WATER SYSTEM PLANNING GUIDELINE

Sydney WATER

Welcome to Sydney Water's Water System Planning Guideline (WSPG).

It replaces the planning section and other relevant parts from the WSAA Water Supply Code of Australia (SW Version) and similar purpose internal documents.

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Version 1 September 2014

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Section 0: Document control

Document control

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Water System Planning Guideline

Section 1: Introduction to the Guideline

Version 1

September 2014

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Section 1- Introduction to the guideline

1.1 Introduction

1.1.1 Purpose and aim

The purpose of the Water System Planning Guideline is to guide planners in the planning of water and recycled water systems.

The aim of the guideline is to provide a water supply system that meets Sydney Water's obligations under our Act, Operating Licence and Customer Contract for:

- water quality
- continuity of supply
- pressure
- a successful and efficient business.

1.1.2 Objectives and audience

The objectives of this document are to:

- facilitate efficient and consistent planning of water infrastructure within Sydney Water
- provide a consolidated guideline for planning work
- provide guidance on System Integrated Planning (integrating drivers such as growth, renewals and reliability)
- provide justifications for the adopted requirements and criteria
- include updated and new planning criteria from recent reviews.

The audience includes:

- internal planners
- external planners carrying out water planning work for, or on behalf of, Sydney Water.

1.1.3 Planners' responsibilities

In addition to applying the information and guidelines provided throughout this document, planners will be responsible to add value by:

- reviewing the function of assets to ensure they are fit for purpose
- continually searching for opportunities to improve the system, even if considered outside the original scope

- challenging criteria with the aim of improving performance or financial viability.

To further emphasise these responsibilities, the following is from the book, *Water Distribution Systems: Simulation and Sizing* **(Reference 30)**:

> *'During the work of running the model to determine pipe sizes, the engineer needs to reflect occasionally on how the project is meeting its goals. Is the project improving service to 100 customers at a cost of $10 million? Is the project such that it can be upsized or extended marginally to solve some other problem? Since the project was proposed, has another project been constructed that makes this project deferrable...*
>
> *In some instances, an engineer may identify a completely different type of solution than the one originally proposed at the beginning of the study.'*

The water system is continually improved by planners fulfilling their role and adding value. This, of course, makes it difficult to fully define a planning brief at the start of the project. This needs to be taken into account when estimating timeframes and budgets for planning projects.

1.2 Scope of the guideline

1.2.1 Scope

This document covers planning of drinking and recycled water network systems (delivery, distribution, reticulation).

It mainly focuses on planning for:

- infill or greenfield developments
- renewal of existing assets
- reliability
- system monitoring
- water quality and pressure management.

The scope covers major planning projects (eg Sydney-wide) all the way through to minor projects (eg renewal of small-sized mains). The planner needs to match the requirements of this guideline with the scale of the project, realising that many minor projects may not require much planning.

1.2.2 Omissions

It does not cover:

- planning for water treatment facilities, ie treatment processes. However, it recognises that the treatment plant is part of a total system
- planning for the total water cycle, ie incorporating wastewater and stormwater systems. However, it recognises that these other systems may form the source of supply for some water systems
- fire-fighting (Refer to **Clause 1.2.3** below)
- the detailed process of how to use the water modelling system (**Reference 55**)
- anything other than planning, such as detail design or operational activities.

1.2.3 Fire-fighting

The Sydney Water manual *Supply of Water for Fire-Fighting Purposes*, in Section 8.1 Legal, states that:

> 'There is no specific requirement placed on Sydney Water in the Act, the Operating Licence of the Customer Contract to make water available for fire-fighting purposes. However, there is a general obligation on Sydney Water to provide a water supply system not prone to failure and would meet the community needs, including fire-fight activities.'
>
> And:
>
> '…Sydney Water does not guarantee that water supplies for fire-fighting purposes will be available at all times and under all conditions.'

Therefore, Sydney Water does not assess fire-fighting demands when planning the water system. Sydney Water also does not specifically provide capacity for bushfire events. However, Sydney Water has developed rules regarding minimum pipe size requirements for new areas (Refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**) and plans for a reliable system.

Sydney Water (Liveable City Solutions - Urban Growth) also provides a pressure advisory report under an IPART-approved structured fee. The report will be useful in the design of domestic and fire services from Sydney Water mains. The relevant Australian Standards also recommend regular operational and maintenance regimes plus independent certification to be arranged by the owners.

The report considers the current system configuration, demands and level of development, plus additional customer advised demands. However, due to the rate at which development occurs, likelihood of mains renewals and possibilities of changes in demand, the report will be valid only for 12 months. Sydney Water also has the prerogative to make network changes that would improve operating performance and to perhaps beneficially re-allocate supply to service growth. Advised results cannot be used to indicate a permanent mains configuration or pressure condition.

1.3 Fit with other documents

1.3.1 History

The oldest document found on rules for water supply is *The Water and Sewerage of Sydney*, 1939, compiled by F.J.J Henry **(Reference 52)** who by that time had served 50 years at the Water Board. It advised that the basis of storage aimed at in Sydney is two maximum days' supply for each surface zone and one maximum day for elevated reservoirs.

The oldest existing planning document is the *Water Investigations Sub-Branch Staff Handbook, 1968* (**Reference 6**). It advised that the handbook was issued for the guidance of officers engaged in investigation work.

TIPS 5 (**Reference 5**) was introduced in 1986 and focused on planning for water pumping stations (WPS), rising main and reservoir components of a system, as well as how staging of these components would be managed. The major change of approach that was introduced in TIPS 5 was that both the reservoir and input system (WPS and rising main) should be considered as a total system with a combined capacity to maintain reserve storage at the end of any cycle of days of high demand. Before 1986, planning criteria had required both the reservoir and the input system to have a capacity equal to the ultimate maximum day demand of the water supply zone.

In 2002, various draft guideline documents were created, including the *Water network analysis and design manual'*, in four chapters. These were never finalised.

A *Design Criteria Guidelines Supplement* (**Reference 9**) was developed in 2010 to update information in the WSA Code 2002 (WSA-03-2002-2.2).

A booster guideline (**References 7 and 8**) was developed in 2004 and in 2010 to complement the new technology available for booster pumping stations. This document was merged into the *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.

1.3.2 Other planning documents and WSPG

This guideline merges:

- previous drafts of guideline documents
- the planning and other relevant sections from the Water *Supply Code of Australia, Sydney Water Edition* **(Reference 1)**. The remaining WSAA Code (Water) will be used for design and construction information

- *Technical Information Policy & Strategy TIPS 5* **(Reference 5)**. Most of the requirements from this document are shown in **Section 5: Infrastructure Planning.**
- *Design Criteria Guidelines Supplement* (**Reference 9**). Refer to *Design Demand Rates for Water Assets* (SAP) **(Reference 2)**.

The main documents now used for planning are:

- this guideline
- *Water and recycled water system growth servicing strategy (GSS) criteria and guidelines 2012* **(Reference 27)** for growth servicing strategic planning only. The GSS is not a detailed servicing strategy and as such, does not consider multiple options for optimisation to solve capacity issues. The GSS focuses on providing an insight into the long-term strategy based on the latest growth projections
- *Sustainability Planning Manual* **(Reference 18)**. This manual provides guidance for project teams and managers in interpreting and balancing relevant social, environmental, technical and financial considerations, in consultation with stakeholders.

Figure 1 shows information used for water system planning.

Not shown on the diagram is the recently developed procedure *Strategic Infrastructure Planning* **(Reference 57).** The procedure outlines a series of key activities to be followed and is applied to SAS staff and service providers who are part of a team that develops servicing or asset strategies.

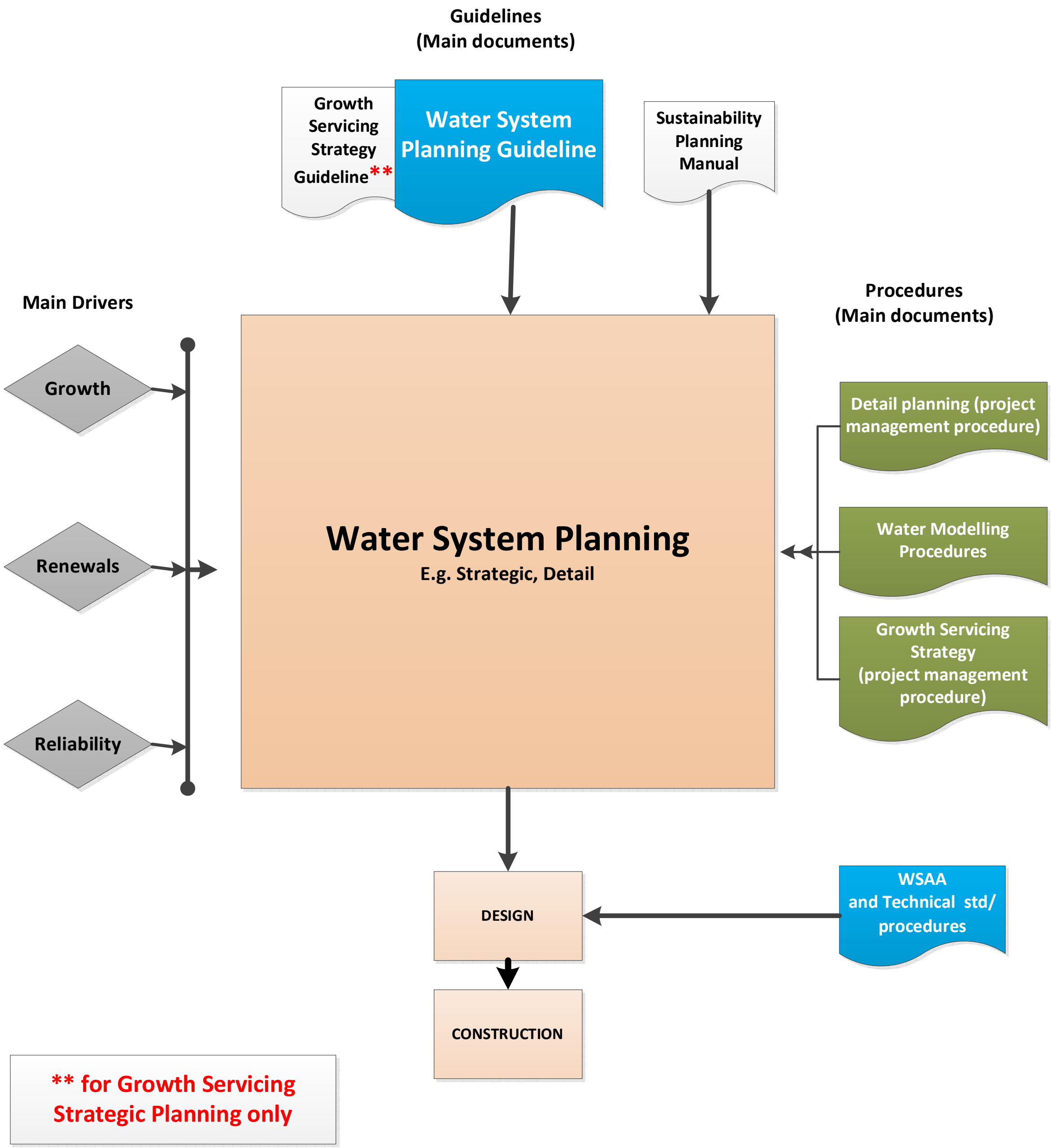

Figure 1 - 1Water planning information (Schematic)

Inconsistencies between any of these documents should be resolved or agreed by the relevant parties and, if appropriate, this guideline should then be updated.

1.3.3 Future

Possible future work may include merging this guideline with the *Water and recycled water system growth servicing strategy (GSS) criteria and guidelines 2012* **(Reference 27)**.

1.4 Drivers for change

The planning context has changed in the last few decades. **Table 1 - 1** shows the major drivers of the ideas and requirements in this guideline.

Table 1 - 1 Drivers for change

Game changers	Implications for planning
More infill growth compared to greenfield growth (infill growth is expected to be about 70%) Aging infrastructure. More renewals planning compared to the past	Need to develop better information on how to plan for and integrate all drivers, including growth, renewals and reliability. Existing areas are now subject to much more planning, where more and more mains eventually will require renewal. Any planning for growth areas needs to consider future renewals. Any planning for renewals needs to include the growth component (renewals may sometimes fully cater for future growth in the area). Opportunities arise to re-assess reliability in the system.
Many candidates for renewals have changed their function since they were built	A 'resizing/reconfiguration' requirement is generally required when planning in existing systems. In some cases, the function has changed so much that the candidate for renewal is no longer required.
Monitoring and controls are now much more sophisticated than a decade or more ago	Much better data (on pressures, flows etc) and controls now exist. The data helps better define the current system and enables a refined approach to driving the existing assets harder. Also, assets are more able to be controlled in real time (assists in emergencies).
Pressure changes	Sydney Water has introduced more than 180 pressure reducing valve (PRV) zones. These need to be taken into account when doing infill growth or renewal planning.
Demand management and other issues (for example industrial decline, the changing nature of development, etc) have reduced both maximum and average day demands since 2000 by about 20%.	Current baseline demands are lower than they were before 2003. It is possible that bounce-back of demands may occur. Therefore, monitoring of this issue is required as well as undertaking a sensitivity analysis when planning.
There are now better information and techniques for analysing risks	Concepts such as risk cost can be introduced into the planning process to assist in improving consistency when reviewing reliability.
Introduction of improved Water Modelling System	Better sizing of infrastructure and analysis for reliability is possible. Factors of safety can now be relaxed in some way given the level of detail in the models as well as accuracy of results (considerably greater connectivity). The information available (eg customer count) can now be used for better risk and economic evaluation.

1.5 Document structure

The guideline has been divided into five sections to facilitate the update, review and release process. The structure follows the planning process in principle, explained briefly in **Table 1 - 2**.

Table 1 - 2 WSPG structure and content

Number	Title	Content
Section 1	Introduction to the Guideline	The introduction to the document contains general planning objectives, scope with exclusions, changes in the planning context and a brief history of other planning documents. It also provides information on governance, roles and responsibilities, along with definitions and references.
Section 2	Water System Planning	This section provides detail on the different planning phases and integrates the drivers of growth, renewals and reliability into planning. It also provides water quality, monitoring and energy requirements for planning.
Section 3	Water Demand and Growth	This section provides guidance on how to consider system demands for growth and reliability planning. It also provides default demand rates.
Section 4	System Hydraulics (Pressure)	This section describes pressure requirements (drinking water and recycled water for existing and new systems). It also provides guidance on how to manage system pressure issues.
Section 5	Infrastructure Planning	This section provides information on system optimisation at the asset level. It incorporates TIPS 5, with additional information on reservoirs, pumps, water mains, valves etc.

1.6 Context

1.6.1 Definitions

The definitions listed below are complementary to the Glossary of Terms provided in the *Water Supply Code of Australia, Sydney Water Edition,* (**Reference 1**).

Term	Definition
Base model	A hydraulic model that describes a water system at a particular time including all infrastructure and operational controls as planned or designed.
BASIX	BASIX-the Building Sustainability Index, Ensure homes are designed to use less potable water and be responsible for less greenhouse gas emission by setting energy and water reduction targets for house and units.
BI Data	Extracted information from corporate data warehouse that contains IICATS historical data
Consequence cost	The cost of the impact or inconvenience. Consequence cost = cost ($/property/day) x days impacted (days) x number of properties.
Design pressure	Design pressure has a factor of safety added to the operating pressure. This is used in the design phase. Limiting pressures, both maximum and minimum, that the designer allows for in the design of a safe and suitable pipeline system. These pressures are used to determine: • A suitable pipe material to meet expected operating pressures for the duration of the system life • Structural requirements associated with the pipeline pressure • Pipes network arrangement to service customers in terms of elevation (acceptable range of residual pressures) and distance (acceptable minimum residual pressure after headlosses) For design pressure criteria refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1).**
Diurnal pressure variation	A daily variation in system pressure between periods of high and low water usage (normally between day and night, or between any high and low demand period) at any location.
Downtime	The mean time to repair.
Dual water supply system	Refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1).**
Failure rate	The number of failures each year.

Term	Definition
Flexibility	This is a design attribute that considers uncertainty. Flexible designs fall into three major categories: those that enable the system to change its size, those that enable changes in function or capability, and those that protect against particular failures or accidents **(Reference 50)**
Full supply level (FSL)	This is the level at the top of the operating storage.
Head	Pressure expressed in terms of the height of a column of water (in metres head). The head is a factor of 9.81 (nominally 10) lower than the equivalent value in kPa, eg 800 kPa = 80 m head.
Headloss	An indication of pressure loss in pipelines due to friction commonly expressed in metres
Hydraulic grade line (HGL)	Refer to *Water Supply Code of Australia, Sydney Water Edition (***Reference 1**). HGL = pipe level above the datum (metres) + pressure (metres). The datum is usually zero metres (AHD) Australian height datum (AHD).
Likelihood	Chance of something happening.
Main tap	The point of connection of the property to Sydney Water's water supply main.
Maintainability	This is a design attribute that reflects the ease, accuracy, safety, and economy of performing maintenance actions **(Reference 33)**
Maximum minute demand	Maximum demand that a system or part of a system is required to supply in any one minute of the year (also called peak minute demand). It is often expressed as a daily rate.
Mean Failure Rate	Mean Failure Rate is the average failure rate with which an element fails or an event occurs over a specific period of time.
Minimum minute demand	Minimum demand that a system or part of a system is required to supply in any one minute of the year. It is often expressed as a daily rate.
Minimum operating level (MOL)	This is the level at the top of the dead storage (or bottom of reserve storage). It is the lowest level in the reservoir that enables water to flow from the reservoir without air entrapment.
Net hectare	Gross hectare less areas occupied by reserves, parks and those set aside for special uses (includes roads)
Operability	This is a design attribute that considers the ease and success for operations staff to maintain the system within its performance requirements.

Term	Definition
Operationally adjusted RSL	Operationally adjusted RSL are set by certain constraints like- pressure limitations in the zone, water quality, reservoir structural integrity, the availability of alternative supply paths, reservoir is covering multiple supply zones etc. This is generally at a higher level than the required design RSL (based on demand).
Operating pressure	Refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.
Operating storage	This is part of the reservoir that is used for economical running of the input system, eg the water pumping station (WPS) and rising main. The reservoir normally cycles within this storage. Amount of storage provided to accommodate diurnal fluctuations in demand and to cater for demands exceeding the maximum allowable inflow rate and required to optimise running of the total system, eg the water treatment plant, water pumping stations, rising mains, distribution and transfer mains. The reservoir normally cycles within the operating storage range defined by the maximum upper window level and the minimum low window level under automatic IICATS control.
Pumped system	Refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.
Reliability	The extent of the system or component to perform its required functions under stated conditions for a specified period of time: • includes abnormal operation (that can be foreseen) • the 'stated conditions' or reliability levels are negotiated and defined with stakeholders (customers and regulators) • increased reliability can be provided by the inclusion of redundancy and operation flexibility • the consequence of a reliability failure can be reduced by things such as a reserve pump, additional valves etc. In relation to the overall robustness of the system, reliability can be seen as the probability of success
Resilience	The ability to recover from, or adjust easily, to rare or extreme events, or change: • Recovery from an extreme event with greater understanding/learning.
Reserve storage level (RSL)	Refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.
Reserve storage	Refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.
Reservoir capacity	This will be equal to the operating storage plus the reserve storage.
Reticulation main	Refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.

Term	Definition
Sensitivity analysis	The 10% demand sensitivity was derived from reviewing some delivery system maximum days that showed an average 5% difference year to year for the Water Wise period. At a zone level, this sensitivity is likely to be higher (some higher, some lower).
Service pressure	Refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.
Shutdown block analysis	An analysis that occurs when a section of water main/asset/facility between valves is isolated. It is for the purpose of measuring the consequence.
System	An integrated set of elements that accomplish a defined objective.
Supportability	This is a design attribute that considers the personnel, logistics and spares available to service maintenance activities.
Transfer main	Refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.
Trunk main/network	A combination (network) of larger diameter water mains (≥DN 375) necessary to ensure an adequate supply of water to, and within, reticulation networks (systems) and generally not available for connection. Refer to *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.
Water Wise Rules	Water Wise rules are simple common sense everyday actions to replace drought restrictions in Sydney, the Illawarra and the Blue Mountains. Water Wise commenced on 22 June 2009. They are: • Watering, including with sprinklers and irrigation systems, is allowed any day before 10 am and after 4 pm to avoid the heat of the day. • All hand-held hoses must have a trigger nozzle. • No hosing of hard surfaces such as paths and driveways. Washing vehicles is allowed. • Fire hoses may be used for fire-fighting activities only.

1.6.2 Abbreviations

Acronym	Definition
AC	Asbestos cement
ADD	Average day demand
ADWG	Australian Drinking Water Guidelines
AICV	Automatic inlet control valve
AVV	Anti-vacuum valve
BASIX	Building Sustainability Index
BEP	Best efficiency point
BI	Business intelligence
BI Data	Extracted information database from IICATS
BR	Break rate/s
BTS	Bureau of Transport Statistics
CBD	Central business district
CICL	Cast iron cement (mortar) lined
CV	Control valve
DCV	Delivery control valve
DDF	Daily demand factor
DICL	Ductile iron cement (mortar) lined
DP&E	The Department of Planning & Environment
DV	Dividing valve
ECC	Emergency Control Centre
EICV	Emergency Inlet Control Valve
FR	Failure rate
FSL	Full supply level (of a reservoir)
GSS	Growth servicing strategy
HGL	Hydraulic grade line
HYDRA	Sydney Water's geographical information system
I&C	Instrumentation and control

Acronym	Definition
IECV	Inlet emergency control valve
IICATS	Integrated Instrumentation, Control, Automation and Telemetry System
MDD	Maximum daily demand (that occurs during a given period)
MDP	Maximum demand period
MFF	Mean failure rate
MHD	Maximum hour demand
ML	Megalitre
ML/day	Megalitres per day
MMD	Maximum minute demand
MNF	Minimum night flow
MOL	Minimum operating level
MWD	Maximum week demand
NPSH	Net positive suction head
NPV	Net present value
NRW	Non-revenue Water
OASIS	Overflow Abatement Customer Information System. Mapinfo table containing property details including population projections
PRV	Pressure reducing valve
RSL	Reserve storage level
RTU	Remote terminal unit
RV	Reflux valve
SCADA	Supervisory Control and Data Acquisition
SOC	System Operations Centre
SP	Service pressure
SV	Stop valve, also sluice valve
TIPS	Technical Information Policy & Strategy; a series of SW's internal instructional documents
UBL	Unavoidable background leakage
UFW	Unaccounted for Water

Acronym	Definition
VSD	Variable speed drive
WFP	Water filtration plant
WMS	Water modelling system
WPS	Water pumping station
WSAA	Water Services Association of Australia Limited

1.6.3 Document control and governance

This guideline is an electronically controlled document and is subject to the AMQMS Document and Records Management Standard Administrative Procedure under the BMIS system, for electronic management of documents. Documents referenced by this guideline and controlled by procedures under other content management systems will continue to be managed under those systems, unless specifically transferred to SWIM. **1.6.4** below lists the main responsibilities that apply specifically to this guideline.

The review period and process for this manual is as required on a needs basis. For the 'Process diagram' to update the document information, refer to **Appendix A:.**

1.6.4 Roles and responsibilities

Position Title	Responsibility
SaAS	• Accountable for the guideline • Audit the implementation of the guideline
EES	• Responsible for guideline review and update • Responsible for the WSAA Code and design criteria documents, including content. • Responsible for the technical specifications, including content • Coordinates development for the review of technical specifications • Ensures document formatting is consistent and the template has been applied
Networks	• Responsible for the operation of the water system to meet its performance requirements • Provides operational input and advice on system resilience and reliability • Develops contingency plans based on system capacity and resilience
Hydraulic System Services	• Responsible for monitoring and remote operation of Sydney Water's water and wastewater assets, on a 24 x 7 basis via the System Operations Centre (SOC) • Operation of the trunk water system to achieve optimum performance within agreed operational parameters to achieve least $/ML cost • Forecasting daily demand and scheduling treated water

	flows and trunk water system operations • Optimisation of energy usage in system optimisation • Provides operational input and advice on system resilience and reliability • Develops contingency plans based on system capacity and resilience
Document Author	• Responsible for drafting documents • Responsible for reviewing/incorporating 'change requests' and managing the review cycle • Ensures that all relevant stakeholders have been consulted
Document Reviewer	• Responsible for reviewing the content of the document
Document Controller	• Responsible for ensuring correct document formatting is applied to documents • Ensures appropriate reviews have been selected

1.6.5 Training and competencies

Include those who need to be aware of this document and/or trained in any procedures/equipment.

Process/Procedure	Business Unit/Position
Planning	SaAS, EES, Urban Growth, Service Delivery – Networks, Project and Services (Hydraulic System Services)

1.6.6 References

Reference number	Document type	Title
1	ACP0028	*Water Supply Code of Australia, Sydney Water Edition* – Latest version
2	AMQ0038	Design Demand Rates for Water Assets (SAP)
3	AMQ0057.doc	Leakage Management Plan 2010-15
4	AMQ0059.doc	Calculation & Reporting - Corporate Waterbalance From Storages
5	AMQ0071	Water Supply System Design - TIPS 5
6	AMQ0107	Water Investigations Sub-branch - Staff Handbook No 32, 1968
7	AMQ0109 (Archived)	Guidelines for selection of small self-contained water booster stations, April 2004 (draft)
8	AMQ0109 (Archived)	Guidelines for selection of small self-contained water booster stations, July 2010 (final draft)

9	AMQ0138	Design Criteria Guidelines Supplement, April 2010
10	AMQ0138.05	BASIX Water Savings Monitoring – December 2009
11	AMQ0140	Review of the Programs to Minimise Inadvertent Ingestion of Recycled Water in Residential Recycled Water Systems, January 2010
12	ACP0029	*Sewage Pumping Station Code of Australia,* WSA 04-2005-2.1, Sydney Water Edition-2012
13	AMQF0029	System Reliability Decision Framework
14	AMQ0573(draft)	Asset Hierarchy
15	AMQ0138 (archived)	Design Criteria Guidelines Supplement, April 2010
16	AMQ0138	Water Design Diurnal Curves.xls
17	AS4536	Australian standard for Life cycle costing
18	BMIS0144	Sustainability Planning Manual
19	BMIS0161	Options Library - Average Water Use Model
20	BS ISO 15686-5	Life Cycle Costing
21	HSP0070	Flow Isolation and/or Flow Management (FIFM)
22	HSS0009	Instrumentation and Control Standards TOG_TS01
23	HSS0005	Flow Monitoring Station Standards TOG_TS05
24	QMAF0021	Operational Risk Management Procedure
25	QMAF0021	Risk Management - Operational Risks
26	QMAF0018	Corporate Risk Register, Sydney Water
27	DM-AP-00021263	Water and recycled water system growth servicing strategy criteria and guidelines 2012
28	SWIM (196891)	Reliability Technical Supplement
29	WPIMS5293	The Standard Operating Procedure: Investigating, Measuring and Reporting Water Pressure

30	Book	*Water Distribution Systems: Simulation and Sizing*, 1990, Lewis Publishers, Thomas M. Walski, Johannes Gessler, John W. Sjostorm
31	Draft	System Integrated Planning - Framework (SaAS)
32	Handbook	*INCOSE. Systems Engineering Handbook v2.0*, 2000
33	Handbook	*Systems Engineering and Analysis*, Blanchard and Fabrycky, 5th Edition
34	iConnect	Sydney Water Act 1994
35	iConnect	Operating Licence 2010-2015
36	iConnect	Energy Management https://elogin.ads.swc/wps/myportal/iConnect/SydneyWater/?CDF=CT_006061
37	Internet	http://www.eng.auburn.edu/~dbeale/ESMDCourse/Chapter2.htm#Summary
38	Internet	Australian Drinking Water Guidelines http://www.nhmrc.gov.au/guidelines/publications/eh34
39	Internet	Australian Guidelines for Water Recycling
40	Internet	Variable Speed Driven Pumps – Best Practice Guide, British Pump Manufacturers Association and GAMBICA Association Ltd: http://www.bpma.org.uk/filemanager_net/files/gpg344_variable_speed_best_practice_for_pumps.pdf)
41	One hard copy (with Milan Rubcic) or available to buy	Australian Pump Technical Handbook
42		Deemed to comply construction drawings for water flowmeters – currently in draft stage
43	HSS00051	Flow Monitoring Station Standards TOG_TS05
44	HSS00092	Instrumentation and Control Standards (General) TOG_TS01
45	HSS00082	Water Distribution System related Instrumentation and Control Standards TOG_TS02
46	HSS00061	Potable Water Pressure Monitoring Standards TOG_TS04

47	WPIMS5293	Water Pressure Investigation, Measurement and Reporting SOP
48	Sydney Water web site	'Water Efficiency Report'
49	Contact the Energy team at energy@sydneywater.com.au	'Energy Smart Asset Resource' (workbook/tool, under development)
50	Book	Flexibility in Engineering Design, Richard de Neufville and Stefan Scholtes, Massachusetts Institute of Technology 2011.
51	Document	The Water and Sewerage Supply of Sydney, F.J.J Henry, Sydney Water, 1939.
52	SWIM (365931)	The Water Supply and Sewerage of Sydney, 1939
53	iConnect	IICATS I&C Standards
54	iConnect	IICATS Water System Volume 1 – Functional Design Specification
55	SWIM	WMS QMS documents
56	Document	Economic Appraisal Guidelines – Guidance on climate change for asset and infrastructure assessments. Treasury Circular, NSW TC 10/12, 15 September 2010
57	Procedure SWIM (288415)	Strategic Infrastructure Planning

1.6.7 Attachments and/or appendices

Attachment/Appendix number	Title
Appendix A	WSPG-Development and Update Process

1.6.8 Document control

Title: Water System Planning Guideline, Section 1: Introduction to the Guideline		
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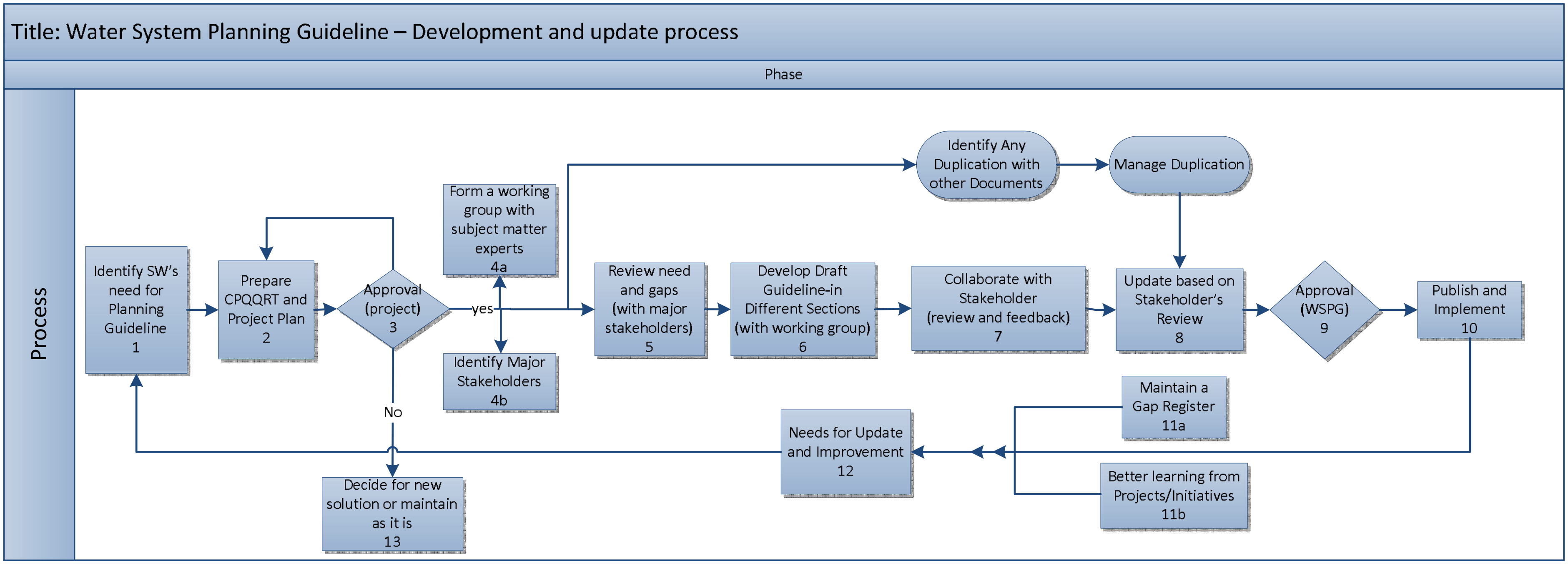
1.6.9 Revision control chart

Version number	Date revised	Brief description of change
1	September 2014	New Document

Appendix A: WSPG-Development and update process



Water System Planning Guideline

Section 2: Water System Planning

Version 1

September 2014

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Section 2: Water system planning

2.1 Introduction

This chapter provides information on how to undertake system planning. It focuses on:

- the requirements of system integrated planning and how it is incorporated into Sydney Water's planning phases, especially the 'generate options' phase. This provides the opportunity for cost reduction and system improvements
- system water quality issues and planning requirements
- system monitoring requirements for pressure and flow
- initial information on energy consideration.

2.1.1 Introduction to systems

'A system is an assemblage or combination of functionally related elements or parts forming a whole' – Systems Engineering and Analysis, Blanchard and Fabrycky (**Reference 33**).

A system can be a water supply system, a climate system, a transport system, a human, or a combination of all. These systems sit within a surrounding environment and interact with each other as shown in **Figure 2 - 1** .

When planning a new water supply system, consideration is required of climate, customers, and regulators, other stakeholders, eg Sydney Catchment Authority (SCA), that are external to the water supply system. A set of requirements is provided for the water supply system to interact effectively with other systems.

For an existing water supply system, the original function of the asset and the system it sits within may have changed over many years and thus it may be prudent to re-configure the water system rather than just re-size the asset. The change creates a new system definition.

This guideline assists in developing and evolving the water supply system.

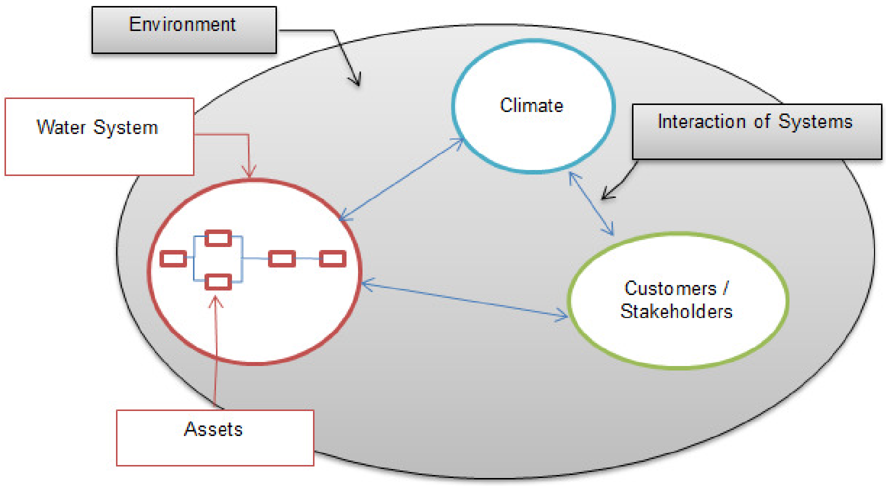


Figure 2 - 1 Systems concept

2.1.2 Introduction to system integrated planning

System integrated planning is defined as an approach where synergies within and between drivers such as growth, renewals and reliability are identified and addressed. New concepts in the approach include:

- improving the reliability analysis (where required) by performing:
    - shutdown block analyses
    - qualitative and quantitative risk assessments where relevant. The assessments should include scenarios for both planned and unplanned operation and/or maintenance
- taking future renewals into account in the planning phase (where required) by finding the:
    - remaining life expectancy within the planning horizon.

The purposes of system integrated planning are to ensure that:

- the drivers such as growth, renewals and reliability are reviewed in planning
- the right amount of planning happens for each growth/reliability project or renewal candidate
- planning requirements for projects are foreseen and scheduled.

The *System Integrated Planning - Framework* (**Reference 31**) provides details on the implementation of system integrated planning, such as a simplified flow logic process.

This section incorporates the system integrated planning approach into the 'water system planning phases'. Sydney Water's planning phases are based on the decision-making phases contained in the *Sustainability Planning Manual* (**Reference 18**).

2.1.3 Risk assessment and risk management

2.1.3.1 General

Risk assessments (qualitative or quantitative) may need to be undertaken at different stages of planning. The categories to be assessed would typically include financial, environmental, energy, customer service and regulatory compliance. Any assessments should include input from key stakeholders (including strategists, system operators etc) to ensure that the potential risks are raised, assessed and managed.

In relation to water quality, the risk assessment shall follow the risk assessment process outlined in the *Australian Drinking Water Guidelines* (**Reference 38**) and the *Australian Guidelines for Water Recycling* (**Reference 39**) respectively, where relevant.

2.1.3.2 Qualitative and quantitative risk assessments

Qualitative risk assessments develop a risk score from information on likelihood and consequence. Risks are then ranked according to the risk score.

When developing controls (mitigation solutions), it is worth considering those controls that partially reduce the risks, especially if a large capital saving can be achieved. This involves a typical trade off situation, ie, trying to balance the reduction in risk with the capital cost of the various solutions.

To consider the value for money of projects, a quantitative risk assessment can be used. This assessment uses the concept of risk cost, and together with the cost of the mitigation solution, the planner can derive a benefit to cost ratio. This ratio enables a ranking of mitigation solutions based on value for money (formulae shown below in **Table 2-1**).

A management review is used to make the final decision and this review uses all information available, including results of both the qualitative and quantitative risk assessments.

For more information on qualitative risk assessments, refer to the *Operational Risk Management Procedures*; *Risk Management - Operational Risks* and Sydney Water's *Corporate Risk Register* (**References 24, 25 and 26** respectively).

For more information on quantitative risk assessments, refer to the *Reliability Technical Supplement* (**Reference 28**). The basic formulae used are shown below in **Table 2-1**.

Table 2 - 1 Risk cost formula used in a quantitative assessment

Risk Cost ($NPV) = Risk Cost ($ each year) x 12.97

Where:

a) $12.97 = 1/(1+0.075) + 1/(1+0.075)^{2} + \ldots 1/(1+0.075)^{50}$ (present value analysis)

b) 0.075 is equal to the assumed discount rate of 7.5% and

c) 50 is the assumed number of years of analysis

Risk Cost ($ each year) = Mean Failure Rate (each year) x Consequence Cost ($)

Benefit/Cost = Risk Cost Reduction/Mitigation Cost

The following simple example explains how risk cost can be used. It has been taken from NSW Treasury Circular (**Reference 56**). A further more detailed example of how risk cost can be used for a water main renewal is in **Appendix D:**.

'Example: Climate Change Adaption Project

Sea level rise is a gradual long term process and its potential future impacts on government assets will require considered case by case assessments by responsible agencies addressing the issue as part of their strategic planning/risk assessment framework.

Planning and management of public assets likely to be affected by long term sea level rise, taking account of expected asset life and need, might cover for example:

- upgrade of existing assets where and when justified, or undertaking relocation (including progressive relocation over time) where feasible and appropriate - for example when an asset is approaching the end of its economic life, or when potential future sea level impacts determine;
- assessing at the appropriate time through economic appraisal methods whether engineering or other works may be appropriate, including assessment of whether the particular infrastructure is expected to be relevant in 50 or 100 years (in light of technological change, changes in community needs, etc); and

avoiding, redesigning, or upgrading future investments likely to be exposed to high risks.

For adaptation of an existing asset or for assessment of a new asset, as far as possible the estimated benefits (damages avoided) should be compared with the costs of asset adaptation. Where the likely damages avoided are uncertain, as they nearly always are, they should be expressed in terms of expected damage costs avoided.

For example if there is a 1 in 20 chance of a $10 million damage event in the year, the expected damages are $10m * 0.05 = $0.5 million per annum. Allowing an asset life of 50 years, in a simple case, this could be $0.5 million for each year 1 to 50.

Using the central discount rate of 7% [assumption at the time], the present value (PV) of these damages avoided equals:

$$PV = \$0.5m / 1.07 + \$0.5m / 1.07^2 \ldots + \$0.5m / 1.07^{50} = \$6.9 \text{ million}$$

Accordingly a capital expenditure on adaptation could be justified if it is less than $6.9 million. It would not be justified if the expenditure exceeded $6.9 million.'

2.2 Water system planning phases

The water system planning phases cover planning for:

- greenfield developments
- infill developments
- upgrading existing assets/systems
- renewals
- reliability projects.

Sydney Water's planning phases (with the addition of the monitoring and review phase) are:

1. define objectives
2. generate options
3. select evaluation criteria
4. screen options
5. perform detailed options assessment
6. recommend preferred option
7. monitoring and review.

The phases are not necessarily sequential and iterations are often required.

The focus of incorporating the requirements of system integrated planning into Sydney Water's planning phases is to generate appropriate options to improve the system/s as a whole. More detail on the planning phases is provided below, especially the 'generate options' phase.

2.2.1 Define objectives

Problem/opportunity statements are provided for the project.

Problem/opportunity statements may not be limited to a specific issue, as surrounding system problems/opportunities may also be identified. This is to ensure that any developed solution gives the best value for the total system. This implies that defining the scope of any planning study at the start of the project is difficult, especially with complex water systems. It may be necessary to review these statements as planning proceeds.

The following focus areas are supplied to assist in developing objectives:

- Provide capacity to service future growth and integrate staging requirements.
- Ensure system performance standards for pressure and water continuity meet Operating Licence standards.
- Ensure water quality performance meets Operating Licence standards.
- Embed redundancy into systems and assets, including reviewing possible emergency conditions that a total system may experience, including the failure of a bulk water supply.
- Account for renewals into any future system design.
- Ensure reliability, maintainability, supportability, operability and resilience of the system.
- Ensure flexibility of the system for future uncertainties.
- Ensure energy management is reviewed.
- Account for environmental and heritage Impact.
- Ensure monitoring and control provisions comply with IICATS I & C standards.
- Ensure least life cycle cost.
- Achieve transparency of investment and planning decisions.
- Reduce risk while achieving a significant return on investment.
- Undertake a system-wide criticality and vulnerability review.
- Provide for future decommissioning.
- Embrace customer needs.

2.2.2 Generate options

This is the most critical planning phase. It is here that many considerations must be taken into account to ensure the system is improved with each planning study. It is here that planners especially add value. Details are shown below.

Generate options by following these key steps, which take growth, renewals and reliability into account during the planning phase of a project.

Step 1 – Develop the existing water system/s model

Develop an existing system's water model (if the base model is not available). Ensure that:

- the existing system model is updated with demand and any system or operational changes. Check with the Network operators regarding any known deficiencies, faulty (closed) valves, customer complaints or special enquiries, pump performance tests
- controls are validated and adjusted if required. There are many types of controls currently being used in the WMS, for example, time varying windows and fixed level controls
- the existing model is validated
- surrounding water systems and trunk models are available to check for reliability scenarios.

Step 2 – Develop the future water system/s model

Develop the future system/s water model for different planning horizon/s. Ensure all known future demands and system changes are considered, including those for surrounding water systems.

In order to consider major greenfield development, adjacent to an existing area, the planner needs to assess the adequacy of the existing system capacity to serve the growth. It will require assessing the system capacity and operating characteristics at potential connection points, over different planning horizons (years).

Future demand for planning should be calculated based on the criteria in **Section 3: Water Demand and Growth** of this guideline.

Step 3 – Determine system deficiencies

To determine system deficiencies:

- Use the existing system/s water model to assess current deficiency or constraints (ie water quality, pressure and maintaining capacity) of the system. Check with the 'network or treatment operators' regarding any known deficiencies and reliability issues.
- Use the future system/s water model to assess the future deficiency, in terms of capacity, water quality etc, of existing assets in the system to service the new development.

Deficiencies can be determined at a functional level based on whether the water system provides the required level of service or level of efficiency.

Some water system deficiency issues are outlined in **Appendix A:**.

Step 4 – Develop possible options

Options for a preferred solution will need to take into account growth, renewals and reliability, as well as any inadequacies.

Developing options to satisfy specific design requirements and provide the best solution may require some form of iteration to take into account the drivers for growth, renewals and reliability, which would include factors such as cost, value, reliability, maintainability, resilience etc. This approach enables planners and decision-makers to develop better performing, more reliable and low life cycle cost solutions. **Appendix B:** provides a list of methods to generate and improve options.

Information on the individual drivers is shown below.

Growth

The planner should analyse the system for different growth/planning horizons using the relevant hydraulic model(s). Growth/planning horizons should be defined for planning work based on information including population projection, staging in growth, major development phases, and other planning milestones.

Appropriate options will need to be developed for system deficiency (on existing systems), or for new development areas to provide the required level of service.

New assets to service growth areas may impact on the proposed/expected renewal of existing assets. In some circumstances, growth projects may render the existing assets redundant.

Developing options for growth should also evaluate any opportunities to improve system reliability.

Section 5: Infrastructure Planning provides criteria and requirements to determine the new asset size.

Renewals

Identify potential renewals required within the planning horizon in the area under study (based on residual life and/or from the short-term renewal list) and include in the planning.

The renewal of assets and facilities requires an assessment of current and future needs for the system to evolve and continue to meet its requirements and objectives. Many older systems have assets and facilities in service that either no longer serves their original purpose, or the purpose has changed. A review of the system should take into account future growth, reliability issues and other proposed renewals.

Future critical renewals within the planning horizon (say 30 years) need to be considered. A sensitivity analysis and risk assessment can be undertaken to consider the trade-offs between how different renewals influence each other within the system of interest and how the renewals would be staged and integrated.

Check if existing critical assets nominated for renewals can be:

- decommissioned (fully or partially or instead build a new asset/facility somewhere else in the system)
- re-routed (for water mains)
- relocated
- duplicated
- upsized (insufficient capacity)
- downsized (over capacity)
- consolidated (eg three mains reduced to two mains).

When developing options, each renewal candidate should be tested for decommissioning or mothballing to quantify the consequence. If decommissioning is unacceptable the solution to the problem can be any type of capital or operating solution. (Refer to **Appendix B:** on how to generate different options).

For the renewal of reservoirs and pumping stations, reconfiguration of the system is not often the preferred option, but should be investigated. However, consider the cost of repair and rehabilitation solutions now and into the future, which can be small and therefore may not justify any change to the system. Alternatively, large expenditure on major works may justify intervention to change the system.

For water main renewals, a maintenance analysis will generally determine the length of pipe for investigation. This can range from several pipe barrels to many kilometres. When assessing options for water mains in complex systems, there can be many options (as shown in the list above), which need to be tested to ensure that the best value for money solution is found. Shutdown block analysis is also required to test the options for reliability (Refer to ***Reliability*** below for more detail).

Reliability

A reliability assessment including shutdown block analysis shall be undertaken for planned maintenance and unplanned events on every critical component in the system (such as critical water mains and facilities) or for those components that are likely to change due to reconfiguration.

This assessment may include both product and asset failures, such as climate change events impacting on the system (eg bushfires, high winds, flooding) and external events (eg power and telemetry outages, raw water quality/quantity issues etc).

Section 3: Water Demand and Growth provides information on demands for reliability analysis.

A qualitative risk assessment and a quantitative risk assessment should be considered where appropriate to evaluate each option. These are explained in **Clause 2.1.3.**

Determine options to address component failures. Look to address multiple component failures with a single option. Also, look to creating bi-directional links where water can be supplied in both directions in an emergency. These aspects may improve the economic viability of any solutions.

Planned inspection and maintenance of critical assets is generally undertaken on a periodic basis generally between five and 20 years depending upon the criticality of the asset, eg reservoirs, tunnels and large diameter pipelines. These are usually taken offline for several months during low demand periods from March to September. In some cases double isolation (Refer to *Flow Isolation and/or Flow Management (FIFM)* **Reference 21**) is required to ensure safe entry to the asset.

The planner shall determine the needs to maintain water supply where isolation of critical assets and facilities is required for planned maintenance, and embed this into the system design when creating (growth) or changing (renewals) a system.

Preferred options are chosen based on the economic benefits exceeding the cost of the option. Value for money in reliability improvement generally comes from integration with growth or renewal projects.

For additional concepts and generating options on reliability refer to **Appendix C:** and *Reliability Technical Supplement* (**Reference 28**).

Other considerations

Other considerations in developing options include:

- resizing and/or reconfiguration. These may add additional options or affect the options already nominated, so some degree of iteration may be required before options are finalised (once the resized and/or reconfigured assets are obtained, further investigation is required to determine the feasibility of staging the transition to the future system design without impacting customers' standard of service)
- creating options. These can be a mixture of operational and/or capital solutions. This may also include accepting a risk and responding through developed contingency plans, or by new contingency measures (Refer to **Appendix C**).
- life cycle costs. These should be used when undertaking options analysis, refer to the *ISO Life Cycle Costing* (**Reference 20**).
- risk assessments, including developing mitigation options
- the reassessment of any criteria and requirements (if value can be obtained)
- the use of sensitivities where appropriate
- the staging of assets. A review based on an economic evaluation and operational requirements, eg customer demand, water quality etc
- a review of the failure points for treatment and catchment systems, as the system boundary for water systems is from the catchment to the tap. Hence, the scope may include non-Sydney Water assets (eg our bulk water supplier)
- a consideration of the maintainability, supportability, operability and resilience during planning. These issues need to be discussed with operators and maintainers. Refer to **Appendix C**

For ideas on generating and improving options, refer to **Appendix B:**.

2.2.3 Select criteria

For system performance criteria information (eg demand, pressure, sizing of assets etc), refer to **Sections 3, 4**, and **5** of this guideline.

For general option evaluation criteria, refer to the *Sustainability Planning Manual* (**Reference 18**).

2.2.4 Screen options

Develop a short-list from the list of options (where relevant).

2.2.5 Perform detailed options assessment

The selection of a preferred option may involve a multi-criteria analysis depending on the complexity of the project. Steps in the analysis include:

- weighing evaluation criteria where applicable and determined on a project-by-project basis, refer to the *Sustainability Planning Manual* (**Reference 18**).
- selecting or developing a model/tools/method for the analysis
- evaluating alternatives
- running a demand sensitivity analysis.

The planner should run a demand sensitivity analysis. This is to measure incremental cost impacts and risks to customers. The options developed and any additional capital expenditure required for demand sensitivity should be documented for review. In certain circumstances, if the sensitivity analysis reveals a marked change in costs or risks to customers, it may be necessary to revise the preferred option.

Generally, the sensitivity analysis range is equal to the demand ±10% (note in **Section 1, Clause 1.6.1**). Applying it to all the options in a detailed options assessment may not be warranted, as the preferred option may be clear in the multi-criteria analysis. Hence, determining whether to use demand sensitivity analysis on all the options in the detailed options assessment should be reviewed on a project-by-project basis. However, demand sensitivity analysis is required on the preferred option for each growth/planning horizon.

2.2.6 Recommend the preferred option

Once the preferred option is known, a needs specification and functional baseline can be defined, in order for the delivery process to be enabled.

Planners must provide a network schematic showing major asset information and valve locations, in order that the results of the planning process can be understood by the designers.

2.2.7 Monitoring and review

After the project has been delivered, a review is required of whether the actual system performance matches the performance specified. This can be achieved by using existing monitoring devices (flow meter, pressure gauge etc) and feedback from operators. If any gaps occur, then these should be addressed.

For an example of how the planning phases are used in planning for a renewal, refer to **Appendix D:**.

2.3 System water quality

2.3.1 Background

Section 2 of the 2010-2015 Sydney Water Operating Licence (**Reference 35**) outlines the requirements for managing water quality. It states that 'Sydney Water must manage drinking water quality to the satisfaction of NSW Health in accordance with the *Australian Drinking Water Guidelines* (ADWG) unless NSW Health specifies otherwise'. A similar requirement applies to recycled water using the *Australian Guidelines for Water Recycling* (**Reference 39**).

The ADWG requires the use of a multi-barrier risk management approach to allow Sydney Water to effectively deal with and manage water quality issues and risks from the catchment through to the customer's tap. From a risk perspective, microbial impacts are generally considered the most critical to manage due to the potential immediate impacts (eg within 12 to 24 hours) and the potential to infect those who may not have consumed the same water.

To protect public health and meet regulatory requirements in relation to microbial risks, Sydney Water generally applies the following strategy:

1. Treatment (eg filtration and disinfection) of raw water prior to entering the distribution system to remove and/or inactivate microbial pathogens (the treatment processes also remove/minimise other contaminants, microbial food sources, and physical material that can assist microbial regrowth and biofilms within the distribution system, and reduce the ability to maintain an effective disinfectant residual).

2. Maintenance of a disinfectant residual level throughout the distribution system to minimise any microbial regrowth and minimise the impact of any re-contamination.

3. Minimise the risks of recontamination (eg reservoir roofing, disinfecting new mains, backflow prevention, cross connections etc).

2.3.2 Issues

From an operational perspective, the design of the distribution system can have a significant negative impact on the above strategies. This can reduce the availability and effectiveness of management options to control water quality within the distribution system and correspondingly increase the risk of failing to meet microbial water quality targets.

There are a number of factors that can lead to water quality deterioration within the distribution system. These include:

- water age. Various water quality parameters will change or be impacted by the length of time the water (each litre) stays in the supply network (eg decay or consumption of disinfectant residual, increase in pH from leaching of cement-lined pipes etc). Very long water ages can occur due to dead-end pockets of water such as balance reservoirs with a single inlet/outlet main, ultimate design pipes commissioned on initial stage demands, systems running at low demands for long periods of time or for high quantity security during bush fire alert periods etc
- materials that come in contact with water (eg pipe material, linings, paint coatings etc) can lead to components from leaching or corrosion products entering the water phase
- the velocity of water, which can lead to sedimentation of particles and/or scouring/erosion of pipe surface materials and surface biofilms
- the type of disinfectant being used (eg chlorination or chloramination) and the potential issues associated with each (eg free chlorine residual does not last very long, but can lead to THM formation , while monochloramine lasts longer, but can lead to significant issues such as nitrification)
- events introducing contaminants into the distribution system (ie treatment plant issues, broken mains, leakage from reservoir roofs, cross-connections, backflow etc)
- chemical/biological characteristics of treated water, which can interact or be impacted by one another within the distribution system (eg if the pH changes then the disinfection residual may not be as effective, or it may lead to precipitation of other components etc)
- the pipe network, which can be viewed as a living ecosystem (eg containing biofilms and various non-pathogenic microbiological flora and fauna) that needs to be controlled by strategies such as disinfection residual, food/nutrient minimisation, system cleanliness etc
- the inability to find points through the system to provide effective in-system water quality management, typically disinfection residual addition (ie points where all the water passes through, all of the time, in one direction)
- the point of system connection between new supply sources and existing system configuration resulting in new/changed flow paths and potential taste issues associated with mixing sources of raw water (eg desalination water and dam water)
- mixing chloraminated water with free chlorinated water.

Most of the above issues are time-dependent to varying degrees and can be managed by minimising the water age within the system.

There will always be a limitation on how much the water age can be minimised, while still maintaining an acceptable supply security. Consequently, the system design needs to maximise the ability to manage water quality through the system by providing points where the quality can be effectively monitored and impacted. In the vast majority of cases this will involve the ability to add disinfectant residual, or in a few cases adjustment of pH, and will largely involve key trunk mains and reservoir arrangements where all the water passes all of the time.

Reservoirs are a considerable focus as they are large bodies of water that can account for a significant proportion of the water age occurring in a system. If mixed effectively, the addition of disinfection residual into these storages can be very effective as they provide disinfection contact time prior to supplying the customers fed from their outlets. The variation in chlorine residual is then kept to a minimum.

The placement of reservoirs within the supply zones however, can have significant water quality advantages or disadvantages. It is generally preferred that all water to a zone is fed first through the reservoir for easier water quality management options. Placing the reservoir off to the side as a balance reservoir, or at the end of a pumped zone, usually leads to negative water quality impacts that are hard to manage.

From a whole-of-system planning perspective the interaction between the system and water filtration plant needs to be understood from two perspectives. Firstly, the stated design capacity for a water filtration plant does not infer that it can produce this volume under all conditions. As the raw water quality degrades, the quantity of water that can be produced will decrease – in some conditions quite substantially, eg 50%. The size of the plant treated water reservoir/s and system total storage to demand ratio therefore needs to be carefully considered. Secondly, water filtration plants may not behave well under frequent production rate changes. Thus the plant/system storage capability and operation should be checked against plant operating contract for BOO plants and with 'network or treatment operators' for Sydney Water Plants for defined permissible ramp rates and flow changes permitted per day.

It may also be necessary to consider any risks associated with the high reliability requirements of known key customers in areas subject to planning.

Historically, water supply planning and design have generally been based on pressure and quantity requirements with minimal consideration given to water age or water quality impacts. To maximise the effective management and maintenance of water quality management, the above issues must be considered within the planning process from the outset rather than as an add-on after commissioning.

2.3.3 Planning for water quality

Major new schemes or changes in systems (ie PRV zones, boosters) will require a water quality/system study that investigates potential impacts on existing assets/supply areas (both upstream and within the area). This should include water age, disinfection residual plant capacities, and mixing capability at reservoirs etc. Any costs associated with managing these impacts must be included with the options/scheme.

Assessment of the water supply scheme should take into consideration the existing water quality entering the planned scheme, particularly the type (free chlorine vs chloramine), raw water source and the typical levels of disinfectant residual present. Each type of residual may present differing concerns for the management of water quality.

The following are requirements in the planning process:

- Perform a water age analysis for medium to large size projects. Consider the need for additional treatment assets when water age is higher than three days from the last treatment point. Include costing in budgets for new assets for water quality requirements.

  If disinfection plants are required as part of the distribution/reticulation system, they shall be located so as to ensure an adequate disinfection contact time and adequate chlorine residual prior to water delivery to properties.

- Consider, subject to an overall trade-off analysis, that the water supplied to a zone should flow through the reservoir.

- Where new assets are required, consider the options for staging with smaller assets to reduce water age:

  - For reservoirs, consider staging and/or setting operating levels to initially utilise only a portion of the available storage with different settings, if required, for summer and winter.

  - For mains, consider large diameter main capacity to be staged by the initial provision of a smaller diameter main, followed by additional mains as the demand increases and/or provision of additional treatment points and facilities.

- Review the water quality in any asset that could present a stagnant water issue, eg:

- a floating reservoir with a common inlet/outlet main off to the side of the main supply trunk main
- a reservoir at the end of a pumped rising main (supplying the zone as well)
- standpipe style reservoirs
- mains with permanent ends to be avoided by the provision of link mains or looped mains. Particular care shall be taken at the boundaries between supply zones, where the dead-end length shall be minimised.

- Check for flow reversals and change in velocities and review for possible controls.
- Include input from appropriate stakeholders (area network representatives, water quality personnel, technical support staff etc). It will help to identify any concerns involving local system issues, risks etc that may need to be considered with respect to water quality targets.

For additional detail on *Reticulation Design for Water Quality,* refer to *Water Supply Code of Australia, Sydney Water Edition* (**Reference 1**).

2.4 System monitoring

2.4.1 General

In a water supply system, the following hydraulic parameters are commonly monitored:

- Level - reservoir, chamber and channel level gauges.
- Pressure - pressure gauges.
- Flow - flow meters.
- Pump unit run hours & efficiency (RTU),
- Water Quality – Chlorine residual analysers, temperature gauges, pH analysers, turbidity analyser

The following requirements are for permanent monitoring via IICATS. Additional temporary monitoring is used from time-to-time to diagnose and solve network problems.

2.4.2 The water system hierarchy

A discussion of the water system hierarchy is warranted as many of the requirements for monitoring are related to the levels and boundaries created by the hierarchy.

The water network is extensive and complex comprising a large number of pipes, reservoirs, pumping station and valves. The network is segmented into tree-like systems and follows a hierarchy to achieve the levels of service and practically manage the network.

There are four levels in the water system hierarchy with the lowest level being pressure zones supplying between a few hundred to thousands of properties where the pressures will be limited within a range. Supply zones comprise a number of pressure zones usually supplied by one or more reservoirs. Distribution systems are a collection of supply zones and delivery systems are a collection of distribution systems, typically supplied from a water treatment plant.

The boundaries between the systems are maintained by closed valves. The structure of the water system hierarchy is described in the *'Asset Hierarchy'* document (**Reference 14**), currently under review with the ADI. At each level in the hierarchy, the network is discrete other than the primary (normal) route of supply. Secondary routes of supply also exist and are used from time-to-time to transfer water between systems.

2.4.3 Water level, flow and pressure monitoring-applications

Typical applications of water level monitoring are contained in the IICATS standards and include:

- monitoring that the network assets are performing as designed and configured, including reservoirs, channels and chambers
- controlling critical assets such as automatic inlet control valves (AICVs) and pumping stations and outflow from clear water tanks.
- providing critical data for the efficient scheduling of the network (supply, water quality, energy management)
- providing critical data for the calibration of demand and hydraulic models
- being combined with flow meter data, providing detailed demand data for supply zones
- being combined with a weir, flow rate in a channel.

Typical applications of pressure monitoring are contained in the IICATS standards and include:

- monitoring that the total system and individual assets are performing as designed and configured; including pumping stations, pressure control valves and sectioning valves are in the correct configuration
- monitoring that levels of service targets are being met (and the operating licence is complied with and rebates correctly given)
- providing critical data for the calibration of hydraulic models.

Typical applications of flow meters are contained in the IICATS standards and include:

- monitoring that the total system and individual assets are performing as designed (including energy requirements) and configured, including pumping stations, pressure control valves and sectioning valves
- controlling critical equipment such as Pressure Reducing Valves, Pressure Boosting stations and Chemical Dosing Equipment
- monitoring the progress of urban development and demand trends

- monitoring and reporting of water loss via water balances
- monitoring and managing water loss via Minimum Night Flow measurement
- providing critical data for the calibration of demand and hydraulic models and measuring the impact of demand management initiatives
- providing critical data for the efficient scheduling of the network assets (supply, water quality, energy management)
- scheduling treated water production and controlling outflow from clear water tank
- custody transfer measurement between suppliers (SCA and BOO) and Sydney Water.
- Improving knowledge and system operational behavioural understanding;

2.4.4 Water level, flow monitoring

2.4.4.1 System boundaries

The boundaries between systems at any level in the hierarchy can be at:

- treatment works
- reservoirs
- pumping stations
- automatic inlet control valves (AICVs)
- manual sectioning valves (DVs).

As a general principle, the transfer of water across boundaries should be monitored. There are several thousand DVs, which are only used infrequently to transfer water and usually as an emergency response. Generally, it is not economic to monitor flow through these valves.

Table 2-2 shows a guideline to be applied when deciding if the flow across a boundary will be monitored.

Table 2 - 2 Monitoring of flows across a boundary

Transfers between systems supplying different grades of water	Yes
Outlet of treatment works	Yes
Delivery system boundary	Yes
Distribution system boundary	Yes
Supply zone	Usually (not warranted for very small supply zones)
Pressure zone	Usually (not warranted for very small pressure zones)

2.4.4.2 Reservoirs

Supply zones are supplied from one or more reservoirs. The level in each reservoir will be monitored. As reservoirs are also on the boundary between systems, the flow between systems will be monitored at the reservoirs. Preferably the flow will be measured at the outlet of the reservoirs. However, if this is not possible the inlet will be monitored.

2.4.4.3 Pumping stations

Typically, pumping stations pump to one set of reservoirs supplying one supply zone. Occasionally the pumping station may pump to more than one supply zone via separate rising mains.

The flow in each rising main will be monitored at the pumping station. The upstream and downstream pressure at the pumps will also be monitored (both suction pressure and delivery pressure). This information is also useful to monitor energy performance.

2.4.4.4 Automatic control valves

Automatic control valves include AICVs, PRVs and PSVs. Some valves are sited with reservoirs, while some are located remotely within the network. The following requirements will be applied to the following valves in **Table 2 -3**.

Table 2 -3 Automatic control valves

AICV	Gate position (only when used partially open)
PSV	Gate position and upstream pressure
PRV	Upstream pressure, downstream pressure and flow.

2.4.5 Water pressure gauges

Water pressure gauges will be placed at key locations in the network as follows:

- At the critical points of pressure zones. Critical points are the points in the network where hydraulic modelling indicates that pressure will be lowest. This can either be due to high ground elevation and/or high headloss at high demands. A pressure gauge will be placed in all locations where pressures are currently estimated to fall to less than 20 m at some time in the year. At least one gauge will be placed in each area.
- At other locations on the trunk or reticulation network (usually at the highest points) where gauges are needed (usually to ensure customers are receiving adequate pressure).

2.4.6 Flow monitoring for demand verification

For reviews of design demands (ie to justify the next stage of assets with more realistic demand data), flow monitoring will be required on specific property types (ie single dwelling, multi dwelling), rather than for the whole zone.

General recommendations to selecting specific demand monitoring properties are:

- identifying pockets with the same demand patterns, such as single dwelling, multi dwelling etc. Selecting the size of the area to be monitored depends on properties available to extract the specific demand profile – the bigger the size the better and diversity needs to be considered
- identifying the areas to capture customers' changed demand behaviour (ie greenfield areas, areas with BASIX features, rainwater tanks etc)
- identifying areas with different geographical locations, occupancy rate and lot sizes etc
- identifying at least two discrete areas, if economically justified, to provide redundancy in case of failure of any flow meter. Consider the frequency suitable for design demand verification
- aiming to minimise the number of dividing valves required
- avoiding, if possible, closing any valves in a zone to keep supply zone integrity intact
- choosing, if possible, existing areas with flow metres, eg pressure managed areas (PRV or booster zones).

2.4.7 General information required for flow meter selection

Flow meters can provide both volumetric measurements and flow rate trends. Volumetric data can be used for water balancing and leakage measurement. Flow rate trends can be used for hydraulic analysis, operational planning and to obtain demand profiles to capture average and maximum demands.

The selection of appropriate size and type (technology) is crucial with respect to water main size, flow range, pressure, location, pump and budget.

Planners need to consider maintainability of the system to identify any operational requirements for recommended system monitoring. This investigation needs to be done in consultation with the appropriate stakeholders.

The following information can assist in the planning and detail design/selection of a flow meter:

- Pressure requirements upstream and downstream of a metering location.
- Size and arrangement of water mains upstream and downstream of a metering location.
- Maximum and minimum flow range, with fire flow requirements (if any).
- Minimum flow velocity requirements.
- Level of meter accuracy required.
- Use and importance of data requirements.
- Meter reading and signal generating device specification and arrangement.
- Shutdown limitations or plan.
- Isolation requirements for the works.
- Recommendation for appropriate by-pass assembly with isolating valve, so that repairs can be made without shutting off the supply on critical mains.

2.4.8 IICATS I & C standards for water distribution system assets

The Sydney Water IICATS system requires standardisation of water supply system field monitoring instrumentation, such as flow, pressure and level monitoring devices installed on water supply infrastructure.

IICATS I&C (Instrumentation and Control) standards are developed as a central design and installation reference for planners, designers, consultants and contractors to refurbish Sydney Water assets to required standards.

These standards contain technical specifications for each instrument type including the functional, performance, physical and installation requirements as well as prequalified suppliers for flow meter and pressure transmitters. Standards also include IICATS interface requirements such as remote terminal unit (RTU) input/output connections and telecommunications.

The following specific I&C standards applicable to the water distribution system assets shall be used as reference documents:

1. *Instrumentation and Control Standards (General)* TOG_TS01 (**Reference 44**)
2. *Water Distribution System related Instrumentation and Control Standards* TOG_TS02 (**Reference 45**)
3. *Potable Water Pressure Monitoring Standards* TOG_TS04 (**Reference 46**)
4. *Flow Monitoring Station Standards* TOG_TS05 (**Reference 43**)
5. *Pressure Reducing Valve Standards* (Note: under development and will be available in the near future).

2.5 Energy management

Sydney Water is pursuing strategies to improve energy efficiency, reduce energy costs and greenhouse gas emissions. Some of the more significant measures under these strategies include (Refer to **Appendix E:**):

- negotiation of long-term energy supply contracts to maintain low energy rates
- renewable energy generation
- long-term partnerships in the energy and resource sectors to achieve efficiencies
- consideration of energy-related aspects in the planning, creation, operation, maintenance, renewal and disposal of assets
- generation of green commodities from renewable energy and greenhouse gas emission reduction projects.

Sydney Water is also required to meet specific corporate targets **(Reference 36)**, such as maintaining our purchase of grid electricity to levels achieved in 1998.

For the above reasons, planners are to consult with the Energy and Eco-efficiency Group and operations from the early stages of renewal and growth projects. The unit will assist with formulating and implementing project measures that are consistent with Sydney Water's energy-related corporate targets. An 'Energy Smart Asset Resource' (workbook/tool, under development) is also available from the Energy and Eco-efficiency Team. This tool will provide the latest energy costs, usage and high level considerations requires assessing energy at different stages of asset lifecycle. The Team should be contacted for the latest version.

The tables in **Appendix E:** includes energy efficiency and renewable energy measures (though the opportunities are not limited to the list) which should be considered when planning for development or replacement of assets.

While some of these measures are applicable during the design phase, planners should consider reducing energy requirements and improving energy efficiency where possible and include the relevant information in the life cycle costing for any option.

2.6 Context

2.6.1 Definitions, abbreviations and references

Refer to **Section 1: Introduction to the guideline, Clause 1.6**.

2.6.2 Attachments and/or appendices

Attachment/ Appendix number	Title
Appendix A:	Example of water system deficiencies
Appendix B:	Ideas for generating and improving options
Appendix C:	Generating options for reliability
Appendix D:	Penrith North Supply Zone example
Appendix E:	Energy efficiency-list of most measures

2.6.3 Document control

Title: Water System Planning Guideline, Section 2: Water System Planning		
Current review date: June 2015	**Review Period:** 1 year **Risk Rank = High**	**Registered file:** 2014/00004985
BMIS file name:	AMQ0562.2	
Document owner:	Craig Crawley - Strategy Manager, Servicing & Asset Strategy	
Prepared by:	Farhana Rifat - Servicing & Asset Strategy Paul De Sa - Servicing & Asset Strategy Chris Moore - Servicing & Asset Strategy Fernando Gamboa - Servicing & Asset Strategy Tony Cartwright - Servicing & Asset Strategy	

Major Stakeholders Consulted/Reviewer:	Anil Jaiswal - Servicing & Asset Strategy Bob Wickham - Urban Growth Chris Salkovic - Service Delivery Craig Crawley - Servicing & Asset Strategy Daryl Gilchrist - Engineering & Environmental Services David Gough - Servicing & Asset Strategy Frank Kanak - Service Delivery Peter Fisher - Servicing & Asset Strategy Richard Schuil - Engineering & Environmental Services Sum Tong - Engineering & Environmental Services Aravinda Stanley - Servicing & Asset Strategy David Zhang - Servicing & Asset Strategy Ed Braithwaite - Service & Asset Strategy Gaetano Illuzzi - Engineering & Environmental Services Graham Couchman - Engineering & Environmental Services Gregory Appleby - Liveable City Program Janssen Chan - Engineering & Environmental Services Julie Horne - Engineering & Environmental Services Mark Angles - Product & Asset Management Executive Mark Obuchowski - Engineering & Environmental Services Nihal Balasuriya - Networks Persephone Rougellis - Service & Asset Strategy Peter Cresta - Networks Phil Duker - Treatment Philip Woods - Liveable City Program Richard Wajzer - Urban Growth Robert Ius - Hydraulic System Services Sarah Vierboom - Liveable City Program Suganthini Niranjan - Engineering & Environmental Services Suhanti Thirunavukarasu - Engineering & Environmental Services Vajira Samarasinghe - Engineering & Environmental Services
Approval and Endorsement	See end of 'Section 0' of WSPG

2.6.4 Revision control chart

Version number	Date revised	Brief description of change
1	September 2014	New document

Appendix A: Example of water system deficiencies

Pressure issues	Systems with very low or high pressure during maximum hours should be reviewed for augmentation. For desirable pressure range, refer to **Section 4: System Hydraulics**.
Bottlenecks	The planner should consider mains with high velocities or headloss rates. For velocity and headloss requirements, refer to the Water Supply Code of Australia, Sydney Water Edition (Reference 1). However, velocity and headloss should be refined with improvement criteria to optimise any augmentation solution. Pressure reducing or sustaining valves may also contribute to problems and their settings should be investigated where appropriate.
Pump capacity issues	If all units in a station are running and the downstream reservoir cannot recover this can be an indication of a capacity deficiency in the input system (combination of pump, rising main and reservoir).
Storage capacity	If a supply zone's reservoir is supplied via gravity and its RSL is breached, then this indicates either a storage capacity issue or inlet supply capacity issue.
Operational issues	Pressure reducing/sustaining settings, pressure management zones and rezoning strategies may cause problems. Adjusting the operational settings can improve a problem area, though it must not be at the expense of other areas where it would cause failures.
Lack of reliability	Full or partial back-up supply (or contingency arrangements) may not be available

Appendix B: Ideas for generating and improving options

Table 2 -4 provides a list of methods to help generate or improve options.

Table 2 -4 List of methods

Methods	Comments
Idealised design/ discontinuous improvement	If the system was destroyed, how would you re-design the system without constraints using today's technology?
Forced	Develop an alternative option where the assets in question are 'forced' to be decommissioned. This is to move the planners' view of the system to a different perspective.
Seeking opportunities	Try to find solutions that mitigate other existing problems. Value for money is obtained where a single solution mitigates multiple problems or meets multiple requirements. For example, a link between two zones can provide redundancy for many component failures in both zones. Or re-routing a water main to pick up an existing problem along the way.
Partial risk reduction	An option that reduces risks to a certain level may be more cost effective than totally removing the risk (Refer to **Appendix D**:).
Economical	What can be built to provide a benefit to cost ratio of more than/equal to one? The aim is to find options that provide an economical solution.
Staged approach	An option where assets are built at different times to align with demand increases and to reduce life cycle costs
Continuously design out	Keep designing out problems or constraints until there is an unacceptable risk and value for money. Look within the immediate and surrounding systems for small tweaks, eg cross-connections from adjoining or trespassing mains, or small changes to controls.
If this was your money what would you do?	This is a question posed to redirect the planner's perspective to the customers' point of view, or willingness to pay. Example: How would you feel if you were asked to pay $5 million for this renewal? How many questions would you ask? The planners' response should be that everything has been challenged and justified. Essentially this is how we ensure value for money.
Challenge Assumptions	Identify an assumption that limits the number of possible alternatives choices. Deny the assumptions. Explore the consequence of the denial.

Appendix C: Operating and Capital Solutions

Operational Solutions

Operational solutions include:

- using accessible spare capacity across the system
- using accessible excess storage across the system
- rezoning
- contingency plans using portable PRVs, pumps, generators, layflat hose and tinkering. The reliability of supply to customers can be improved where contingency plans are created and practised
- temporary valve changes
- demand management
- maintenance

The following are considerations for operational solutions:

- Maintainability:
  - access and egress to repair large critical assets and facilities
  - time taken for maintenance crews to manually operate valves
  - time to detect, respond, repair, and re-instate assets or facilities
  - the ability to take critical assets offline for planned maintenance

- Supportability
  - staff availability
  - the availability of spares, temporary generators and pumps, internal and external to Sydney Water

- Operability
  - limitations of telemetry
  - operating protocals and schedules for normal and abnormal operation scenarios

- Resilience (for major incident and emergency responses)
  - Emergency Control Centre (ECC) protocols and capability
  - Contingency plans

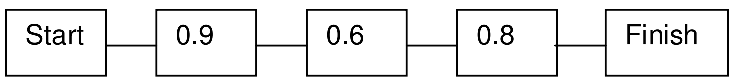
Capital Solutions

Capital solutions include, where feasible:

- improving asset/system capacity or redundancy. This involves adding new assets or increasing storage. For example, increasing reserve storage over and above the 1/3 maximum day demand (MDD) reserve storage, adding extra pumps in a pumping station, having connection points for generators or mobile diesel pumps, and link mains between systems.
- strengthening the asset. This involves increasing the capability of the existing asset, facility or system to withstand a certain event, eg reservoir strengthening for earthquakes.

Reliability problems

A chain of assets in a series configuration may provide poor reliability as a whole. In the case shown in **Figure 2-2**, the chain has a reliability of 0.432 (0.9 x 0.6 x 0.8). The chain itself is weaker than the weakest link (in our case – a reliability of 0.6), signalling that there are likely to be multiple solutions required to improve the system. These may be within this system or from another system.



(* Numbers relate to the reliability of the asset)

Figure 2 - 2 Reliability problems - series

Reliability options - capital

Figure 2-3 provides a conceptual layout that includes two systems.

The following generic reliability options (shown diagrammatically as A,B,C and D in **Figure 2** - 3) for various assets need to be considered when reviewing reliability:

- Option A - Local redundancy for a single component failure (eg back-up generator).
- Option B - System level redundancy (eg bi-directional link between systems) for multiple component failures.
- Option C - System level redundancy for only the source of supply. Customers are still vulnerable to many component failures if ‘B’ is not provided. Solution ‘B’ is preferred over ‘C’ because it provides redundancy to more components (*this implies that end-to-end system design can provide very high system reliability to customers, eg Woronora link to/from City Tunnel, Cascades link to/from Orchard Hills).*
- Option D - Strengthening of an existing component for common mode failures (eg reservoir strengthening, improving treatment capability).

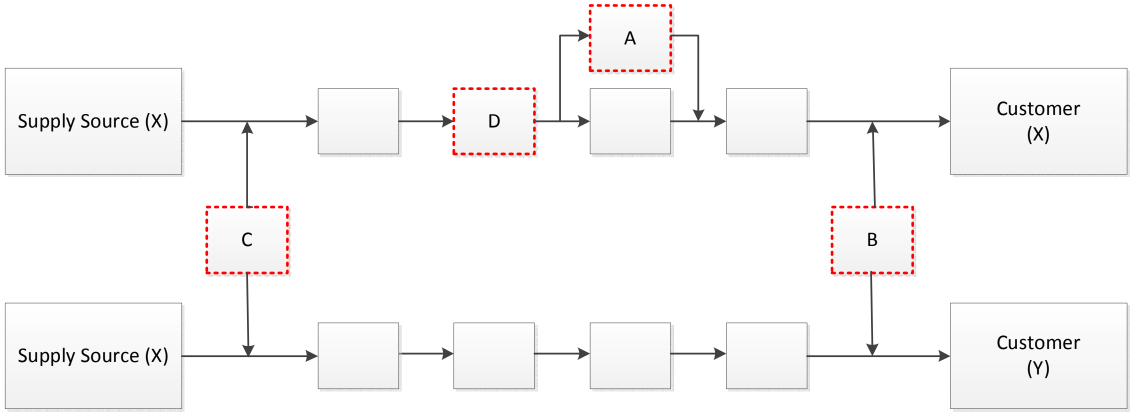


Figure 2 - 3 Examples of reliability solutions for system design

Appendix D: Penrith North Supply Zone example

Penrith North Supply Zone

Example of the 'System Integrated Planning' approach has been presented here through the renewal of a 375 mm water main in Penrith (refer to water main 'ED' in **Figure 2-4**).

This example is set out as per **Clause 2.2.1 to 2.2.7** above.

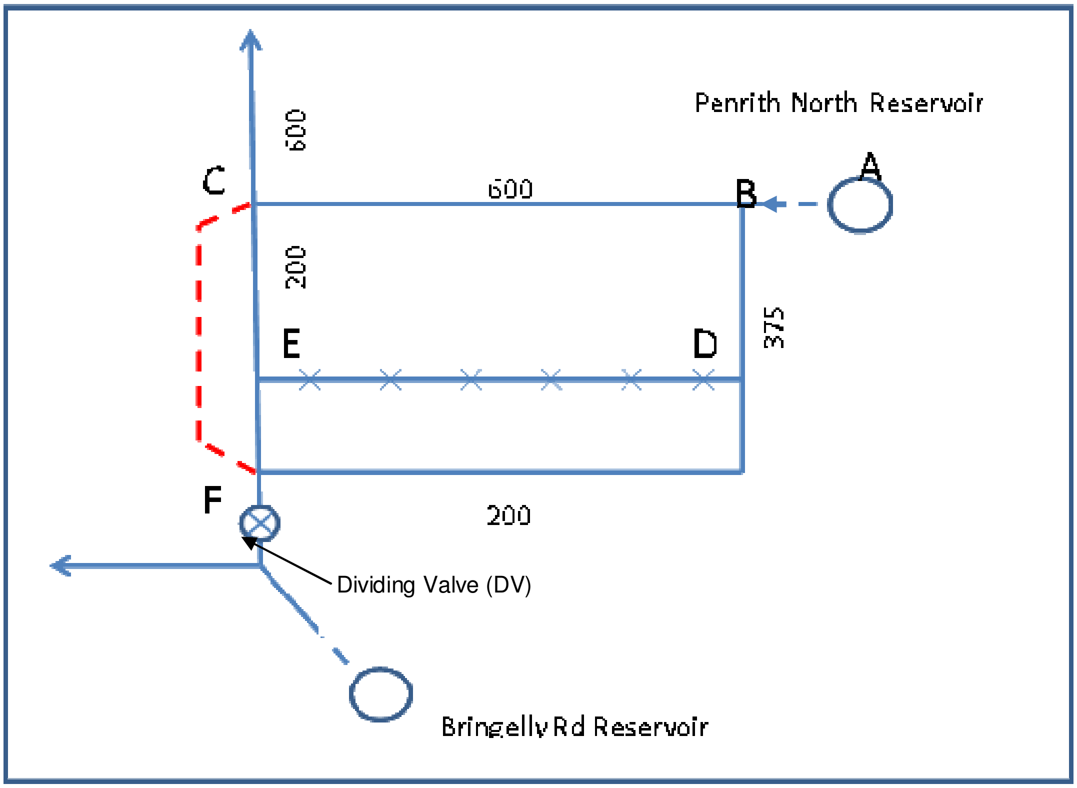


Figure 2 - 4 Schematic of Penrith North Supply Zone renewal

1.1 Define objectives

The problem that initiated the investigation was:

- An old main has reached the end of its service life ('ED' in is two kilometres in length of both 300 mm AC (1935) and 375 mm CICL (1935)). Main 'ED' has no direct customers.

However, there is a single outlet main from Penrith North Reservoir, which provides an opportunity to improve reliability.

Considering the problem and opportunities around the system, the objectives are to:

- re-optimise the system
- address other possible future renewals required within the planning horizon in the planning process

- ensure that any required asset is sized for future growth
- improve performance and reliability where economically viable
- ensure water quality requirements are met
- ensure value for money with acceptable risk.

1.2 Generate options

The baseline model and growth model have been developed to assess the system deficiency for different drivers.

Growth

A baseline model of the Penrith North System was run for current MDD. A future model was then run for future MDD at 2031. This included an additional 4,000 properties due to growth. Analysis showed that at 'F' the pressure results were 17 m and eight metres respectively.

Renewals

To look for other options besides a like-for-like renewal, other renewals in the area have been explored to consider in the scope. There were no other proposed renewals in the nearby area, so other renewals are not an issue in this example.

Expanding the boundaries of planning from the immediate surrounds, other options are generated to solve this problem using the following list:

- Decommission.
- Re-route.
- Relocate.
- Upsize/downsize/slipline.
- Consolidate.
- Seek opportunities.

However, a run of the future MDD model with the 'ED' decommissioned (especially as there were no customers connected to the main) shows negative pressure of -8 m near 'F'. This does not meet the pressure requirements. Therefore exploring other options is required.

Different options have been generated to address the capacity and renewal issue:

- Like-for-like renewal 'ED' on .
- Amplifying the main 'CF' on from 200 mm to 375 mm would compensate for the decommissioning of 'ED'.

Reliability

With a new main 'CF' the system configuration has changed. Therefore checking the reliability of the new system configuration is required to ensure that reliability requirements are met.

Shutdown block analyses were undertaken of the new system configuration. This is to test whether the risk level in the system has been escalated too high and whether there is value for money in providing redundancy.

Shutdown block analyses, for emergency situations, are undertaken under ADD in this case. The analyses may also use MDD or Maximum Week to test for sensitivities.

Table 2 -5 provides a qualitative risk assessment for each shutdown block. The last column in this table shows the results of the qualitative risk assessment using Sydney Water's corporate risk matrix

Risk scores of three and above generally require investigation to determine any appropriate mitigation solution, subject to value for money review and management review. The analysis showed (refer to **Table 2 -5**) that 'AB' and 'BC' have high risk costs and severe and moderate consequences with risk scores of four and five respectively. The risk is therefore acceptable with a contingency plan, unless value for money can be achieved by a capital solution.

For the reliability analysis, the question then becomes what combination of mitigation solutions can provide value for money to mitigate each shutdown block.

To address reliability for the system, the options considered for the detail assessment are:

- 'ED' on of two kilometres of DN375 - costs $3 million.
- Amplifying the main 'CF' on from DN200 to DN375 for 860 m costs - $1.5 million.
- Opening the existing Dividing Valve (DV) near 'F' on . This supplies water from Bringelly Rd reservoir zone. An operating cost of $10,000 has been considered appropriate in this example.

1.3 Select criteria

System performance criteria (for demand, pressure, sizing of assets etc) are referenced in this guideline (Section 3, 4, 5). Where requirements are specific to the Penrith North System, they are to be included. In this case there are no further requirements specific to this system.

This example has used investment cost and risk cost as primary criteria for option assessment.

1.4 Screen options (capacity)

The investment cost has been used to short-list two options:

- Like-for-like renewal 'ED' on of two kilometres of DN375 - costs $3 million.
- Amplifying the main 'CF' on from DN200 to DN375 for 860 m - costs $1.5 million.

As the saving for the amplification of 'CF' compared to the renewal of 'ED' was about $1.5 million or 50%, the amplification of 'CF' is the preferred option. The selection of the preferred option for capacity was based on cost only as both options meet capacity requirements.

However, this does not preclude 'ED' to be an option for improved reliability.

1.5 Perform detailed options assessment

The next level of detail option assessment uses the result of shutdown block analysis. As all the options meet capacity requirements risk cost has been used for the options assessment criteria.

Table 2 -5 provides a risk cost assessment for each shutdown block. It uses the risk cost formulae for each shutdown block to calculate the risk cost ($NPV). Detail is shown below on how risk cost is calculated.

Running shutdown block analyses for the 600 mm mains ‘AB’ and ‘BC’, the major feeds from Penrith North reservoir, also highlighted the benefits of amplifying the main ‘CF’. If any of ‘AB’ or ‘BC’ is out of commission, a reasonable supply of water (about average day demand) can be supplied in emergency situations to customers north of ‘C’ through ‘CF’ from the adjacent zone (Bringelly Road) via a dividing valve at ‘F’. A shutdown block analysis for the preferred main ‘CF’ also showed that opening the dividing valve at ‘F’ would also be a suitable mitigation solution.

Table 2 -6 provides benefit to cost ratios (B/C ratios) for the cost of solutions.

There are further options that could be analysed including ‘CF’, but these have not been shown in **Table 2 -6** in order to simplify this example.

How to calculate risk cost of Section ‘BC’- an example:

Assumptions

- Break rates (BR) for a 100 mm water main (CICL) – 30 breaks/100 km (for this example).
- Number of customers affected: 3,000.
- Downtime of ‘BC’: two days (advised by operator).
- Consequence rate ($) = $500/customer/day (for this example).

Risk cost formula used in a quantitative assessment for Section ‘BC’:

Risk cost ($NPV) = risk cost ($ pa) x 12.97

Risk cost ($ pa) = mean failure rate (MFR) x consequence cost

Benefit/cost = risk cost reduction/mitigation cost

Mean failure rate (MFR):

Mean failure rate (MFR) for this example = break rate {(x/100 km) x (100 mm/diameter (mm))} * length (km). See the Reliability Technical Supplement **(Reference 28)** for further details.

FR of ‘BC’= {30/100 km x (100 mm/600 mm)} x 1.93 km = 0.096 per year

During the useful life of the main, an estimated mean failure rate is 0.096 per year.

Consequence cost:

Consequence cost = Customer days x consequence rate

= (Number of customers affected x down time) x consequence rate

= 3,000 x 2 days x $500 = $ 3 million

Risk cost (RC):

Risk cost ($NPV) = FR x consequence cost x 12.97 (theoretical factor)

= 0.096 x $ 3,000,000 x 12.97 = $3.7 million

B/C ratios:

B/C ratio = $3.7 million/$3 million = 1.23 (for option renew 'ED')

B/C ratio = $3.7 million/$1.5 million = 2.47 (for option amplify 'CF')

Analysis

The results show that the risk cost for Sections 'AB' and 'BC' are $2.8 million and $3.7 million respectively. This indicates that provision of redundancy up to these amounts would be economical.

The analysis shows that spending $3 million to renew 'ED' and $1.5 million to amplify 'CF', as redundancies, provides B/C ratios of 1.253 and 2.47 respectively.

Both of these options appear economical to proceed, with 'CF' delivering a higher B/C ratio than 'ED'.

However, the provision of a dividing valve from Bringelly Rd near 'F' also provides redundancy, under each shutdown block analysis, with much higher B/C ratio.

The DV also provides alternative supply for outage of 'AB', which has the highest consequence. This is something that renewal of 'ED' cannot provide.

Hence the DV near 'F' provides better value for money when compared with 'ED'.

1.6 Recommend the preferred option

The preferred option for capacity is:

1. Laying a new main DN375 for 860 m ('CF'). This option costs $1.5 million.

The preferred options for reliability to single supply from Penrith reservoir are:

1. Laying a new main DN375 for 860 m ('CF'). This option costs $1.5 million (note that this is the same as for the 'capacity' case above).
2. Using the existing dividing valve at 'F' for an emergency supply. This provides the greatest value for money in terms of redundancy (when required) against the single main supply from Penrith North Reservoir.

The overall result is therefore:

1. Laying a new main DN375 for 860 m ('CF' on). This option costs $1.5 million.
2. Using the existing dividing valve at 'F' for an emergency supply.

The example highlights how reconfiguration of the system and testing shutdown blocks can re-optimise the system when a renewal has been generated.

1.7 Monitoring and review

After implementation, system performance needs to be reviewed for the selected option. This can be achieved by using existing monitoring devices (flow meter, pressure gauge etc) and feedback from operators.

Table 2 -5 Risk cost and risk score of each shutdown block element

Shutdown Block Analysis
Penrith North Renewal

Section	Diameter (mm)	Length (m)	Material	Failure Rate / 100km (100mm)	Mean Failure Rate	(1 in X) p.a.	Number of Customers	$/dw/day	Existing Redudnancy (Days)	Downtime (Days)	Customer Days	Community Consequence Cost ($)	Risk Cost $p.a.	Risk Cost $ NPV	Qualitative Risk Assessment: Likelihood	Consequence	Risk Score
AB	600	735	CICL	30	0.037	27.2	6000	500	0	2.00	12000	$ 6,000,000	$ 220,500	$ 2,859,885	Very Unlikely	Severe	4
BC	600	1933	CICL	30	0.097	10.3	3000	500	0	2.00	6000	$ 3,000,000	$ 289,950	$ 3,760,652	Very Unlikely	Moderate	5
BD	250	421	CICL	30	0.051	19.8	1000	500	0	0.25	250	$ 125,000	$ 6,315	$ 81,906	Very Unlikely	Minor	6
CF	375	860	CICL	30	0.069	14.5	1000	500	0	0.50	500	$ 250,000	$ 17,200	$ 223,084	Very Unlikely	Moderate	5
DF	200	2100	CICL	30	0.315	3.2	1000	500	0	0.25	250	$ 125,000	$ 39,375	$ 510,694	Unlikely	Minor	5

The number of customers has been populated with estimated numbers only in all cases.

Table 2 -6 Comparison of solutions for shutdown block analysis

Benefit to cost ratio of each solution vs shutdown blocks

					Solutions and cost	
					Renewal of 'ED' $3,000,000	Open DV Bringelly Rd $10,000
Shutdown block sections	Diameter (mm)	Length (m)	Material	Risk cost $ NPV	B/C Ratio	B/C Ratio
AB	600	735	CICL	$2,859,885	-	286.0
BC	600	1933	CICL	$3,760,652	1.3	376.1
BD	250	421	CICL	$81,906	-	-
CF	375	860	CICL	$223,084	-	-
DF	200	2100	CICL	$510,694	0.2	51.1
				Preferred B/C	0.0	713.1
				Outcome	Not economical	Economical

Table 2 -6 shows that opening the DV from Bringelly Rd provides more redundancy than renewal of 'ED' and also provides far greater value for money.

Appendix E: Energy efficiency and Renewable Energy - list of key measures

Table 2 - 7 Energy Efficiency Options – Shorter Term Benefits

Opportunity	Current status	Current economic viability	Criteria
Metering	All new pumps and upgrades should include installation of pressure, flow and power monitoring. Monitoring is critical to be able to measure the ongoing performance of the pump station and continue to optimise its' operational performance.	Very good (N/A)	If possible pressure, flow and power monitoring should be integrated so the same data intervals are used and the meters log at the same time eg all on the hour. Suggested 15 minute logging intervals are used. Monitoring is more important on larger assets.
Gravity/Minimise head requirements	Make use of gravity wherever possible rather than relying on pumps Considering absolute lifting requirements will minimise the overall energy input required.	Very good (< 5 years)	Consider the total head of different options considered. Can the total head be minimised.
Ventilation of pump stations	Optimising fan size and operation of the fan (fan may not need to run 24 hours).	Good (< 5 years)	Is continuous ventilation required?
Water and wastewater pump sizing	Oversized pumps are inefficient. Design to typical flow with second pump to handle peak period pumping rather than operating a large pump at a fraction of capacity most of the time.	Very good (<10 years)	System is expected to have significant diurnal or seasonal fluctuations.
Modular approach	If flows are expected to significantly increase in the future, consideration should be given to installing pumps optimised for existing flows (to avoid installing pumps that are too large), and modularising future installations	Very good (<10 years)	Are flows likely to increase significantly? Consider staging of pumps across asset life to meet increasing demand; if increasing demand is predicted. Pump size can be optimised to current and not future demand, reducing energy use.
VSD	VSDs may be applicable with some pump applications. VSDs can improve efficiency by adjusting pump curve, reducing frictional head etc. They may be particular effective on system that have considerable flow fluctuations. VSDs use about 4% of pump power to operate.	Good (< 5 years)	Are there system fluctuation?

Table 2 - 8 Renewable Energy/Fuel Switching Options – Generally Longer Term Benefits

Opportunity	Current status	Current economic viability (likely payback)	Criteria
Natural gas power generation for pumps	In some areas (especially Ausgrid) it may be economically viable to use gas generators for powering pumps rather than importing grid electricity.	Marginal (<10 years)	Is there likely to be a natural gas connection to the site?
Wind small scale	Not cost effective at present, but is a much greater chance of development approval.	Weak (10 – 20 years)	Is there a piece of land available roughly 20m x 12m free of buildings, services and other immovable encumbrances (which is within or adjacent to the Sydney Water site)?
			Is there significant topography that could affect the wind flow, ie land contours rising >10 m above the turbine site within 500 m or >15 m within 1,000 m, or cliff-lines?
			Are there likely to be buildings/structures greater than 5 m high within 500 m of the site?
Solar PV	Currently not cost effective, but costs are rapidly decreasing. Excellent option for sites with maximum demand in afternoons	Marginal (10 – 15 years)	Are there likely to be buildings or ground space available.
			Are there likely to be tall buildings or anything else that could cast significant shadows over the available roof area?
			Are there likely to be any reservoirs, lagoons or other areas that need covering and are free from significant sun shadowing?
Integrated Micro hydro	If sufficient head is present a micro hydro could be installed.	Marginal (10 – 15 years)	Site specific, a connection "behind" the sites power meter will be required to make the project feasible.

For assistance with assessment of these options please contact the Energy and Eco-efficiency Team.

Water Planning Guideline

Section 3: Water Demand and Growth

Version 1

September 2014

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Section 3: Water demand and growth

3.1 Introduction

This section covers Sydney Water's approach on how to consider growth and demand for planning for drinking and recycled water.

While this document provides general guidelines and criteria applicable to most planning scenarios, it does not limit a planner's responsibility to exercise engineering judgement and, if required, to adopt improved approaches.

3.1.1 General

As part of the planning process to provide customers with a total water supply system that best meets their needs at a price they are willing to pay, each water supply scheme is planned in stages to ensure optimal use of assets. This ensures that new facilities are only provided where needed and augmentation done only when required. To do this effectively we need to forecast population and demand over a planning horizon, generally 25 to 30 years.

Demands are affected by various factors including:

- water restrictions
- water conservation education campaigns
- introduction of the Building and Sustainability Index (BASIX)
- penetration of water efficient appliances and fixtures
- non-revenue water management programs
- introduction of alternative water products
- changes in development lot sizes
- pricing
- local climatic factors (rainfall, evaporation, temperature, humidity, winds, etc)
- demographics
- development types (infill/greenfield)
- type of use (indoor/outdoor/recreational)
- different demand categories (residential/commercial/industrial/special use).

3.2 System demands

3.2.1 Overview

Demands vary day-to-day and generally rise and fall with the seasons. Seasonal variation in water demand is often due to outdoor usage. It is not uncommon for supply zones to experience individual days where demand exceeds twice the average day demand during a hot, dry summer period. During low demand periods (typically winter or wet and cold periods), minimum demand for an individual day can fall below 70% of average day demand.

3.2.2 Temporal demand variation

Sydney Water typically designs water systems based on maximum system demands. Understanding demand variation over the years, months, weeks and days is crucial to selecting fit for purpose assets.

Diurnal patterns are unit curves used in modelling to simulate diurnal demands. These are important mainly when sizing the reticulation network (Refer to **Figure 3-1** for an example of a typical residential diurnal curve). Different property types will have different diurnal patterns, and in some cases it may be necessary to develop new diurnal patterns for high water users that behave differently to other properties and have a considerable influence in the flow distribution.

Commercial and industrial demand patterns vary markedly from residential diurnal curves. As well as having different profiles, the peak factors for these demand types will be different and occur at other times of the day compared to residential consumption.

In determining the maximum consumption for a particular water supply area, the planner should consider the combined effect of different types of consumption within the zone and determine when combined maximum demand occurs.

The Water Modelling System (WMS) database has default diurnal curves for maximum days to be used for various demand types.

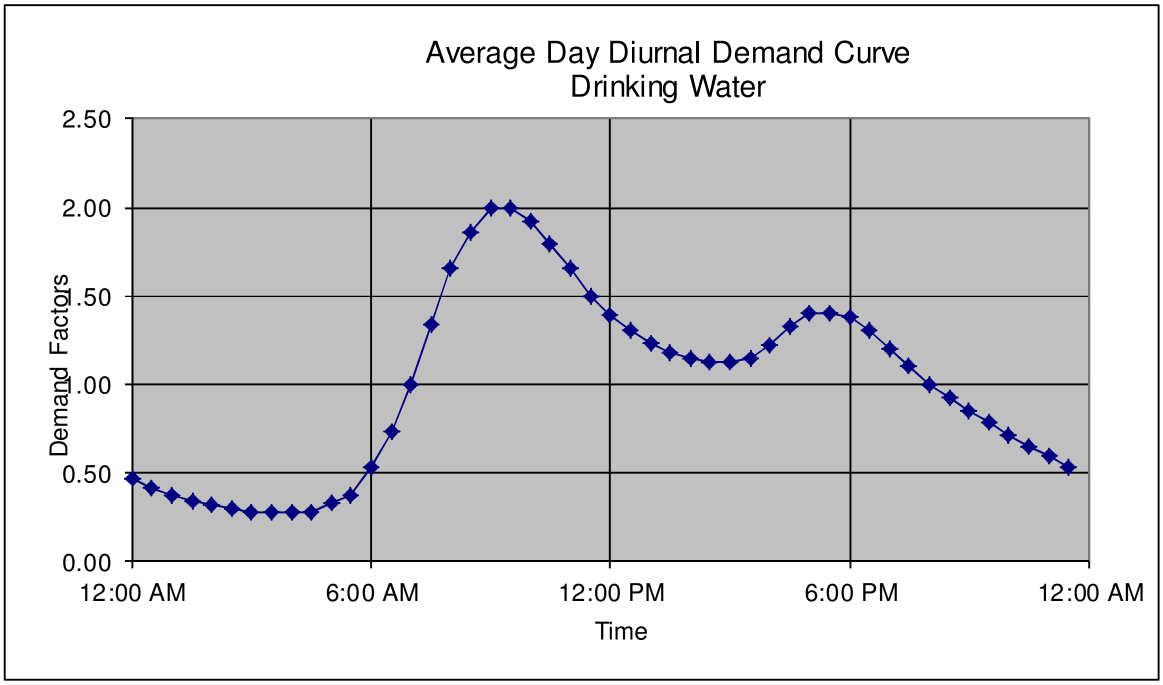

Figure 3 - 1 Typical residential average day demand curve

3.2.3 Demand considerations for planning

Water system assets are generally sized for a specific demand type. **Table 3-1** outlines various assets and the respective demand types (a guide only).

Considerations in calculating demands include:

- Planning of transfer infrastructure to allow receiving reservoirs to recover from prolonged high demand events. Under some circumstances, this means that transfer systems need analysing for a maximum design demand period. Calculation of demand will need to consider all the demands from downstream systems in the transfer system.
- Reticulation systems to be generally sized for maximum hour demand events to ensure that all customers receive adequate pressure throughout the day.
- Current maximum demand sequences, maximum day and maximum hour events are best determined from historical data.
- Care should be taken that the adopted maximum demand events are not distorted by abnormal operations such as main breaks or temporary operational changes.
- BASIX requirements for new developments (since 2004) should be taken into account. Latest studies on existing BASIX compliant properties showed that BASIX reductions affect the average demand of affected dwellings more than their maximum day demand.

- Dual supply systems need special attention. Single supply systems are more prevalent and distribute only drinking water to customers. Dual supply systems serve customers within the supply area with additional infrastructure to deliver recycled water for non-drinking purposes. The production of recycled water does not always match the demand. Consequently topping up these systems from the drinking supply is often required and must be considered in planning.

Table 3 - 1Guide to design demand types for system assets

System	Asset	Demand type				
		Max Week/Max Demand Period	Max Day	Max Hour	Max Minute	Min Minute
Bulk water	Raw water supply	✓	✓			
	Water filtration plant	✓	✓			
Delivery system	Water pumping station	✓	✓			
	Service reservoir	✓	✓			
	Trunk transfer mains	✓	✓	✓		
Supply system	Water pumping station – surface	✓	✓			
	Service reservoir – surface	✓	✓			
	Water pumping station - elevated			✓		
	Service reservoir – elevated			✓		
	Outlet mains (single reservoir zone)			✓		
	Outlet mains (dual purpose)	✓	✓	✓		
	Reticulation mains			✓		
	Local booster pumps (no storage)				✓	✓
	Flow meter				✓	✓
	Valve/pressure reducing valve/ pressure sustaining valve			✓		

3.2.4 Estimation of current demands

The methodology for estimating current demands is described below:

3.2.4.1 Average day demand

Average day demand (ADD) components are average customer metered consumption and non-revenue water.

To determine ADD, consider the average historical customer metered consumption for the previous six financial years (a financial year is recommended to capture a whole summer period), if possible. An appropriate amount of non-revenue water will need to be added to this calculation (Refer to Clause **3.2.5**).

In addition, determining ADD for major demand categories within the zone will help to establish per property demand for the zone to apply to new growth or to determine an estimated future maximum day demand (Refer to Clause **3.2.4.2**).

3.2.4.2 Maximum day demand

Current maximum day demand (MDD) for an existing supply zone or transfer system is determined by one of the following methods (in order of preference):

- An analysis of the last ten consecutive financial years of IICATS data to select the day with the highest demand over 24 hours.

  If the results of the last ten years are inconsistent or there seems to be apparent anomalies, a review of the analysis or timeframe (to be either lengthened or shortened) may be required. Examples include:

  - The timeframe may include restriction periods, which in some instances may have a high demand, eg, if watering gardens is only allowed in a supply zone on one day of the week. However, instances like this need to be reviewed as to the likelihood of them happening again.
  - A major industry has started/closed in the last ten years

- Where suitable IICATS data is not available, ADD can be calculated from customer billing data as described in clause **3.2.4.1** and factored with locally derived scaling factors, with appropriate allowances for non-revenue water (Refer to clause **3.2.5**). The default demand factors outlined in **Appendix A:** should only be used as a last resort, as they tend to be conservative. The planner must be aware of any significant growth or changes in property demand in the supply zone that has occurred in the MDD calculation period and account for that appropriately.

For a greenfield development, use the demand from a similar zone/s (where there is similarity in customer type, lot size and population) in the vicinity. Only use the default demand rates from **Appendix A:** as a last resort, as they tend to be conservative. Monitor the actual consumption for possible future adjustment of demands for planning of further stages of a project.

Where there is less than ten years of IICATS data, the planner shall undertake a sensitivity analysis and risk assessment between the two methods.

3.2.4.3 Maximum hour demand

Maximum hour demand (MHD) does not necessarily occur on the same day as the MDD. Current MHD for an existing supply zone or transfer system is determined by one of the following methods (in order of preference):

- An analysis of the last ten years of 15 minutes of IICATS data (where not available use hourly IICATS data) to select the maximum hour event.

  Refer to clause **3.2.4.2** for comments under maximum day demand if the results are inconsistent, or there seem to be anomalies.

- Where suitable IICATS data is not available, but MDD demand is available for the system, use locally derived scaling factors to obtain the MHD. The default demand factors outlined in **Appendix A:** should only be used as a last resort, as they tend to be conservative.

For a greenfield development, use the demand from a similar zone/s (where there is similarity in customer type, lot size and population) in the vicinity. Only use the default demand rates from **Appendix A:** as a last resort, as they tend to be conservative. Monitor the actual consumption for possible future adjustment of demands for planning of further stages of a project.

3.2.4.4 Maximum design demand period

Maximum design demand period is used as the basis for determining whether a water system can recover from a number of days of high demand. Generally, it only needs to be used where system demand exceeds input capacity.

For existing supply zones and greenfield development, a period of eight highest consecutive days is used. The daily demand factors are given in **Appendix A:, Table 3 - 7** .

For existing delivery system assessments, collect historical demand data from Hydraulic System Services (HSS) to determine daily demand factors.

For recycled water systems, refer to **Appendix A:, Table 3 - 7** for daily demand factors**.**

3.2.5 Non-revenue water (NRW)

Previously known as Unaccounted for Water (UFW), Non-Revenue Water (NRW) is consumption unaccounted for through customer metering over a set period of time (usually the most recent financial year). For the components of NRW, refer to **Appendix D:**.

The volume loss due to leakage depends on the system design, construction, operation, and maintenance practices. In urban systems the majority of leakage occurs at connections and property water services (hence the allowance for NRW is usually based on the number of connections/water services rather than on the length of mains). Leakage is also dependent upon average pressure, ie generally the higher the pressure, the higher the leakage.

For more details on how Sydney Water manages water leakage to meet the Operating Licence and Metropolitan Water Plan, refer to the *Leakage Management Plan 2010-* (**Reference 3**).

The NRW rate that planners should use will be either:

- The existing NRW rate for the supply zone (preferred if known). Any significant calculated NRW variation from the current financial year's Sydney-wide NRW figure from the "Water Efficiency Report" (or outside the range of 5-15%) should be investigated. An inconsistency could point to operational problems that need to be resolved, ie open boundary valves, water theft in rural areas or excessive leakage.

  or

- 12% of total metered supply zone consumption where NRW can't be calculated. However, this value needs to be verified before use based on the year-end results published on the web in the *Water Efficiency Report* (**Reference 48**).

No additional allowance is needed if demands are based on IICATS flow metering (eg for bulk supply metering), as NRW is already included.

3.2.6 Other design demands for water system component design

3.2.6.1 Maximum minute demand

Maximum minute demand refers to the highest flow rate occurring over a one minute period. Maximum minute demand is relevant to the design of in-line boosters, flow meters and pressure reducing valves for small service areas (under 100 hectares as a guide). IICATS records flows in 15-minute intervals or less (based on information available for the system) which can be used to derive maximum minute demand.

In the absence of any other information from the system, refer to the design charts in **Appendix E:.**

3.2.6.2 Minimum minute demand

Minimum minute demand is used in the design of flow meters, pressure reduction valves and booster stations to ensure that assets (including bypass arrangements) can operate over the full range of flows encountered.

Minimum minute demand usually occurs during night hours (2-4 am) when there is little or no customer activity. It is the sum of:

1. unavoidable background leakage (UBL) below the threshold of modern detection equipment, eg typically small weeps from joints
2. minimum residential usage, primarily due to toilet flushing at night
3. minimum non-residential usage. There will be times during the year when non-residential activity is likely to be at, or close to zero. Do not allow for this unless there is sufficient evidence to base an estimate.

For further understanding on how to calculate minimum water demand, refer to **Appendix F:.**

3.2.6.3 Minimum weekly demand

The minimum weekly demand is required to assess system impacts such as when the Kurnell Desalination Plant is in operation. In this case, the Potts Hill delivery system is likely to experience its maximum pressures during this demand period

This demand may be used to study other issues, such as storage balancing and reviewing pump efficiencies for the pumping stations along the City and Pressure Tunnels.

3.2.7 Reliability based demands (shutdown block analysis)

Approach for reliability demands

Sydney Water employs a risk based approach to the provision of redundancy. It is generally regarded as unrealistic to have a full back-up supply available to all customers all of the time due to the excessive cost.

There is a need to balance spending too much capital on redundancy and reducing impacts on customers. Undertaking qualitative and quantitative risk assessments, determining the cost of a mitigation solution, developing a benefit cost ratio for the mitigation solution and organising a management review will ensure that cost effective mitigation solutions are developed (refer to **Section 2: Water System Planning** of this guideline).

Our Operating Licence does allow for a certain number of customers to lose continuity, eg during a mains break. The current annual target is a maximum of 40,000 customers affected for longer than five hours.

Reliability demands

Reliability demands can be used in the design of systems for abnormal (planned and unplanned) operating conditions. They are used to:

- Test the adequacy of existing assets.
- Develop mitigation solutions to a chosen level of service (demand scenario)

Each critical element of the system is to be tested by choosing the appropriate demand scenario from the following list:

- Maximum Hour
- Maximum Day Demand (MDD)
- Maximum week
- Ninety percent of MDD – generally for pumping stations without the standby in operation. Note: Above 90% of MDD represents about 1% of days in the year, or 3 to 4 days in the maximum week sequence.
- Average day demand (ADD)
- Peak hour on an average day

As an example on which demand scenario/s would be used for a shutdown block analysis for a water main, maximum hour and peak hour on an average day would be generally chosen in the first instance. It is unusual for testing to show that a maximum hour back up supply is available.

When using an ADD event for testing of a shutdown block, a different likelihood and consequence is usually developed compared to an MDD event. Thus a different risk score and risk cost generally occurs for the two scenarios. The inclusion of two (or more) scenarios can improve the decision making process.

The preferred mitigation solution is generally based on the demand scenario that provides acceptable residual risk and/or value for money. It can be chosen from the above demand scenarios as well as the following:

- Minimum day demand. This demand is usually around 0.5 – 0.8 ADD (Refer to **Appendix G:**).
- Emergency demand - 100 litres/person/day.
- Drinking requirements only - 10 litres/person/day (tankering and bottled water).
- A scenario developed specifically for a project

An alternative methodology is to apply the ‘working backwards’ strategy, ie determine what demand provides a value-for-money solution or a change in risk score.

Appendix G: shows information on demands for a number of delivery systems.

Mitigation solutions may be capital or operational (including contingency plans). (Refer to **Section 2: Water System Planning**).

Discussion on criteria

It is difficult to set criteria on a Sydney-wide basis for demands that are to be provided in an abnormal situation. A customer’s ability to be unaffected by a major asset failure may depend on their location in the Sydney region.

As an example of this, providing a back-up supply of average day demand to customers in the Woronora delivery system is relatively easy as a major link is already connected to the Prospect system. However, providing a back-up supply to the customers in the Nepean delivery system requires a long pipeline from the Macarthur system, which is very expensive. Hence tankering and bottled water may be required for some extended failures, depending upon the operational solutions.

In practice to date, for the planning of critical water main renewals, it has been generally found that:

- A MDD or MHD back-up supply was generally not available. Designing a MDD or MHD back-up supply was generally not suitable, due to the lack of existing pipework capacity and the excessive cost to augment to meet this requirement. Generally, reserve storage is the only available redundancy in the system.

- An ADD or the morning peak (on an average day) back-up supply was available on many occasions, as the remaining system still in service was not operating at maximum capacity, thus spare capacity exists.

From the above, it can be seen that reliability should be reviewed to ensure that each customer be supplied with the best outcome available from the qualitative and quantitative risk assessments, subject to a management review.

Other considerations

These include:

- Planned maintenance activities can extend for several months and are usually undertaken during lower demand periods, eg tunnel and reservoir shutdowns occur between March and September. The analysis of the previous 10 years of demands should therefore be based on the same months of the shutdown, subject to a risk assessment.

- Minimum day demand (the lowest recorded day without restrictions) would be an expected target demand rate where restrictions are implemented during incidents, subject to a risk assessment. This demand usually aligns with wet or cold days where outdoor and washing machine usage is very low. Christmas Day is commonly a low demand day. Recent experience (in March 2014 in the Macarthur water supply system) suggests asking customers via the media to voluntarily conserve water did not reduce demands significantly.

- Bottled water or tankers may be required to supply water to customers when continuity is lost. This is not a design issue, but should be considered in risk assessments to determine whether it is practical to respond in this way (based on the size of the demand required). Refer to clause **3.2.7**.

- Drought demand rates. While not mentioned here, these need to be developed on a case-by-case basis.

3.3 Growth and demand forecasting

3.3.1 Growth

Population growth forecasts are a key input into the planning process and provide an insight into future infrastructure needs as well as future capital investment needs. Sydney Water typically sources growth information from:

- The Department of Planning & Environment, councils and property developers (residential growth projections). Short and medium projections are sourced from the Metropolitan Development Program (2010/11 – 2019/20 MDP Residential Forecasts). The long-term forecast is sourced from DP&E's population data (projections to 2036). For major growth areas such as the South West Growth Centre (SWGC), North West Growth Centre (SWGC), and West Dapto, more detailed growth projections can be obtained separately from DP&E. Forecasts for Wollondilly LGA can be updated by the planner as advised by UrbanGrowth NSW (formed through the integration of Landcom and the former Sydney Metropolitan Development Authority).
- Employment forecasts developed by the Bureau of Transport Statistics (BTS), councils and developers (non-residential growth projections).
- OASIS property table (an internal Sydney Water source).

3.3.2 Growth demand forecasting

To calculate 'growth demands' on a water system use one of these approaches:

1. Determine the per capita consumption by demand category (for the definition of Sydney Water demand categories refer to **Appendix C:**) for the existing relevant supply area and apply the relevant per capita demand* on each new development (preferred method where possible).

**Be aware that even in situations where demand behaviour in an area is known, this may not always reflect future consumption behaviour for new dwellings.*

2. Where suitable IICATS data is not available, use the demand from similar zone/s (where there is similarity in customer type, lot size and population) in the vicinity to obtain MDD and MHD. The default demand factors outlined in **Appendix A:** should only be used as a last resort, as they tend to be conservative.

To minimise the uncertainty of projected demand trends and to validate the assumptions on consumption, staging of future works and monitoring of actual growth demands over time is generally preferred.

3.3.3 Future maximum day demand

Demand forecasts are based on forecast growth to identify future system deficiencies and develop concept augmentation options. It is important that demand forecasts:

- are determined for each supply zone or trunk system (Sydney-wide estimates cannot be used)
- follow a consistent methodology as described below.

Current MDD must be calculated before projecting future MDD (for calculation methods refer to clause **3.2.4**). The planner must establish the current MDD for each individual supply zone or where applicable for each pressure managed sub-zone within the project boundary.

The current MDD provides a baseline from which the demand growth will be applied and to determine per capita consumption rates for residential categories in that zone. These consumption rates in conjunction with the growth projections and the present MDD will allow the planner to forecast future MDD for each planning horizon. The MHD factor determined for the current case is also used for future demand scenarios. This may require the alteration of the diurnal pattern so that it incorporates the current MHD to be used for future scenarios.

Commercial and industrial growth will be considered and the rate of change will be based on the growth/reduction shown in the employment figures produced by the BTS. Hence if x% reduction is predicted, then x% reduction is applied to the existing non-residential properties in the area in question.

For the definition of different levels of industrial water usage refer to **Appendix C:.**

3.3.4 Design demand rate review management

Sydney Water has developed the *Design Demand Rates for Water Assets (SAP) - AMQ0038* (**Reference 2**) to assist in the revision of design demand rates to ensure infrastructure is appropriately sized considering the change of customer water usage and local variability. It includes the following key processes:

1. Plan the process (including development of an implementation plan).
2. Deliver the implementation plan (including any monitoring requirements).

3. Evaluate and review (including data management and analysis of data).
4. Implement the changes.

Estimated design demand rates will be subjected to periodical future review, based on actual demands from field monitoring.

3.4 Context

3.4.1 Definitions, abbreviations and references

Refer to **Section 1: Introduction to the guideline, Clause 1.6**.

3.4.2 Attachments and/or appendices

Attachment/appendix number	Title
Appendix A	Design demand rates
Appendix B	Average day data
Appendix C	Definition of different demand categories
Appendix D	Components of NRW
Appendix E	Theoretical value to calculate maximum minute demand
Appendix F	Recommendation on how to calculate minimum water demand
Appendix G	Demand distribution for reliability and risk-based approach

3.4.3 Document Control

Title: Water System Planning Guideline, Section 3: Water Demand and Growth		
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Approval and Endorsement	See end of 'Section 0' of WSPG

3.4.4 Revision control chart

Version number	Date revised	Brief description of change
1	September 2014	New Document

Appendix A: Design demand rates

Design demand rates provided in this document will replace the values in the *Water Supply Code of Australia, Sydney Water Edition* (**Reference 1**).

Note that:

- the criteria below are the default values to be used for future development **in the absence of any other available information**
- planning of small areas (less than 100 ha or 1,000 properties) which, on account of diversity in demand patterns, can have higher maximum demand. Refer to *Guidelines for selection of small self-contained water booster stations,* April 2004 (**Reference 7**).

For the definition of residential, commercial, and industrial (light and medium) demand categories, refer to **Appendix C:.**

Design rates for single supply systems

Default demand rates for single supply system planning are provided:

- in **Table 3-2** (Residential Demand)
- in **Table 3 - 3** (Non- Residential Demand).

The demand rates contained in the tables include the leakage component.

Table 3 - 2 Dwelling-based default demand rates for planning residential water supply systems

New release areas and major urban consolidation

Item	Design criteria	Units[5]	Drinking water
Design demands for drinking water supply network that are BASIX compliant (rainwater tanks may be installed).			
Single dwelling residential	Average day demand	kL/dwelling/day	0.75 Refer to Note 1 and Note 2
	Max day demand	kL/dwelling/day	2.20 Refer to Note 3
	Max hour demand	kL/dwelling/day	= 2.5 x maximum day = 5.500. Refer to Note 4
Town house (<30 units/net/ha)	Average day demand	kL/unit/day	0.7
	Max day demand	kL/unit/day	1.6
	Max hour demand	kL/unit/day	= 2.2 x maximum day = 3.52
Multi-unit (30 - 60 units/net/ha)	Average day demand	kL/unit/day	0.63
	Max day demand	kL/unit/day	1.35
	Max hour demand	kL/unit/day	= 2.0 x maximum day = 2.7
Multi-unit (61 - 100 units/net/ha)	Average day demand	kL/unit/day	0.53
	Max day demand	kL/unit/day	1.09
	Max hour demand	kL/unit/day	= 2.0 x maximum day = 2.18
Multi-unit (101 - 140 units/net/ha)	Average day demand	kL/unit/day	0.44
	Max day demand	kL/unit/day	0.88
	Max hour demand	kL/unit/day	= 2.0 x maximum day = 1.76
Multi-unit (>140 units/net/ha)	Average day demand	kL/unit/day	0.42
	Max day demand	kL/unit/day	0.8
	Max hour demand	kL/unit/day	= 2.0 x maximum day = 1.6

Note that,

1. This is the total demand and includes the rainwater supply. This criteria is to be used for shutdown block analysis as well. Refer to **Appendix B:.**
2. The drinking water usage minus the rainwater supply (ie drinking water meter reading) is 0.55 kl/dwelling/day. This criterion is to be used for average drinking water and power calculations. Refer to **Appendix B:.**
3. Considering water consumption with rainwater tanks use water to the same extent as in dual reticulation system, (demands of DW) 0.8 plus (demand of RW=outdoor + toilets) 1.4.
4. Due to lack of actual data on BASIX houses with rainwater tanks, this number is assumed based on the previous maximum hour WSAA number in Table 2.1 (WSAA Version 2002) of 90 kL/Nha/day with a density of 16.4 dwellings per net hectare. However, current densities at Rouse Hill tend to vary around 14 to 17 dwellings per net hectare.
5. For the conversion to Net Hectares (NHa), where no better information exists, assume 0.8 x gross hectare with a density of 16.4 dwellings per net hectare.

Table 3 - 3 Non-residential design demands for drinking water supply planning

(new development areas)

Item	Design criteria	Units[1]	Drinking water
Design demands for drinking water supply system for non-residential development			
Light industrial	Max day demand	kL/NHa/day	40
	Max hour demand	kL/NHa/day	1.6 x Max day demand = 64
Medium industrial	Max day demand	kL/NHa/day	66 Moved old light Industrial into the medium category
	Max hour demand	kL/NHa/day	= 1.6 x maximum day
Heavy industrial	Demands	kL/NHa/day	Based on individual industrial need
Suburban commercial	Max day demand	kL/NHa/day	41 63 kL/NHa/day For large shopping complexes such as Westfield, Centro, Roselands etc the City Rise Commercial.
	Max hour demand	kL/NHa/day	=2.0 x maximum day demand
City high rise commercial* *(600 persons/ floor ha)	Max day demand	kL/ floor ha/day	63
	Max Hour demand	kL/ floor ha/day	=2.0 x maximum day demand
Note that: 1. Where no better information exists, assume net hectares (NHa) = 0.8 x gross hectare.			

Design rates for dual water supply system (includes recycled water systems)

A dual water supply system supplies customers with drinking water and recycled water. Demands need to be calculated separately for the two systems.

The following are general requirements or assumptions:

- Unless otherwise directed, both the drinking and recycled system shall be designed for 100% washing machine usage.
- Assume that cooling towers are supplied from the drinking water supply system.

Default demand rates for dual supply system planning are provided in:

- **Table 3 - 4** for single dwelling of dual reticulation supply systems.
- **Table 3 - 5** for Medium Density Residential of dual reticulation supply systems.
- **Table 3 - 6** for non-residential development

The demand rates contained in the tables include the leakage component.

Table 3 - 4 Single dwelling design demand rates for dual water supply system planning

Item	Design criteria	Units	Drinking water[1] (includes 100% of washing machine usage)	Recycled water[1] (includes 100% of washing machine usage)
1. Single dwelling residential	Average day demand	kL/dwelling/day	0.50 Refer to **Appendix B:**	0.35
2. Single dwelling residential	Max day demand	kL/dwelling/day	0.80	1.6
3. Single dwelling residential	Max hour demand	kL/dwelling/day	= 2.7 x maximum day = 2.160	= 3.6 x maximum day = 5.76

Note that:

1. Demand rates consider 100% washing machine usage on both drinking water and recycled water.

If otherwise directed by Sydney Water, to supply washing machine usage from one source only (either drinking water or recycled water), demand for alternative source will be reduced by the demand rates considered for washing machine usage under each scenario and the amount will be as follows:

- Reduce average day rate by 0.10 kL/dwelling day
- Reduce maximum day rate by 0.20 kL/dwelling/day
- Reduce maximum hour rate by 0.16 kL/dwelling/day*

*As washing machine usage maximum demand occurs during morning, maximum hour demand rate (usually during afternoon) is less than maximum day demand rate for washing machines.

Table 3 - 5 Medium density residential design demand rates for dual water supply system Planning

Item	Design criteria[1]	Units	Drinking water[2] (includes 100% of washing machine usage)	Recycled water[2] (includes 100% of washing machine usage)
1. Town house (<30 units/net/ha)	Average day demand	kL/unit/day	0.500	0.350
	Max day demand	kL/unit/day	0.70	1.1
	Max hour demand	kL/unit/day	= 2.45 x maximum day = 1.71	= 3.2 x maximum day = 3.52
2. Multi-unit (30 - 60 units/net/ha)	Average day demand	kL/unit/day	0.375	0.320
	Max day demand	kL/unit/day	0.60	0.95
	Max hour demand	kL/unit/day	= 2.29 x maximum day = 1.37	= 3.0 x maximum day = 2.85
Multi-unit (61 - 100 units/net/ha)	Average day demand	kL/unit/day	0.375	0.300
	Max day demand	kL/unit/day	0.60	0.70
	Max hour Demand	kL/unit/day	= 2.29 x maximum day = 1.37	= 2.47 x maximum day = 1.73
Multi-unit (101 - 140 units/net/ha)	Average day demand	kL/unit/day	0.375	0.250
	Max day demand	kL/unit/day	0.60	0.50
	Max hour demand	kL/unit/day	= 2.29 x maximum day = 1.37	= 1.71 x maximum day = 0.85
Multi-unit (>140 units/net/ha)	Average day demand	kL/unit/day	0.375	0.220
	Max day demand	kL/unit/day	0.60	0.40
	Max hour demand	kL/unit/day	= 2.29 x maximum day = 1.37	= 1.8 x maximum day = 0.72

Note that:

1. For high density multi-unit type developments the default design demand rates do not include an allowance for irrigation of the surrounding landscape. This issue should be reviewed on a case-by-case basis.
2. Demand rates consider 100% washing machine usage on both drinking water and recycled water.

If otherwise directed by Sydney Water, to supply washing machine usage from one source only (either drinking water or recycled water), demand for alternative source will be reduced by the demand rates considered for washing machine usage under each scenario and the amount will be as follows:

- Reduce average day rate by 0.10 kL/dwelling day.
- Reduce maximum day rate by 0.20 kL/dwelling/day.
- Reduce maximum hour rate by 0.16 kL/dwelling/day.*

*As washing machine usage maximum demand occurs during morning, maximum hour demand rate (usually during afternoon) is less than maximum day demand rate for washing machines.

Table 3 - 6 Non-residential design demand rates for dual water supply system planning

Item	Design criteria	Units	Drinking water	Recycled water
Light industrial	Max day demand	kL/NHa/day	Where possible assessed on individual basis or 20 kL/Ha/day	Where possible assessed on individual basis or 20 kL/Ha/day
Light industrial	Max hour demand	kL/NHa/day	= 1.6 x maximum day	= 1.6 x maximum day
Medium industrial	Max day demand	kL/NHa/day	Where possible assessed on individual basis or 33 kL/Ha/day	Where possible assessed on individual basis or 33 kL/Ha/day
Medium industrial	Max hour demand	kL/NHa/day	= 1.6 x maximum day	= 1.6 x maximum day
Heavy industrial	Demands	kL/NHa/day	Assess on individual basis	NA
Commercial	Max day demand	kL/NHa/day	Where possible assessed on individual basis or 21 kL/Ha/day or 31.5 kL/Ha/day* *For large shopping complexes such as Westfield, Centro, Roselands etc the City Rise Commercial design rate of should be used.	Where possible assessed on individual basis or 21 kL/Ha/day or 31.5 kL/Ha/day* *For large shopping complexes such as Westfield, Centro, Roselands etc the City Rise Commercial design rate of should be used.
Commercial	Max hour demand	kL/NHa/day	= 2.0 x maximum day	= 2.0 x maximum day
Irrigation	Average day demand	kL/NHa/day	Only permitted off recycled system	= 1/3 maximum day demand
Irrigation	Max day demand	kL/NHa/day	Only permitted off recycled system	Where possible assessed on individual basis or 7 kL/Ha/day
Irrigation	Max hour demand	kL/NHa/day	Only permitted off recycled system	To be restricted to maximum day rates. Maximum demands to be met by onsite storage.

Table 3 - 7 Maximum week demand sequence default factors

Day	MDD factor for DW Supply	MDD factor for RW Supply in Dual Retic
1	0.78	0.75
2	0.92	0.85
3	0.92	0.91
4	1.00	1.00
5	0.94	0.94
6	0.93	0.94
7	0.92	0.96
8	0.68	0.73

Supply systems with rainwater tanks

Sydney Water does not currently consider any allowance (reduction) for rainwater tank supply in design maximum demands (eg maximum hour, maximum day or maximum week demands) for single or dual water supply systems. Rainwater tanks are assumed to be fully depleted during maximum day events.

Appendix B: Average day data

Table 3 - 8 Average day data from BASIX water savings monitoring

Item	Dual reticulation system*	Rainwater tank system
	2008 - 2009	
Analysable sample (number of dwellings)	123	1139
Average BASIX benchmark consumption (kL/dw/day)	0.91	0.89
Average target potable water consumption (ie BASIX benchmark – 40%) (kL/dw/day)	0.55	0.53
Average actual potable water consumption (kL/dw/day)	0.50	0.56
Actual recycled water or rainwater consumed (kL/dw/day)	0.22	Not available
Total water consumption (kL/dw/day)	0.73	Not available
Average actual potable water percentage savings relative to BASIX benchmark	44.20%	36.00%

Table 3 - 10 shows average day data from several sources including *BASIX Water Savings Monitoring* – December 2009 (**Reference 10**).

Table 3 - 9 Average day data from Rouse Hill monitoring

Rouse Hill area 108 and 282 reticulation data	Area 282	Area 108	Average of 390
2008 - 2009			
Drinking water (kL/dw/day)	0.45	0.48	0.46
Recycled water (kL/dw/day)	0.35	0.23	0.32
Total water consumption (kL/dw/day)	0.80	0.71	0.78

Flow meters were installed in December 2008 at Rouse Hill to monitor water and recycled water demands.

Table 3 - 10 Average day data from BASIX and Rouse Hill monitoring

Consumption based on averages from two data sets for dual reticulation system	*	Rouse Hill average	Average	Final assumed value for dual reticulation system
Drinking water (kL/Dw/Day)	0.50	0.46	0.48	0.50
Recycled water (kL/Dw/Day)	0.22	0.32	0.27	0.25
Total Water (kL/dw/Day)	0.73	0.78	0.75	0.75

*Based on BASIX water savings monitoring report

Table 3 - 11 Assumed average day data

For rainwater tank system	Final assumed value
Drinking water consumption (kL/dw/day)	0.55
Rain water consumption (kL/dw/day)	0.20
Total water consumption (kL/dw/day)	0.75*

*Total water consumption consistent with dual reticulation system

Appendix C: Definition of different demand categories

Demand categories	Description
Residential	Domestic demand is a major component of demand in Sydney Water's area of operations. It can be divided into two components, indoor and outdoor use. Indoor use includes clothes and dishwashing, cooking, toilet flushing, washing and showering, cleaning, etc. Indoor consumption is relatively constant over the year. Outdoor use includes garden watering, topping up swimming pools, washing vehicles, etc. Outdoor consumption is higher in summer and varies with rainfall, garden type and soil type. Again based on demand variation, Residential demands are categories as Single dwelling (Low Density-LD) and multi-unit (High Density-HD). Single dwellings are houses, and multi-unit includes: ▪ flats, units and apartments ▪ semi-detached, terrace houses, townhouses etc.
Non-residential	Non-domestic demand is categorised into: a) Industrial b) Commercial c) Special uses d) Rural
a) Industrial	**Light industrial:** refers to areas largely characterised by general and neighbourhood business, transport, warehousing and storage industries, retailing including medium to large sized shopping centres dominated by bulky goods retailers (furniture, whitegoods and other homewares). **Medium industrial:** refers to areas likely to have a large number of demand-intensive industries. **Heavy industrial:** Usually industries with very high water consuming processes, eg paper mills, refineries, petro chemical factories, beverage plants, soft drink industry etc.
b) Commercial	Commercial demands include shops, shopping centres, accommodation industry, offices and clubs. Use of air conditioning gives these industries maximum summer loadings. Sydney Water sources commercial projections directly from the Transport and Population Centre.
c) Special uses	Special uses include: • Parks and gardens • Institutions (hospitals, nursing homes, jails, etc) • Clubs, hotels, motels Educational establishments (Schools, colleges)
d) Rural	Demand estimates for rural properties in areas supplied by Sydney Water's system make domestic supply the first priority; however, it also includes reasonable allowances for market gardening or other rural activities. Such allowances are based, where possible, on actual consumption data in similar areas with appropriate extrapolation to allow for future growth. Applications for rural property connections are treated on their individual merits and the available system characteristics at the point of connection.

Appendix D: NRW components

Non-revenue water (NRW) is the sum of unbilled authorised consumption, apparent losses and real losses. The make-up of NRW components is detailed below.

Table 3 - 12 Components of non-revenue water

Non-revenue water	Unbilled authorised consumption	Unbilled unmetered consumption	Sydney Water unmetered (Metered but not read STPs) properties Sydney Water operational use Fire use and fire testing Unmetered construction use Stopped customer meters	1% of total supply
		Unbilled metered consumption	Sydney Water metered STPs (metered and read)	0.05% of total supply
	Apparent losses	Unauthorised consumption		0.1% of total supply
		Customer metering inaccuracies		2% of total billed metered consumption
	Real losses	Real losses		85 Litres/connection/day (2011/12 results)

Unbilled authorised consumption includes those components of authorised consumption that are not billed and do not produce revenue. Apparent Losses include all types of inaccuracies associated with customer metering, plus unauthorised consumption (theft or illegal use). Real losses are physical water losses from the pressurised system, up to the point of measurement of customer use. It is the annual volume lost through all types of leaks, bursts and overflows depends on frequencies, flow rates, and average duration of individual leaks, bursts and overflows.

For details on the definition of the water balance with NRW, refer to *Calculation & Reporting - Corporate Waterbalance from Storages* (**Reference 4**).

Appendix E: Theoretical value to calculate maximum minute demand

Design charts

Small service areas (under 100 hectares) can experience higher maximum minute demands than provided for by the general water supply design allowances in the default demand rates table (refer to **Figure 3 - 2**). This may lead to pressure problems in some areas, generally for short periods of time on high demand days.

A simulation model developed for Sydney Water by the Department of Public Works and Services has been used to estimate maximum minute demands for a wide range of small service areas with a wide range of residential housing types and maximum day demands.

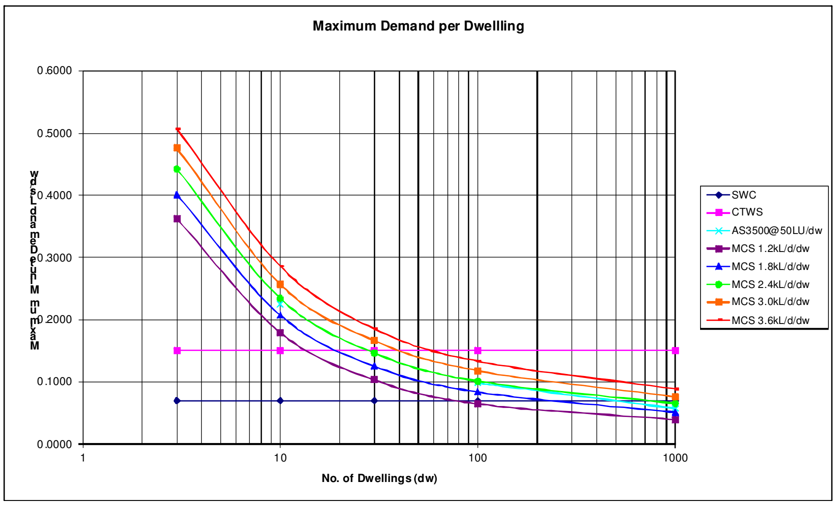

Figure 3 - 2 Design chart - Maximum demand versus duration

The maximum minute demand per dwelling relationships shown in **Figure 3 - 2** is the design chart for maximum demand in small service areas under 1,000 dwellings where a maximum day demand per dwelling has been adopted as the basis for design.

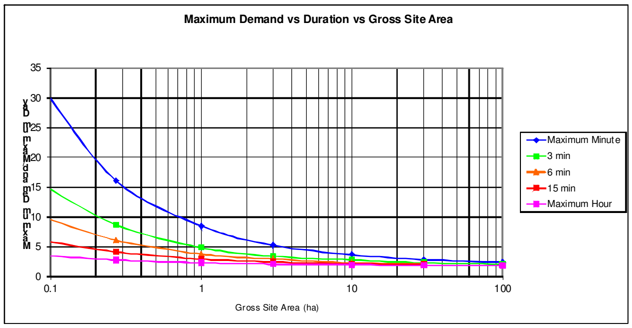

Figure 3 - 3 Maximum demand vs duration vs gross site area

The maximum demand/maximum day demand relationship shown in **Figure 3 - 3** is the design chart for maximum minute demands in small service areas less than 100 hectares where a maximum day demand per hectare has been adopted as the basis of design. This method is generally less accurate than **Figure 3 - 2** and gives conservative solutions.

Appendix F: Minimum water demand calculation

The minimum instantaneous demand estimation method recommended by the International Water Association (IWA) is shown below.

1. For populations less than 10,000, use UBL only [1, 2, 3, 4], this is:

$$Minimum\ demand\,(L/s) = \frac{1}{3600}(20\,Lm + 1.25\,Nc)\left(\frac{P}{50}\right)^{1.5}$$

2. For populations equal or greater than 10,000, use UBL plus minimum residential usage[1, 2, 3], this is:

$$Minimum\ demand\,(L/s) = \frac{1}{3600}(20\,Lm + 1.25\,Nc)\left(\frac{P}{50}\right)^{1.5} + \frac{Vt}{60}\left(0.001\,Po - 3\sqrt{0.001\,Po}\right)$$

Where:

Lm = length of mains (km)

Nc = number of connections to the main[2]

P = average pressure in the area (m)

Vt = toilet flush volume (allow three litres where it is not known)

Po = population

Notes:

1. The number of connections is not the number of properties, as vertical strata typically have multiple properties from a single connection. A good quasi for connection count is the number of customer meters plus the count of unmetered properties and fire services (the latter is typically a small number that can be ignored).
2. This relationship can be used on a system of any size or age, where it is 'well managed'.
3. Assuming minimum residential usage at night is primarily due to toilet flushing, which can be minimal for a small system (population below 10,000).

Appendix G: Demand distribution for reliability and risk based approach

The demand distribution for each delivery system is shown in **Figure 3 - 4 .**

It highlights that:

- smaller delivery systems have a higher diversification of demands, ie a higher maximum day and a lower minimum day
- about 80-90% of daily demands are within 20% of average day demand for most delivery systems.

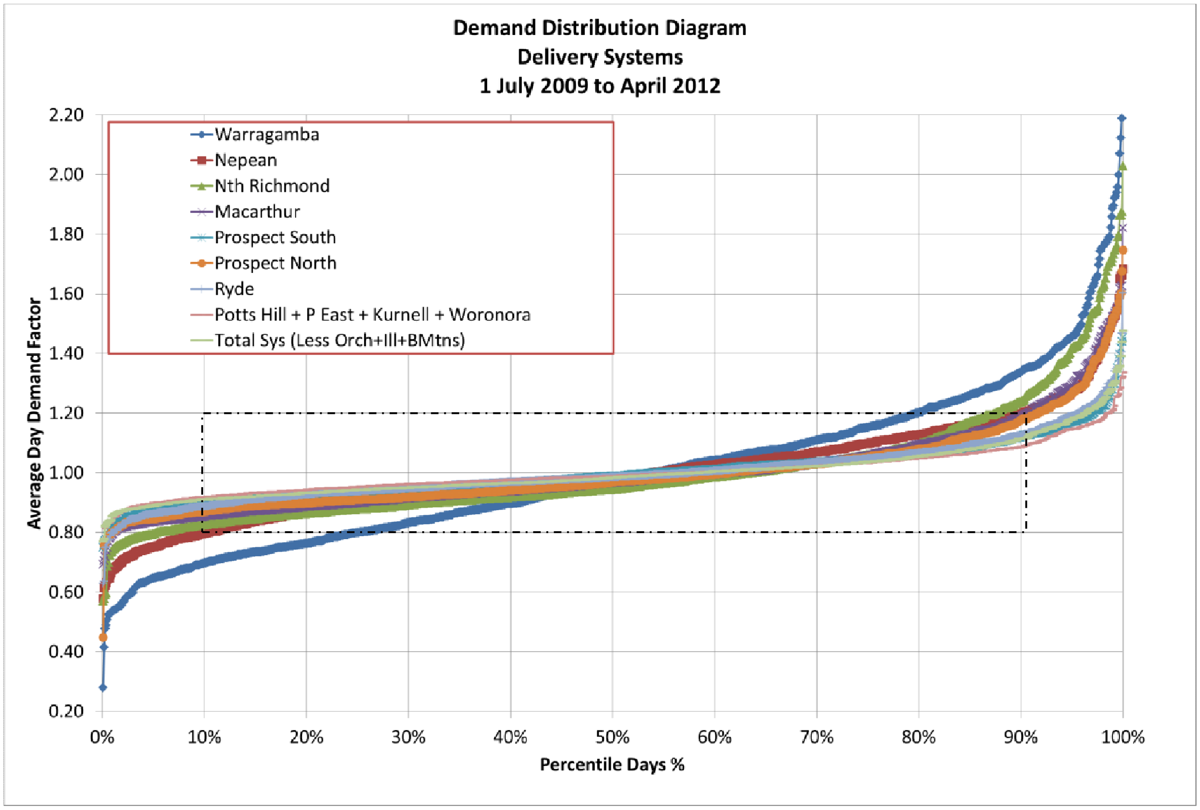

Figure 3 - 4 Demand distributions for different Systems

Risk-based demands – Delivery systems

Table 3 - 13 shows data taken from demand distribution curves. The table shows the average number of days per year that a particular demand event will occur. This data can be used in risk assessments and economic evaluations.

Table 3 - 13 MDD demand factor frequency (July 2009 to April 2012)

Average number of days per year as a demand factor				
System	0.7-0.8 x MDD	0.8 – 0.9 x MDD	0.9 -1.0 x MDD	1.0 X MDD
Warragamba	6.88	4.71	1.45	0.36
Nepean	34.7	8.33	3.26	0.36
North Richmond	11.6	5.43	1.09	0.36
Macarthur	15.2	7.60	0.36	0.36
Prospect South	120	19.2	2.53	0.36
Prospect North	17.4	6.88	1.09	0.36
Ryde	29.3	6.16	0.36	0.36
Potts Hill + Woronora	17.0	50.3	4.71	0.36

Demands for reliability

Table 3 - 14 shows data taken from the demand distribution curves. The table shows the minimum week and minimum day demands for each delivery system. These can be used in a sensitivity analysis to determine value for money when designing system redundancy.

Table 3 - 14 Minimum week and day factors (July 2009 to April 2012)

System	ADD ML/d	Demand factors of ADD	
		Average of min week	Min day
Warragamba	2.8	0.71	0.41
Nepean	9.7	0.76	0.62
North Richmond	15.5	0.80	0.58
Macarthur	66	0.83	0.71
Prospect South	105	0.86	0.76
Prospect North	191	0.83	0.76
Ryde	190	0.83	0.64
Potts Hill + Woronora	663	0.88	0.82

Sydney WATER

Water System Planning Guideline

Section 4: System Hydraulics (Pressure)

Version 1

September 2014

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Section 4- System hydraulics (pressure)

4.1 Introduction

This section covers service pressure requirements for new and existing systems.

4.1.1 General

Figure 4-1 shows the variation of pressure and hydraulic grade lines with system demand for different demand conditions. For definitions refer to **Section 1: Introduction.**

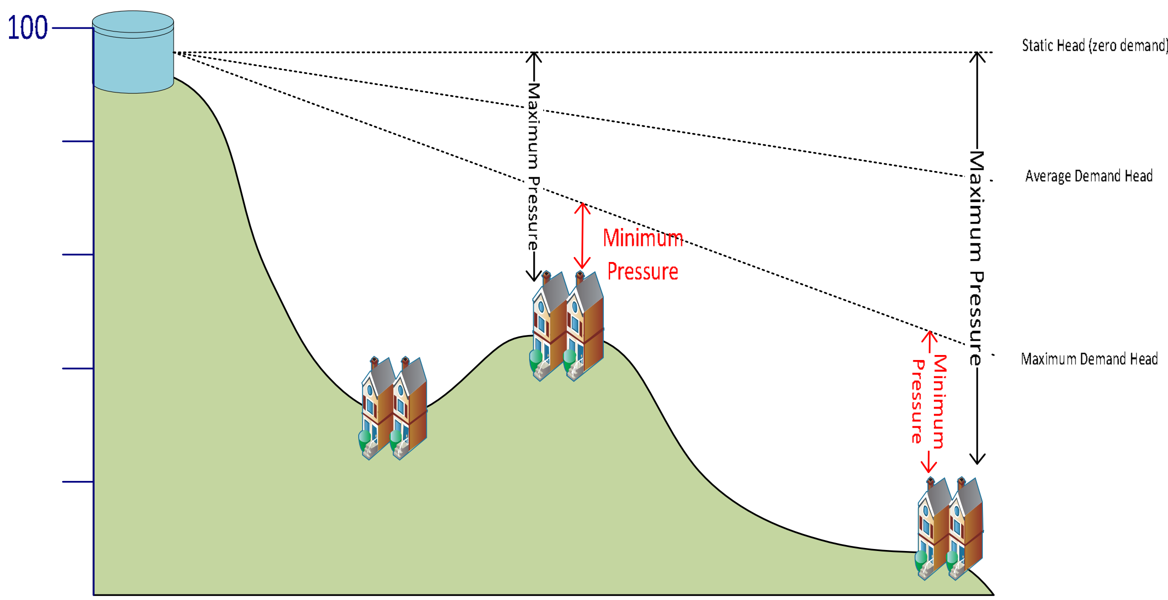

Figure 4 - 1 Concept of pressure and hydraulic grade lines in water system

The different pressure profiles of a water supply system are presented in **Appendix A:, Figure 4 - 2 .**

4.2 Service pressure

Service pressure requirements only apply to reticulation systems. Service pressure for a customer is measured at the main tap. Transfer mains and those distribution mains that do not supply directly to consumers may operate at higher or lower pressures than reticulation mains, eg from three metres up to say 350 metres.

Where there are no customers being supplied, the allowable minimum operating pressure in trunk and reticulation systems is three metres under normal operating conditions.

In gravity systems, maximum service pressures usually occur when the reservoir is at Full Supply Level (FSL) under minimum demand conditions. In pumped systems, maximum service pressures occur at maximum suction head with the pump operating at zero discharge head. In practice, for both cases pressures in the system could go higher due to pressure transients. For more detail on transients refer to **Clause 4.3.1.2.** An operating pressure limit may be specified by Sydney Water.

The minimum pressure specified in the Operating Licence is 15 metres, however, some exceedances of this limit are permitted. Refer to *Sydney Water Operating Licence* (**Reference 35**). A lower minimum service pressure may be provided based on financial and risk considerations, and is subject to Sydney Water approval.

For design pressures, refer to the *Water Supply Code of Australia, Sydney Water Edition*, *Clause 3.2* (**Reference 1**).

4.2.1 Single supply system service pressures

Single supply system service pressure limits in new areas are shown in **Table 4-1**.

Table 4 - 1 Service pressure (SP) limits for new single supply systems

Service pressure limit	Single supply (metres pressure) All areas (except CBDs) (Refer to Note 1)	Single supply (metres pressure) CBDs (Refer to Note 1)
Maximum (qualified – refer to Note 2)	60	60
Desirable maximum (Note 2)	50	50
Desirable minimum (Note 2)	20	25
Desirable minimum range for boosted pressures (Note 2) for inline boosters	20-25	
Desirable minimum for un-boosted pressures (Note 4) for inline boosters	12	

Single supply system service pressure limits in existing areas are shown in **Table 4 - 2**.

Table 4 - 2 Service pressure (SP) limits for existing single supply systems

Service pressure limit	Single supply (metres pressure)	
	All areas (except CBDs) (Refer to Note 1)	**CBDs** (Refer to Note 1)
Maximum	Existing pressures	Existing pressures
Desirable maximum (Note 2)	The long-term aim is to reduce to 60 m or less where financially viable	The long-term aim is to reduce to 60 m or less where financially viable
Desirable minimum (Note 2)	15	20
Desirable minimum for creating pressure managed areas (Note 3)	25	25
Desirable minimum range for boosted pressures (Note 2) for inline boosters	20-25	
Desirable minimum for un-boosted pressures (Note 4) for in-line boosters	12	

NOTES:

1. CBD areas refer to Sydney City, Parramatta and other similar CBDs.
2. Subject to a financial evaluation – refer to the further information below:
    a. For maximum pressures, the aim of the restriction in new systems to 60 m is to maximise the life of our assets and to lessen the effect on customers' appliances, especially hot water systems. However, this limit is qualified as it must be balanced against the requirement to avoid over-investment in trying to reduce high pressures in certain areas. There are numerous existing areas with pressures of 80 metres and above.
    b. For desirable maximum pressures in new systems, the aim of having a desirable maximum of 50 m is to align with the requirement in AS/NZS 3500.1 that the maximum static pressure at any outlet, other than fire service outlets, within a building does not exceed 500 kPa.
    c. For the desirable minimum pressures of 20 m in new systems and 15 m in existing systems, the aim of providing desirable limits, rather than fixed limits, is to avoid the situation where over investment may occur. Any solutions developed should minimise operator intervention.
    d. This desirable minimum pressure for existing systems includes in-fill growth.
    e. The desirable minimum pressure for commercial and industrial customers is 25 m.
3. The limit is provided for guidance to minimise the effect on existing customers. This limit needs to be reviewed on a case by case basis.

4. Un-boosted pressures for in-line booster systems during abnormal operation. This limit needs to be reviewed on a case by case basis.

4.2.2 Dual supply system pressure

Table 4 - 3 and **Table 4 - 4** provide the service pressure limits on dual reticulation systems for new and existing areas respectively.

Unless otherwise specified by Sydney Water, the non-drinking water supply system should be designed with an available static head 5 m lower than the drinking water supply system, subject to a financial evaluation and the risk assessment developed in accordance with the *2006 Australian Guidelines for Water Recycling* (**Reference 39**).

Service pressure requirements for dual reticulation systems in CBD areas will need to be discussed with Sydney Water.

Table 4 - 3 Service pressure (SP) limits for new dual reticulation systems

Service pressure limit	Dual reticulation (metres pressure)	
	Drinking water	Non-drinking water
Maximum (Note 2 in **4.2.1**)	60	60 (Note 1)
Desirable maximum (Note 2 in **4.2.1**)	50	50 (Note 1)
Desirable minimum (Note 2 in **4.2.1** and Note 2)	20	15
Desirable minimum range for boosted pressures (Note 2 in **4.2.1**) for inline boosters	20-25	
Desirable minimum for boosted areas when pump is not operating (Note 4 in **4.2.1**) for inline boosters	12	

Table 4 - 4 Service pressure (SP) limits for existing dual reticulation systems

Service pressure limit	Dual reticulation (metres pressure)	
	Drinking water	Non-drinking water
Maximum	Existing pressures	Existing pressures. (Note 1)
Desirable maximum (Note 2 in **4.2.1**)	The long-term aim is to reduce to 60 m or less where financially viable	The long-term aim is to reduce to 60 m or less where financially viable
Desirable minimum (Note 1 and Note 2 in **4.2.1**)	20	15
Desirable minimum range for boosted pressures (Note 2 in **4.2.1**) for inline boosters	20-25	
Desirable minimum for un-boosted pressures (Note 4 in **4.2.1**) for inline boosters	12	

NOTES:

1. These pressures may need to be lowered to maintain pressure differential between drinking and recycled water.

2. Subject to an financial evaluation, the desirable minimum for commercial and industrial customers is:
    a. For drinking water: 25 m
    b. For non-drinking water: 20 m.

4.2.3 Reliability planning

When assessing (hydraulic modelling) planned shutdowns and incidents for defining the consequences on customers, **Table 4 - 5** shows the pressure ranges that are to be used for presentation of results (as a minimum) (Refer to **Section 3: Water demand and growth**).

Table 4 - 5 Shutdown service pressure ranges for system assessment (modelling)

Pressure range (metres)
>15
3 – 15
< 3

4.3 Pressure issues

4.3.1 Operational pressure variation

4.3.1.1 Variation in pressure

Significant diurnal pressure variation throughout the day may cause customer complaints. It is important to aim to minimise customers' pressure variation and implement mitigation measures where economical.

4.3.1.2 Transients/water hammer

Transient pressure events occur when fluids in closed pipe systems experience changes in velocity. They can be significant when the fluid in motion is forced to stop or change direction suddenly. This is usually caused by fast opening and closing valves, pump units starting or stopping where water hammer control devices are not provided (eg delivery control valves), use of stand pipes, or power failure causing pumps to crash stop without the control valve closing first. Transient pressure conditions can also be caused by commercial and industrial customers when testing their fire-fighting services.

The pressure wave that ensues from a significant transient event can cause major problems, from noise and vibration, to pipe and fitting collapse and pump unit or fitting damage. It is possible to reduce the effects of the water hammer pulses with water hammer control devices.

Transient analysis is mostly considered during the detail design phase to ensure that the choice of materials, control parameters and water hammer surge protection devices are appropriate to mitigate the risk. However, planners must recommend transient analysis where there is:

- potential for high pressure fluctuations in the system, eg pumped mains, control valves, PRVs
- a long main (especially where the longitudinal profile contains more than one high point and column separation is likely to happen)
- very high pressures
- any known existing system damage due to water hammer.

The water modelling system (WMS) has a 'transient adviser', which can be used during the planning phase to identify potential problem areas due to transient pressures in a system. Full transient analysis requires specialised software.

4.3.2 Chronic poor pressure problems

There may be isolated small areas where pressures will/have become inadequate to meet the minimum pressure requirement of the operating licence.

There may be several reasons for consistently low pressures in an area (even during low-demand periods), including the elevation of customers' properties relative to the reservoir level.

The cost of any solution needs to be justified, especially when a small number of properties are involved.

Options to rectify poor pressure problem areas for existing or new systems include:

- amplification/renewal of water main to reduce headlosses
- decreasing demand on the system (demand management)
- rezoning to an alternative supply zone, on a temporary or permanent basis
- installing link mains between reservoir zones to provide a rezoning capability
- linking mains within the reticulation system for connectivity improvements
- installing water booster pumps (for details on booster station planning criteria, refer to *Water Supply Code of Australia, Sydney Water Edition,* Part 1, Chapter 6: System Pressure Management (**Reference 1**). For un-boosted pressure requirements for boosted areas, refer to **Clause 4-4**
- installing pressure sustaining valves
- constructing an elevated reservoir (if cost-effective)
- checking for unmetered demands, fire service compliance tests and unaccounted for leaks
- managing water carters' access points and flow rates.
- non-asset solutions, change in system operating protocols or asset control parameters.

All activities related to existing water pressure problems will be addressed in accordance with the *Water Pressure Investigation, Measurement and Reporting SOP (***Reference 47).**

4.3.3 Active pressure reduction

Active pressure control/reduction is the process of actively managing the water pressure variation or high pressures to reduce leaks and breaks in the distribution systems.

Pressure reduction measures should be considered at the initial planning stage of the supply network or at a later post-development stage.

Retrofitting pressure reduction measures in an area already developed can be complex to implement due to:

- creating excessive numbers of dead-ends (which may lead to poor water quality)
- changing service levels delivered to existing customers, including pressure available at customers' fitting outlets
- the impact on existing private fire suppression system capability
- catering for growth
- affecting adjacent areas
- reducing the interconnectivity in the zone that may have an impact on hydraulics for customers outside/inside the PRV zone.

Pressure reduction should be considered for areas:

- experiencing excessively high pressure
- that have a high main break history in combination with high pressure (for existing systems)
- that have a high estimated leakage in combination with high pressure (for existing systems).

Any proposed solution should be based on financial considerations, technical feasibility, operational maintainability and operability and any adverse impact on existing/critical customers within the zone of influence.

Possible measures are (not limited to) rezoning (permanent or temporary), providing a dedicated inlet main, installation of PRVs etc. Pressure reduction criteria by PRVs are presented below.

4.3.3.1 Pressure reduction by PRVs

A common application of PRVs is to manage high pressure or pressure variation (reasonable variation is 20-40 m).

General planning criteria

- Pressure reduced schemes are mainly considered for areas that experience pressures greater than 60 m on average. For existing supply areas, selection of a site for pressure management should also consider the number of connections (more connections are likely to lead to more leakage) and the water main break history.
- There is no practical maximum limit to the number of customers that can be pressure managed in a zone. An area with a small number of properties would only be considered if it were financially viable.
- Pressure management is ideally suited for areas with a high proportion of residential customers. Areas with non-residential/large water users need special consideration. They may have pressure dependent services within their properties that need to be considered in the design of the scheme.
- The methodology of staging pressure management in growth areas needs special attention due to avoid possible fragmentary approach to mains installation and sizing of the PRVs.
- In established areas, pressure management shall be carried out according to an integrated system approach rather than schemes selected in isolation.

  Planning of a PRV should also consider addressing any specific local issues and risks to determine the size of assets, the location, appropriate controls and whether modulation is used.
- A financial viability check should include possible water saved and the likely long-term reduction in water main repairs from pressure reduction (compared to a base case), as compared to the cost of retrofitting thr PRV. However, a new system will be less likely to incur breaks and leaks, so a wider economic appraisel would be more appropriate.
- An economic appraisal of PRV schemes should consider the cost to each property owner compared to the avoided cost of customers not having to fit and maintain private PRVs on their water service to comply with AS/NZ 3500. It then needs to compare the cost to Sydney Water of installing PRVs with the costs of individual properties to comply with AS/NZ 3500.

Location

Ideally the largest main heading into a proposed pressure reduction area should be selected as the main to fit a PRV. The selection process shall also consider system impacts in the remainder of the zone to assess contingency event scenarios once the largest main into the proposed pressure reduction area is dedicated to a PRV. The selected location should be checked with the design teams for suitability of associated civil works. Dual PRV feeds may need to be considered in the design for large supply areas and those with a high risk profile.

System Planning and Modelling

Information required for the sizing and control points with the pressure requirements of the PRVs will be generated from the hydraulic models. The planner can determine what areas are ideal for pressure reduction by comparing areas with relatively low ground levels in the supply zone to the supply zone reservoir's FSL.

The planner also should study the following requirements to plan a PRV zone:

- Consider pressure settings appropriate for flows ranging from current minimum hour demands to future maximum hour demands (including growth for the area in question). For minimum pressure in pressure reduced areas, refer to **Table 4 - 2**.
- Identify the critical pressure point in the zone (hydraulically most disadvantaged location) and a point representing its average pressure, where pressure gauges will be installed for monitoring.
- Identify any requirements for additional valves, cross connections and booster stations.
- Assess the impact on supply pressure or existing service levels due to any boundary breach (open dividing valve etc) or loss of interconnectivity within and outside the zone.
- Assess the effect on water quality due to the existence of dead-end mains at the boundaries of the pressure controlled areas, ie on both sides of boundary isolating valves.
- Identify the method of control. Selection of pressure control should assess the impact on fire-fighting and capability. For detail of PRV controls refer to **Appendix B:**.

4.4 Context

4.4.1 Definitions, abbreviations and references

Refer to **Section 1: Introduction to the guideline, Clause 1.6**

4.4.2 Attachments and/or appendices

Attachment/appendix number	Title
Appendix A:	Different pressure profiles for water supply system
Appendix B:	Different controls for PRV

4.4.3 Document control

Title: Water System Planning Guideline, Section 4: System Hydraulics (pressure)		
Current review date: June 2015	**Review period:** 1 year **Risk rank = high**	**Registered file:** 2014/00004985
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Major Stakeholders consulted /reviewers:	Anil Jaiswal - Servicing & Asset Strategy Bob Wickham - Urban Growth Chris Salkovic - Service Delivery Craig Crawley - Servicing & Asset Strategy David Gough - Servicing & Asset Strategy Frank Kanak - Service Delivery Peter Fisher - Servicing & Asset Strategy Richard Schuil - Engineering & Environmental Services Sum Tong - Engineering & Environmental Services Bob Wickham - Urban Growth, Ed Braithwaite- Service & Asset Strategy Gaetano Illuzzi - Engineering & Environmental Services Gordon Aiken - Networks Julie Horne - Engineering & Environmental Services Mark Obuchowski - Engineering & Environmental Services Richard Wajzer - Urban Growth Robert Ius - Project and Services Suganthini Niranjan - Engineering & Environmental Services Suhanti Thirunavukarasu - Engineering & Environmental Services Thaya Thayanithy - Networks	
Approval and Endorsement	See end of 'Section 0' of WSPG	

4.4.4 Revision control chart

Version number	Date revised	Brief description of change
1	September 2014	New Document

Appendix A: Different pressure profiles for water supply systems

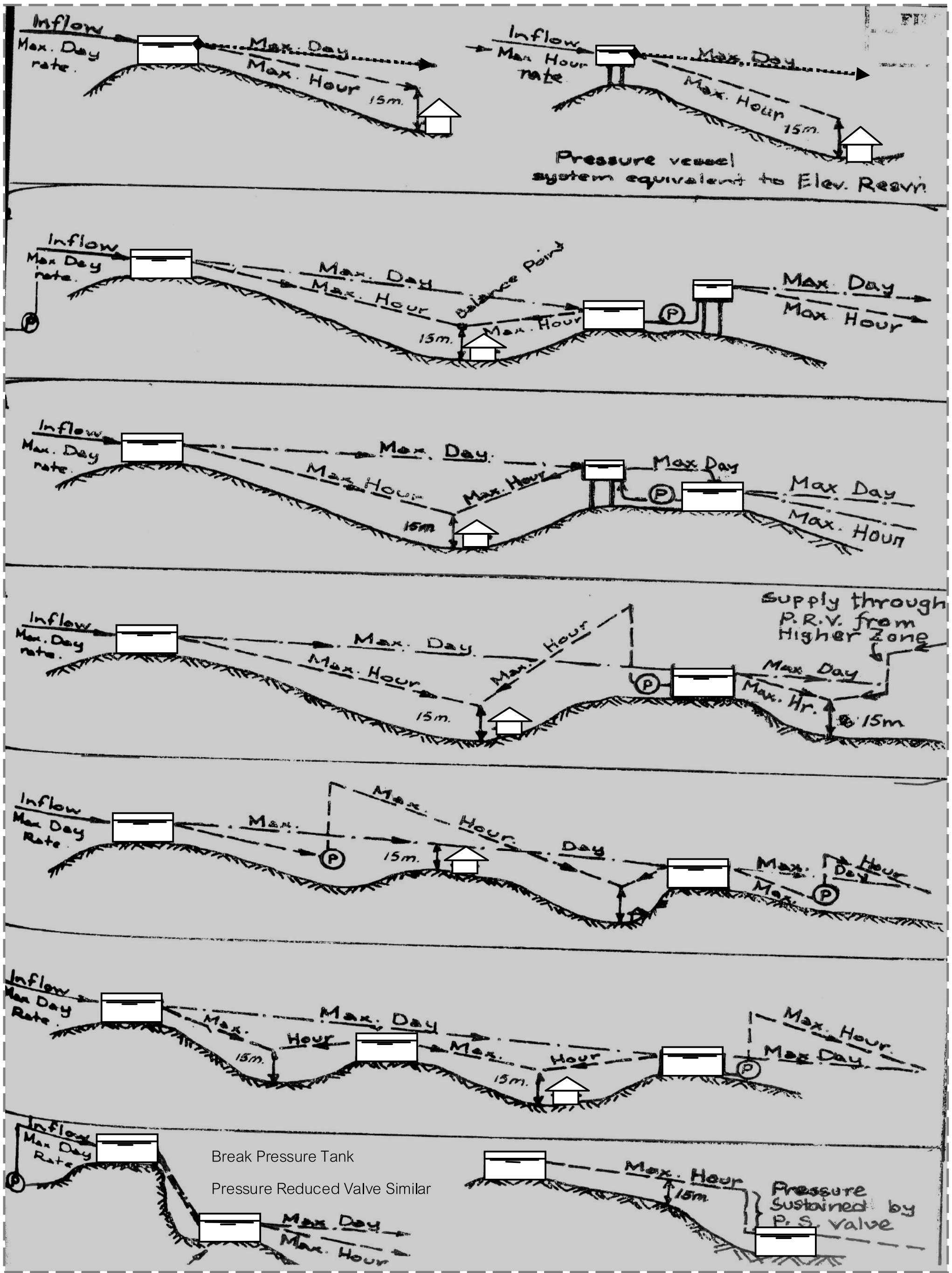

Figure 4 - 2 Water supply systems with different pressure profiles.

Refer to *Water Investigations Sub-branch - Staff Handbook No 32*, v49 (**Reference 6**).

Appendix B: Different controls for PRVs

Pressure reducing valves (PRVs) can be operated by one of the following methods:

- Static pressure setting: The valve/s are given a target downstream pressure setting to maintain and will regulate the opening of the valve to maintain that pressure. It achieves the pressure reduction required, but is disadvantageous in that during periods of high system flow (thus high headloss) pressures at the extreme points of the system can be lower than they should be. Typically as a result, the setting for the valve is set conservatively higher to compensate for these high flow events.

- Time regulated pressure setting: Under this approach different settings are programmed in the valve for various times of the day. Typically during the night a lower pressure setting will be applied for expected low night flows, with a higher setting being applied to peak events during the day. The higher setting will compensate for headlosses in the system that occur during maximum demand events, so that the most disadvantaged customer always receives the required pressure. This type of pressure reduction may not be suitable where seasonal or diurnal demand events are significantly different from the norm (such as winter or weekend demands), as the valve is programmed for a specific set of events based on time.

- Flow regulated (modulating) pressure setting: This methodology of pressure reduction relies on actual flow going through a flow meter nearby to determine the pressure setting. The valve will be set up to regulate a higher pressure setting during peak flow events (to compensate for headlosses within the system) and lower pressure during low flow events such as the middle of the night.

- The combined flow and time regulation setting: This methodology is the preferred IICATS method of regulation as this provides the greatest operational flexibility. Refer to IICATS Pressure Reducing Valve Standards for detailed functional description. The majority of PRV under IICATS control use this control methodology.

Water System Planning Guideline

Section 5: Infrastructure Planning

Version 1

September 2014

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Section 5: Infrastructure planning

5.1 Introduction

This section focuses on the assets in the water system and how assets are planned to be part of the system. It discusses factors for consideration in the selection and sizing of any asset (reservoirs, water pumps, water mains etc) during greenfield/infill/renewals planning.

5.2 Optimising WPS, rising main and reservoir components

5.2.1 Requirements

The planner will consider both the reservoir and input system as a total system, each component having any capacity, provided that at the end of any cycle of days of large demand, the adopted reserve storage remains.

5.2.1.1 Input capacity

Overall, the input system (eg treatment plants or other sources, the water pumping stations rising mains, gravity distribution and transfer inlet mains) is to have the capacity to maintain reservoirs level above the reserve storage level (RSL) over the chosen design period.

For a water pumping station the operating protocol shall be:

- at demand equal to or less than 90% maximum day demand – only the duty units operate
- at demands higher than 90% of maximum day demand – all units operate including the standby unit.

Both of the above criteria must be met in determining the requirements of system components.

5.2.1.2 Reservoir capacity

Service reservoir storage capacity shall consist of operating storage and reserve storage.

Figure 5- 1 shows the various levels and storage components for a reservoir (for definitions, refer to **Section 1: Introduction**).

The reserve storage is to be equal to one third of maximum day demand (refer to **Appendix A:**), subject to a risk assessment and certain exceptions shown below. This is to ensure that about eight hours will be available to the most critical point in a severe hot spell in a high consumption period to remedy any failure, such as a power outage or a break in the input system.

For the risk assessment, refer to **Clause 2.1.3** and **Section 2 Appendix B and C**. The risk assessment shall consider the characteristics of the zone/system to determine the risk (consequences and frequency) to water supply continuity and pressure in the event of a system component failure. When considering any known risk or hazard the likelihood or magnitude of the hazard can be reduced (asset maintenance) through steps taken to eliminate it (system redundancy) and provisions made for the residual risk (reserve storage). In particular actual failure modes, availability of alternative supply source/s, type of mains and duration of facility outages shall be assessed. However, there are different ways of mitigating risks by reducing consequences or probabilities of occurrence or both, eg through maintenance, system redundancy (reducing likelihood) or accepting some residual risk, such as through the size of reserve storage.

Clause 5.3.3 has listed different factors to determine the service reservoir storage capacity for a system.

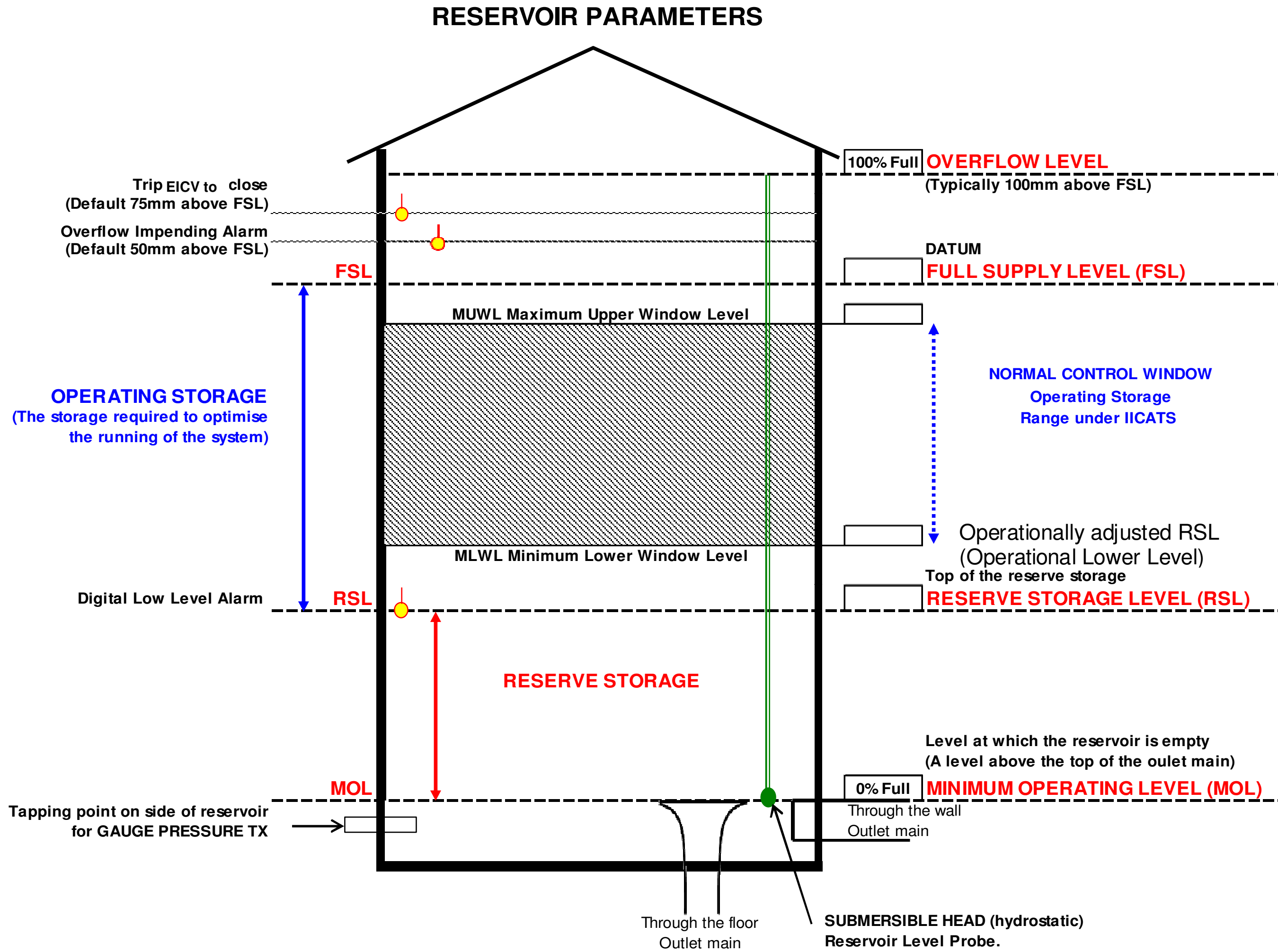


Figure 5 - 1 Reservoir storage

Exceptions

Exceptions to specification of reserve storage of one third of the maximum day demand requirement are:

1. Existing systems

   If the 1/3 maximum day reserve storage cannot be economically provided then actual failure modes and alternative supply should be considered to determine the risks to the water supply, in the event of a system component failure. No net depletion of the operating capacity over the system design period is permitted, eg where the design period is one day, no net depletion of the operating capacity over a maximum day 24-hour period is permitted.

2. Isolated systems

   Small isolated systems (eg Helensburgh, Hargrave Hts, Saddleback, Stanwell Park) may require greater security of supply by having more than 1/3 maximum day reserve storage plus the operational storage. This may be because of a single supply source through difficult terrain that will require more time to detect and repair failures. Any maintenance requirements and identified critical customers may also have to be considered.

3. Large interconnected systems

   For an individual reservoir within a large system, reserve storage may be available at another location that has a direct feed to that zone, in which case the 1/ maximum day reserve storage need not be provided for that reservoir (eg Prestons Reservoir supplied from Liverpool Reservoir), provided the whole system has 1/3 maximum day reserve storage plus operational storage.

4. Elevated reservoirs

   Elevated reservoirs are normally used only for very small pumped supply systems. The design of elevated reservoirs shall follow the same basic principles above.

   Elevated reservoirs should be restricted in size to a maximum of 4 ML or 1/6 maximum day reserve storage plus operational storage, whichever is the smaller. The shortfall in storage should be placed, if practicable, in the supply source zone, or surrounding zones. Otherwise the reserve storage should be in a connected surface storage.

   The various failure cases (eg inlet main, WPS) for an elevated reservoir system should be analysed, with only one system component to fail at any one time. This is to determine if supply can be maintained to the zone from an onsite surface reservoir or an alternative supply sources at a minimum residual head of 3 m at maximum hour demands. If this residual head cannot be maintained, then the system should be assessed for amplification, based on economic considerations.

Often, elevated reservoirs will be provided with only minimal reserve storage where a basic supply to customers can be provided from an adjacent surface reservoir.

5.2.1.3 Outlet mains

These are to be sized so as to provide a minimum pressure as per **Section 4: System Hydraulics** during normal operation of the system, with consideration given to maximum pipe velocities and minimum pipe sizes, eg industrial, commercial areas etc.

5.2.1.4 Design demand period

The design demand period is the period of time a design analysis should cover in order to size system components, eg service reservoirs, pumping stations and rising mains.

The reserve storage level (RSL) should be determined by an analysis carried out over a design demand period, eg based on consumptions equal to maximum day demand, two or three maximum consecutive days etc. This means the storage level will gradually fall over a number of consecutive days until the maximum depletion (ie the RSL) is reached, after which it will gradually recover. To determine the maximum demand period and daily demand factors (DDF), refer to **Section 3: Water Demand and Growth.**

5.2.2 Application of design principles

5.2.2.1 Initial design of system components

The design of the system components is based on the requirements above and the future maximum day demands.

Consideration should be given to staging works, eg a large reservoir storage requirement may be split into two smaller reservoirs built at different times.

For an initial design in growth areas, the following can be used to size the system components:

- Reservoir capacity equal to 2/3 maximum day demand, ie 1/3 maximum day reserve storage plus 1/3 maximum day operational storage. The input system is to have a capacity equal to the maximum day demand.
- Where long rising mains are required, consider providing a larger operational storage and less than maximum day input system capacity.

- For elevated systems, use maximum hour input system capacity with the reservoir capacity equal to 1/6 maximum day demand plus operational storage required for pump control.

5.2.2.2 Staging

Consideration shall be given to staging of assets to suit development-related increased demand, aesthetic and landscaping requirements.

A graphical method to determine staging has been presented below:

- Identify various upgrade options at various system demands to determine when the reservoir will deplete below the RSL.
- Analysis of different demands for each augmentation option can be presented as a line where it crosses the line of required reserve storage, project a horizontal line until it crosses the demand growth curves and read the corresponding years in the horizontal axis from the demand growth curves. The choice of demand growth curve depends on whether the standby pumping unit was used in the analysis (use the 100% Maximum Day Curve if including the standby unit, or use the 90% Maximum Day Curve if excluding the standby unit). The earlier year of the 90% and 100% maximum day cases is chosen, as the year amplifications are required for each option scenario.
- The most economical method of staging the amplifications is determined from a full life cycle cost analysis (capital and system operating and maintenance costs are to be balanced; ie weigh up the option of providing additional operating storage against pumping station capacity, which is especially critical for long transfer mains/systems).
- Refer to **Appendix C:** for a worked example.

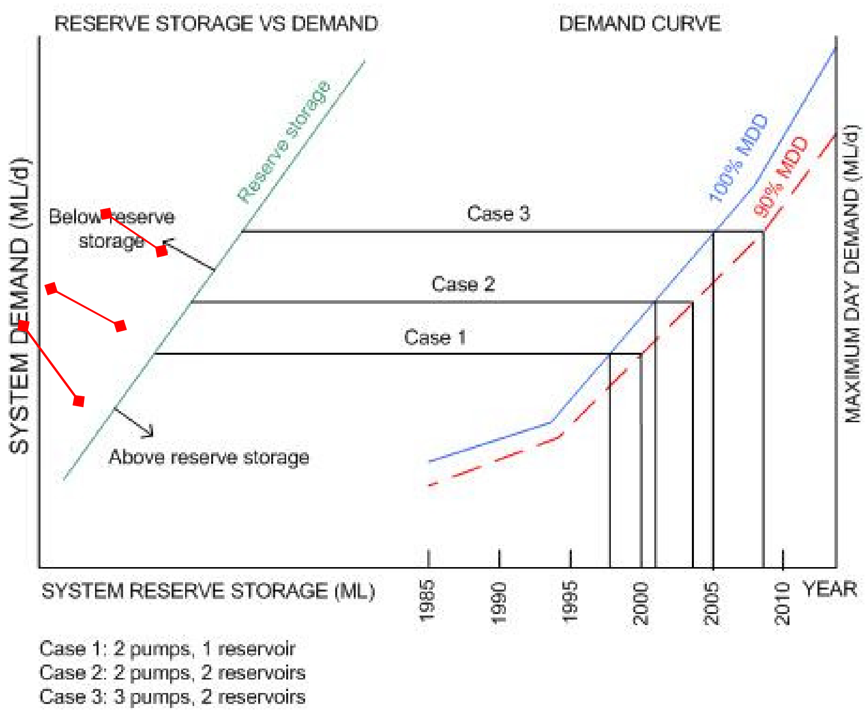


Figure 5 - 2 Graphical method for staging works

- **Figure 5 - 2** shows, using the demand at which the line of the required reserve storage is crossed, the year this is reached for the 100% or 90% maximum day cases is read from the demand growth curves. The choice of curves depends on whether the reserve pumping unit was used in the analysis (ie use the 100% maximum day curve if the reserve unit was running, and the 90% maximum day curve if the reserve unit was not running). The earliest year of the 90% and 100% maximum day cases is chosen as the year the amplification is required.
- The most economical method of staging the amplifications is determined on a present worth basis.

5.2.2.3 Reservoir control levels

Consideration should be given to a more flexible approach to reservoir control levels. When there is low system demand, the reservoir control levels should be set to reduce the number of pump starts per hour. However, this is not a critical requirement providing that the maximum number of pump starts per hour is not more than that recommended by the pump motor manufacturer.

As the system demand approaches the pumping capacity, the reservoir control levels can be raised to ensure that the pumps are running earlier on a maximum day to maintain the reservoir above the reserve storage. This would have the effect of deferring any system amplifications.

The cut-in level for the stand by unit should be set so that it cuts-in on a 100% maximum day, but not on a 90% maximum day.

When optimising the system, the planner needs to understand that the level controls have many possible settings between FSL and RSL. The IICATS system can handle variable profile control window (where the capacity is greater than 2 ML) under different seasonal demand conditions or for abnormal operating conditions such as a bushfires. However, the setting of these level controls in model runs should not necessarily be limited to the current values.

Planners should note that the RSL may be adjusted in the future to cope with changing demands or any system modifications, such as the decommissioning of an adjacent reservoir.

Also, there can be operationally adjusted RSLs which can be set by certain constraints, e.g pressure limitations in the zone, water quality, reservoir structural integrity, the availability of alternative supply paths or the reserve storage in the reservoir is covering multiple supply zones. These are generally at a higher level than the required RSL (based on demand).

Operationally adjusted RSLs are listed in *Water and Recycled Water System Growth Servicing (GSS) Strategy Criteria and Guidelines 2012* (**Reference 27**). If required, planners should obtain an operationally adjusted RSL update from Hydraulic System Services (HSS).

5.3 Reservoirs

5.3.1 General

Reservoirs are primarily designed to:

- provide a buffer within the supply system to maintain supply even during extreme diurnal demand variations
- provide reserve capacity to meet emergency demand conditions including power outages, pipe failures etc
- supply water at the required pressure range and reduce pressure fluctuations in the distribution system
- provide contact time for water treatment operation, such as chlorination
- ensure system reliability from reserve storage or as alternative supply.

5.3.2 Type of reservoir

Reservoirs within Sydney Water's operating area may be classified according to:

- functionality of reservoir (dam, balance tank, pressure break tank, supply reservoir etc)
- type (surface, underground, standpipe, or elevated)
- material (steel, reinforced concrete, prestressed concrete or earth)
- operating need - temporary or permanent.

5.3.3 General planning considerations

Reservoir requirements should be based on comprehensive risk analysis for the system, including input from relevant operational (network and treatment) and maintenance areas in Sydney Water.

Surface reservoirs are usually designed not to exceed 15 m in depth. However, this needs to be reviewed on a case-by-case basis.

The following factors shall be addressed in determining the service reservoir storage capacity required for a system:

- Availability of alternative supply source(s).

- Functionality of the reservoir (delivery system/ supply zone reservoir).
- Type of demand (non-critical/recreational demand or demand for critical services where it has impact on public health and welfares /operating licence requirements) to be served from the reservoir.
- Life cycle cost (capital and system operating and maintenance costs are to be balanced, ie weigh up the option of providing additional operating storage against pumping station capacity, which is especially critical for long transfer mains/systems).
- Water quality (inlet/outlet pipework configuration, operational detention time, mechanical mixing, disinfection residual detention time, etc).
- Operating storage capacity versus pumping station or supply capacity. Operating storage shall cater for demands exceeding the maximum available inflow rate and economical operation of the system.
- Reserve storage capacity needed to enable emergency maintenance work to be carried out on the supply system.
- Ratio of estimated long-term demands to short-term demands (more economical to provide initial storage with provision for additional storage).
- Reservoir site aspects (space limitations).
- Summer and winter operational requirements of the reservoir.
- Flow meter and control arrangements.
- Energy management.
- Maintainability.

Storage for a water supply zone can be shared across multiple interconnected reservoirs. This is encouraged for growth areas where multiple smaller storages may provide a better financial and water quality outcome than a single large storage.

The RSL is to be set based on the outcome of risk assessment and system analysis to ensure that the required design service pressure is supplied to the most disadvantaged point in the reservoir zone. For a detailed understanding of reservoir sizing and storage requirements refer to **Clause 5.2.1.2**.

5.3.4 Location/site considerations

Service reservoirs shall be located to achieve a reasonable balance throughout the supply zone between competing design requirements including pressure, water quality and cost (refer to **Clause 5.3.3**).

Planner also should consider the following:

- Locate the service reservoir as close to the centre of consumption as possible, as shown in **Figure 5-3.** Note that the location of a reservoir has a marked effect on the fluctuations in pressure to portions of the distribution system.

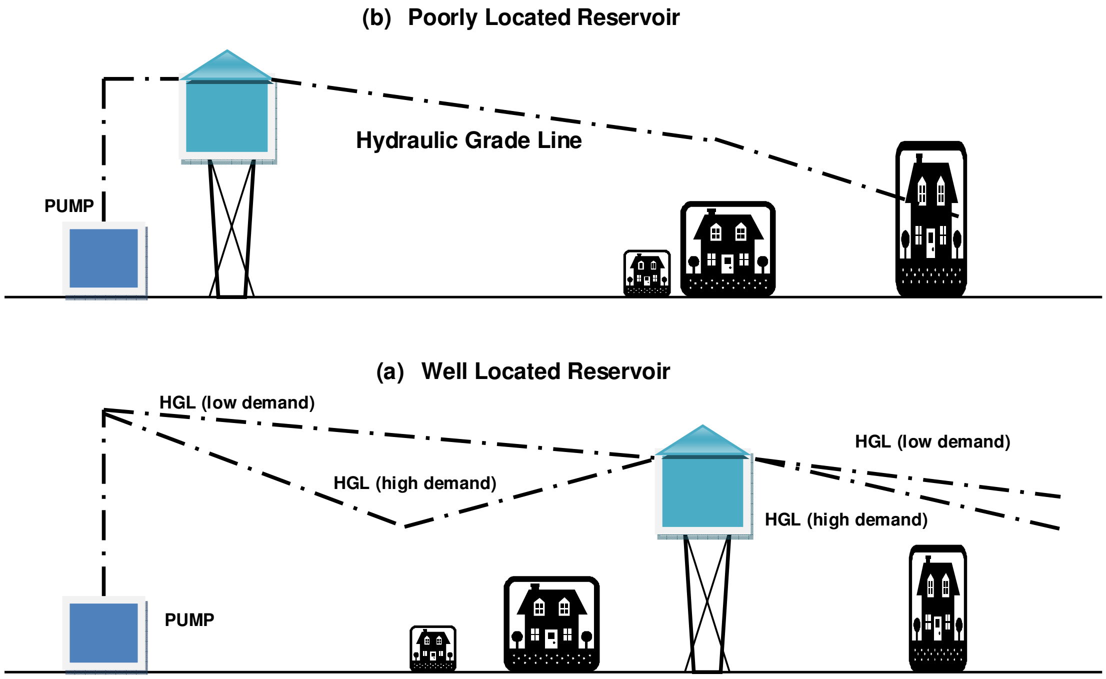


Figure 5 - 3 Location of reservoir

- Ensure the maximum number of customers is served by gravity flow. Preferably provide separate inlet and outlet pipework to maximise water turnover and to minimise the portion of the system customers receiving direct pumped supply.

- Avoid having the reservoir 'floating on the system'. This occurs when a service reservoir is located at the end of a system and is connected to the network by a common inlet-outlet pipe. The reservoir fills under these conditions when the rate of supply exceeds demand and discharges via the same trunk main when the demand in the system exceeds the supply rate water. This installation is prone to water quality deterioration due to the long residence time of the stored water in both the reservoir and the pipework. It also creates high pressure fluctuations at the beginning of the system especially where pumping is involved.

- Provide a suitable layout for inlet/ outlet (preferably separate), scour, overflow and reservoir bypass pipework to maximise functionality under operational/maintenance activities.
- Any special operational requirements (i.e large vehicle access etc).
- Provide connections to cater for potential capacity upgrades.
- Avoiding flood-prone and other environmentally restricted sites.
- Aesthetic issues, including shadow effects on the surrounding areas.

Refer to **Appendix B:** for examples of reservoir layouts.

5.3.5 Emergency inlet control valve

For existing systems, an increase in inlet size and peak instantaneous flow may exceed the current overflow capacity. This may lead to overtopping of the reservoir and possible collapse or damage both to Sydney Water assets and the surrounding environment and customers. To prevent this, an Emergency Inlet Control Valve (EICV) is commonly used.

5.4 Pumping stations

5.4.1 General

Where possible, the water supply system should be designed to supply water primarily by gravity, within the transfer, distribution and reticulation main systems. However, variations in topography may preclude or limit the viability of a gravity system, in which case pumping stations may be used to provide the additional hydraulic gradient necessary to transfer water to and/or meet the flow and pressure needs within supply areas.

This decision should also be assessed with other alternatives. Planners should evaluate the alternatives against technical, environmental, financial, life cycle cost and other relevant criteria to provide evidence that pumping will be the most suitable servicing solution for the specific system.

Pumping station/s may be used to:

- supply water to reservoir
- transfer from reservoir to reservoir
- distribute water directly to the trunk or reticulation system
- boost pressure.

General functional requirements for a pump would be to:

- supply water to a surface or elevated reservoir taking into consideration system demand
- provide adequate head.

For information on different types of pumps and variable speed drive (VSD) pumps, refer to **Appendix D:** and **Appendix E:**.

For booster station planning and design requirements, refer to the *Water Supply Code of Australia, Sydney Water Edition* (**Reference 1**).

5.4.2 General planning considerations

5.4.2.1 Sizing Considerations

The following information is required to determine the size and type of pumping units for a system:

- Discharge rate and variations in the discharge rate.
- Total head or pressure to deliver and the range of total heads.
- Vertical position or level at which a pump may be installed to maintain priming. This will influence the type of pump, eg horizontal, vertical, borehole or submersible.

The total head that the pump is expected to provide is made up of the static lift (head) and system losses. For basic understanding of total system head component, refer to the *Sewage Pumping Station Code of Australia, WSA 04,* Sydney Water Edition (**Reference 12**), or any other relevant sources.

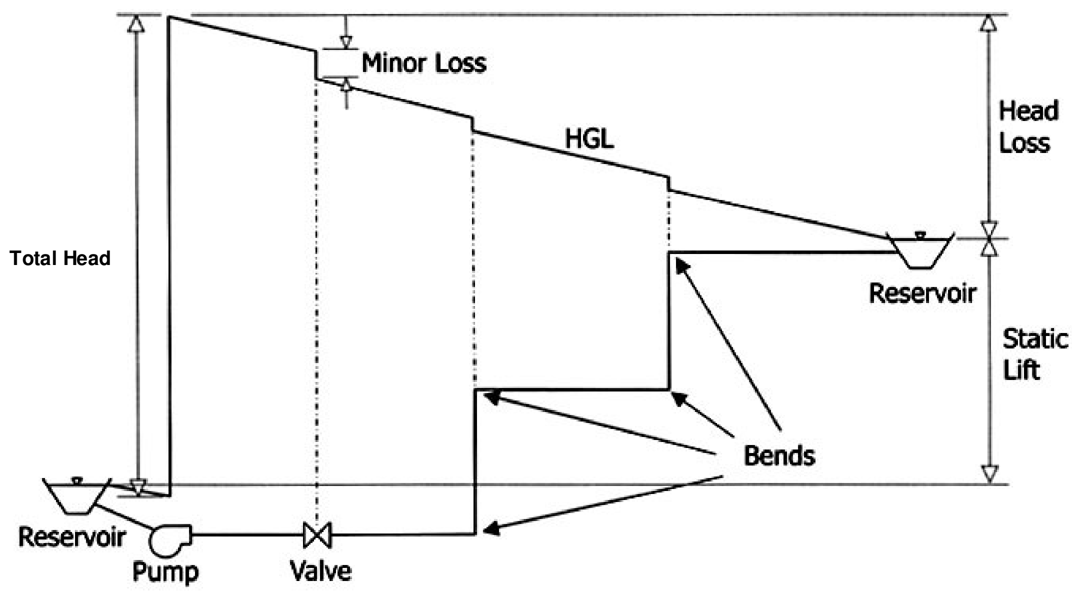


Figure 5 - 4 Schematic of hydraulic grade line for a pumped system

(Walski, *et al.* 2001 Figure 2.16)

Figure 5 - 4 shows the static head varies depending on the water levels between two reservoirs and a schematic of losses in a system.

The water pumping station needs to be considered as an integral part of the supply system. It needs to be sized and installed considering the interaction of all components including pumping units, suction and delivery mains, and reservoirs, and associated aspects of performance requirements, staged capital investment and ongoing maintenance costs (Refer to **Clause 5.2.2.1**).

Refer to **Section 3: Water Demand and Growth, Clause 3.2.3** for general guidelines relating to the use of appropriate demand to determine pump capacity (considering reservoir operating storage).

However, where significant operating storage can be provided, pumping station capacity may be reduced provided that the operating storage in the service reservoir can be replenished within the specified design period. In this situation, capital and system operating and maintenance costs also needs to be balanced, ie weigh up the option of providing additional operating storage against pumping station capacity, which is especially critical for long transfer mains/systems.

Additional issues that should be considered include water quality, energy, maintainability, operability and reliability.

5.4.2.2 Pump Efficiency and other considerations

Pumps must be planned to operate as close as possible to peak efficiency at most times. Variable speed drives should be considered in situations where the flow and head range vary considerably. Pumps should never operate outside the 50-120% of their best efficiency point (BEP) capacity or in a range where they can be damaged due to cavitation.

Consider having either multiple pumps in parallel or variable speed pumps to avoid running large pumps for very short periods per day and frequent start-stops per hour. However, options will be subject to economic evaluation, including energy efficiency and life cycle maintenance costs. Maintenance costs for VSD units are generally higher than for fixed speed units. VSDs also reduce the overall pumping unit efficiency. However, a VSD unit negates the need to install a delivery control valve if this was required for a fixed speed unit.

As systems change, due to growth, rezoning and pump deterioration etc, it is important to undertake regular system reviews to verify that existing pumps meet the changed requirements of the system and continue to operate within the designed pump efficiency range.

Consider the provision of sufficient gauging and metering to enable checking of pump efficiency. Real time monitoring of pump efficiency is a good option for large, complex pumping stations with multiple units. Real time pumping efficiency can be obtained by measuring differential pressure (across the suction and discharge manifold of each pump unit) in addition to discharge flow and motor power.

Monitoring of parameters indicating pump wear can also be used to determine when a pump needs maintenance. Efficiency trends, such as the one shown in **Figure 5 - 5** below, can be developed over the life of the pump to show impact of pump deterioration and maintenance.

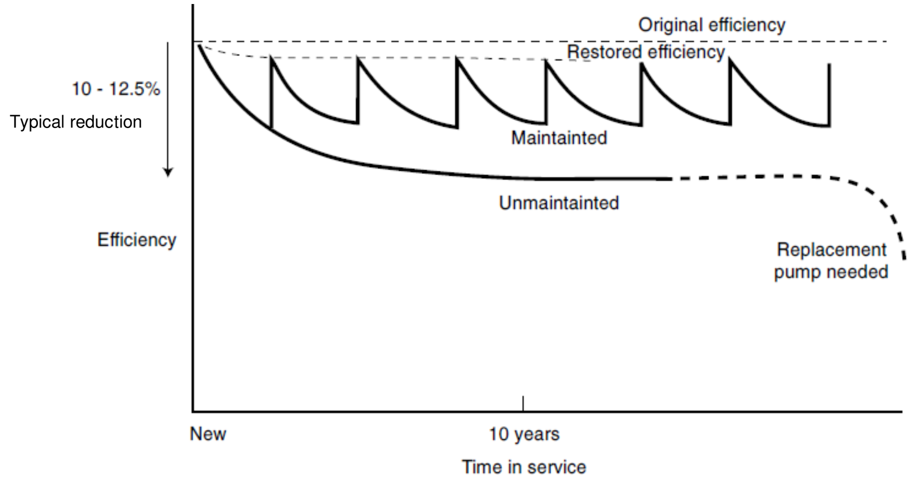


Figure 5 - 5 Pump efficiency trend over life period

Planners should consider recommending water hammer analysis on pumping station connected mains (suction and rising mains) (Refer to **Section 4: System Hydraulics, Clause 4.3.1.2**).

Other considerations include:

- Minimising environmental (eg flooding) and social impact (eg noise).
- Assessing surge conditions arising from normal pump starts and stops, power failure during pumping and, the effectiveness of any necessary surge reduction measures taken. Also assess the impact of surge on connected pipe systems.
- Electrical power capacity needs to cater for operation of all units (ie all duty units plus a standby unit).
- The net positive suction head (NPSH) available should be greater than the NPSH required by the pump under full operating range.
- Consider the need for alternative power supply to the facility (standby feeder), providing auxiliary-powered pumps (diesel, alternative power supply etc) to enable continuity of supply during power outages.
- For monitoring requirements refer to **Section 2: Water System Planning**.

5.4.2.3 Number of pumping units

In general, the number of units required is driven (though not limited to the following factors):

- to meet the system characteristics (reservoir to reservoir, reservoir to reticulation, reservoir to reservoir and reticulation, reticulation to reticulation, other pumps, etc)

- to cater for the range of flows and heads that the pumping station is planned for
- to consider appropriate staging
- to meet the frequency distribution of delivery flows required
- to obtain lower Life Cycle Costs (LCC).

A general rule of thumb is that a minimum of two units be provided. For large capacity pumping stations, three or more units may be required.

If an alternative supply is available to the zone, two units may be sufficient even for large capacities, subject to a risk assessment.

A standby pump unit is to be provided in addition to the one or more duty units, with automatic controls to alternate all pumps between duty and stand-by functions. A standby pump may not be required where sufficient reserve storage or an alternative supply is available, subject to a risk assessment and financial evaluation.

5.4.2.4 Reliability issues

For reliability purposes, consider the inclusion of a by-pass arrangement around a water pumping station. This arrangement would allow for the installation of an emergency (possibly diesel) pump set when the water pumping station has failed for some reason.

In certain circumstances for reliability purposes, it may be advisable to ensure that the water pumping station is bi-directional. This is, the design of the pumping station be such that the normal direction of the water flow may be reversed to cover an emergency situation.

5.5 Water mains

5.5.1 General

It is common to classify water mains by size or function. The following table indicates some common categorisation.

Type of water main	Definition
Conduits	Very large pipelines either on the surface or in tunnels
Trunk mains	Transfer or distribution main
Feeder mains	Mains (350 mm to 900 mm in diameter) that feed reticulation mains in an area
Critical water mains	Mains ≥ 375 mm in diameter and mains at critical locations.
Rising mains (or delivery mains)	Mains from pumping stations to reservoirs can be of any size
Suction mains	Mains to pumping stations
Inlet and outlet mains	Mains to and from reservoirs

5.5.2 General planning considerations

Typical configurations are illustrated in **Appendix F:**. In determining the general layout of mains, consider the following factors:

- Whether existing mains need to be replaced due to their physical condition.
- Whether new mains are required to provide additional capacity.
- Main location to allow easy access for operation, repairs and maintenance.
- System security.
- Water quality as indicated by disinfectant residual and water age.
- Staged construction by using smaller initial mains and/or providing additional treatment points such as reservoirs.
- Whether alternative sources of supply are to be used for the initial service of an area pending development of in-fill areas (based on a reliable forecast of the rate of in-fill development).
- Location of valves for shut off areas and zone boundaries including double isolation requirements.

- Connection between different water managed zones should be avoided. However where its unavoidable, appropriate valve arrangements should be considered to separate different pressure managed zones.
- Avoidance of dead-ends where practical.
- Provision of dual or alternative feeds to minimise customer disruptions.
- The environmental impact of both construction and operational phases.
- Provision for maintenance of critical assets, eg pumping stations and operation during reservoir or tunnel isolation.

5.5.3 Velocity and headlosses

For velocity and headloss requirements, refer to the *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.

5.5.4 Pipeline material friction factors

The friction factors of different pipeline materials are noted in the water modelling system.

5.5.5 Minimum pipe sizes

For minimum pipe size requirements, refer to the *Water Supply Code of Australia, Sydney Water Edition* **(Reference 1)**.

Alternative minimum pipe diameters may be specified for particular developments in CBDs or other high growth areas (ie www.planning.nsw.gov.au/urbanactivation).

5.6 Flow controls

5.6.1 General

Valves of various types are used to control flow and pressure in the water system (Refer to **Figure 5 - 6** for examples). Also see **Section 2: Water System Planning** for general monitoring requirements.

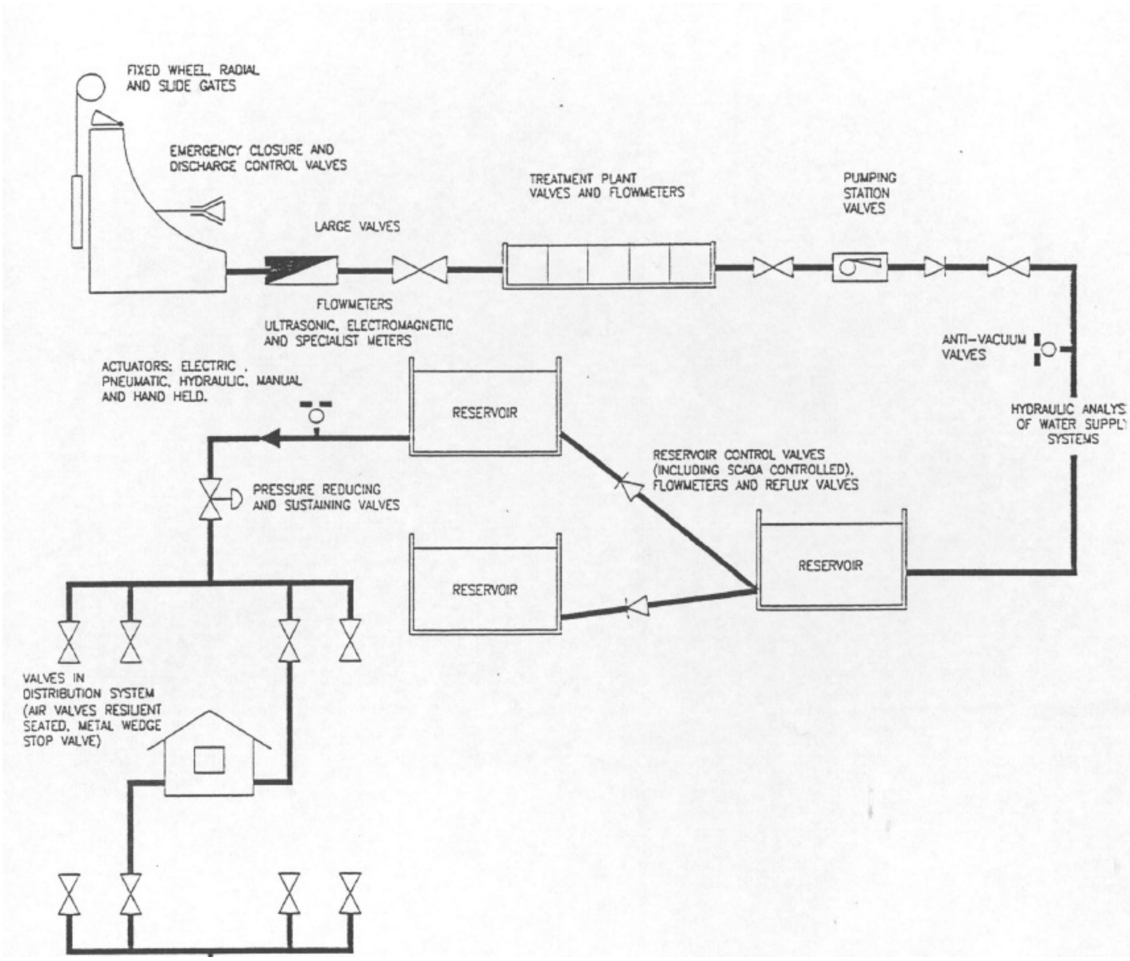


Figure 5 - 6 Typical valves used in the Sydney Water system.

Planners should provide a network schematic showing major new valves' location or any changes to existing valves' operation within the study area and any relevant adjacent areas.

5.6.2 Applications

For the application of valves, refer to **Appendix G:**. However, this information is more relevant to designers and provided here as general information for planners.

For details on design criteria of valves, refer to *Water Supply Code of Australia, Sydney Water Edition* (**Reference 1**).

5.7 Context

5.7.1 Definitions, abbreviations and references

Refer to **Section 1: Introduction to the guideline, Clause 1.6**.

5.7.2 Attachments and/or appendices

Attachment/appendix number	Title
Appendix A:	Understanding 1/3 of a maximum day reserve storage
Appendix B:	Reservoir site layout examples
Appendix C:	Example – Graphical Method for Staging Works
Appendix D:	Pump types
Appendix E:	Variable speed drives (VSD)
Appendix F:	Typical network layout
Appendix G:	Valve applications

5.7.3 Document control

Title: Water System Planning Guideline, Section 5: Infrastructure Planning		
Current review date: June 2015	**Review period:** 1 year **Risk rank = High**	**Registered file:** 2014/00004985
BMIS file name:	AMQ0562.05	
Document owner:	Craig Crawley - Strategy Manager, Servicing & Asset Strategy	
Prepared by:	Farhana Rifat - Servicing & Asset Strategy Paul De Sa - Servicing & Asset Strategy Chris Moore - Servicing & Asset Strategy Fernando Gamboa - Servicing & Asset Strategy Tony Cartwright - Servicing & Asset Strategy	
Stakeholders consulted/reviewer:	Anil Jaiswal - Servicing & Asset Strategy Bob Wickham - Urban Growth Chris Salkovic - Service Delivery – Product & Asset Management Craig Crawley - Servicing & Asset Strategy Daryl Gilchrist - Engineering & Environmental Services David Gough - Servicing & Asset Strategy Frank Kanak - Service Delivery - Networks Peter Fisher - Servicing & Asset Strategy Richard Schuil - Engineering & Environmental Services Sum Tong - Engineering & Environmental Services Aravinda Stanley - Servicing & Asset Strategy David Zhang - Servicing & Asset Strategy Ed Braithwaite - Service & Asset Strategy Gaetano Illuzzi - Engineering & Environmental Services Graham Couchman - Engineering & Environmental Services Janssen Chan - Engineering & Environmental Services Julie Horne - Engineering & Environmental Services Mark Obuchowski - Engineering & Environmental Services Matthew Stark - Urban Growth Milan Rubcic - Engineering & Environmental Services Nihal Balasuriya - Service Delivery- Networks Persephone Rougellis - Service & Asset Strategy Rajiv Madhok - Engineering & Environmental Services Richard Wajzer - Urban Growth Robert Ius - Service Delivery - Hydraulic System Services Suganthini Niranjan - Engineering & Environmental Services Suhanti Thirunavukarasu - Engineering & Environmental Services Thaya Thayanithy - Service Delivery - Networks Vajira Samarasinghe - Engineering & Environmental Services	
Approval and Endorsement	See end of 'Section 0' of WSPG	

5.7.4 Revision control chart

Version number	Date revised	Brief description of change
1	September 2014	New Document

Appendix A: Understanding 1/3 of a maximum day reserve storage

The following failure scenario determines how effective 1/3 of a maximum day demand is as reserve storage. Assumptions are:

- The standby unit in a pumping station has failed.
- The remaining pumps can pump 90% of the maximum day demand.
- The demand sequence factors are as shown in **Table 5 - 1** (over eight days).
- A 1/3 of a maximum day demand in reserve storage.

Results – **Table 5 - 1** shows that the reservoir level cycles down to near MOL over the eight-day maximum week sequence, ie the reservoir would deplete to about 0.23 MDD below the RSL (on Day 7) and then would start to recover. Having 1/3 of a maximum day demand as reserve storage would mean that the supply would not be interrupted.

Table 5 - 1 Reserve storage during maximum demand week period

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Demand sequence factors	0.78	0.92	0.92	1.00	0.94	0.93	0.92	0.68
Daily deficit (if > than 0.9 input capacity)	0.00	-0.02	-0.02	- 0.10	- 0.04	- 0.03	- 0.02	+0.22
Accumulated deficit as a factor of max day demand	0.00	-0.02	- 0.04	- 0.14	- 0.18	- 0.21	**- 0.23**	- 0.01

Appendix B: Reservoir site layout examples

Reservoir site layouts

Where more than one reservoir is required to service a zone, planner must ensure that all reservoirs are able to equalize. The connecting pipe work must be sized, so that the full storage can be accessed, hence eliminating head diffrencec between reservoirs. Failure to provide this will result in lead and lag conditions being experienced between the two reservoirs. This results in loss of operational volume as the system can only be operated by the level in the lead reservoir. We already have some sites where this condition is present and the lag can be as much as 1m (or 8% loss of effective operation storage).

Figure 5 - 7 shows a layout of a reservoir installation to supply an extensive high-level area for which the provision of large elevated storage is uneconomical. Water feeds into a small elevated reservoir in off-peak periods and, when full, overflows into a surface reservoir. The AICV is controlled by the water level in the surface reservoir. When the water in the elevated reservoir falls, the local water pumping station draws water from the surface reservoir and supplies the zone. The pump cuts out after replenishing the elevated reservoir.

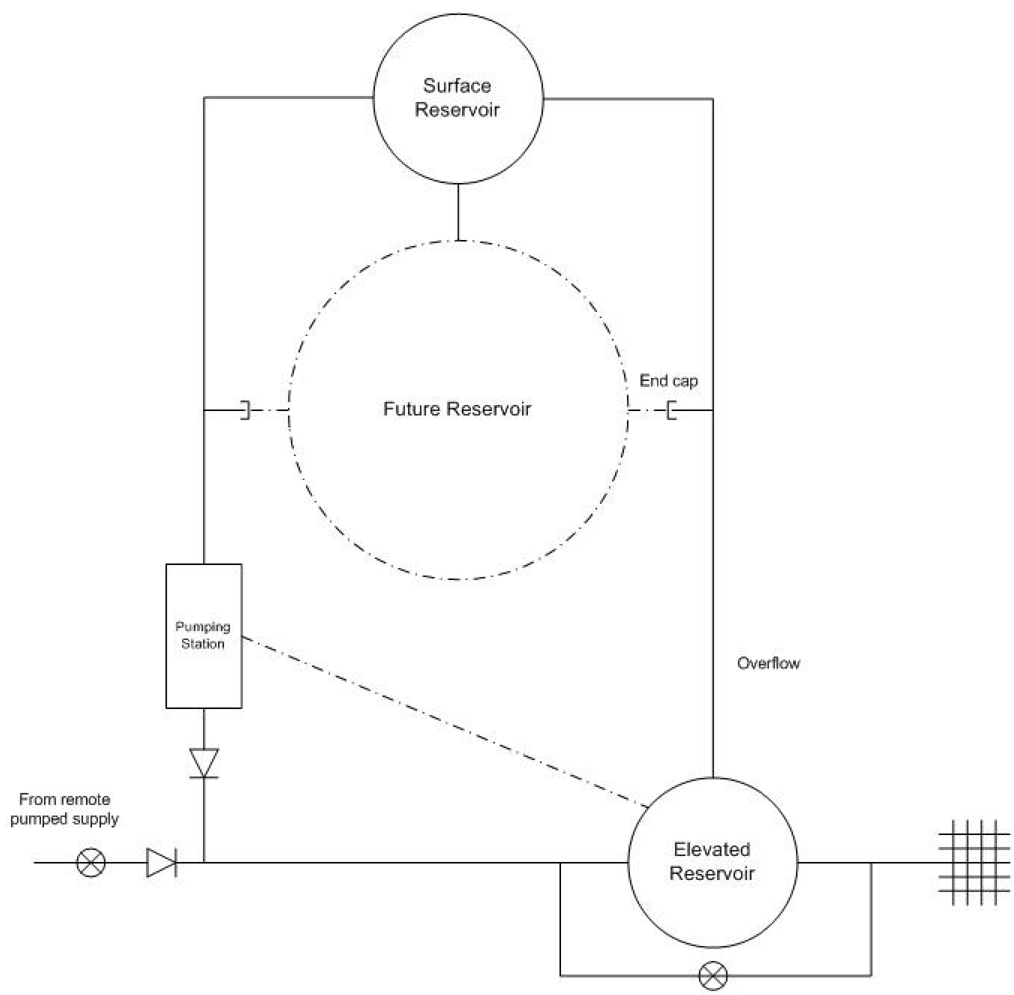


Figure 5 - 7 Elevated reservoir site layout with future large surface reservoir

Figure 5 - 8 shows a combined arrangement of a surface reservoir and an elevated reservoir to supply two zones isolated from each other with a dividing valve (DV). The surface reservoir supplies a low level zone and the elevated reservoir supplies a high zone.

Note that in this arrangement there is a combined inlet and outlet main. This option would need to be assessed financially, as well as for water quality, against an arrangement with an additional single main to the reservoir and a PRV.

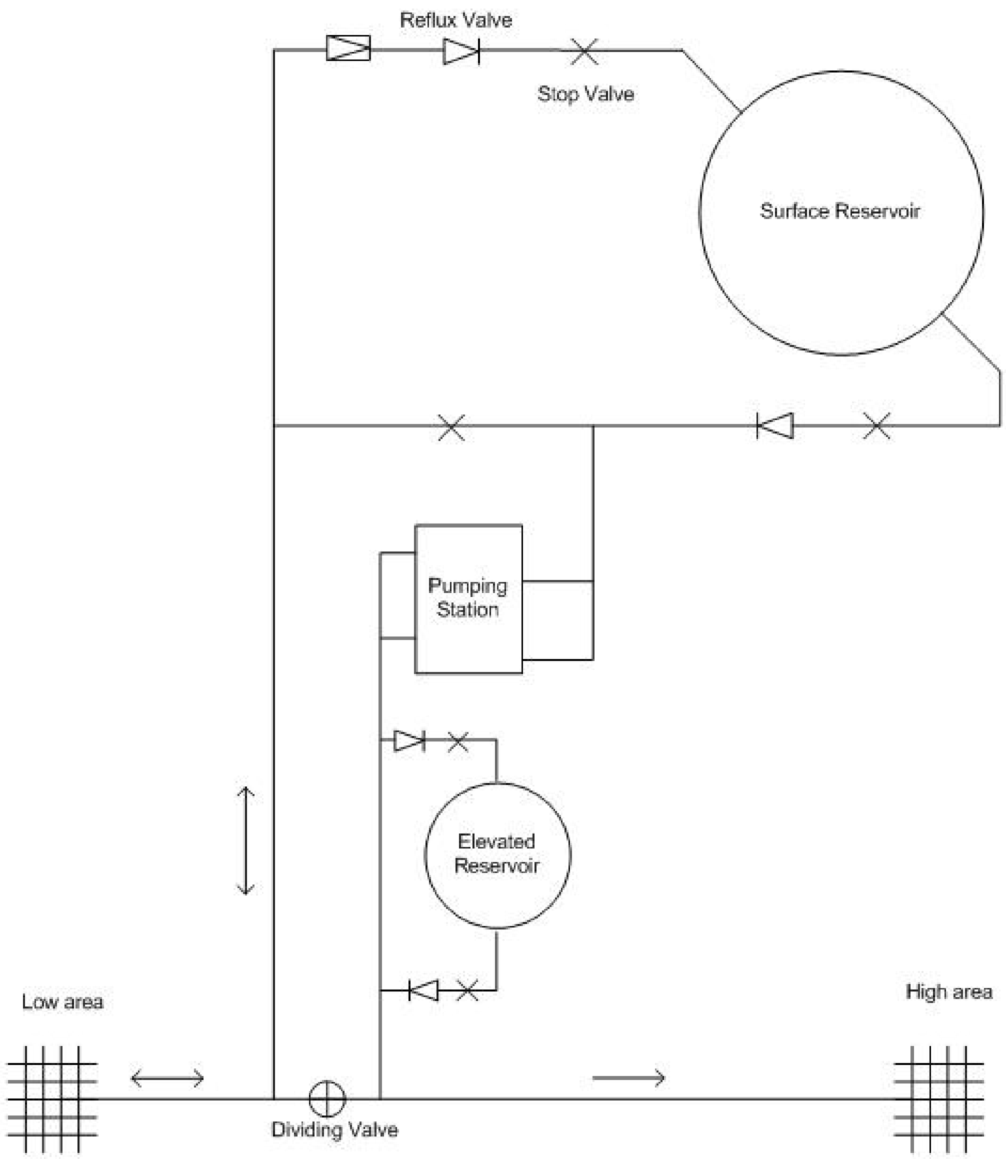


Figure 5 - 8 Typical elevated and surface reservoir site layout

Figure 5 - 9 shows a small temporary reservoir constructed to supply a new area of small initial consumption with provision for the construction of a permanent reservoir when development and consumption increases.

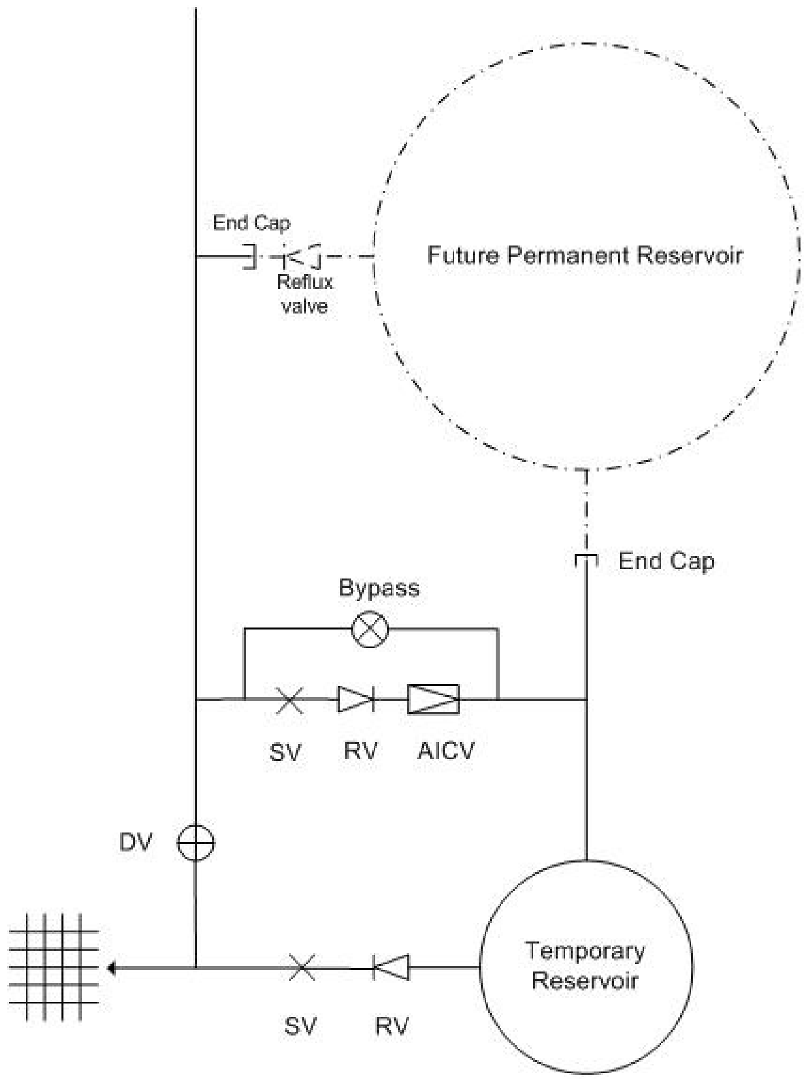


Figure 5 - 9 Typical temporary reservoir site layout

Appendix C: Example – Graphical method for staging works

The following example was formulated in 1986 based on the Minchinbury system. At that time,

Existing system (Figure 5 - 10)

a) 1 duty, 1 standby 1300 kW units WP0184

b) 1 x 40 ML reservoir at Minchinbury.

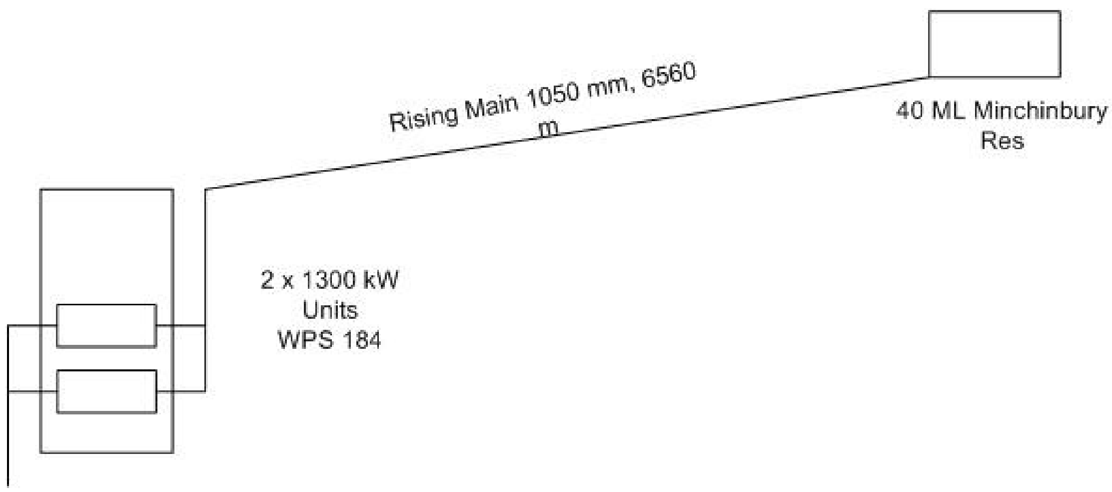


Figure 5 - 10 Existing Minchinbury system in 1986

Demand curve

2010 MDD = 185 MLd

Reserve storage

Reserve storage = 1/3 MDD

Pump capacity - 1300 kW units in WP0184, with different pumping units,

No. Pumps	Capacity MLd
1	110
2	175
3	210

Design period

Using the distribution figures for the maximum design period (Refer to **Section 3: Water Demand and Growth, Table 7**.

The actual design period will depend on the ratio of pump capacity to MDD, that is:

$$Pump\ capacity\ \ ratio\ = \frac{Pump\ \ capacity}{MDD}$$

PCR	Design period (days 7.00 am to 7.00 am)	DDF sequence	DDF sequence to be used in the cumpter model run
> 0.95	1	1.00	0.93, 1.00, 0.95
> 0.93	4	1.00, 0.95, 0.95, 0.97	0.93, 1.00, 0.95, 0.95, 0.97, 0.79
> 0.88	5	0.93, 1.00, 0.95, 0.95, 0.97	0.88, 0.93, 1.00, 0.95, 0.95, 0.97, 0.79
> 0.80	6	0.88, 0.93, 1.00, 0.95, 0.95 , 0.97	0.80, 0.88, 0.93, 1.00, 0.95, 0.95 , 0.97, 0.79

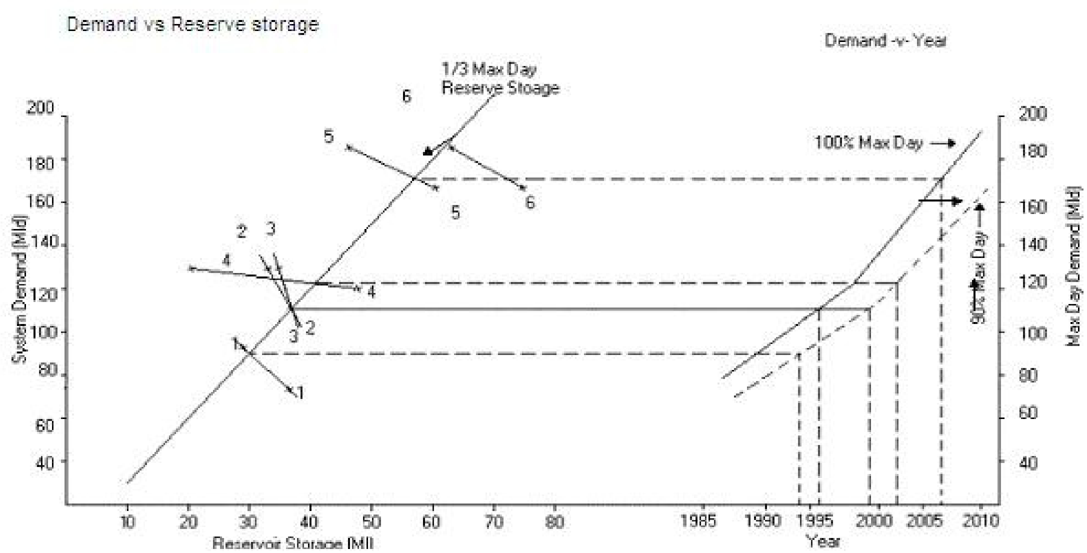
Cases to analyse

Case	No. Pumps	Res size ML	% MDD	Amplification
1	1	40	90	None
2	2	40	90	WPS (additional duty unit)
			100	None
3	3	40	100	WPS (additional duty unit)
4	1	40 + 60	90	Reservoir
5	2	40 + 60	90	Reservoir and WPS (additional duty unit)
			100	Reservoir
6	3	40 + 60	100	Reservoir and WPS (additional duty unit)

Computer Model runs

Case	MDD (ML/d)	Pump capacity (ML/d)	PCR	Design Period (days)	Reservoir storage (ML)	Reservoir storage/ MDD
1	74.0	110	>1.00	1	36.4	0.49
	92.5	110	>1.00	1	28.9	0.31
2	111.0	175	>1.00	1	36.7	0.33
	129.5	175	>1.00	1	32.4	0.25
3	111.0	210	>1.00	1	36.7	0.33
	129.5	210	>1.00	1	34.8	0.27
4	120.3	110	0.91	5	47.7	0.40
	129.5	110	0.85	6	20.5	0.16
5	166.5	175	>1.00	1	60.3	0.36
	185.0	175	0.95	4	46.3	0.25
6	166.5	210	>1.00	1	74.8	0.45
	185.0	210	>1.00	1	62.9	0.34

Amplifications timing



Cases analysed:

1. 1-pump, 1 x 40 ML reservoir
2. 2-pumps, 1 x 40 ML reservoir
3. 3-pumps, 1 x 40 ML reservoir
4. 1-pump, 1 x 40 ML + 1 x 60 ML reservoirs
5. 2-pumps, 1 x 40 ML + 1 x 60 ML reservoirs
6. 3-pumps, 1 x 40 ML + 1 x 60 ML reservoirs

Figure 5 - 11 Staging of Minchinbury Reservoir works

i. Existing system consisting of:
1 duty and 1 standby unit WPS 184
1 x 40 ML reservoir

Read timing of required amplification from **Figure 5 - 11**

(i) 90% maximum day (case 1): 1994
(ii) 100% maximum day (case 2): 1996

Upgrade requited in 1994.

ii. Existing system with WPS amplification consisting of:
2 duty pumps and 1 standby unit WPS 184 F
1 x 40 ML reservoir

Read timing of required amplification from **Figure 5 - 11**

(i) 90% maximum day (case 2): 1999
(ii) 100% maximum day (case 3): 1996

Upgrade required in 1996.

iii. Existing system with reservoir amplification consisting of
1 duty pump and 1 standby unit WPS 184
1 x 40 and 1 x 60 ML reservoirs

Read timing of required amplification from **Figure 5 - 11**

(i) 90% maximum day (case 4): 2002

(ii) 100% maximum day (case 5): 2007.

Upgrade required in 2002.

Staging options

Option 1
WPS amplification: 1 duty unit in WPS 184 in 1994
Reservoir amplification: 60 ML reservoir at Minchinbury in 1996

Option 2
Reservoir amplification: 60 ML reservoir at Minchinbury in 1994
WPS amplification: 1 duty unit in WPS 184 in 2002

Economic Evaluation

Following identification of the various staging options a full life cycle cost economic evaluation shall be undertaken of each option to determine the preferred option.

Preferred Option (Figure 5 - 12)

In this example the preferred option on a life cycle cost basis was Option 2 (reservoir amplification 1 x 60 ML reservoir at Minchinbury in 1994, WPS amplification 1 x 1300 kW unit in WPS 184 in 2002).

Note that the upgrade of Minchinbury Reservoir was completed in 2008 and it involved a second on-site 40 ML reservoir.

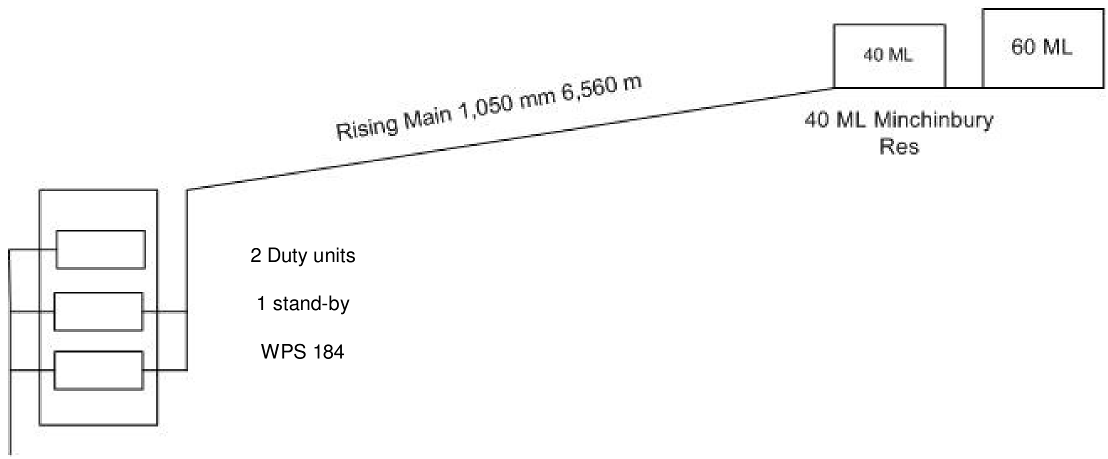


Figure 5 - 12 Proposed Minchinbury system in 2010

Appendix D: Pump types

There are many ways of classifying pumps. A classification by mechanical configuration considers two main types:

The below classification complies with the *Australian Pump Technical Handbook* (**Reference 41**).

- Rotodynamic pumps
- Positive displacement pumps

Rotodynamic pumps are further classified into:

- Centrifugal pumps
- Peripheral pumps
- Special pumps

Centrifugal pumps are generally divided into three types:

- Radial flow
- Mixed flow
- Axial flow

Sydney Water mostly uses centrifugal pumps for water applications.

Centrifugal pumps characteristics

In centrifugal pumps the liquid acquires energy in the form of velocity as it passes through the impeller passages. The velocity head is converted into pressure head by the volute or spiral shaped pump casing that directs the liquid from the outer perimeter of the impeller to the pump discharge.

Sydney Water mostly uses fixed speed pumps and is starting to use variable speed drive (VSD) pumps primarily at booster pumping stations. In some cases, eg systems with high friction head losses or/and wide range of flows and heads, variable speed drives (VSD) may be a viable alternative to fixed speed drives.

When the head or pressure requirements are such that a single impeller cannot satisfy them, it is usual to supply multi-stage pumps. The total head developed is equivalent to that of a single stage, multiplied by the number of stages included. Pump performance and efficiency deteriorate over time as the equipment ages.

Unlike positive displacement pumps, centrifugal pumps operating at constant speed can deliver any capacity from zero to a maximum value that depends on pump size, design, and system conditions. The total head developed by the pump, the power required driving it and the resulting efficiency vary with capacity.

Advantages of using centrifugal pumps include:

- Capacity for high flow rates.
- Low capital cost.

- Minimal wear under normal operation due to few moving parts (ie no gears, pistons or valves).
- High reliability of operation and low maintenance cost.
- Adaptability for direct motor and engine drive without use of expensive gears.
- Small floor space required (compact and easy to disassemble for maintenance).
- Quiet operation.
- Smooth, non-pulsating delivery.
- Can be operated in a wide range of duty points.
- Will successfully handle liquids carrying solids in suspension, providing the pump is designed to suit conditions.
- Can be equipped with VSDs for efficient flow control options and energy savings through speed reduction.

Appendix E: Variable speed drives (VSD)

Pumps that experience highly variable demand and/or head conditions or operate in systems that have high friction losses (ie ‘steep’ system characteristics) are often good VSD candidates. VSDs use electronic controls to regulate motor speed which, in turn, adjusts the pump’s output. The principal advantage of VSDs is better matching between the fluid energy that the system requires and the energy that the pump delivers to the system.

As system demand changes, the VSD adjusts the pump speed to meet this demand, reducing the energy lost to throttling or bypassing excess flow. The resulting energy and maintenance cost savings may justify the investment in the VSD. However, VSDs are not practical for all applications, eg systems that operate against high static/low friction head (ie ‘flat’ system characteristics). Detailed analysis is required under these circumstances. A short guide on how to assess VSD opportunities is given below.

Assessment of VSD opportunities

Some of the factors that should be weighed when considering application of VSDs are:

1. A fundamental requirement for considering VSDs should be that flow (or in a more limited sense, head) requirements change over time. If the system flow and head requirements are essentially fixed, efforts should concentrate on ensuring a properly sized pump (which should also be a consideration, regardless of whether a VSD is employed).
2. The greater the proportion of the system head that is static, the less effective will be the VSD. This is particularly true if the flow requirements vary significantly. Parallel pumps are, on the other hand, most effective in systems that are dominated by static head. Parallel pumps need not all be identical; in fact there are some systems where a small pump could meet system requirements 80-90% of the time, and supplemented by a parallel, larger pump for the occasional higher flow condition.
3. The pumps must operate enough hours during the year to justify applying VSDs (when based on a simple payback, a pump station with multiple pumps may only have the lead pump equipped with a VSD).
4. The effective range for a VSD pump can be increased by selecting the pump such that the pump operating point is to the right of (ie greater than) the best efficiency point (BEP) when operating at the highest anticipated flow requirement. This allows the pump efficiency to initially increase as speed is reduced.
5. The motor and electrical system should be verified to be suitable for VSD applications. This is particularly important if a VSD is being added as a retrofit.
6. If a VSD is being retrofitted to systems with switch-based controls, such as a float-type level control system that causes the pump to be started or stopped at distinct levels, continuously variable instrumentation, such as a level indicator, will need to be added for control purposes.

The following steps can be followed in assessing the feasibility of VSDs:

- Analyse daily water demand profile to determine flow requirements at different times of day.
- Analyse system curves to identify system constraints (minimum static head and flow range).

- Use pump information (rated speed, motor size, efficiency, net positive suction head (NPSHr) to draw pump curves at different speeds using the affinity laws, and check feasible operation ranges according to manufacturer's recommendation.
- Calculate pump operating points using flow data from the demand profile and head-flow data from the system curve.
- Calculate power requirements for all pump operating points. Note: Overall pumping units (pump – motor – VSD) efficiencies shall be used in power calculations. VSDs generally reduce the overall efficiency by about 6% due to heat losses in the VSDs and motors caused by harmonics.
- Calculate energy savings by comparing the VSD pump load profile to the base case (fixed speed pump, cut-in/cut-out operation). This information is available from the Energy and Eco-efficiency Team. The Team should be contacted for the latest figures.
- Calculate electricity cost savings using tariff and demand information.
- Conduct a risk assessment taking into account the following elements:
    - Water quality (reservoir cycling vs constant level)
    - Mechanical (speed to avoid cavitation or excessive vibration)
    - Electrical (harmonics and other motor losses)
    - Hydraulic (minimum/maximum head, continuity of supply)
- If required, modify VSD pumping profile according to risk mitigation measures
- Estimate capital and installation costs (eg quotes from suppliers)
- Perform financial evaluation to determine payback and financial viability

For more information refer to *Variable Speed Driven Pumps – Best Practice Guide*, British Pump Manufacturers Association and GAMBICA Association Ltd (**Reference 40**).

Appendix F:Typical network layout

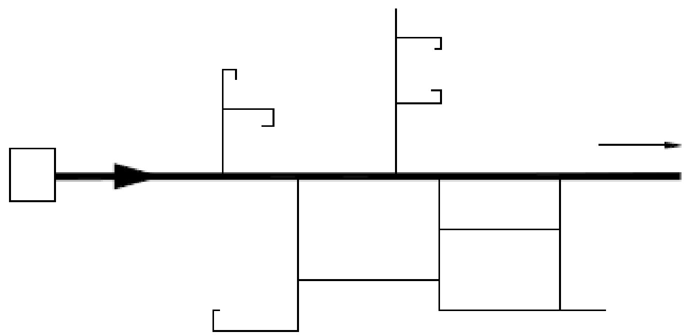


Figure 5 - 13 Single transfer/distribution main, minor network and dead-end branch mains (not preferred due to low turn-over in dead-end mains)

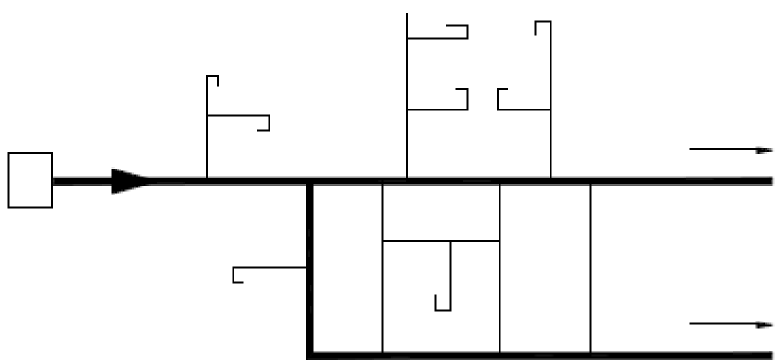


Figure 5 - 14 Single transfer/distribution main, network with multiple distribution mains and branch mains with reduced diameter dead-ends

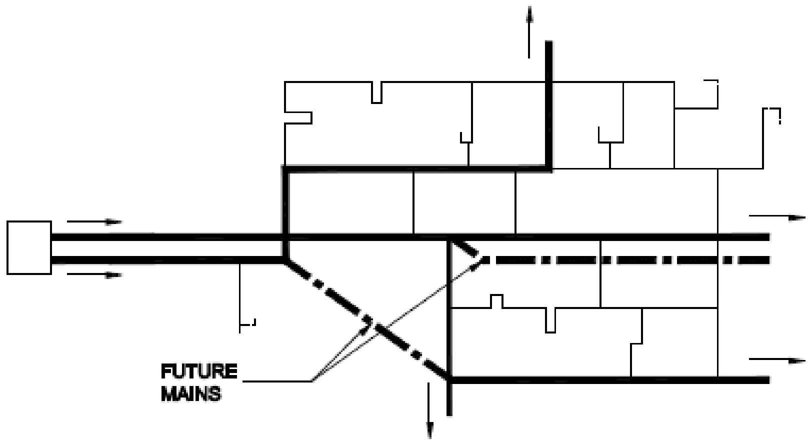


Figure 5 - 15 Twin transfer/distribution mains, network with multiple distribution mains, looped mains and link mains to minimise dead-ends, some reduced diameter dead-end mains and staging of provision of mains

Figure 5 - 15 is preferred to provide multi-direction supply with small shut-off areas, mains redundancy and looped, linked or reduced diameter mains to maximise water turn-over.

Appendix G: Valve applications

Table 5 – 2 provides the common valve applications in Sydney Water. However, details on valve requirements will be considered during the design phase and added here for the planner's information only.

Table 5 - 2 Common valve applications in Sydney water

No	Name	Types	Control	Location	Operation	Application	Setting
1	Air valve (AV)	Double orifice		High points relative to the hydraulic gradient) in mains. Increase in downward slope, reduction in upward slope, long length of pipeline in level terrain. On both sides of the section valve when the flow in a main could be in either direction. Next to a pumping station. Downstream of pressure reducing devices	Automatic	Vent air during pipeline filling, admit air during pipeline scouring and release air during normal pipeline operation	Not adjustable
2	Anti-vacuum valve (AVV)	Single orifice		High points in mains	Automatic	Capable of admitting large quantities of air into the pipeline to prevent vacuum conditions in pipelines or tanks	
3	Automatic Inlet Control Valve (AICV) Also (altitude or float valve)	Butterfly valve, globe valve	Level of water within the reservoir	Inlet to reservoir.	Automatic (electric, or hydraulic)	Primary function is to control flow into a reservoir	Fully open/closed position. The flow modulating function or the pressure sustaining function can be accommodated into the open/closed function of the AICV
4	Pump delivery control valve	Metal seated butterfly valve		The outlet side of a pump		Assist fixed speed pumps starts and stops. Prevent pressure surges within the suction or delivery pipework	Opens after pump starts and closes before pump stops.

5	Dividing valve (DV)	Gate		Reservoir zone boundaries	Manual	Isolate the connecting pipework between two supply zones	Closed (normal mode)
6	Emergency inlet control valve (EICV)	Butterfly valve, globe valve	Reservoir overflow	Inlet to reservoir and within reservoir site	Automatic (electric, hydraulic)	Prevent overflow if AICV fails	Open (normal mode)
7	Pressure reducing valve (PRV)	Globe Plug Piston Needle Butterfly	Fixed outlet pressure Time of day profile Flow compensating	Anywhere in supply zone where high pressures are experienced	Hydraulic control, Modular electronic units	Manage the water pressure supplied to a high pressure area. Suitable for leakage control applications	The flow compensating PRVs regulate the outlet pressure as a function of flow through the valve Adjustable to upstream pressure
8	Pressure relief valve (PReV)	Globe Plug Piston Needle	Fixed inlet pressure	The size and location based on water hammer analysis. Generally located near natural drainage	Automatic	Downstream of a pressure reducing valve to avoid excessive pressure build up Protection of a pipeline against excessive pressure due to hydraulic transients	The pilot senses the rise in pressure and fully opens the valve
9	Pressure sustaining valve (PSV)	Globe Plug Piston Needle	Fixed inlet pressure	Generally located at the inlet to the reservoir	Automatic	Maintain a minimum set pressure on the u/s side of the valve irrespective of variations in outlet conditions	
10	Non-return valve (NRV)	Swing check, tilting disc, nozzle, spring loaded duo-check	Prevents reverse flow	Inlet/outlet connection to reservoir, on pump discharge side	Automatic	Discharge side of pump: prevent reverse flow when the pump stops. Inlet of reservoir: prevent draining of reservoir in case of inlet main break. Rising main: water hammer control	
12	Scour valves	Gate		Low points in pipeline profile	Manual	De-water pipelines	
13	Stop valve (SV)	Gate, butterfly		Pipelines	Manual (hand wheel or tee key) with or without gearbox	Use to isolate water mains and as bypass, scour and air valve or AVV isolator. Open-close application, not suitable for regulation	Fully open/closed position