demolition or relocation. There are currently no assets identified for possible decommissioning and disposal.

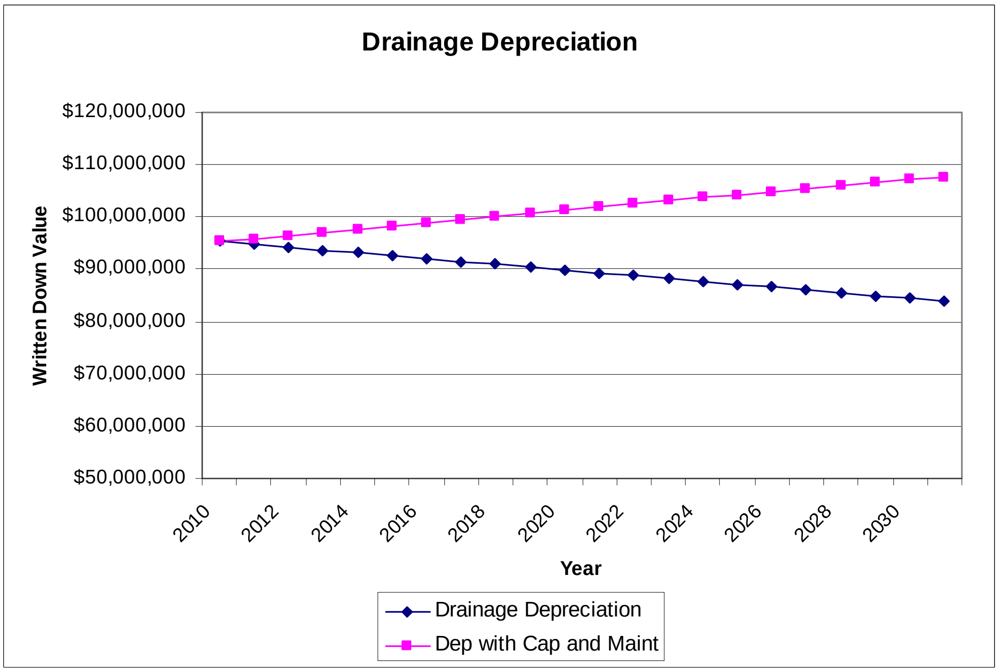
6. FINANCIAL SUMMARY

This section contains the financial requirements resulting from all the information presented in the previous sections of this asset management plan. The financial projections will be improved as further information becomes available on desired levels of service and current and projected future asset performance.

6.1 Financial Statements and Projections

The financial projections are shown in Fig 4 for planned operating (operations and maintenance) and capital expenditure (renewal and upgrade/expansion/new assets).

Fig 4. Planned Operating and Capital Expenditure



Note that all costs are shown in current 2010/11 dollar values.

6.1.1 Sustainability of service delivery

There are two key indicators for financial sustainability that have been considered in the analysis of the services provided by this asset category, these being long term life cycle costs and medium term costs over the 15 year financial planning period.

Medium term – 15 year financial planning period

This asset management plan identifies the estimated maintenance and capital expenditures required to provide an agreed level of service to the community over a 15 year period for input into a 15 year financial plan and funding plan to provide the service in a sustainable manner. See figure 5 for a financial outlook.

Fig 5. Projected Budget 15years in 2010/11 dollar values

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Capital	$450,000	$463,500	$515,000	$515,000	$515,000	$515,000	$515,000	$515,000	$515,000	$515,000	$515,000	$515,000	$515,000	$515,000	$515,000
Maintenance	$618,000	$618,000	$618,000	$618,000	$618,000	$618,000	$618,000	$618,000	$618,000	$618,000	$618,000	$618,000	$618,000	$618,000	$618,000
TOTAL	$1,068,000	$1,081,000	$1,133,000	$1,133,000	$1,133,000	$1,133,000	$1,133,000	$1,133,000	$1,133,000	$1,133,000	$1,133,000	$1,133,000	$1,133,000	$1,133,000	$1,133,000

Council's long term financial plan covers a 25 year planning period, as shown in the figure above. The total maintenance and capital renewal expenditure required over the 25 years is expected to bring the assets, both WSUD and conventional pit and pipe systems close to the renewal cost of these assets.

This is an average expenditure of between $0.9M and $1.1M per year of maintenance and capital combined.

6.2 Key Assumptions made in Financial Forecasts

This section details the key assumptions made in presenting the information contained in this asset management plan and in preparing forecasts of required operating and capital expenditure and asset values, depreciation expense and carrying amount estimates. It is presented to enable readers to gain an understanding of the levels of confidence in the data behind the financial forecasts.

Key assumptions made in this asset management plan are:

- Useful life of static structures such as GPTs, pits and pipes are up to 200 years
- Useful life of systems such as detention basins are between 100 and 200 years

Accuracy of future financial forecasts may be improved in future revisions of this asset management plan by the following actions.

- Undertaking an inventory and in-depth cost analysis of floodgates
- Undertaking and including an open channel inventory and cost analysis

7. PLAN IMPROVEMENT AND MONITORING

7.1 Performance Measures

The effectiveness of the asset management plan can be measured in the following ways:

- The degree to which the required cashflows identified in this asset management plan are incorporated into council's long term financial plan and Strategic Management Plan;
- The degree to which 1-5 year detailed works programs, budgets, business plans and organisational structures take into account the 'global' works program trends provided by the asset management plan;

7.2 Improvement Plan

The asset management improvement plan generated from this asset management plan is shown in Table 7.2.

Table 7.2 Improvement Plan

Task No	Task	Responsibility	Resources Required	Timeline
1.	Floodgate inventory and cost analysis.	Assets and CWS		11/12
2.	Open Channel inventory and cost analysis.	Assets		11/12

7.3 Monitoring and Review Procedures

This asset management plan will be reviewed during annual budget preparation and amended to recognise any changes in service levels and/or resources available to provide those services as a result of the budget decision process.

The Plan has a life of 4 years and is due for revision and updating within 2 years of each Council election.

REFERENCES

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APPENDICES

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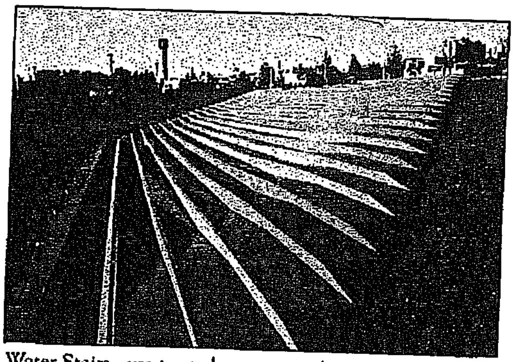
DRAINAGE SUMMARY

		Replacement Value	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Headwalls	660	$587,400	$486,625	$483,688	$480,751	$477,814	$474,877	$471,940	$469,003	$466,066	$463,129	$460,192
Pipes	280.8km	$69,476,459	$59,189,111	$58,841,729	$58,494,347	$58,146,964	$57,799,582	$57,452,200	$57,104,818	$56,757,435	$56,410,053	$56,062,671
Pits	11355	$14,517,690	$12,402,284	$12,329,696	$12,257,107	$12,184,519	$12,111,930	$12,039,342	$11,966,753	$11,894,165	$11,821,576	$11,748,988
GPTs	50	$4,998,800	$4,767,802	$4,742,808	$4,717,814	$4,692,820	$4,667,826	$4,642,832	$4,617,838	$4,592,844	$4,567,850	$4,542,856
Ponds	71	$19,186,831	$18,441,748	$18,345,813	$18,249,879	$18,153,945	$18,058,011	$17,962,077	$17,866,143	$17,770,209	$17,674,274	$17,578,340
TOTAL		**$108,767,180**	**$95,287,570**	**$94,743,734**	**$94,199,898**	**$93,656,062**	**$93,112,226**	**$92,568,390**	**$92,024,554**	**$91,480,718**	**$90,936,883**	**$90,393,047**

2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
$457,255	$454,318	$451,381	$448,444	$445,507	$442,570	$439,633	$436,696	$433,759	$430,822	$427,885	$424,948
$55,715,288	$55,367,906	$55,020,524	$54,673,142	$54,325,759	$53,978,377	$53,630,995	$53,283,612	$52,936,230	$52,588,848	$52,241,465	$51,894,083
$11,676,399	$11,603,811	$11,531,223	$11,458,634	$11,386,046	$11,313,457	$11,240,869	$11,168,280	$11,095,692	$11,023,103	$10,950,515	$10,877,927
$4,517,862	$4,492,868	$4,467,874	$4,442,880	$4,417,886	$4,392,892	$4,367,898	$4,342,904	$4,317,910	$4,292,916	$4,267,922	$4,242,928
$17,482,406	$17,386,472	$17,290,538	$17,194,604	$17,098,669	$17,002,735	$16,906,801	$16,810,867	$16,714,933	$16,618,999	$16,523,065	$16,427,130
$89,849,211	**$89,305,375**	**$88,761,539**	**$88,217,703**	**$87,673,867**	**$87,130,031**	**$86,586,195**	**$86,042,359**	**$85,498,524**	**$84,954,688**	**$84,410,852**	**$83,867,016**

Waterfall

Journal of the Stormwater Industry Association



Water Stairs - use treated stormwater from precinct wetland to provide "cascading water feature". WSUD, Taking it to the Streets - Malcolm Eadie reports. Page 26

Deterioration, Depreciation & Serviceability of Stormwater Pipes

By understanding the way stormwater pipes deteriorate in the field and the service hydraulic capacity reductions due to external factors, it changes the way we should be depreciating the pipe assets. The Markov model analysis by Peter Coombes, Tom Micevski & George Kuczera of the University of Newcastle provides a new insight into how Local Government Asset Managers should reassess depreciation rates to improve financial accounting & free up capital for new works.

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Deterioration, Depreciation and Serviceability of Stormwater Pipes

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Introduction

Stormwater pipes are provided to convey stormwater from streets and adjoining properties without nuisance from storm events of a given frequency as defined by average recurrence interval (ARI) (Institution of Engineers, 1987). The high costs associated with the installation and maintenance of stormwater pipe networks, as with other forms of buried infrastructure, demand that an accurate evaluation of their structural condition and the level of service provided by the pipes is essential for their effective management. This provides the motivation for this study, which models the deterioration of stormwater pipes as a Markov process and then discusses the serviceability provided by stormwater pipes. A detailed description of this study is provided by Micevski et al. (2002).

Furthermore, current Australian accounting standards (AASs), namely AAS27 (AARF, 1996), require that Local Government prepare annual financial statements. These statements must include, amongst other things, the depreciated amount for the stormwater pipes that are under their control. AAS27 calls upon AAS4 (AARF, 1997), which describes various depreciation methods. Both accounting standards rely on the Local Government Asset Accounting Manual (LGAAM; DLGC, 1995) to define the depreciation method. The LGAAM does not give a useful life for stormwater pipes; however, useful lives for sewerage and water supply pipes are provided. These useful lives are 80 years for water mains, while sewerage pipes range from 40-70 years.

The currently accepted industry practice is to use linear depreciation over a useful life of either 70 or 100 years for stormwater pipes. A more rational approach to assessing depreciation is to base it on structural deterioration.

The structural condition, and hence structural deterioration, of stormwater pipes is estimated through the use of condition ratings. The condition ratings take the form of five discrete states. These states are selected for consistency with the condition ratings specified within the LGAAM. State 1 represents a pipe in a near new condition, while state 5 represents a pipe in an unserviceable, i.e. failed, condition. These states are described in Table 1.

Review of the literature revealed that Markov models for infrastructure deterioration are quite common, with road bridges being a frequent candidate for analysis. For example, Cesare et al. (1992) estimated the Markov transition probabilities for various bridge types and bridge components using non-linear programming methods.

Structural Condition	Physical Description
1	Near perfect condition
2	Some superficial deterioration
3	Serious deterioration, requiring substantial maintenance
4	Level of deterioration affects the fabric of the asset, requiring major reconstruction or refurbishment
5	Level of deterioration is such to render the asset unserviceable

Table 1: Description of structural condition states (DLGC, 1995)

Some deterioration models for sewer pipe networks have been developed. Røstum et al. (1999) modelled the deterioration of Norwegian sewer pipes using a cohort survival model based on the Herz (1996) distribution. Mailhot et al. (2000) estimated the structural deterioration of a Canadian sewer network using a Weibull distribution model. Wirahadikusumah et al. (2001) modelled the deterioration of American combined sewer pipes using a Markov model calibrated to an exponential regression curve. However, the deterioration processes affecting sewer and stormwater pipes are considered to be different. Sewer pipes are subject to internal attack by acids associated with sewage, whereas stormwater is relatively clean, resulting in pipe damage being caused primarily by external factors.

No deterioration models for stormwater pipe networks were found within the literature. However, it is noted that Jacobs et al. (1993) used chance constrained multi-objective programming to optimally schedule the rehabilitation of a stormwater drainage network. Their model assumes that pipes deteriorate linearly with time and aims to minimise the total expected costs from rehabilitation and expected losses from wear out and flooding.

The principal contribution of this study is the application of a multi-state Markov model to simulate the structural deterioration of stormwater pipes. Bayesian methods are used to calibrate the model and statistical hypothesis tests are used to validate the suitability of the model.

The organisation of the paper is as follows. The next section provides a brief overview of the case study involving data from the stormwater network located in Newcastle, NSW. The Markov model is introduced and the procedures used to calibrate and validate the Markov model, as well as the theory associated with these procedures are discussed. The results of the case study then follow. Finally, the results from laboratory studies of serviceability of stormwater pipes are presented along with a discussion of results.

Case Study Description

Data Source

The data set used in the case study was obtained from the Newcastle City Council (NCC) stormwater asset database. The data set consisted of a total of 497 pipes. Information recorded for each pipe included asset identification, condition rating, survey, and other general pipe information. All pipes were situated within road reservations, and so were subject to traffic loadings.

The total length of pipes within the database is 17 km, whilst the length of the entire NCC stormwater network is 380 km - providing a sample size of approx. 4.5%.

The pipes ranged in age from 3 to 110 years, with approximately 60% of pipes being contained within the 51 and 56 year age groups. In accordance with industry practice and accounting standards, NCC uses linear depreciation over a useful life of 70 years. The replacement value of the network was estimated, in 1997, to be approx. $145 million.

Condition Evaluation Procedure

The structural and serviceability condition ratings of the stormwater pipes were assessed using the SEWRAT computer program, which is a component of the evaluation system contained within the Australian Conduit Condition Evaluation Manual (Water Board, 1991). SEWRAT provides a condition rating based on the number and severity of defects affecting a pipe. Defects are assessed using closed circuit television (CCTV) surveys of a pipe. When a defect is encountered, a score is allocated based on the type and severity of the defect. On completion of the survey, SEWRAT then calculates three scores. These being the peak (maximum total score for a single metre length), mean (total score divided by the total length), and average (total score divided by the number of defects) scores.

The pipe is then graded according to threshold values of the peak, mean, and average scores, with the worst grading of the three being used. SEWRAT uses a three state grading system. This is unsuitable for Local Government requirements, which requires a five state system in accordance with Table 1. Coombes (1997) found state 5 to be redundant for stormwater pipes. State 5 represents a pipe that cannot convey water. This is not observed in the field, where even extremely structurally damaged stormwater pipes can still convey stormwater effectively (see Figure 1). Thus, a four state grading system was adopted using the first four structural condition states described in Table 1. The data was classified using this four state system.

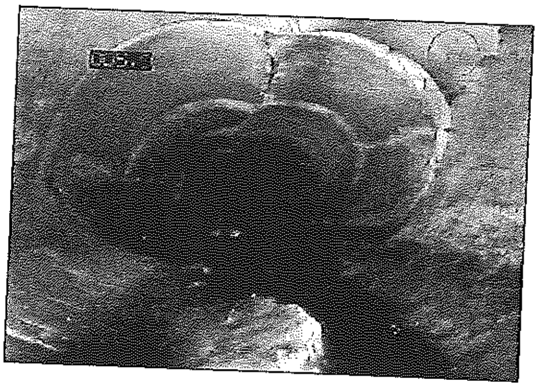

Figure 1: Extremely damaged pipe that still conveys stormwater effectively

Pipe Categories

The data set was classified according to the pipe categories preser within the data set. These pipe categories were then sub-classifie into their constituent values. Table 2 summarises the categorie used within this study.

Analysis / Category	Data Set / Category Value (Number of Samples)
Entire Data Set	Entire Data Set (497)
Split Sample	split1 (249), split2 (248)
Diameter	d<600 (376), d≥(600 (121)
Material	conc (342), VC (135)
Soil Type	all (296), pod (201)
Exposure	A2 (216), B2 (238), C (43)
Serviceability	s1 (191), s2 (88), s3 (101)

Table 2: Categorisation of stormwater pipe data

The entire data set was randomly split into two separate data sets, labelled as split1 and split2, for use within the split sample analyses.

Pipe diameter was separated into two categories values representing small and large pipes. Small pipes (d<600) have diameters of less than 600 mm while large pipes (d≥(600) have diameters of 600 mm or greater. The distinction at 600 mm ensured that a sufficient number of pipes were available to permit a reliable investigation into the effects of pipe size.

The two major pipe construction materials, concrete (conc) and vitreous clay (VC), were used. There were some other materials present within the data set; however, these contained insufficient numbers to justify analysis.

Two major soil types, alluvial (all) and podzolic (pod), were used. The alluvial soil consisted of Fullerton alluvial soil only. The podzolic soil is a collection of three separate soil types, those being Duckhole podzol, grey brown podzolic, and Thornton brown podzol soils. The combination into a single grouping is acceptable because these soils are similar - all have been formed through the weathering of similar parent rock.

The exposure classifications - A2, B2, and C - were derived from the AS3600 (Standards Australia, 1994) exposure classifications, and are summarised in Table 3. The AS3600 exposure classification system is intended for concrete members, and was considered appropriate for use here because over two thirds of the pipes are concrete.

Classification	Description
A1	Pipes more than 1 km from the coastline
B2	Pipes within 1 km from the coastline
C	Pipes within 1 km from the coastline and within tidal zones

Table 3: Modified AS3600 classifications

The serviceability ratings - serviceability conditions 1, 2, and 3 (s1, s2, and s3 respectively) - were obtained directly from SEWRAT surveys of the pipes. The serviceability condition provides a measure of the severity of the defects that affect the hydraulic performance of a pipe. Serviceability conditions 1 and 3 respectively represent the pipes that are the least and most affected by serviceability defects.

Markov Model

The Markov model describes a stochastic process where the probability of jumping into a state at time t+1 only depends upon the state previously occupied at time t. The transition probability matrix P describes the probability of changing states within each time interval. The P matrix used in this study is based on the four state model previously described in Table 1. Hence:

$$\mathbf{P} = \begin{bmatrix} P = 1-(P_{12}+P_{13}+P_{14}) & P_{12} & P_{13} & P_{14} \\ 0 & 1-(P_{23}+P_{24}) & P_{23} & P_{24} \\ 0 & 0 & 1-P_{34} & P_{34} \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (1)$$

where P_{ij} is the transition probability from state i in year t to state j in year t+1. Note that $P_{ij} = 0$ for $i > j$. This imposes the constraint that pipes cannot improve in condition. Also, $P_{44} = 1$ because state 4 is the worst possible state. State 4 is known as an absorbing state, that is, once entered it cannot be left. It is further noted that P_{ij} are independent of pipe age - representing a homogeneous Markov model.

The probability of being in state j, in year t+1, can be determined through the application of the total probability theorem:

$$p_i^{t+1} = \sum_{i=1}^{j} P_{ij} x p_i^{t} \qquad (2)$$

where p_i^t is the probability of being in state i in year t.

The Markov model provides a conceptually sound model for the deterioration process. The Herz and Weibull models, as used in sewer deterioration models, were considered inappropriate models for stormwater deterioration. These models assume that a pipe can be in one of two possible states - either a functioning or a failed state (Hoyland and Rausand, 1994, p. 214). However, when a pipe fails, we only know that it has left its current state - we do not know which state it has then entered. In some circumstances it may be reasonable to assume, upon failure, that the pipe progresses to the next worst state; although, this does not seem appropriate for stormwater pipes because the structural condition of a stormwater pipe does not necessarily deteriorate gradually. Gradual deterioration is more likely to occur for the serviceability condition, due to the progressive build up of sediment and debris, and through increased root intrusions. The structural condition is most likely to deteriorate through a damage event, such as an earthquake, an overladen truck, or through mine subsidence. Hence, the Herz and Weibull models are not appropriate - a pipe may deteriorate into the next worst state, or may skip one or more states in accordance with the severity of the damage event. These multi-state transitions are permissible within the Markov model.

Model Calibration and Validation

Micevski et al. (2002) describe in detail the calibration of the Markov model to the data set, and the procedures used to verify that the Markov model is consistent with the deterioration process. Briefly the calibration was undertaken using a Bayesian analysis. The objective was to infer the posterior distribution of the parameters which describes all that is known about the parameters given the data. The Metropolis-Hastings (M-H) algorithm was used to evaluate the posterior distribution.

Hypothesis testing allows one to establish whether the proposed probability model is consistent with a set of observations. Within this analysis, there were two separate hypotheses to be tested. The first hypothesis to be tested was that the observations are distributed according to the (hypothesised) Markov model. This assesses whether the Markov model is appropriate for stormwater pipe deterioration. This testing is performed using the entire data set and through split sample analyses. Note that the split sample analysis is a more rigorous test because it uses data independent of that used in the model calibration.

The second hypothesis to be tested is that pipes having different category values deteriorate according to the same Markov model. This test affords an understanding as to whether the pipe category value has an influence on the deterioration process. It is noted that these are split sample tests because the data, contained within each set of category values analysed, are independent of each other.

The hypothesis testing procedure used was the Chi squared (X^2) test based on the Pearson X^2 statistic:

$$X^2 = \sum_i \frac{(O_i - E_i)^2}{E_i} \qquad (2)$$

where O_i and E_i are respectively the observed and expected number of pipes in group i, where a group refers to the pipes with a particular condition rating at a particular observed age. Micevski et al. (2002) describe the rules for grouping the data to ensure that the X^2 statistic approximates the X^2 distribution accurately.

Verification of Markov Model Assumption

The verification that the data are distributed according to the Markov model was performed in two ways - using the entire data set and through the split sample analyses (split1/split2 and split2/split1). An explanation of the doublet notation (data 1/data 2) is required. Data 1 refers to the data set to which the parameters have been calibrated (using the M-H algorithm), whereas data 2 is used to test the model hypothesis (using the X^2 test). That is, the transition probabilities are estimated using data 1, and then the model is compared with the observations contained within data 2.

The resultant transition probabilities and the X^2 test results are detailed in Tables 4 and 5 respectively. The split sample tests suggest that the Markov model is consistent with the data (at the 5% significance level). Thus, the Markov model is an appropriate model for stormwater pipe deterioration.

Transition	Analysis Entire Data Set	 Split1/Split2	 Split2/Split1
1 to 2	0.0101	0.0087	0.0071
1 to 3	0.0016	0.0004	0.0039
1 to 4	0.0002	0.0007	0.0004
2 to 3	0.0021	0.0161	0.0005
2 to 4	0.0542	0.0219	0.0237
3 to 4	0.0009	0.0012	0.0048

Table 4: Expected posterior transition probabilities (model verification)

Analysis	X^2	df*	$X^2_{(0.05,df)}$
Entire Data Set	36.155	27	40.112
Split1/split2	26.155	16	26.295
Split2/split1	27.385	19	30.143

*df = Degrees of freedom

Table 5: Statistical analysis results (model verification)

It is important to appreciate that considerable parameter uncertainty exists. This uncertainty arises from limited sample data and can be displayed using posterior histograms of the transition probabilities produced by the M-H algorithm - Figure 2 presents histograms obtained for the entire data set analysis. Note that the vertical lines indicate the mean values of each parameter. The mean values of the transition probabilities pass near the peak values of the histograms, except for P_{13}. This is a result of the secondary peak near zero, which slightly skews the mean value towards this peak.

Category Analysis

The various pipe categories were analysed for category value differences, and the results of the X^2 tests are summarised within Table 6. Four of the five pipe categories analysed (diameter, construction material, soil type, and exposure classification) rejected the null hypothesis. This indicates that the Markov models for the category values, contained within each of these pipe categories, are statistically different - implying that the deterioration process is different for each of these category values.

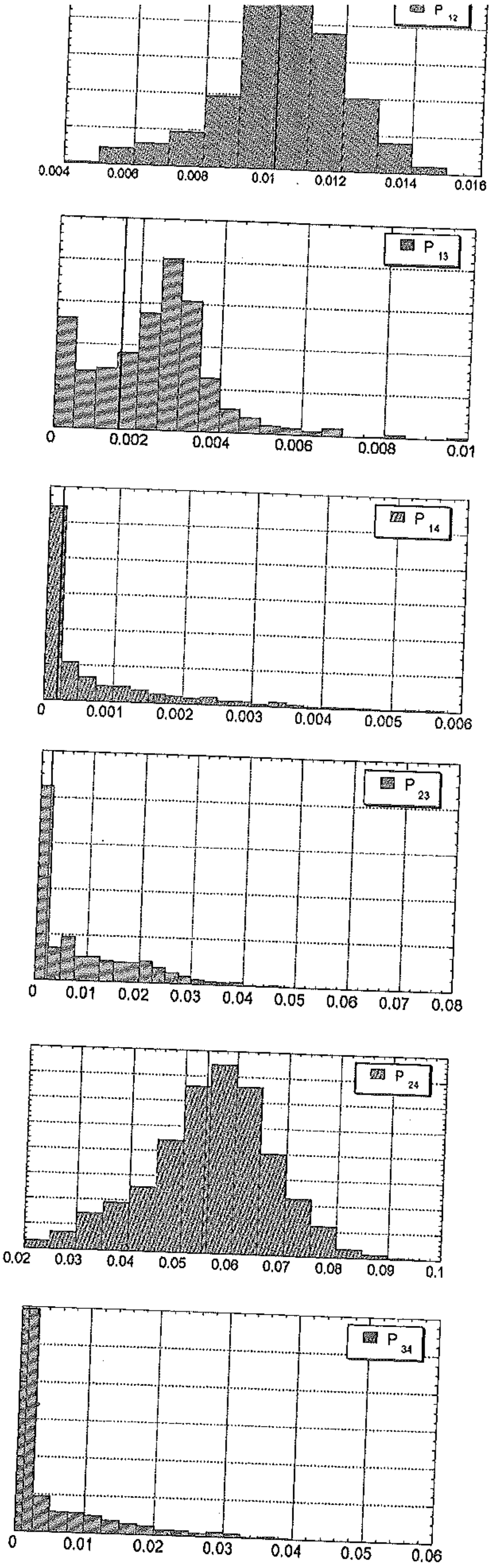

Figure 2: Histograms of transition probabilities (entire data set).

Analysis	X^2	df*	$X^2_{(0.05,df)}$
d<600/d≥600	32.557	8	15.507
d≥600/d<600	64.965	21	32.6701
conc/VC	117.551	4	9.487
VC/conc	370.271	30	43.772
all/pod	30.480	18	28.868
pod/all	44.009	10	18.306
A2/B2	57.640	7	14.067
B2/A2	55.687	18	28.868
s1/s2	7.280	4	9.487
s1/s3	4.378	5	11.070

*df = Degrees of freedom

Table 6: Statistical analysis results (category analysis)

Pipe diameter was found to affect deterioration. The deterioration of smaller pipes was greater than that of larger pipes. A possible explanation for this is that pipe designers are underestimating the traffic loadings or the cover requirements for these smaller pipes, resulting in increased pipe damage for smaller pipes.

Pipe construction material affects deterioration. The results show that concrete pipes are stronger and more durable than vitreous clay pipes, as one would expect.

Soil type was found to affect deterioration. Pipes in alluvial soils deteriorate more rapidly than those in podzolic soils. This might be a result of the different formational environments of the soils. The podzolic soils are formed through the weathering of rocks, whilst the alluvial soils are deposited from a saline environment. Also, the alluvial soils are much more likely to be acid sulphate soils (Fityus, 2001, pers. comm.). These factors may increase the rate of deterioration due to the increased salt (chloride) content accelerating corrosion within the predominantly concrete pipes, and also through the sulphuric acids, formed by the acid sulphate soils, attacking the pipes.

The exposure classification influences deterioration. It should be noted that no statistical comparisons using the category value C were possible, due to insufficient data being available for use in the X^2 test. Nonetheless, an effect was still obvious with B2 pipes deteriorating at a faster rate than A2 pipes. This effect might result from B2 pipes being located near the coastline (see Table 3). This could increase the rate of corrosion, and thus deterioration, of the predominantly concrete pipes due to the increased salt (chloride) content.

The serviceability condition did not affect deterioration. The serviceability condition is based on defects that affect the hydraulic, not structural, performance of a pipe. Thus, it is not unexpected that no influence on structural deterioration was detected. The reason for the model only being calibrated to the data in serviceability condition 1 is that this category value contained almost twice the amount of data compared to the other two category values (serviceability conditions 2 and 3). Also, these two category values had the vast majority of the data clustered into the age groups of 51 and 56 years.

This difference in the deterioration rates, for the various category values, is illustrated within Figure 3, which gives the expected proportion of pipes in condition 4 as a function of age. The graph shows that the deterioration rates for the category values vary significantly, confirming the results obtained in Table 6.

Comparison to Accounting Standards

The depreciation curves derived to meet AAS27 requirements assuming useful lives of 70 and 100 years for stormwater pipes are significantly different to the deterioration curve estimated by the Markov model. This is illustrated in Figure 4, which shows that the AAS27 depreciation curves quite significantly overestimate the deterioration of stormwater pipes. This highlights the need to derive infrastructure deterioration models from observed performance, rather than notional performance. Assuming that the average age of stormwater pipes in a Local Government area is 60 years and the replacement value of the pipes is $145 million the impact on the Council's fiscal position is shown in Table 7.

Item	AAS27 (70 years)	AAS27 (100 years)	Markov
Average Structural condition at 60 years	4.5	3.5	2.5
Written down value	$20.8 M	$87 M	$108.8 M
Annual depreciation cost	$2.07 M	$1.45 M	$0.6 M

Table 7: Impact of different depreciation strategies on a Councils' fiscal position

As shown by the written down values in Table 7 the use of straight-line depreciation methods substantially under estimates the structural value of the stormwater pipe infrastructure. This dramatically increases the annual depreciation costs that the council will have to pay.

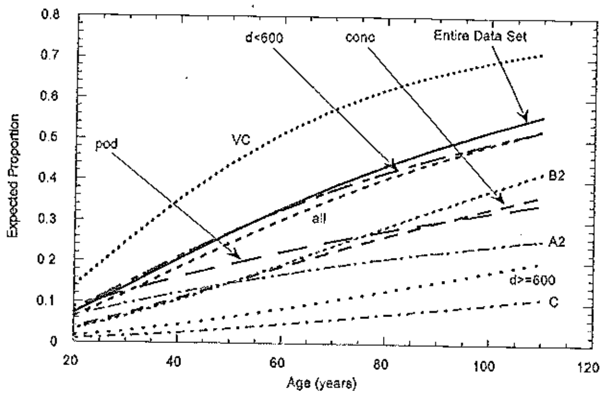

Figure 3: Comparison of Markov Model deterioration curves for structural condition 4.

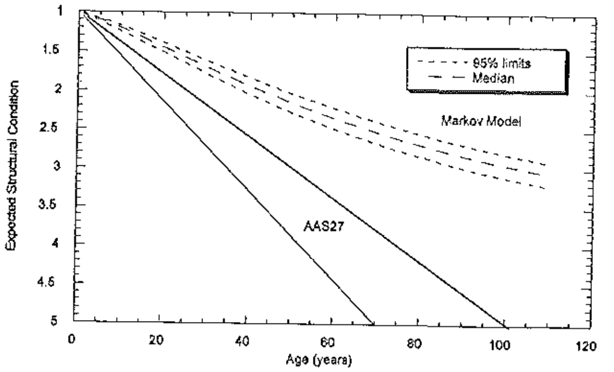

Figure 4: Comparison of AAS27 depreciation and Markov model curves.

Serviceability

Stormwater drainage systems are constructed to provide a service to the community. Stormwater pipes are provided to convey stormwater from streets and adjoining properties without nuisance. No structurally unserviceable pipes were found during the CCTV surveys although 35% of pipes in the NCC survey were found to be functioning in a badly damaged state (structural condition = 4). No relationship between the SEWRAT structural and serviceability ratings was found.

The serviceability condition is an indicator of the hydraulic performance provided by the pipe and thus should be an important factor in stormwater pipe network management. As the hydraulic performance of a pipe decreases, the number of pipe surcharges becomes more frequent due to the associated blockages and intrusions within the pipe. When these surcharges become too frequent, the pipe needs to be refurbished or replaced. This suggests that a combination of both structural and serviceability conditions should be considered when determining a stormwater pipe network management strategy.

An examination of the serviceability rating process from the Australian Conduit Condition Evaluation Manual (Water Board, 1991) revealed that the weighting of the serviceability rating is dominated by non-structural events such as intrusion into pipes by tree roots (Figure 5) or blockage by silt and debris (Figure 6).

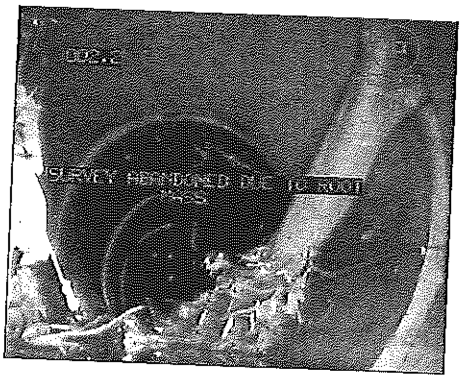

Figure 5: Intrusion into pipe by tree roots

Figure 6: Sedimentation of a stormwater pipe

Processes that partially block a stormwater pipe such as sedimentation, intrusion by tree roots and collection of debris will affect the hydraulic capacity of the pipe resulting in a reduced level of service. Inspection of the CCTV surveys revealed a number of common blockages in pipes including concrete debris, sedimentation, vertical displacement, tree roots and combinations of concrete debris, tree roots and sedimentation.

To assess the hydraulic capacity, and hence serviceability of stormwater pipes it is necessary to relate obstructions observed in the pipe to expected loss of serviceability. Obstructions to flows in a pipe will cause a head loss (h_L). Typically such a head loss is assumed to be proportional to the velocity head or the kinetic energy of the flow

$$(h_L) = K \frac{V^2}{2_g} \tag{4}$$

where V is average velocity in the pipe (V), g is the gravitation constant and K is a dimensionless coefficient. Depending on ho much the pipe is over-designed the increase in head lo associated with an obstruction may increase upstream water leve to cause surcharging from pits and a resultant loss of serviceabilit

Values of K for different types of obstruction can be estimate experimentally. Laboratory experiments were conducted by Da (2000) and Konetschnik (2001) using a 100 mm diameter pipe retrofitted with various types of obstructions, for variou discharges ranging between 0.008 m³/s to 0.017 m³/s. Thes experimental scenarios are shown in Figure 7 and described ir Table 8.

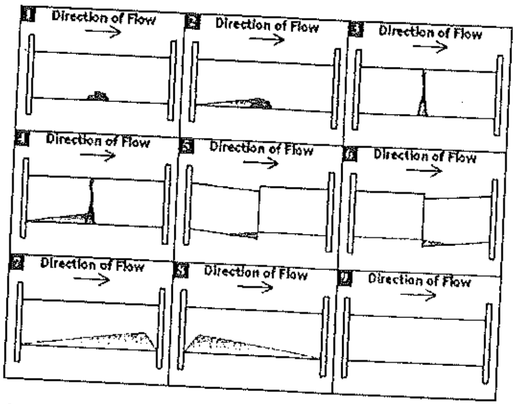

Figure 7: Longitudinal plans of the physical modelling scenarios.

The physical models of the pipes, including obstructions, are shown in Figure 8. Small pieces of concrete were glued to the bottom of the pipe to simulate a small-scale collapse in the pipe, a tree branch was glued in the pipe to simulate a blockage by a tree root, a pipe was split in two to simulate a vertical displacement and a build up of sediment in the pipe was simulated using resin.

Scenario	Obstruction
1	Concrete debris
2	Concrete debris & sediment
3	Tree root
4	Tree root & sediment
5	Vertical displacement
6	Vertical displacement reversed
7	Sediment
8	Sediment reversed
9	Control with no obstruction

Table 8: Description of the pipe obstruction scenarios tested in the laboratory

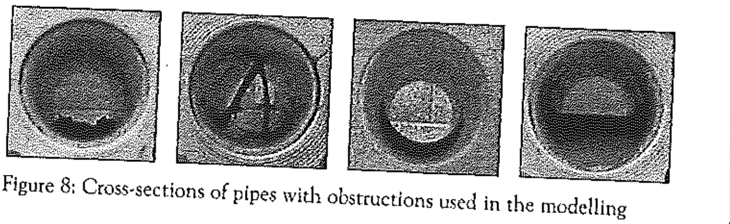

Figure 8: Cross-sections of pipes with obstructions used in the modelling

The experimental values for K are listed in Table 9. The results show that K is affected by both the area obstructed and the nature of the obstruction. For example, scenarios 4, 7 and 8 have similar obstructed areas but quite different K values. The tree root penetrates the whole cross section disturbing the whole flow field whereas the sediment presumably only disturbs the lower part of the flow field.

Scenario	Obstruction	Reduction in pipe area (%)	Experiment K
1	Concrete debris	18.7	0.099
2	Concrete debris & sediment	24.4	0.085
3	Tree root	34.1	0.172
4	Tree root & sediment	48.8	0.408
5	Vertical displacement	17.2	0.08
6	Vertical displacement reversed	16.6	0.079
7	Sediment	43.4	0.094
8	Sediment reversed	43.4	0.094

Table 9: Loss coefficients (K) for pipe obstruction scenarios.

The ability to estimate the value of K for different types of obstruction in pipes is important. The serviceability defects recorded during SEWRAT surveys in accordance with the Australian Conduit Condition Evaluation Manual identify the obstruction type, severity and location in pipes. If a reliable relationship between the serviceability rating from SEWRAT surveys and expected losses in pipes can be developed the opportunity exists to rationally assess the level of service provided by a pipe.

A complicating issue in assessing the level of service is network interaction. In flat networks obstructions can cause extensive upstream surcharging for the design storm. In contrast, in steep networks, surcharging may be very limited or even non-existent because pipes may be considerably overdesigned from a conveyance perspective. An exploratory analysis by Konetschnik (2001) of stormwater drainage systems in the Newcastle area using the WUFS rainfall/runoff model (Kuczera et al., 2000) demonstrated that obstructions in pipes operating close to their design capacity can increase the incidence of surcharges from nearby upstream drainage pits. Furthermore it was found that as the number of obstructions in pipes increased the adequacy of the network to cope with short duration high intensity storms decreased significantly.

The effect of obstructions is not spatially uniform. The asset manager needs to target those parts of the system where pipes are operating close to or at their design capacity during the design storm. understanding the hydraulics of the pipe network can produce considerable savings in asset monitoring because the problem locations can be apriori identified.

Conclusion

This study has presented a homogeneous Markov model for the structural deterioration of stormwater pipe infrastructure. The Markov model was shown, both conceptually and through statistical analyses, to be an appropriate model for stormwater pipe deterioration. Various pipe characteristics were found to influence the deterioration process. These were pipe diameter, construction material, soil type, and exposure classification, whilst the pipe serviceability condition was found to not affect the deterioration. The depreciation requirements of Australian accounting standards and the Department of Local Government were shown to significantly overestimate the actual deterioration of stormwater pipes.

Significantly, the level of service provided by a pipe is not necessarily related to the structural condition of the pipe. Stormwater drainage systems are constructed to provide a service to the community. Although structural condition ratings used in local government asset accounting provide a value for a stormwater asset there is no apparent relationship between the structural condition of the asset and the service it provides. Stormwater pipes have a value other than their structural value because they provide a service to the community. The question that needs to be asked is what is the value of the service?

We suggest that the level of service provided by the pipe depends on its position in the network and on factors diminishing its original hydraulic capacity such as intrusions by tree roots, sedimentation and collection of debris. The defects identified in serviceability ratings from SEWRAT surveys can be assigned loss coefficients. Use of such coefficients in a hydraulic model of the pipe network will enable an assessment of surcharge frequency and hence the serviceability of the pipe. It is suggested that a combination of both structural and serviceability conditions should be considered when determining a stormwater pipe network management strategy.

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[TM1] This discussion and the discussion for serviceability should go together. So I have moved this discussion further down in the document — so both discussions appear together.