SA Water

Water Expertise

Technical Standard

# TG 0530 – Sewer network hydraulic design considerations to minimise network odour impact

**Version**: 2.0.
**Date**: 25 November 2025
**Status**: Final.
**Document ID**: SAWG-TE-0530
**Confidentiality:** OFFICIAL

Government of South Australia

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# Documents superseded by this standard

The following documents are superseded by TG 0530:

a. TG 0530 Version 1.0

# Significant/major changes incorporated in this edition

Updated in this version of the Technical Guideline include:

a. Updated in accordance with the SA Water technical Guideline Template Version 8.3 and the SA Water Style and Writing Standard Feb 2025 version, including revised disclaimers.

b. Internal references updated.

c. Text changes within the body of the document are highlighted in yellow for clarity.

d. Update to align with new Technical Guideline for Odour and Corrosion (TS 0854).

# Document controls

## Version history

| Version | Date | Author | Comments |
|---|---|---|---|
| **1.0** | 01-02-2021 | SA Water | Final for Issue |
| **2.0** | 25-11-2025 | Matt Rolfe | Issued for use |

Template: Technical Standard Version 8.3, 28 October 2025

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# Executive summary

This Technical Guideline outlines sewer network design considerations for minimisation of network odour impacts. It only considers odour generation and is not intended as a hydraulic design standard. Any sewer design undertaken by SA Water shall follow all the relevant procedures, with hydraulic design requirements taking precedent over this guideline document.

Designing a sewer network that has no odour is prohibitively expensive, but the effort made to reduce and manage the causes of odour and corrosion during design can reduce some of the impacts and will provide considerably longer-term benefit to SA Water.

The cause of sewer odour and corrosion problems starts with the formation of sulphide in the wastewater. Sulphide formation is a biological process that reduces sulphates and other sulphur compounds to sulphide under anaerobic conditions. Anaerobic conditions exist in pressure mains, siphons, in the sediment and deeper levels of sewers and wet wells. The sulphide formed is subsequently released to the sewer headspace, where it can cause corrosion of concrete and metals or be released to the atmosphere where it may cause odour problems.

The preferred approach in sewer design for odour control is:

e. Prevention of sulphide formation.

f. To release the sulphides to atmosphere in a location where there will not be adverse impacts if possible (to remove sulphides from the system).

g. To keep the sulphide in the liquid phase by reducing turbulence and maintaining adequate sewer head space to allow air flow with minimal restriction.

h. If the above are insufficient or not possible, some form of control to prevent corrosion and odour problems.

Minimising sulphide formation is the first step in managing odour and corrosion for sewer design, and key considerations are:

- Controlling the hydraulic retention time in pressure mains and wet wells to avoid anaerobic conditions.
- Achieving adequate sewage velocity to achieve natural reaeration, scouring of sediments, and striping for minimising slime layers on pipes.

Once formed, the sulphide will be released to the sewer headspace at a faster or lower rate depending on the level of turbulence. Pressure main discharge locations, steep slopes and drops all promote turbulence and faster sulphide release to the sewer headspace. Ideally the air in the sewer headspace should be released to atmosphere at these locations to prevent the build-up of $H_2S$ levels in the network. If this is not possible due to the sensitive nature of the locations, adopting strategies to reduce turbulence, ensure that the sewer headspace is not too restricted (and does not surcharge) and to allow the free flow of sewer air will be required. The reason for this is that restriction in headspace will increase the pressure which will force air out at uncontrolled locations. Managing the release of sewer gases requires effective containment so that gases are only released at designed locations, such as educts.

The Table below provides a quick reference guide to the sewer network design considerations for minimisation of network odour impacts that are covered in this guideline.

| Design Consideration | Reference |
|---|---|
| **Process of sulphide formation and corrosion** | Section 5.2 |
| **Odour risk level related to HRT and sulphide concentration (for high level analyses only)** | Table 4 |
| **Quantifying Odour Risk** | Section 5.6 |
| **Hydraulic drop design with internal and external drop pipes** | Figure 6 |
| **Applicability of vortex drop structures** | Section 6.3 |
| **Design requirements for vortex drop structures** | Section 6.3 |
| **Design Standards to avoid hydraulic jumps and surges** | Section 7.4 |
| **Gravity sewer design to minimise sulphide generation** | Section 8.3.1 |
| **Pressure main design to minimise sulphide generation** | Section 8.3.2 |
| **Design of pressure main discharge maintenance holes** | Section 9 |
| **Pressure main discharge design to promote non-turbulent conditions** | Table 10 |
| **Design of SPS wet well/inlet maintenance hole incoming sewer discharge** | Section 10 |
| **Requirements for seals on wet wells and maintenance hole covers** | Section 11.1 |
| **Design of wet well inducts and educts** | Section 1.1 |
| **Design of collar type rain guard for a stack** | Figure 23 |

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# 1 Introduction

SA Water is responsible for operation and maintenance of an extensive amount of sewerage infrastructure.

This guideline has been developed to outline sewer network design considerations to minimise network odour impacts.

## 1.1 Purpose

The purpose of this guideline is to provide guidance for use in the design of sewer assets to minimise network odour impacts.

This guideline only considers odour generation and is not intended as a hydraulic design standard. Any sewer design undertaken by SA Water shall follow all the relevant procedures, with hydraulic design requirements taking precedent over this guideline document.

## 1.2 Glossary

Terms and Abbreviations utilised in this Standard are included in the following sections. The definitions presented below are to be used when interpreting this Standard and actions undertaken in relation to this Standard. Where a conflict exists, clarification is to be sought from SA Water.

### 1.2.1 Terms and Definitions

The following is a list of Terms applicable to this document:

| Term | Description |
|---|---|
| **AC vessel, active** | Activated carbon treatment system with forced ventilation, with air flow driven by mechanical fan. |
| **AC vessel, passive** | Activated carbon treatment system with natural ventilation (no mechanical fan). |
| **Accepted** | Determined to be satisfactory by SA Water's Representative. |
| **Allow** | Means that the cost of the item referred to is the responsibility of the Constructor |
| **Constructor** | The organisation responsible for constructing and installing infrastructure for SA Water whether it be a third party under contract to SA Water or an in-house entity. |
| **Contract** | A set of documents supplied to Constructor as the basis for construction; these documents contain contract forms, contract conditions, specifications, drawings, addenda, and contract changes. |
| **Daisy chain** | Two or more sewage pumping stations (SPS) are connected (with or without gravity sewer sections between the two SPS) and operated in series. |
| **Designer** | The organisation responsible for designing infrastructure for SA Water whether it be a third party under contract to SA Water or a Constructor, or an in-house entity.<br>A Designer is a person who effects design, produces designs or undertakes design activities as defined in the *Work Health and Safety Act 2012 (SA)*. |
| **Hydraulic Drop** | SA defines a hydraulic drop as any difference of greater than 0.3 m in water level between sections of pipes, including at junctions of sewers. |
| **Hydraulic Jump** | A jump or standing wave formed when the depth of flow of water changes from supercritical to subcritical state. |
| **Informative** | Means "provided for information and guidance". |

| Term | Description |
|---|---|
| **Manufacturer** | A person, group, or company that owns and operates a manufacturing facility that provides materials for use in SA Water infrastructure. |
| **Person/s** | Each word implying a person, or persons shall, where appropriate, also be construed as including corporations. |
| **Responsible Discipline Lead** | The engineering discipline expert identified in the 'Approvers' table (via SA Water's Representative). |
| **SA Water Representative** | The SA Water representative with delegated authority under a Contract or engagement, including (as applicable):<br>• Superintendent's Representative (e.g. AS 4300 and AS 2124 etc.)<br>• SA Water Project Manager<br>• SA Water nominated contact person |
| **Sensitive Receptors** | Any land that is occupied or facilities used temporarily or permanently where people might be adversely affected (in this instance) by fugitive odour emissions from SA Water's sewer network is designated a sensitive receptor. In such instances, a focus on protecting human health and wellbeing, local amenity and aesthetic enjoyment is required. Examples of such sensitive receptors include, but are not limited to:<br>• dwellings and private open space (including detached dwellings, multiple dwellings, flat/apartment buildings, row dwellings and semi-detached dwellings)<br>• accommodation (excluding caretaker's residence)<br>• child care centres<br>• education centres<br>• informal outdoor recreation that is adjacent to residential zones<br>• camping and caravan parks<br>• indoor recreation facility<br>• medical centres<br>• hospitals<br>• residential aged care facility and retirement villages<br>• outdoor recreation facility, open sports grounds, (regular public use, for example sporting fields) adjacent to residential zones<br>• dining facilities (restaurants, cafes, etc.)<br>• religious institution buildings |
| **Should** | Indicates practices which are advised or recommended, but is not required |
| **Supplier** | A person, group or company that provides goods for use in SA Water infrastructure. |
| **Technical Dispensation Request Form** | This form is part of SA Water's Technical Dispensation Request Procedure which details the process by which those required to comply, or ensure compliance, with SA Water's technical requirements may seek dispensation from those requirements. |
| **Work** | Elements of a project which require design and/or construction. |

### 1.2.2 Abbreviations

The following is a list of Abbreviations, Acronyms and Initialisms used in this document:

| Abbreviation | Description |
|---|---|
| **ADWF** | Average Dry Weather Flow |
| **BOD** | Biochemical Oxygen Demand |
| **BWL** | Bottom Water Level |
| **$CO_2$** | Carbon Dioxide |
| **DMDS** | Dimethyl Disulphide |
| **DMS** | Dimethyl Sulphide |
| **DO** | Dissolved Oxygen |
| **EPDM** | Ethylene Propylene Diene Monomer (rubber) |
| **$H_2S$** | Hydrogen Sulphide |
| **$H_2SO_4$** | Sulphuric Acid |
| **HRT** | Hydraulic Retention Time |
| **MM** | Methyl Mercaptan |
| **ORP** | Oxidation Reduction Potential |
| **OU** | Odour Unit |
| **PDWF** | Peak Dry Weather Flow |
| **PM** | Pressure main |
| **ppb** | Parts Per Billion |
| **ppm** | Parts Per Million |
| **PWWF** | Peak Wet Weather Flow |
| **SA Water** | South Australian Water Corporation |
| **SPS** | Sewage Pump Station |
| **SRB** | Sulphate Reducing Bacteria |
| **STEL** | Short-Term Exposure Limit |
| **TG** | SA Water Technical Guideline |
| **TS** | SA Water Technical Standard |
| **TWA** | Time Weighted Average |
| **VFA** | Volatile Fatty Acids |
| **WSAA** | Water Services Association of Australia |

### 1.2.3 Terminology

The following is a list of specific interpretations for Terminology used in this standard.

- Where an obligation is given and it is not stated who is to undertake these obligations, they are to be undertaken by the Constructor.
- Directions, instructions and the like, whether or not they include the expression "the Constructor shall" or equivalent, shall be directions to the Constructor, unless otherwise specifically stated.
- Where a submission, request, proposal is required and it is not stated who the recipient should be, it is to be provided to SA Water's Representative for review.
- Each word imparting the plural shall be construed as if the said word were preceded by the word "all".
- "Authorised", "approval", "approved", "selected", "directed" and similar words shall be construed as referring to the authorisation, approval, selection or direction of SA Water's Representative in writing.
- "Submit" mean "submit to the SA Water Representative or their nominated delegate".
- Unless noted otherwise, submissions, requests, proposals are to be provided at least 10 business days prior to work commencing or material ordering (unless noted otherwise).

## 1.3 References

### 1.3.1 Australian and international

The following table identifies Australian and International standards and other similar documents referenced in this document:

| Reference | Title |
|---|---|
| **WSA 02-2.2** | *Sewerage Code of Australia*. WSA 02-2002-2.2 Sydney Water Edition Version 4. Water Services Association of Australia (WSAA), 2017. |
| **WSA 04-2.1** | *Sewage Pumping Station Code of Australia* WSA 04 2005 2.1 Sydney Water edition. Water Services Association of Australia (WSAA), 2012 |
| **MMBW-89** | Hydrogen Sulphide Control Manual, 1989 – Technological Standing Committee on Hydrogen Sulphide Corrosion in Sewerage Works. *Hydrogen Sulphide Control Manual: Septicity, Corrosion and Odour Control in Sewerage Systems*. Volume 1. Melbourne and Metropolitan Board of Works. |
| **US-EPA-95** | US EPA Design Manual, *Odour and Corrosion Control in Sanitary Sewerage Systems & Treatment Plants*, US EPA, 1995. |
| **WSAS** | Water Security Agency of Saskatchewan *Sewage Works Design Standard*, 2012. |
| **CoA-18** | City of Omaha *Wastewater Collection Systems Design Manual* (Pre Final), 2018. |
| **WSA 02-3.3** | *Gravity Sewerage Code of Australia*, WSA 02—2014-3.3, Water Services Association of Australia (WSAA), 2014. |
| **CH2M-08** | *Eastern Drop Structure Ventilation System Option Report* (Rev 1a), Reference 370259 CH2M, 2008. |
| **US-EPA-91** | *Hydrogen Sulfide Corrosion in Wastewater Collection and Treatment Systems* (Technical Report), US EPA, 1991. |
| **Carrera** | Carrera L, Springer F, Lipeme-Kouyi G, Buffiere P.; "*A review of sulfide emissions in sewer networks: overall approach and systemic modelling*". *Water Sci Technol*. 2016;73(6):1231-1242. doi:10.2166/wst.2015.622 |

| Reference | Title |
|---|---|
| **US-EPA-74** | *Process Design Manual for Sulfide Control in Sanitary Sewerage Systems*, US EPA, 1974. |
| **MMBW-72** | *Thistlethwayte, D. (editor), The Control of Sulphides in Sewerage Systems*, Melbourne and Metropolitan Board of Works, 1972. |
| **CoLA-1** | Bureau of Engineering Manual Part F – Sewer Design [F700-F726.4], City of Los Angeles, 1993. |
| **CoD-15** | *Water and Wastewater Procedures and Design Manual*, City of Dallas, 2015. |
| **CoLA-2** | Bureau of Engineering Manual Part F – Sewer Design [F730-F740.4], City of Los Angeles, 1993. |
| **Hurse** | Hurse, T.J.; Ochre, P.; *"The Lost Art of Sewer Ventilation", Water 35(3):94-98* (Australian Water Association), May 2008. |
| **Jacobsen** | Hvitved Jacobsen, T. 2002. *Sewer Processes–Microbial and Chemical Processes Engineering of Sewer Networks*. 1st edition. CRC Press, Boca Raton, Florida, USA. |

### 1.3.2 SA Water documents

The following table identifies the SA Water standards and other similar documents referenced in this document:

| Reference | Title |
|---|---|
| **SAW-ENG-ODO-MUL-TSP-002** | Technical Specification for Bio Trickling Filter, Biofilter and Activated Carbon Polishing Odour Control Units, SA Water, SAW-ENG-ODO-MUL-TSP-002, v1.1, 6 June 2023 |
| **TG 0531** | SA Water Technical Guideline – Wastewater Network Ventilation Design, v3.0, June 2025 |
| **TS 0854** | SA Water Technical Standard – Odour and Corrosion, v1.0, May 2025 |

# 2 Scope

## 2.1 Scope and application of this Technical Standard

This Technical Guideline provides guidance on sewer network hydraulic design to minimise network odour impacts. Details of the main odorous compounds in sewage are outlined, followed by a high-level design overview which presents the recommended design approach to minimise network odour impacts. Each of the following design aspects are then outlined in a separate section in the guideline:

a. Hydraulic retention time (HRT) and its impact on sulphide generation and odour production.

b. Hydraulic drops and vortex droppers.

c. Hydraulic jumps and surges.

d. Sewage velocities, sewer gradient and turbulence in pressure mains and gravity sewers.

e. Pressure main discharge maintenance hole design considerations.

f. Sewage pump station (SPS) wet well/inlet maintenance hole incoming sewer discharge arrangement.

g. Seals on wet well covers.

h. Design of wet well inducts and educts.

i. Gravity sewer surcharging conditions and performance criteria.

It is noted that this guideline is focused on hydrogen sulphide ($H_2S$) in terms of its odour impacts, however, $H_2S$ gas can also have a significant impact on corrosion and this is highlighted where relevant.

The guideline TG 0531 Wastewater Network Ventilation Design is a companion guideline which provides specific guidance for the design of ventilation for gravity sewer networks, for the effective management of odour risks.

## 2.2 Technical dispensation

Departure from any requirement of this Technical Standard shall require the submission of Technical Dispensation Request Form (TDRF) for the review and approval (or otherwise) of SA Water Principal Engineer listed in Page 5, on a case-by-case basis.

The Designer shall not proceed to document/incorporate the non-conforming work before the Principal Engineer has approved of the proposed action in writing via the Technical Dispensation Request Form (TDRF).

SA Water requires sufficient information to assess dispensation requests and their potential impact. The onus is therefore on the proponent to justify dispensation request submissions and provide suitable evidence to support them.

Design works that are carried out without being appropriately sanctioned by SA Water shall be liable to rejection by SA Water and retrospective rectification by the Designer/Constructor.

# 3 Odorous compounds in sewers

This section outlines the chemical compounds found in sewers which are known odorants, along with their characteristics and how they are generated.

There are many different compounds that occur in sewer air, ranging from those with no odour to those that are highly odorous. The odorous compounds come from a range of chemical species including $H_2S$, mercaptans (and other reduced sulphides), amines, aldehydes, and volatile fatty acids (VFAs).

Despite the variety, only a handful of odorants occur frequently and with a significant presence. $H_2S$ and methyl mercaptan (MM) are the most predominant, followed by dimethyl sulphide (DMS) and dimethyl disulphide (DMDS). The properties of these compounds are shown in Table 1.

Table 1: Properties of the Most Predominant Odorous Compounds in Sewers

| Odorant | Odour Description | Odour Threshold | Means of Generation |
|---|---|---|---|
| **Hydrogen Sulphide ($H_2S$)** | rotten eggs | 0.51 $ppb_v$ (low) | a. Bacteria in wastewater reduce sulphides to $H_2S$, which is then released to the air phase, especially during turbulence or under low pH. |
| **Methyl Mercaptan (MM)** | rotten cabbage | 0.077 $ppb_v$ (very low) | a. Generated by humans and released in faeces.<br>b. Anaerobic decomposition of sulphur-containing proteins. |
| **Dimethyl Sulphide (DMS)** | disagreeable rotten vegetable / decayed cabbage | 3.0 $ppb_v$ | a. Produced by the bacterial metabolism of methyl mercaptan in sewers.<br>b. Forms under anaerobic conditions. Assumed that pressure mains, siphons and sewage pump stations (SPS) would favour formation. |
| **Dimethyl Disulphide (DMDS)** | garlic-like | 0.022 $ppb_v$ (very low) | a. Forms under anaerobic conditions. Assumed that pressure mains, siphons and SPSs would favour formation. |

$H_2S$ is one of the most predominant odorous compounds in sewage. The physiological effects of $H_2S$ are summarised in Figure 1, and established limits for workplace $H_2S$ exposure are provided in Table 2 for information only, but will not be considered further. Designers should note that very low concentrations of this gas can cause serious health hazards, and the ability to sense it by smell is quickly lost as concentrations increase. Death has resulted from concentrations of 300ppm by volume in air. (refer CH2M-08) Such concentrations can be obtained in an enclosed chamber with high turbulence, from wastewater containing 2mg/l of dissolved sulphide at a pH of 7.0. (refer US-EPA-95)

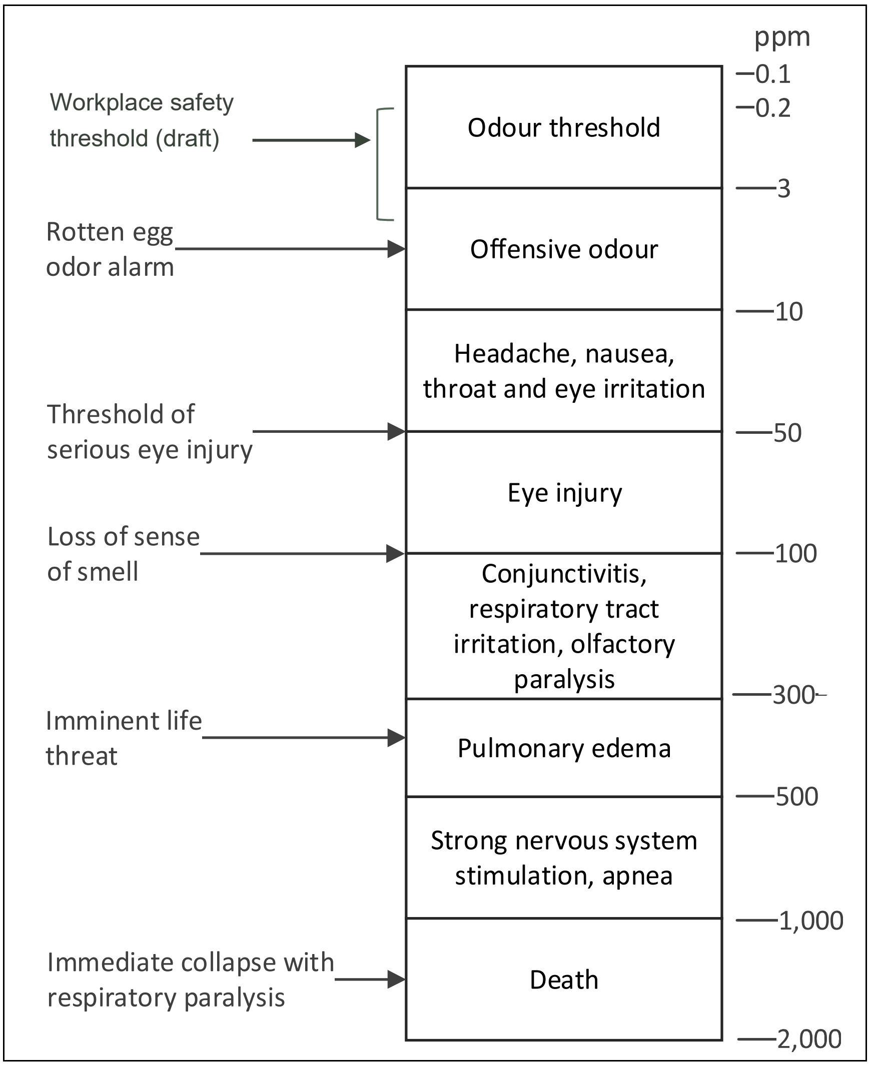



Figure 1: Physiological Effects of $H_2S$ (refer US-EPA-95)

Table 2: Established Limits for Hydrogen Sulphide in the Workplace

| Metric | SafeWork Australia Limit (ppm) |
|---|---|
| **Eight Hour Time Weighted Average (TWA)** | 10 |
| **Short Term Exposure Limit (STEL)** | 15 |

Safe Work Australia released proposed draft changes to the $H_2S$ concentrations in 2019, as shown in Table 2 of 1ppm for TWA and 5ppm for STEL. These are yet to come into effect, however, indicate that more conservative limits are likely to be enforced in workplaces in the future.

# 4 High level design overview

This section outlines a high-level design approach that should be used to minimise network odour impacts. It outlines the prioritisation strategy for adopting the recommendations in the following sections based on specific circumstances.

Designing a sewer network that has no odour will be prohibitively expensive, but the effort made to reduce and manage the causes of odour and corrosion during design can reduce some of the impacts and will provide considerably longer-term benefit to SA Water.

The cause of sewer odour and corrosion problems starts with the formation of sulphide in the wastewater which is subsequently released to the sewer headspace. In the sewer headspace it will cause corrosion of concrete and metals or be released to the atmosphere where it may cause odour problems. Sulphide formation is described in section 5.2. It is a biological process that reduces sulphates and other sulphur compound to sulphide under anaerobic conditions.

Anaerobic conditions exist in pressure mains, siphons, in the sediment and deeper levels of sewers and wet wells. Standards for the hydraulic retention time (HRT) in pressure mains and wet wells to quantify the impacts of anaerobic conditions are provided in section 5.5. Key considerations to minimise sulphide formation, as described in section 8, include achieving suitable sewage velocities which facilitate:

1. Natural re-aeration;
2. Scour of sediments (self cleansing); and
3. Stripping for minimising slime layers on pipe internal walls;

Minimising sulphide formation is the first step in managing odour and corrosion for sewer design.

Once formed, the sulphide will be released to the sewer headspace at a faster or lower rate depending on the level of turbulence. Pressure main discharge locations, steep slopes and drops all promote turbulence and faster sulphide release to the sewer headspace. Ideally the air in the sewer headspace should be released to atmosphere at these locations to prevent the build-up of $H_2S$ levels in the network. If this is not possible due to the sensitive nature of the locations, adopting strategies to reduce turbulence, ensure that the sewer headspace is not too restricted (and does not surcharge) and to allow the free flow of sewer air will be required, and are described in sections 7, 9 and 12. The reason for this is that restriction in headspace will increase the pressure which will force air out at uncontrolled locations. Managing the release of sewer gases requires effective containment so that gases are only released at designed locations. Containment is discussed in section 11 and inducts and educts for ventilation of wet wells are discussed in section 12.

Options for reducing impacts of hydraulic drops are discussed in section 6.

In summary, achieving scour and shear velocities to prevent/minimise sulphide generation, should be the first priority in sewer design. Risk of sulphide release in sensitive areas should then be evaluated on a case-by-case basis for areas such as pressure main discharge locations or other areas where sulphide will be high. The preferred approach for these areas should be:

a. To release the sulphides to atmosphere in a location where there will not be adverse impacts (to remove sulphides from the system).
b. To keep the sulphide in the liquid phase by reducing turbulence and maintaining adequate sewer head space to allow air flow with minimal restriction.
c. If the above are insufficient or not possible, include some form of control.

Put succinctly, the order or priority in sewer design for odour control should be prevention of sulphide formation, mitigation of release to sensitive locations then control to prevent corrosion and odour problems.

# 5 Hydraulic retention time and odour risk

## 5.1 Introduction

This section considers HRT and its impact upon sulphide generation and odour production. It outlines the following:

a. Formation of $H_2S$.

b. Precursors for sulphide generation.

c. Explanation of odour risk and how it is impacted by HRT.

d. Risks of sulphide generation, and what constitutes low, medium and high risk.

e. Quantification of odour risk.

## 5.2 Hydrogen sulphide formation

$H_2S$ formation begins in the wastewater stream. Colonies of anaerobic sulphate reducing bacteria (SRB) active in biofilm layers that line submerged sewer walls reduce sulphates $(SO_4)$ and oxidise biodegradable organic carbon producing sulphide (as sulphide ions, $HS^-$ and $S^=$, and molecular $H_2S$), VFAs and carbon dioxide. When the generated sulphide is in molecular form ($H_2S$), it can move into the gas phase and can be a significant contributor to odour risk from sewers. The processes described are shown in Figure 2.

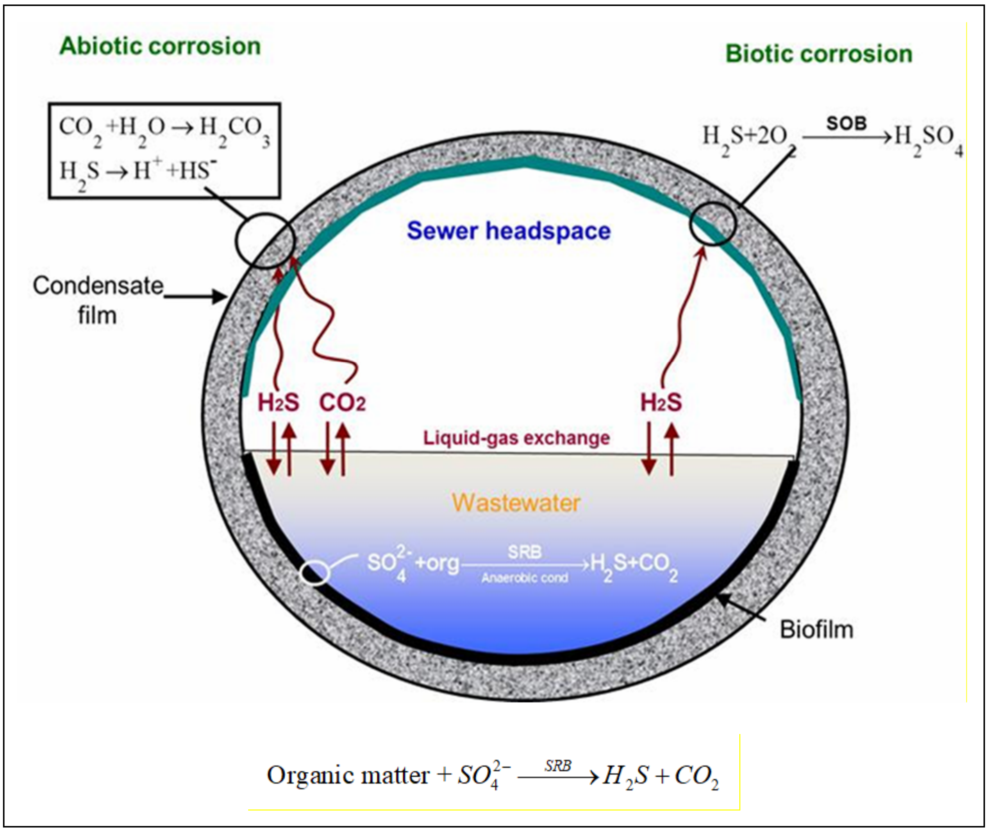



Figure 2: Schematic of sewer processes driving $H_2S$ and corrosion

The amounts of the three-sulphide species present ($H_2S$, $HS^-$, and $S^{2-}$) are pH dependent. As oxidation-reduction potential (ORP) indicates stronger anaerobic conditions in the wastewater and the longer the wastewater is anaerobic, more VFAs are formed which lower the pH of the wastewater. The relative distribution of the three species, as a function of pH, is presented in Figure 3. As can be seen, the amount of $H_2S$ is very sensitive to pH. At a pH of 7, 50% of the total sulphide is present as $H_2S$. At pH <5.5, almost all sulphide is molecular $H_2S$ (>97%) while at pH >8.5, less than 3% is present as $H_2S$.

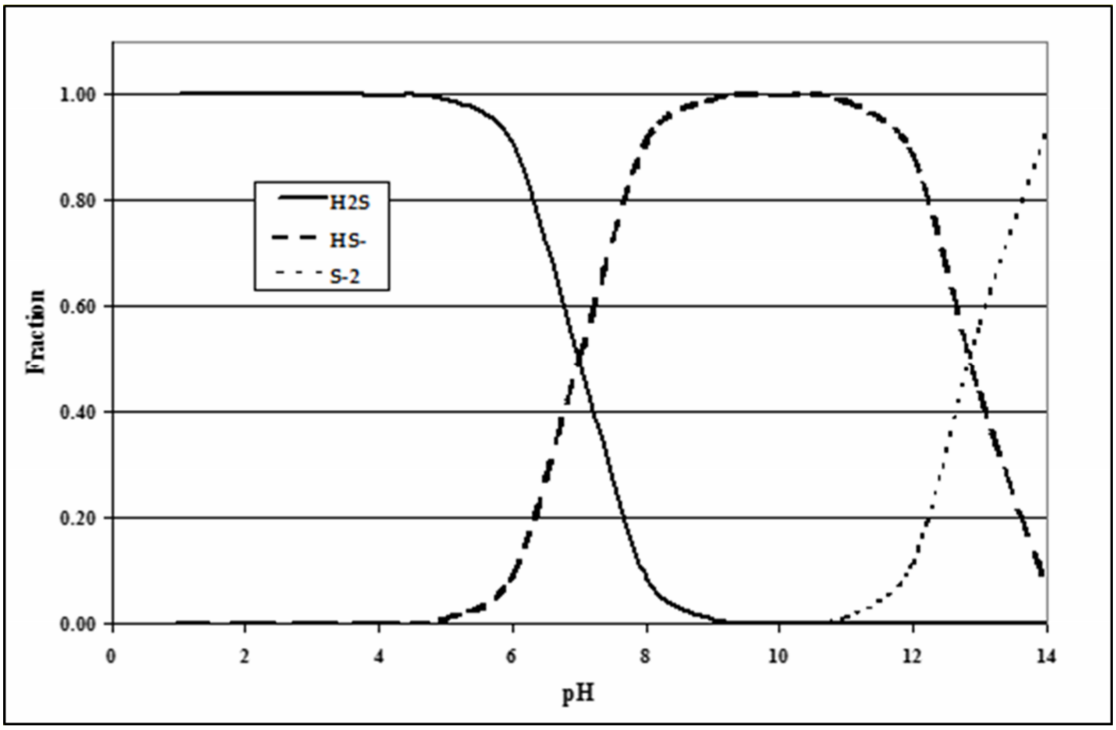



Figure 3: Liquid-Phase Sulphide Distribution and pH

$H_2S$ and carbon dioxide ($CO_2$) are transported through the biofilm into the wastewater stream where some is volatilised into the sewer headspace when the pH is below about 8.5. This $H_2S$ can then be oxidised to sulphuric acid by aerobic biomass on concrete and steel surfaces which leads to corrosion.

Sewage retention times in pressure mains, wastewater characteristics and temperature are the common parameters that impact sulphide levels, and sulphide transfer to gas phase (as $H_2S$) is mostly driven by turbulence and pH with some temperature impacts.

Sulphuric acid ($H_2SO_4$) forms as the $H_2S$ leaves the wastewater, enters the air in the headspace between the wastewater and the top (crown) of the sewer pipe, and diffuses into the condensation present on the crown and walls of the gravity sewer. Along the crown and pipe walls, the $H_2S$ is oxidised by the action of *Thiobacillus* bacteria to form sulphuric acid. Sulphuric acid formation is initially a slow rate process on new concrete due to the high alkalinity of the concrete itself (pH ranging from 11 to 13). *Thiobacillus* are unable to survive under high pH conditions. Aging of the concrete results in a decrease of surface pH to between 7 and 8. At this pH, a different species of *Thiobacillus* colonises the concrete surface, further reducing the pH of the condensate to less than 5. From this point corrosion proceeds faster if other environmental agents ($H_2S$, humidity and temperature) are present. Figure 4 summarises the processes of bacteria colonising the pipe, the change in pipe pH, and the damage done to the pipe.

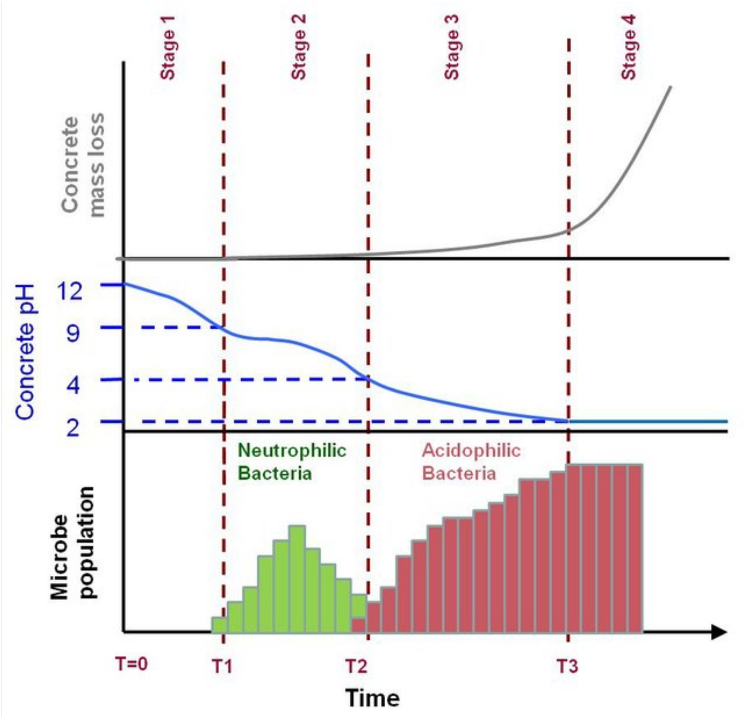



Figure 4: Progression of microbial corrosion of sewer pipe

## 5.3 Precursors for sulphide generation

Many variables directly or indirectly affect sulphide generation in sewers, and hence $H_2S$ release, and sulphuric acid corrosion. These variables are summarised in Table 3 and discussed further below. (refer US-EPA-91)

Table 3: Factors Affecting Sulphide Generation in Sewers (refer US-EPA-91)

| Factor | Effect |
|---|---|
| **Wastewater Characteristics** | |
| **Dissolved oxygen (DO)** | Low DO favours proliferation of anaerobic bacteria and subsequent sulphide generation. |
| **Biochemical oxygen demand (BOD)(organic strength)** | High soluble BOD encourages microbial growth and DO depletion. |
| **Temperature** | High temperatures increase microbial growth rate and lowers DO and $H_2S$ solubility. |
| **pH** | Low pH shifts the equilibrium such that the concentration of molecular $H_2S$ (g) increases; refer Figure 3. |
| **Presence of sulphur compounds** | Sulphur compounds required for sulphide generation. The concentrations of these compounds can be very significant when they are the result of groundwater and sea-water infiltration and in some cases due to trade waste. |
| **Sewer System Characteristics** | |
| **Slope, velocity and change in direction** | Affects degree of reaeration, solids deposition, $H_2S$ release, thickness of slime layer.<br>Note that change in direction can cause similar effects, as velocity suddenly decreases, and turbulence increases. |
| **Hydraulic Drops** | Can promote $H_2S$ release, turbulence and may cause outgassing. Refer to section 6.2. |
| **Turbulence** | Same effect as slope/velocity. |
| **Surcharging** | Reduces oxygen transfer and promotes sulphide generation, will not corrode while surcharged.<br>Can also cause foul air release as the sewer headspace is restricted, causing pressurisation and driving air out of the sewer. |
| **Presence of pressure mains and inverted siphons** | The full pipe will prevent reaeration and provides a large wet area for biofilm growth which can lead to $H_2S$ formation under anaerobic conditions. The inlet end will restrict sewer airflow causing it to be released. The turbulent discharge end will cause release of $H_2S$. |
| **Sewer pipe materials** | Corrosion resistance of pipe materials varies widely. Porous materials, such as concrete, favour biofilm attachment, while comparatively less porous materials such as plastic support a smaller a biofilm and the biofilm is more easily scoured off. However, the reduced biofilm in the headspace means less $H_2S$ is oxidised to $H_2SO_4$. This can result in higher $H_2S$ concentrations downstream. |
| **Concrete alkalinity** | Higher alkalinity reduces corrosion rate. |
| **Accumulated grit and debris** | Slows wastewater flow, traps organic solids. |

For $H_2S$ to be formed, the wastewater must be anaerobic. In properly designed gravity sewers, the velocity of the sewage is such that natural reaeration occurs from the atmosphere in the sewer, helping to replenish any losses of oxygen due to microbial activity. Certain structures and flow conditions often create turbulence of the wastewater, increasing the rate of reaeration and helping to maintain aerobic conditions. However this has the negative effect of causing a greater release of $H_2S$ from the sewage into the sewer gas space.

Sources of turbulence include:

a. Maintenance holes with flows dropping in from the side, i.e. tributaries to main or branch sewers with junction point at the maintenance hole, and/or sewer pipe junctions involving a direct connection of a smaller sewer into the side of a larger sewer pipe at 90° to the larger sewer flow direction.

b. Maintenance holes with flows colliding, e.g. sewage streams entering maintenance holes from opposing directions.

c. Metering flumes, creating localised increased sewage velocity.

d. Hydraulic drops along the sewer at maintenance holes (see section 6).

e. Sections with steep slopes, causing increased sewage velocity and turbulence (see section 8).

f. Pressure main discharges (see section 9). (refer US-EPA-91)

g. Sharp changes in pipe direction.

Under certain conditions dissolved oxygen is depleted faster than it is supplied, causing a change from aerobic to anaerobic conditions. Such conditions can occur in the following:

1. Gravity sewers with low sewage velocities or long retention times.
2. Pressure mains which convey wastewater through a full pipe under pressure with no opportunity for reaeration.
3. Wet wells of sewage pump stations (SPS) having retention times sufficiently long as to cause oxygen depletion due to uptake by bacteria.
4. Other structures or processes where wastewater is detained under near-stagnant conditions with insufficient opportunity for reaeration.
5. Sections of sewer that can lead to significant solids deposition over time.
6. Industrial discharges with high concentrations of BOD.

## 5.4 Risks of sulphide generation

The major risks related to sulphide build-up in sewers are:

a. Corrosion of sewer structures and equipment.

b. Odour nuisance.

c. Health and safety risks to sewer workers.

Corrosion of sewer structures and equipment can be significant, even at low $H_2S$ concentrations. It can lead to pipe, or even street collapses resulting from sewer pipe failure, as well as premature replacement or rehabilitation of pipes, maintenance holes, lift stations and SPSs. Corrosion also compromises structural integrity by corroding equipment, pipe and equipment supports, storage tanks, guard rails, walkways, and grating. Electrical components (e.g. brushes, switches, relays), process instrumentation, air conditioning and ventilation units, and computer systems at SPS and lift stations are particularly vulnerable to $H_2S$ corrosion. Corrosion causes increased maintenance requirements, poor reliability of control systems and often premature replacement or rehabilitation of assets is required.

$H_2S$ is recognisable to receptors in the vicinity of air release points from the sewer due to its rotten egg character. The release of sewer odour results in odour complaints from sensitive receptors. Ongoing odour releases from a sewer can cause reduced liveability and may result in a poor public perception of SA Water, as well as failure to comply with environmental license requirements and possible fines.

$H_2S$ generated in sewers also has potential health impacts on workers. High $H_2S$ levels under maintenance hole covers can cause operator/s to become unwell or even die due to inhaling high levels when covers are opened or entering a confined space without appropriate ventilation and safety precautions.

## 5.5 Impacts of HRT and odour risk

Controlling sulphide production will assist in minimising odour risks associated with sewers. As HRT in sewers and pressure mains increases, the oxygen consumption increases, the ORP decreases, and organic matter becomes increasingly solubilised. These conditions favour the activity of the SRB, which generates odour and can cause corrosion. Thus, in the design of collection systems, minimising HRT can limit the activity of the bacteria and thus the rate of sulphide production. (refer US-EPA-95)

However, sulphide production itself is not of major concern in terms of odour. Sulphides in sewage only have the potential to pose an odour risk if they leave the liquid phase and enter the vapour phase as $H_2S$. Sulphides (in molecular hydrogen sulphide form) generally leave the liquid phase as a result of turbulence or when pH is lower than 8.5.

Odour release from sewers is a part of their operation and so forms part of their design; educts allow air to escape where forces pressure the headspace and inducts allow air in to facilitate ventilation and sewer reaeration. The odour from sewers only poses a risk if foul air is released from the sewer and there are nearby sensitive receptors or operators are affected. The presence of odour where there is minimal to no risk of receiving odour complaints is generally of little concern. However, where there are sensitive receptors or there is a need for operators to access the sewer by cracking maintenance holes thus releasing odour, the presence of $H_2S$ poses an odour risk.

Table 4 below provides a general indication of the odour risk from sewers structures such as pressure mains and wet wells at different HRTs and sulphide levels. The odour risk assumes that foul air is released from the sewer headspace and there are nearby sensitive receptors. It is noted that the sulphide concentrations shown do not necessarily occur at the associated HRTs, as this will be system dependent. The sulphide concentration and HRT are risk indicators; it is not necessary for both conditions shown in the table to exist in order to determine the risk level – either indicator can be used. These indicators are intended for high-level analyses, identifying areas where further investigation should occur.

Table 4: HRT in Pressure mains/Wet Wells and Odour Risk

| Odour Risk Level | Risk Indicators | |
|---|---|---|
| | Sulphide Concentration (mg/L)[1] | Hydraulic Retention Time (Hours)[2,3] |
| **Low** | <0.5 | <2 |
| **Medium** | 0.5 – 3 | 2-4 |
| **High** | >3 | >4 |

Recommended HRTs for the design of pump stations are detailed in section 10.

While the design of a pump station influences the HRT, sometimes an idea arises that involves reducing odours without additional costs by changing the operational times of the pumps. In the case where pumps run only a few times a day, the adjustments seek to increase the frequency of pump operation. There are pros and cons to doing this. Unfortunately, though, for a single line pressure main, there is no difference in the HRT. Running the pump longer and less often means incoming wastewater spends more time in the wet well. Conversely, running

1 Hvitved Jacobsen, 2002
2 The HRT risk levels are based on calculations which apply under ADWF conditions. Although higher HRTs may occur for overnight periods when sewage flows are lower than ADWF, the use of ADWF allows a high level or screening check to quickly identify potential risks. For more detailed assessments, review of HRT using different flow scenarios, e.g. minimum overnight flows, and review of time between pump cycles, can be undertaken to provide a comprehensive understanding of the diurnal variation of risks. Examples of detailed HRT calculations are provided in TS 0854 (Appendix A).
3 HRT for the PM is calculated by dividing the internal volume of the pipe in m3 (cross-sectional area times length) by the average sewage flow in m3/hr.

the pump more often but for shorter periods means that wastewater spends more time in the pressure main than in the wet well.

This is not to say that how the pumps are operated will not affect odour risk, but that it will not make any difference to the HRT, which is ultimately determined by the pressure main size. Running the pump longer less frequently will help scour both the pressure main and downstream gravity sewer, though it may also cause foul air to be released if the gravity pipe experiences a surge. Running the pump for less time, more often will avoid surging but may encourage biofilm growth and sediments to build up.

## 5.6 Quantifying odour risk

As indicated above, odour problems occur when sulphide emissions leave the sewer atmosphere in the form of $H_2S$. The amount of gas released determines the severity of odour risk, and the public's perception of odour is related to the following factors, referred to as the FIDOL factors:

1. Frequency of the occurrence.
2. Intensity of the odour.
3. Duration of exposure to the odour.
4. Offensiveness of the odour.
5. Location.

Odour risks are generally higher for new developments for the following reasons:

- Initially developing areas only have a low number of connections, causing long HRT which results in higher sulphides.
- Proximity to sensitive receptors, who have invested in new properties and are more sensitive to odour issues.
- Sometimes backlog developments result in a daisy chain arrangement of pump stations, or use pressure sewers, both of which causes long HRT under anaerobic conditions.

In order to quantify odour risk from a sewer network or asset, an odour risk assessment should be undertaken to rank the risk and determine a suitable approach to manage odour risks. This risk assessment should consider the following:

a. Proximity to sensitive receptors.

b. Upstream HRT in pressure mains noting that multiple pressure mains in series can have an accumulative effect.

c. SPS size.

d. Daisy chain SPS arrangements.

e. The presence of certain industries that may discharge high BOD, high temperature, or low pH waste.

f. Whether low start-up connections will be an issue.

To quantify odour impacts based on $H_2S$ and dissolved sulphide concentrations, Table 5 defines low, medium, and high-risk odour in terms of dissolved sulphide concentrations in sewage, and $H_2S$ levels in the sewer headspace. The table adopts the widely recognised rule of thumb that 1mg/L of sulphide in the liquid phase in a normal concrete sewer can generate up to 10ppm (90$^{th}$ percentile) of $H_2S$ in the sewer headspace (based on mass transfer between the liquid and vapour phase) and about 20ppm of $H_2S$ for more turbulent areas[4].

Table 5 also shows the actions that should be considered in terms of odour control at exit points for air from the sewer, such as vents and pump stations. It is noted that the need for

4 Higher H2S to dissolved sulphide ratios can be experienced in very turbulent areas, if the pH of the sewage is less than 7, or when the temperature is greater than 25°C.

odour control will be driven primarily by the risk of receiving odour complaints. The risk below assumes that there are nearby sensitive receptors that will be impacted by emissions from sewer assets. If there are no sensitive receptors in the vicinity of emission points, there is unlikely to be a driver for the installation of odour control equipment even if $H_2S$ levels are high.

Further details of odour control requirements are outlined in SA Water's *Technical Guideline on Wastewater Network Ventilation Design (TG 0531)*, including selection of suitable odour control based on sewer infrastructure.

Table 5: Odour Risk

| Risk | Sulphide Concentration (mg/L) | Approximate Headspace $H_2S$ Concentration [5] (ppm, 90th percentile) | Potential Management Response |
|---|---|---|---|
| Low | <0.5 (refer Carrera) | 5 – 10 [6] | No action necessary |
| Medium | 0.5 - 3 | 10 – 30 | Investigate further if the release point is:<br>a. Close to (within 50 m of) critical infrastructure, including schools and hospitals.<br>b. Within 100m of other sensitive receptors (see section 1.2.1). |
| High | >3 | >30 | Consider installing odour control depending on the proximity of sensitive receptors as defined in TS 0854, and assessed odour risk (apply FIDOL factors). |

5 For sewers with non-turbulent flow. Concentrations are 90th percentiles – maximum concentrations can be above these ranges.
6 Up to 20ppm H2S for turbulent sections of sewer.

# 6 Hydraulic drops and vortex droppers

## 6.1 Introduction

Hydraulic drops and vortex droppers are sources of turbulence which can promote stripping of volatile gases such as $H_2S$ or increase the rate of sewage reaeration. If the sewage is fresh with low sulphide concentrations, drops and other causes of turbulence will increase the rate of reaeration and reduce the consequent risks of anaerobic degradation and sulphide generation. However, if sewage is septic or may not always be fresh, then turbulence should be avoided to reduce the release of sulphide from sewage, generating odours and potentially deteriorating the structure.

This section describes hydraulic drops and vortex droppers, and the risks and benefits of each. Methods to minimise the impact of hydraulic drops are outlined, along with situations where vortex droppers should be considered for installation and design requirements.

## 6.2 Hydraulic drops

While any reduction in elevation between two adjacent sewer sections could technically be considered a hydraulic drop, SA Water defines a hydraulic drop as any location where there is a step change down in the sewer level of 0.3 m or more, i.e. a free fall of sewage of 0.3 m or more at a maintenance hole, or at a direct sewer connection (for example, a small sewer discharging into the side wall of a large trunk sewer). However, drops less than 0.3 m difference in water level between sections of pipe can also cause $H_2S$ and odour to be stripped from the sewage, and so any step changes should be avoided, or their impacts evaluated and mitigated if necessary.

An example of a hydraulic drop in a drop structure is shown in Figure 5. Drops can promote aeration of fresh sewage and minimise sulphide generation, and a drop in a large sewer will have approximately the same effect on DO levels as a drop in a small sewer (refer US-EPA-95). However, as the HRT of sewage increases, the sudden drop in water level at drop structures will cause turbulence and stripping of $H_2S$ from sewage into the sewer headspace. If the water level in the maintenance hole rises above the outlet pipe, the maintenance hole will become a source of air release as the air will be pressurised and not have any other means of depressurising, increasing the risk of fugitive odour leaks from the maintenance hole.

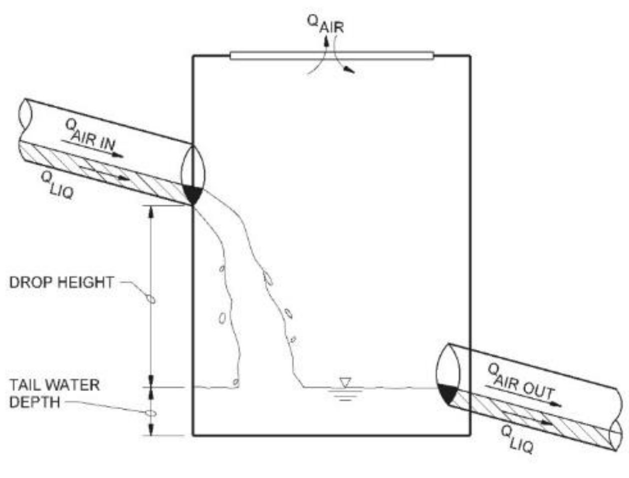
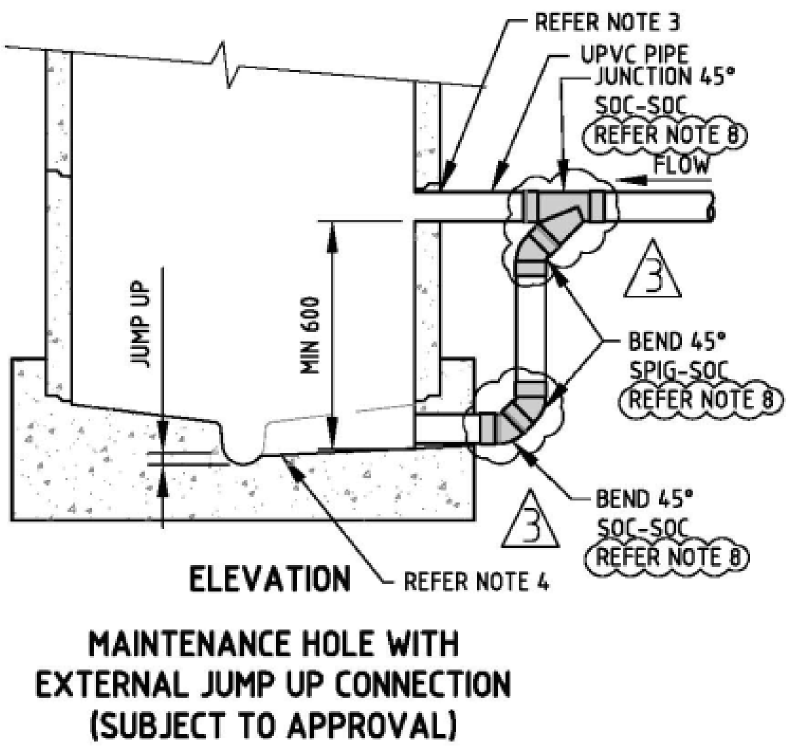



Figure 5: Hydraulic Drop

If the potential for sulphide generation exists, hydraulic drops should be designed to minimise turbulence. If possible, to reduce turbulence and stripping, a transition that allows flow from a higher level to be introduced to below the water level at the base of a drop, i.e. submerged entry, should be adopted. SA Water has installed external and internal jump ups, as shown in

Figure 6-2, to limit the free drop and hence the stripping process at SPS wet wells, which appears to be successful.

Figure 6 below shows SA Water's SCM drawings for internal and external jump up arrangements.



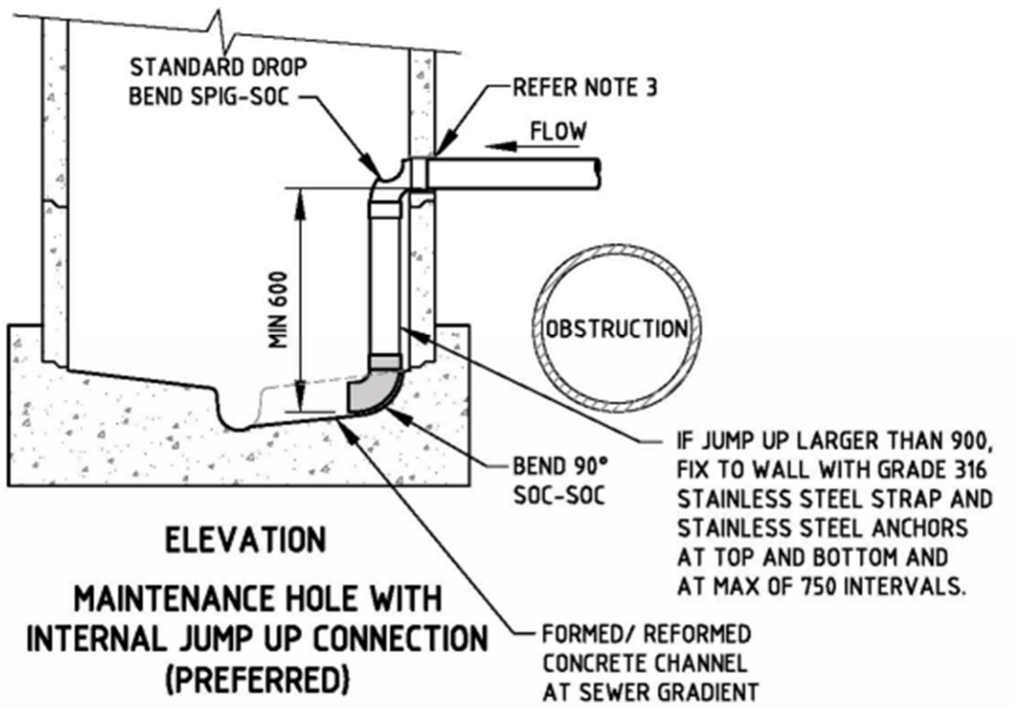
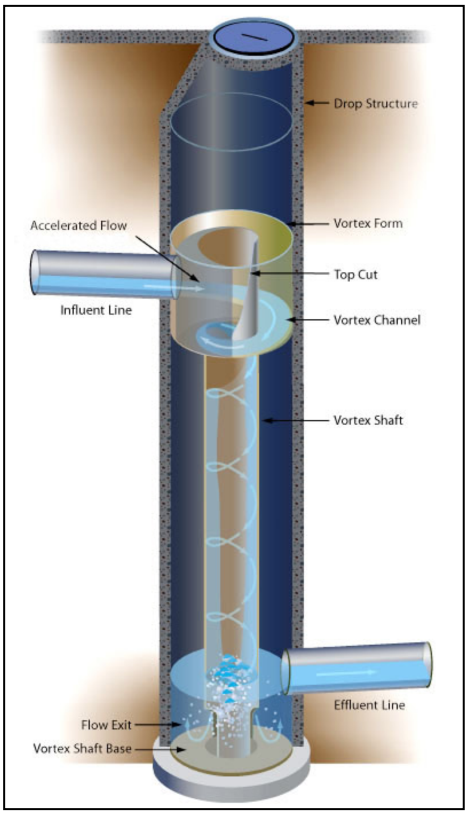




Figure 6: SA Water SCM Hydraulic Drop with Internal (preferred) and External Jump Ups

The materials used to construct jump up structures must be selected based on anticipated corrosion problems.

## 6.3 Vortex droppers

Vortex droppers are used to lead wastewater flows through relatively large drop distances. In a vortex dropper, the flow is directed tangentially to produce a spiral flow pattern. Vortex droppers reduce turbulence (compared to that of a free fall drop) and hence the emission of $H_2S$ and odorous gases, reducing the risk of corrosion within the drop structure. A schematic diagram of a vortex dropper is shown in Figure 7.




*Reference: http://www.vortexflow.com/HowItWorks.htm*

Figure 7: Vortex dropper

The risks and benefits of vortex droppers are summarised in Table 6.

Table 6: Risks and benefits of vortex droppers

| Risks | Benefits |
|---|---|
| • Requires additional costs and complexity to accommodate multiple inlet sewers.<br>• Access for people and equipment can be difficult.<br>• Installation costs may be higher than steepening the sewer elsewhere. | • Maintenance of a continuous air core down the shaft.<br>• Excellent conditions for oxygen uptake.<br>• Minimal accumulation of solids or scum.<br>• Less likelihood of stoppages.<br>• Better energy dissipation.<br>• Virtually maintenance free.<br>• Where sulphide generation potential exists, well designed drops are effective techniques for maintaining aerobic conditions and preventing sulphide generation.<br>• If a traditional drop exists, replacement with a vortex dropper can decrease odour emissions[7] and potentially save the need for external odour control. |

Larger deep sewers ventilate more dramatically and with higher pressures, due to drop structures, and fewer maintenance holes and connections. Drop structures on deep tunnel sewers can be the source of significant additional pressurisation in sewers. Friction drag with the falling water causes pressurisation and eduction (air release) from drop structures.

The WSAA Sewerage Code of Australia WSA 02—2002-2.2 Sydney Water Edition Version 4 (and the more recent WSA 02-2014 Version 3.3) states that vortex droppers provide suitable flow conditions for an inlet to a tunnel or very deep sewer. It recommends that vortex droppers are only installed when simpler and less expensive drop inlets would have a potential for damage or to cause service difficulties. The requirements for vortex droppers in this Code are shown in Table 7. Note well that SA Water does not currently have drop structures that are greater than 10m in depth.

Table 7: Drop Requirements from WSA 02-2.2

| Sewer size (DN) | Drop length (m) | Requirements |
|---|---|---|
| **375 to 525** | <6 | Drop inlet |
| | 6 – 20 | Drop inlet with water cushion at the bottom of drop |
| | >20 | Vortex inlet with water cushion at bottom of drop |
| **>600** | <3 | Drop Inlet |
| | 3-10 | Drop inlet with water cushion at bottom of drop |
| | >10 | Vortex inlet with water cushion at bottom of drop |

[7] While vortex droppers can decrease odour emissions, there may still be an odour risk with them.

Although SA Water currently does not have sufficient drops to justify the installation of vortex drop structures, this section is left for completeness as they may be required at a later date.

The design of the vortex drop should incorporate the following (refer WSA 02-2.2):

a. Vortex drops shall have one inlet only, which shall be to the access chamber at the top.

b. The receiving sewer shall be traversable so as to enable connection.

c. Ventilation shall be provided at both the top and bottom of a drop shaft.

d. Construction materials must be selected based on anticipated corrosion problems.

The deep sewer must accept air from the drop shaft to avoid pressurisation and odour release, and usually, a vortex dropper requires forced ventilation and/or return air recycling. It is noted that return air concentrates emissions. A typical design for a vortex dropper with an air return is shown in Figure 8.

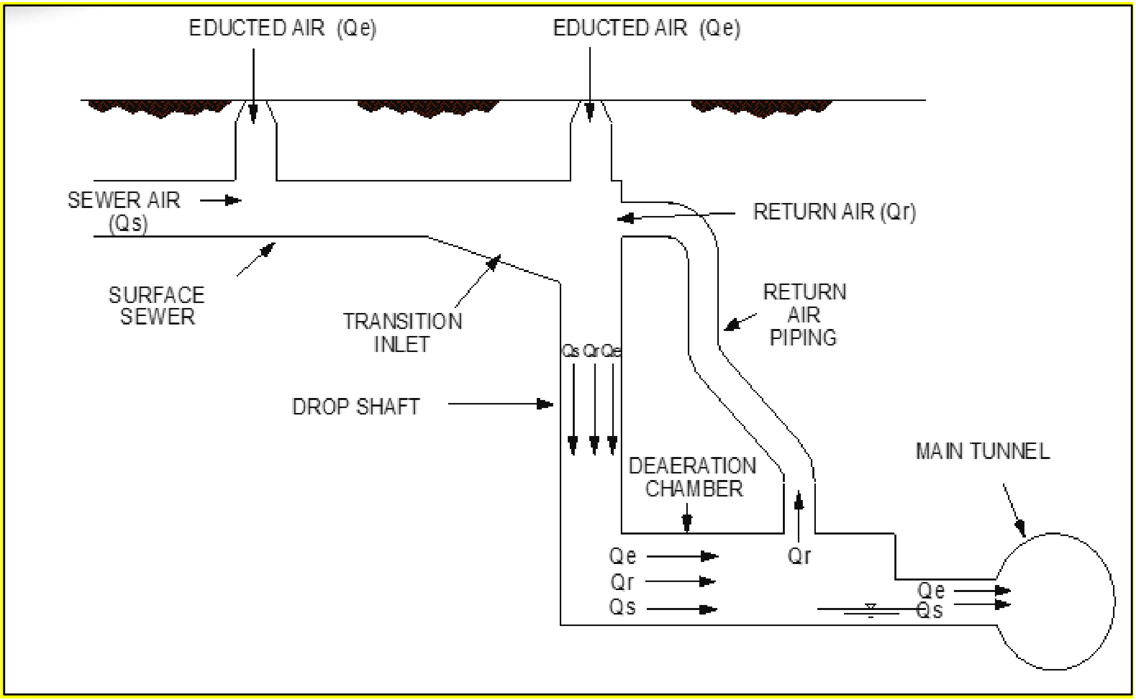



Figure 8: Typical vortex dropper with air return

The volume of air educted for a vortex dropper is proportional to the area of falling water and the diameter of the drop shaft. To estimate the airflow through a vortex dropper, air velocity contours are used to develop empirical relationships for various configurations based on the depth and size of the structure. Deeper drops are affected more by the drop eduction and shallower drops are affected more by the sewer pressure.

# 7 Hydraulic jumps and surges

## 7.1 Introduction

This section describes the impacts of hydraulic jumps and surges on air movement and the release of $H_2S$ in the sewer, along with design practices to avoid these.

## 7.2 Hydraulic jump

A hydraulic jump is a jump or standing wave formed when the depth of flow of water changes from a supercritical to a subcritical state, as shown in Figure 9. A hydraulic jump is often caused by an impediment downstream, such as a weir, a bridge abutment, a dam, or simply channel friction. High velocity flow discharges into a zone of lower velocity, resulting in an abrupt rise in water depth where energy is dissipated as turbulence.

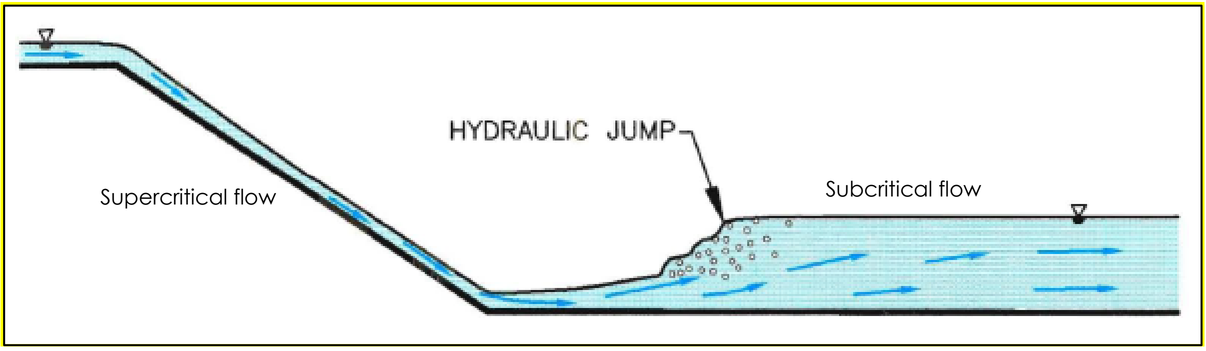



Figure 9: Hydraulic jump

The impact of a hydraulic jump in terms of air movement and $H_2S$ production in the sewer is shown in Figure 10. Hydraulic jumps can pose the following odour and corrosion risks:

a. Potential sewer surcharging at the bottom of sewers with steep grade, causing turbulence and the release of odorous gases
b. Surging that will reduce or prevent airflow along the sewer, with the potential to cause sewer pressurisation and odour release
c. Increased water levels in nearby maintenance holes that may impede flow from incoming sewers
d. If the increased water level caused by a hydraulic surge drops quickly, negative pressure can be generated in the sewer, with enough suction to pull the water traps from connected properties, which can result in odour complaints

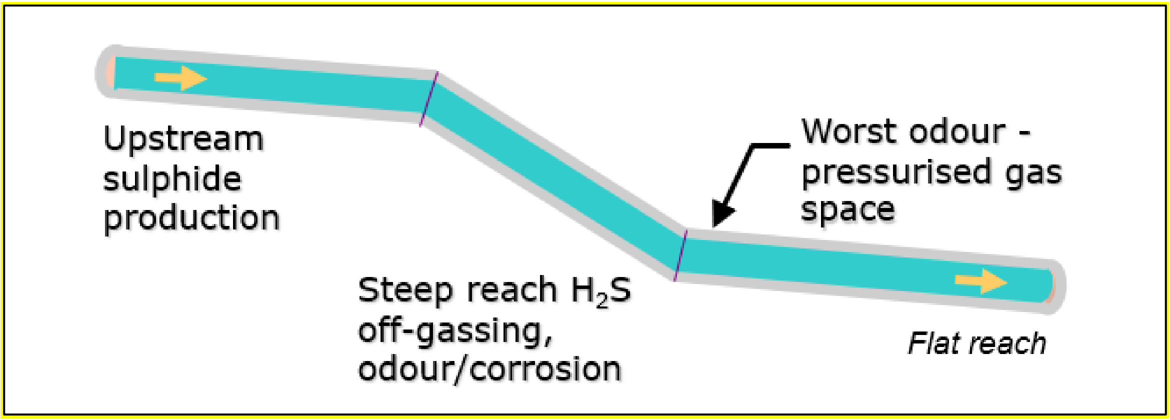



Figure 10: Air Flow Movement at Hydraulic Jump

WSA 02-2002-2.2 sets out design requirements for gravity sewers to manage the impact of hydraulic jumps, including reducing the likelihood of a jump occurring in a maintenance hole by including curved sewers at changes of grade and/or direction, and allowing for adequate ventilation with the use of induct and educts. Minimum requirements are set out in TS 0854.

An additional option to manage a hydraulic jump generated in the sewer due to a junction of flows is to locate the junction downstream of a maintenance hole such that the hydraulic jump occurs in the pipe downstream with no potential for gas release (rather than at a maintenance hole).

The major junction would be constructed within a vault or chamber entered by a maintenance hole at its upstream end (for access), and designed so that air that has been exposed to the high turbulence of the junction will be carried downstream and not exhaled from the maintenance hole (depicted in Figure 11). Due to turbulence and release of $H_2S$ gas at the junction, the junction structure will need to be protected by a lining, and the sewer pipe will need to be protected or constructed of non-corrodible material. The distance downstream that abnormal sulphide concentration will prevail will depend upon the turbulence of the air stream, its velocity and the sewer size. (refer US-EPA-74)

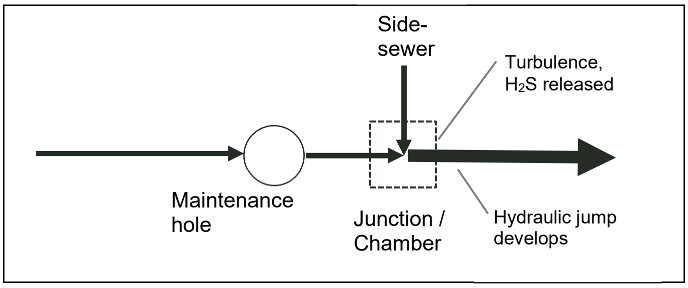



Figure 11: Sewer design to avoid hydraulic jumps

## 7.3 Hydraulic surges

Hydraulic surges are created when the velocity of sewage suddenly changes and becomes unsteady or transient. Fluctuations in the velocity are generated by restrictions such as a pump starting/stopping, a valve opening/closing, or a reduction in line size. Hydraulic surges are different from hydraulic jumps although they can have similar impacts of restricting air movement and air pressurisation. Hydraulic jumps are the result of sewer velocity drop or restriction downstream. Hydraulic surges are the result of a sudden increase in flow, usually caused by a pump starting, causing the water level in the receiving sewer to suddenly rise.

These surges commonly occur downstream of pressure main discharges when pumps start. The sudden surge in sewage flow restricts airflow in the sewer, causing pressurisation which generates turbulence, releasing $H_2S$ into the sewer headspace. The restricted headspace then causes odour release from the sewer, often at uncontrolled locations and with significant airflow, causing odour complaints in the network. The surges can also cause water seals at property connections and/or at sewer junctions to blow out or be sucked out, resulting in odour complaints at connected properties.

Figure 12 below shows smoke testing of the impacts of a hydraulic surge in a sewer upon operation of upstream pumps during morning peak flow. It can be seen that there is a significant volume of air being released close to ground level.

Figure 12: Uncontrolled air release caused by hydraulic surge

## 7.4 Design standards for hydraulic jumps and surges

In general, hydraulic jumps and surges are best avoided to reduce the potential for odour release. The following design standards should be followed:

a. Incorporate a transition to a flatter grade in sewers to absorb some of the momentum slowly and reduce the surge in water levels resulting from grade changes. This could also include using a larger pipe downstream. The design objective is to reduce the water level rise so that the restriction of air movement in the sewer headspace is minimal. Some suggested standards include minimising the pressure differential between the upstream and downstream ends of the pipe (e.g. to less than 5Pa) and/or ensuring that at least 30% of the sewer pipe is open for air movement.

b. Avoid flows from branch sewers dropping into trunk sewers (refer US-EPA-95); instead aim to have branch sewers enter the trunk pipe below the lowest level of the sewage surface in the trunk sewer, with the incoming branch sewer facing the downstream direction (refer MMBW-72) rather than entering the trunk at 90°. See Figure 6, Figure 13 and Figure 15 for examples of this.

c. If a branch sewer joins a trunk with a significant difference in invert levels, consider having the branch sewer end in a maintenance hole which drains into the trunk. This will provide an even transfer of the flow to the trunk. Elements of this are illustrated in Figure 14, where flow from a branch sewer drops into a side chamber, which then drains into the trunk sewer at the trunk invert level.

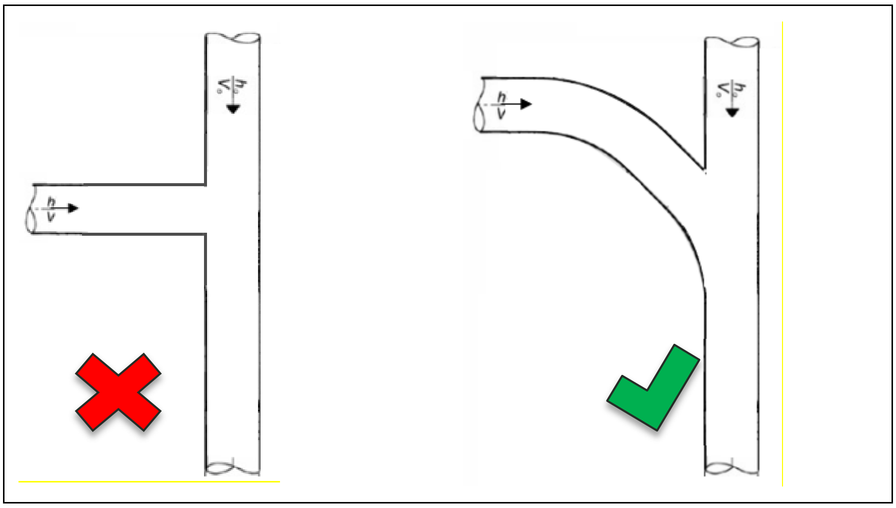
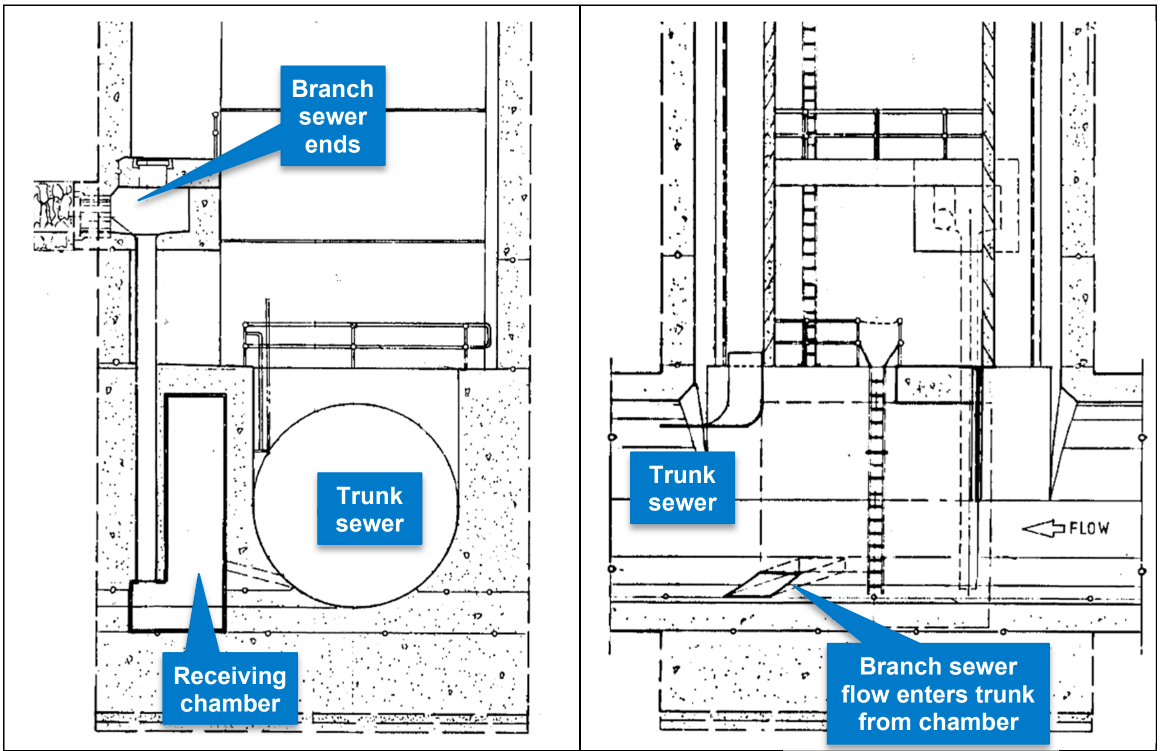


Figure 13: Streamlining branch sewer connections on trunk mains




| Cross-sectional view | Profile view |
|---|---|

Figure 14: Side chamber for merging flow from branch sewer

d. Avoid abrupt changes in grade between upstream and downstream sewer lines.

e. Avoid large differences in velocity between two or more upstream sewer lines entering the same maintenance hole.

f. Make sure the downstream receiving sewer is sized to ensure an airgap as set out in WSA 02-3.3, specifically:

   At peak dry weather flows (PDWF), the maximum depth of flow shall not be more than 60% of the pipe internal diameter.

   This is particularly important near pressure main release points.

g. Avoid acute angles between upstream and downstream lines, as set out in SCM Section 5 drawing set.

h. Avoid large changes in upstream flow, particularly when there is more than one stream that could have significant variation. This can be achieved by minimising intermittent pumping using VSDs on SPSs, and networking SPSs through SCADA so that multiple SPSs do not run at the same time.

Energy loss through transitions should be minimised by streamlining junctions, as illustrated in SCM Section 05 Maintenance Structures, Sheet 7. The overall objectives of the designs are to minimise sewage velocity changes and to ensure any velocity changes at junctions occur gradually, thereby minimising turbulence in the liquid phase. The Water Services Association of Australia (WSAA) Sewerage Code of Australia WSA 02—2002-2.2 Sydney Water Edition Version 4 states that:

- Where hydraulic jumps cannot be avoided, adequate educt / induct ventilation sized to allow sufficient air ingress/egress to minimise increases in sewer gas pressure, should be provided on either side of the possible hydraulic jump, and
- The design should aim to avoid jumps from occurring in maintenance holes by providing horizontal and/or vertical curves in the sewer at changes of grade and/or direction. The curve should be located at a sufficient distance from the maintenance hole such that the jump will not occur in the maintenance hole, and the radius of curvature should not be less than approximately 8x the pipe diameter.

This curving of the sewer is not to be confused with a jump up structure, which may also address hydraulic jumps in some cases; SA Water's preferred jump up structures are discussed in section 6.2. For clarity, an example of an issue with a hydraulic jump occurring in a maintenance hole being solved by curving the sewer the vertically and by using a jump up structure is shown in Figure 15.

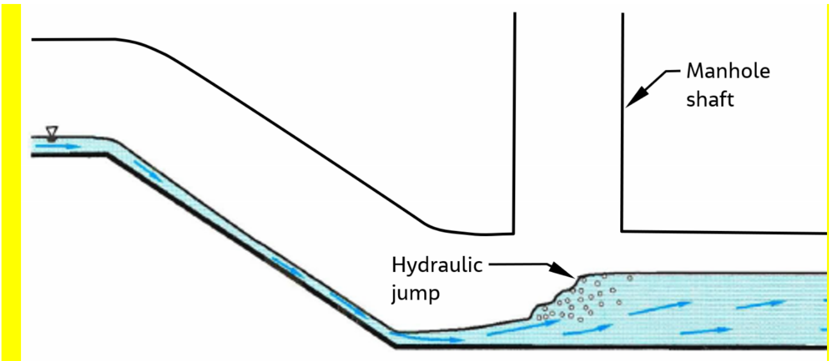
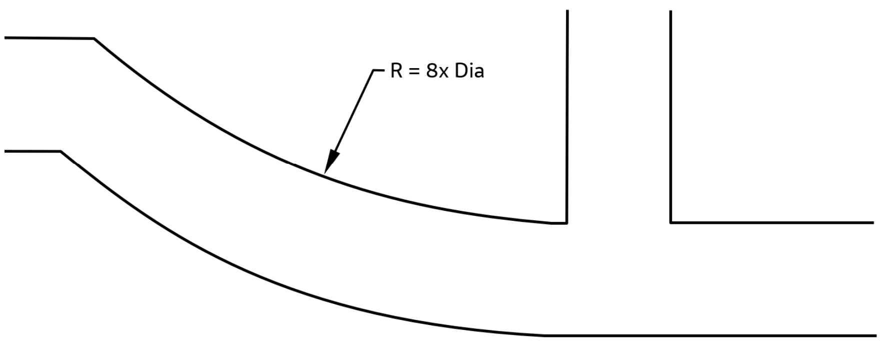
| | |
|---|---|
| Problem: Hydraulic jump in maintenance hole |  |
| Solution 1: Curve the sewer |  |

Figure 15: Potential solutions to a hydraulic jump in a maintenance hole

# 8 Velocities, gradients and turbulence in pressure mains and gravity sewers

## 8.1 Introduction

This section outlines the following:

a. The impacts of sewer velocities for scouring, reaeration of sewage and release of $H_2S$.

b. Recommended sewage velocities and sewer gradients to minimise sulphide generation.

## 8.2 Impacts of sewer velocities for scouring, reaeration of sewage and release of $H_2S$

The effects of velocity on sulphide generation are complex. At low velocities, solids may settle and move slowly and intermittently along the bottom. The loosely deposited solids quickly become depleted of oxygen, and sulphide generation proceeds until the depletion of sulphate or organic nutrients. If the solids are then disturbed by the motion of the water, sulphide is released into the stream. Higher velocities prevent this from happening and increase oxygen absorption into the stream (reaerating the sewage stream), increase the rate of oxygen transfer to the slime layer, and shorten HRT, all of which lead to lower sulphide concentrations.

Higher velocities can also be targeted to control the thickness of wall slimes to limit sulphide production. The overall thickness of wall slimes has been shown to be a function of the shear stress on the pipe wall which, for gravity sewers, is related to the pipe slope and depth of flow. These factors also influence wastewater velocity. Thus, wastewater velocity and thickness of wall slimes are inter-related. The rate of sulphide production remains substantially unaffected by varying velocities until a critical shear stress is reached, above which significant slime growth is prevented. Wastewater velocity can be increased to the point where the slimes are sheared from the pipe wall. This is a very effective method of sulphide control when it is possible to obtain the necessary slope. (refer MMBW-89) Section 8.3.1 outlines design requirements for achieving critical shear stress in gravity sewer design and section 8.3.2 outlines design requirements for achieving critical shear stress in pressure main design.

The sewage velocity principally depends on the mass flow of sewage, the sewer slope and geometry, and the frictional resistance. Each parameter may vary with space and time. The mass flow is directly linked to the pumping time and the pumping capacity. It fluctuates and may turn the flow regime into subcritical or supercritical. The pipe slope can change locally due to local topography, and the frictional resistance varies according to concrete degradation. In gravity sewers, high slope (greater than1%) and high velocity conditions increase the transfer of $H_2S$ from the liquid to the gas phase. (refer Carrera)

Adopting higher velocities to increase the reaeration rate, although very effective, requires steeper slopes for gravity sewers, which usually result in additional costs, in terms of construction costs (increased excavation and number of SPS) and additional power costs for pumping. These increased costs must be compared with the benefits resulting from a significant reduction in the contribution of sulphides to the sewage or the reaeration requirements of the sewage to prevent sulphide build-up.

Another important consideration is the impact of turbulence at higher sewage velocities. Although steeper slopes increase oxygen transfer, thus maintaining aerobic conditions in the wastewater and preventing significant sulphide generation, they can also promote sulphide release due to turbulence.

Achieving scour and shear velocities to prevent sulphide generation, if possible, should be the first priority in sewer design. The risk of sulphide release in sensitive areas should then be evaluated on a case-by-case basis in areas such as pressure main discharge locations or other areas where sulphide concentrations in the wastewater may be high. The priority for these areas should be to try to keep the sulphide in the liquid phase by reducing turbulence and maintaining adequate sewer head space to allow airflow with minimal restriction, as well as some form of control if required. The recommended approach is (in order of priority) prevention, mitigation, and control to prevent corrosion and odour problems.

## 8.3 Recommended sewage velocities and gradients to minimise sulphide generation

The most cost-effective and rational engineering approach to the effective management of odour and corrosion is to develop a hydraulic design that minimises sulphide generation and maintains aerobic conditions in the wastewater. Pipe sizes and slope should be selected to provide sufficient velocities to:

- maintain aerobic conditions,
- prevent solids deposition,
- provide adequate cleansing, and
- prevent sulphide problems and odour generation.

Sewer slope is the key criterion in designing a wastewater collection system to avoid sulphide problems. Sewers designed with long runs at minimum slope are prone to sulphide generation due to long residence times, poor oxygen transfer, and deposition of solids.

Sulphide generation can be a serious problem in new sewers, where actual flows are much less than design flows during the early lifetime of the system, and velocities are inadequate to maintain solids in suspension. Steeper slopes increase turbulence and oxygen transfer, thus maintaining aerobic conditions in the wastewater and preventing significant sulphide generation. (refer US-EPA-95)

The use of pressure mains, inverted siphons, and surcharged sewers should be minimised as these promote anaerobic conditions and thus sulphide generation. (refer US-EPA-91)

### 8.3.1 Gravity sewers

Gravity sewer design needs to consider the following:

1. Self-cleansing velocity – pipes should be sized to achieve self-cleansing velocities as least once a day. (refer WSA 02-2.2).
2. Slime control velocity – in sewers with a diameter of 300mm and above, self-cleansing velocities may not be sufficient to prevent build-up of slime and therefore higher velocities are required for slime control. Refer to Figure 17 for recommended velocities for different sewer sizes.
3. Optimise grades in branch and trunk sewers to minimise turbulence and $H_2S$ release when dissolved sulphide levels are elevated and the location is in proximity to sensitive receptors. This is a balancing act to achieve adequate reaeration and scour velocities while minimising sulphide release, and should be assessed on a case-by-case basis. If sulphides are low, then turbulence is less of an issue. Minimum scour velocities should also be achieved at least once a day to prevent solids deposition.

In reticulation sewers, entry of wastewater from connections is likely to maintain quite high DO levels. In addition, small sewers are generally constructed of uPVC or vitrified clay and are not subject to corrosion due to $H_2S$ generation. Therefore, sewers less than 300 mm in diameter are commonly not designed for slime control. (refer MMBW-89)

Adoption of a slope commensurate with slime control usually allows the selection of a smaller diameter pipe. Whether slime control slopes are warranted will depend on several factors including:

a. The ratio of average dry and peak wet weather flows.
b. Natural surface slopes.

c. Age and composition of sewage.

d. Availability of other methods for increasing the level of DO in the sewage. (refer MMBW-89)

Absolute minimum grades recommended by WSA Sewerage Code of Australia WSA 02—2002-2.2 Sydney Water Edition Version 4 for achieving self-cleansing in circular sewer pipes are shown in Table 8. The larger the sewer, the greater the overall velocity required to achieve the same self-cleansing effect. (refer MMBW-89) Detailed sizing and grading of branch and trunk sewers, and including those larger than DN 750, shall be determined in consultation with SA Water.

The minimum grades shown in Table 8 are noted to be different to SA Water standards in some cases. Where there is contradiction, the higher grade should be applied, as a conservative approach, unless otherwise agreed with SA Water.

Table 8: Absolute minimum grades recommended for self-cleansing, per WSA 02-2.2

| Pipe sizes (DN) | Absolute minimum grade (%) |
|---|---|
| **Reticulation** | |
| **150** | 0.59 |
| **225** | 0.37 |
| **300** | 0.27 |
| **Branch and trunk** | |
| **375** | 0.19 |
| **450** | 0.15 |
| **525** | 0.13 |
| **600** | 0.11 |
| **750** | 0.09 |

Table 9 below shows the recommended sewer velocities for design of gravity sewers. Figure 16 and Figure 17 are referred to in the table and respectively show the critical sewer slopes and minimum sewer velocities for slime control.

Table 9: Recommended gravity sewer design methods

| Criteria | Recommended velocity (m/s) | Notes | Source |
|---|---|---|---|
| Minimum velocity during average flow conditions | >0.6 [8,9] | • Prevent deposition of solids.<br>• Maintain a self-cleaning action in sewers. | US-EPA-95<br>WSAS |
| Desirable velocity | >0.9 | • Where practical. | US-EPA-95 |
| PWWF velocity | >1.1 | • Avoid sulphide problems.<br>• Provide adequate cleansing velocity.<br>• Prevent sulphide and odour generation. | CoA-18 |
| For trunk and branch sewers, wetted cross section average velocity at PDWF | 0.7 | • To achieve self-cleansing of grit and debris. | WSA 02-2.2 |
| Maximum velocity in branch and trunk sewers when sewer flowing full | <3 | • To minimise turbulence and $H_2S$ generation. | WSA 02-2.2<br>WSAS |
| Maximum velocity where practicable in reticulation sewers when sewer is flowing half full | <3 | • Desirable to minimise turbulence and $H_2S$ generation. | WSA 02-2.2 |
| Minimum flow velocity in an inverted siphon | >0.75 (at ADWF)<br>>1.0 (at design flow) | • To ensure flow is capable of transporting solids against gravity. | WSA 02-2.2 |
| Critical sewer slopes for slime control | | • See Figure 16 below | MMBW-89 |
| Minimum sewer velocities for slime control | | • See Figure 17 below | MMBW-89 |
| Critical average wall shear stress of 3.35 Pa (see explanation below) | | • For slime control | MMBW-89 |
| Construct two pipelines instead of one.<br>A flushing system which can add enough flow to achieve the scouring velocities | | • **Where practical to accommodate future and or peak flows.**<br>• **Prevent deposition of solids.**<br>• **Maintain a self-cleaning action in sewers.** | |

8 The recommended scouring velocity of 0.6m/s for pipes flowing one-half full at design flow can result in velocities as low as 0.2m/s during low flow periods early in the design lifetime of the system, thus allowing deposition of sewage solids. While this is undesirable, it cannot be economically avoided in certain instances. Sulphide generated from accumulated solids is generally much less critical than that generated from the slime layer, especially when the accumulated solids are flushed from the system on a daily basis. (refer US-EPA-95)

9 Sewers shall be designed and constructed with such slopes to give a mean velocity of not less than 0.6m/s during average flow conditions with due consideration given to actual depth of sewage flowing in the pipe. Slopes slightly less than those required for 0.6m/s may be considered if the depth of flow will be 0.3 of the diameter or greater for design average flow and provisions can be made for frequent cleaning. Sewers larger than the minimum size required shall be chosen so that the maximum velocity at the peak design flow is not greater than 3.0m/s to minimise turbulence and pipe wear, especially where high grit loads are expected. If higher velocities are unavoidable, special precautions shall be taken to protect against displacement and pipe erosion. (refer WSAS)

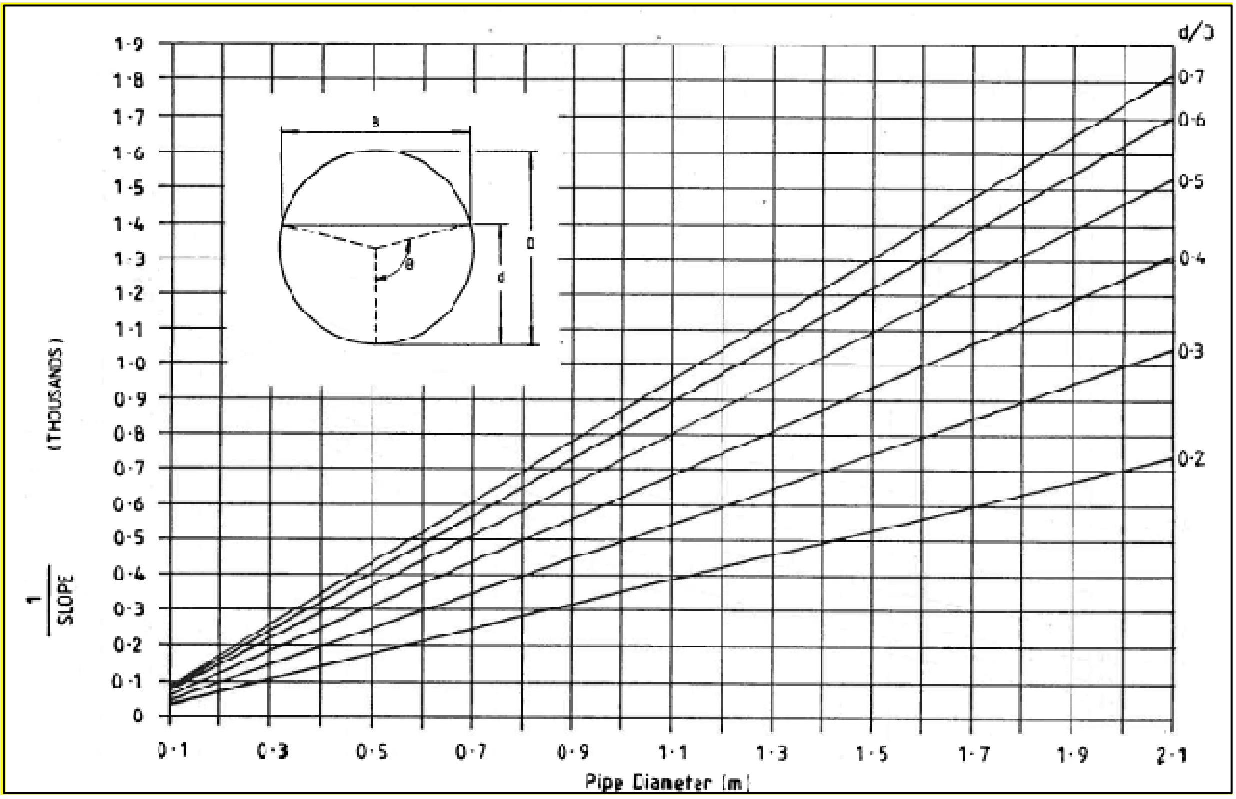



Figure 16: Critical sewer slopes for slime control (refer MMBW-89)

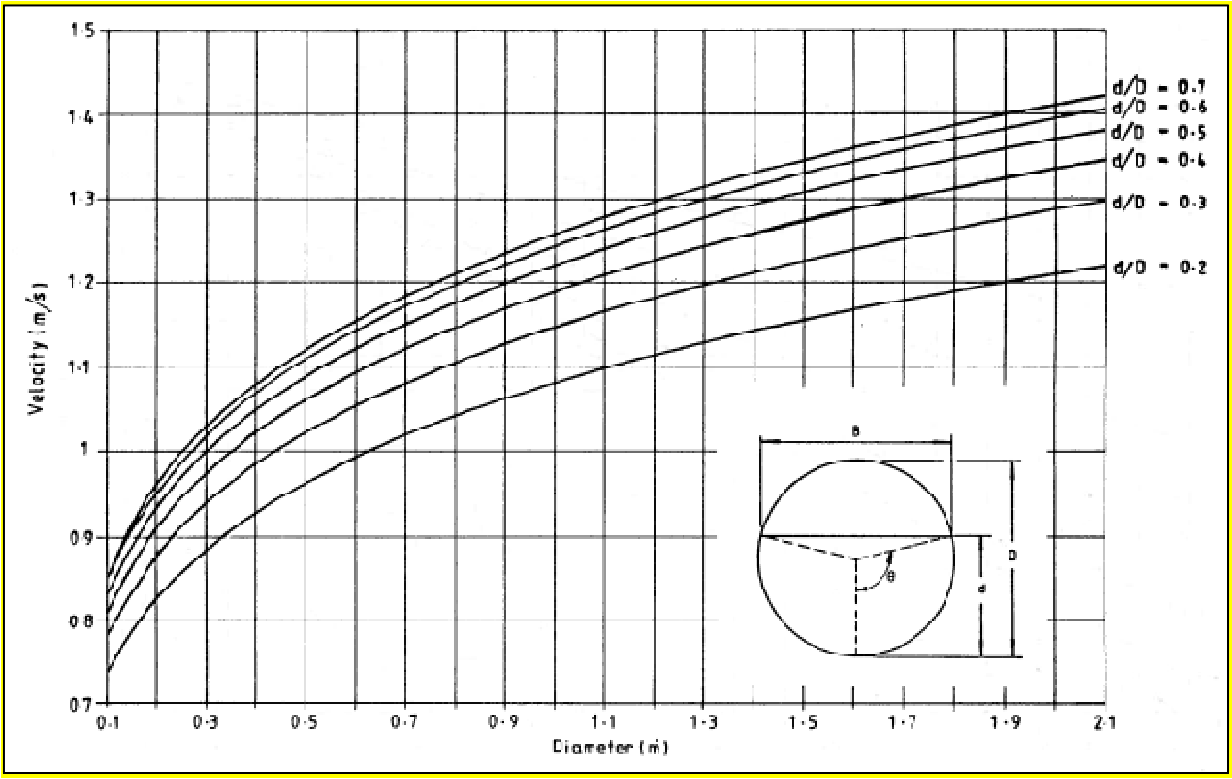



Figure 17: Minimum sewer velocities for slime control (refer MMBW-89)

An alternative approach to the design of gravity sewers based on gradient and velocity to achieve slime control is to maintain a minimum boundary shear stress to prevent suspended particles from settling out on the invert (refer US-EPA-95). As indicated in Table 9, the recommended design criterion to adopt for slime control is a critical average wall shear stress of 3.35 Pa (refer MMBW-89). For sewers with Manning's n = 0.013 or less, a design boundary shear stress in the range of 0.1 5 to 0.20kg/m² will likely keep self-cleaning sewer systems free from sulphide problems. For sewers with n = 0.015 or greater, a design shear stress of 0.2kg/m² should be used. (refer US-EPA-95)

Under certain conditions, sulphide generation may be unavoidable. Sulphide build-up and rates of corrosion can be estimated using Figure 18 or using more sophisticated sulphide models that are available such as the WATS model developed by the University of Aalborg. Where sulphide generation is anticipated, corrosion-resistant materials can be selected, or the alkalinity and thickness of concrete pipe can be specified to help reduce the effects of hydrogen sulphide corrosion. (refer US-EPA-91) Where corrosion-resistant materials are proposed, the Designer must consider the potential impact of the increased rate of transfer of $H_2S$ and odour (due to reduced uptake of $H_2S$ and other gases in the corrosion resistant pipe) to downstream sewers, and the consequent increase in O&C risks for these downstream assets.

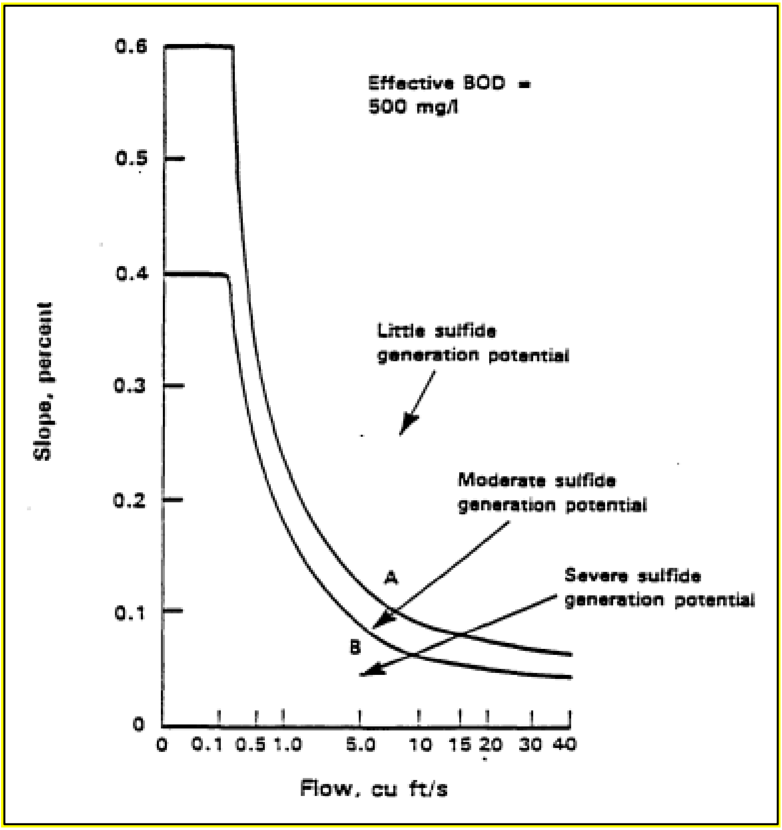



Figure 18: Guide for estimating sulphide generation potential (refer US-EPA-91)

### 8.3.2 Pressure mains

Unlike gravity sewers, pressure mains flow full, so there is no opportunity for natural aeration to occur whilst the wastewater is in the main. Hence, only the oxygen dissolved in the wastewater before entering the pressure main is available for bacterial respiration and sulphide oxidation. Since sulphide generation within pressure mains is due primarily to surface slime, larger pressure main sizes reduce the sulphide generation potential for a given design flow and wastewater characteristics, since they have a smaller surface-area to cross-sectional-area ratios. (refer WSAS)

Recommended design considerations for pressure mains are:

a. Pumps and pressure main systems must be designed to provide a minimum velocity of 0.7m/s (refer WSA 04-2.1) in the downstream gravity sewer when pumping.

b. For pressure mains of diameter less than DN300, a minimum velocity of 0.9m/s is recommended for satisfactory transport of solids through the pressure main, though the preferred minimum is 1.5m/s (when pumping). (refer WSA 04-2.1)

c. Pumps and pressure main systems must be designed to meet the minimum velocities for slime control shown in Figure 20.

d. Scouring velocity must be maintained at a minimum of 1.1m/s in pressure mains for pressure mains of diameter greater than or equal to DN300 and desirably for smaller size pressure mains. (refer WSA 04-2.1)

e. If designing a pressure main for a new development and the resulting retention time is significant (greater than 2 hours; refer section 5.5), consider the following (refer WSA 04-2.1):

    i. Design the PM to serve only the first stage of the development, or

    ii. Design for two (or more) PMs, with the first intended to serve the initial stage of development, and the second PM (and additional PMs) to serve the main stage (or later stages) of the development.

f. Odour and corrosion mitigations, for example gas phase treatments and/or chemical dosing systems, may be required for pressure mains assessed as having elevated risks. The Odour and Corrosion Technical Standard (TS 0854) provides a tool to assess risks and inform appropriate mitigations. The Standard requires the HRT for PMs to be minimised as far as practicable with a target of less than 2 hours based on ADWFs. Figure 21 shows the retention time for different flows and pipes sizes, per 10m of pipe.

g. Where practical, pressure mains should be designed to avoid:

h. High points – because odorous gas can accumulate at these areas and will require an air valve to provide pressure relief and to prevent hydraulic issues. The air valve emissions can result in local odour risks unless managed effectively (see item h below). The internal pipe at the high point of the pressure main can also be exposed to the potentially corrosive gas and unless made of corrosion resistant material would be susceptible to corrosion. Where practicable, the pressure main should be designed such that the pipe is continually rising, and the highest point is at the discharge MH location.

i. Low points – because debris can accumulate at low points along a pressure main, exacerbating the generation of sulphide for the sewer, as well as increasing the risk of hydraulic issues.

j. Standard design to be adopted for scenarios whereby odour risks exist at air valves associated with pressure mains. An elevated odour risk is considered to occur where the expected $H_2S$ (g) levels at the air valve locations are at 10ppm or above (90th percentile values; see section 5.6). The standard design is depicted in SAW drawing 2018-00450-19 (see excerpt in Figure 19) showing the air valves venting through a 200L carbon canister.

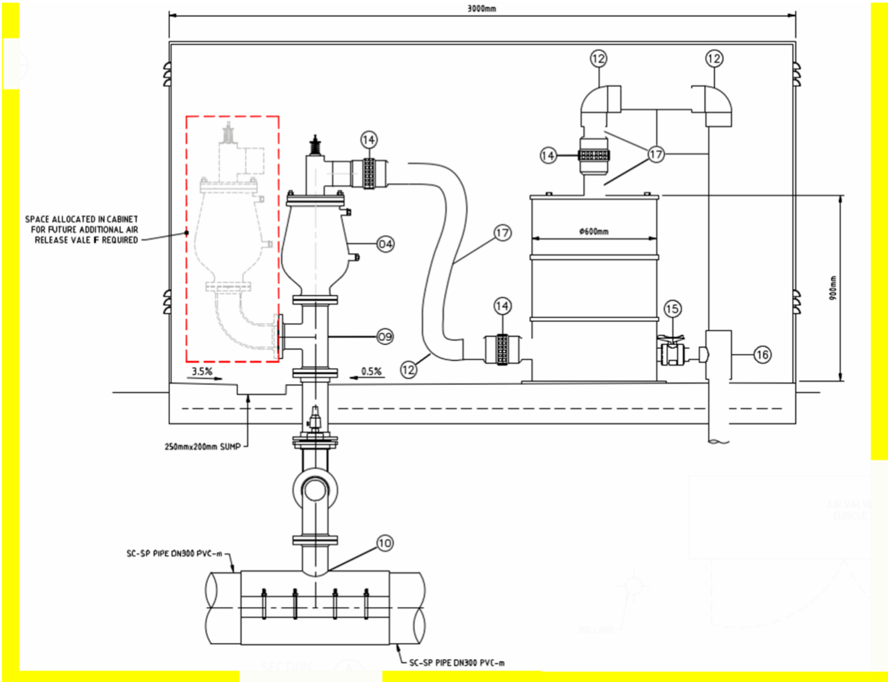



Figure 19: Example of AC cannister installation for PM ARV discharge air treatment

Decisions around the retention time do not necessarily have to be based on average daily flow rates. For example, a SPS may have a relatively short retention time during the day, but a long retention time overnight. It is the responsibility of the designers and operators to determine the level of risk based on whether sensitive receptors are located near the wet well and pressure main discharge, what time the sewage is pumped out (e.g. during peak hour when people leave for work), and the configuration of the discharge (e.g. non-treated vent or active OCU). A chemical dosing system can be installed and programmed to treat either all of the flow or only problematic periods of the day when the incoming flow reduces.

If the criteria listed above are not met, and if the pressure main discharge is in a sensitive area and causing problems, remedial measures may need to be considered in consultation with SA Water. Forced ventilation is one remedial measure as it is used to contain odours by maintaining sewerage gas spaces under slight vacuum to prevent fugitive emissions[10](i) and providing $H_2S$ gas dilution. However, ventilation is not very effective in preventing corrosion; although the $H_2S$ gas concentration and relative humidity can be reduced, the extent of reduction is typically not sufficient to prevent corrosion unless very high ventilation air rates are applied.

To effectively manage odour and corrosion for existing SPSs, the following guidance applies:

a. There is no requirement on how often to run the pumps or what frequency per day. Varying the pump run times changes how long the wastewater spends in the wet well or the PM, but does not change the overall retention time.

b. To manage non-pumping times, there are installations that recirculate water in the wet well, injecting oxygen into the flow before returning it to the wet well. However, this can be expensive. Well washers are relatively cheaper because they do not use oxygen injection equipment but instead aerate the sewage by cycling it up in the wet well and dropping it back to the bottom via a spray (the well washer).

c. Some SPSs have in-well mixers to keep the sewage turning over and reduce the chance of septicity. As for well washers, the basic approach is to keep moving the sewage during non-pumping times.

[10] WSA 04-2.1) mentions putting an induct and educt on the receiving maintenance hole; where odour issues occur with these in place, forced ventilation (with treatment) may be warranted.

d. One action that can benefit the downstream sewer is to change the pump run time (if the pump flow can be varied); reducing it to the minimum, while ensuring there is no wet well flooding, will minimise turbulence at the pressure main discharge end.

e. Keep in mind that despite actions taken in the wet well, once wastewater is in a pressure main, it will go septic as dissolved oxygen levels are depleted (with increasing retention time) unless chemicals (or oxygen) are added.

It is possible that existing older parts of the network do not meet the criteria listed in this section. When an area of the network is due for renewal, upgrade work to align with the recommendations presented here would be beneficial. Similarly, where odour complaints are received from an existing network area, the sewer design should be reviewed and consideration should be given to implementing upgrade works based on an improved sewer design to reduce the likelihood of odour complaints.

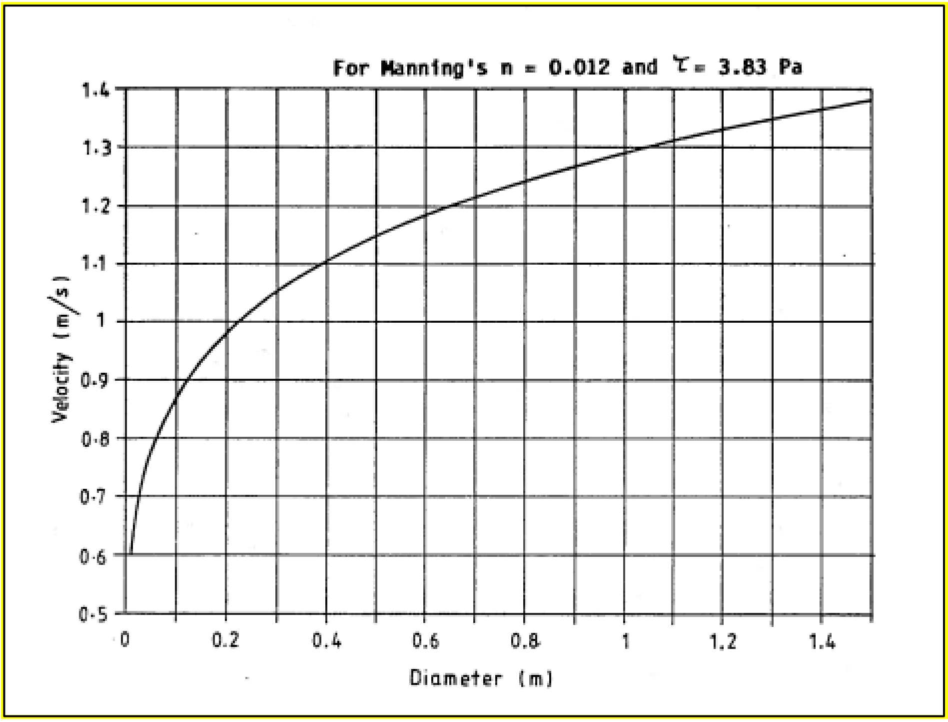



Figure 20: Minimum velocities for slime control in pressure mains (refer MMBW-89)

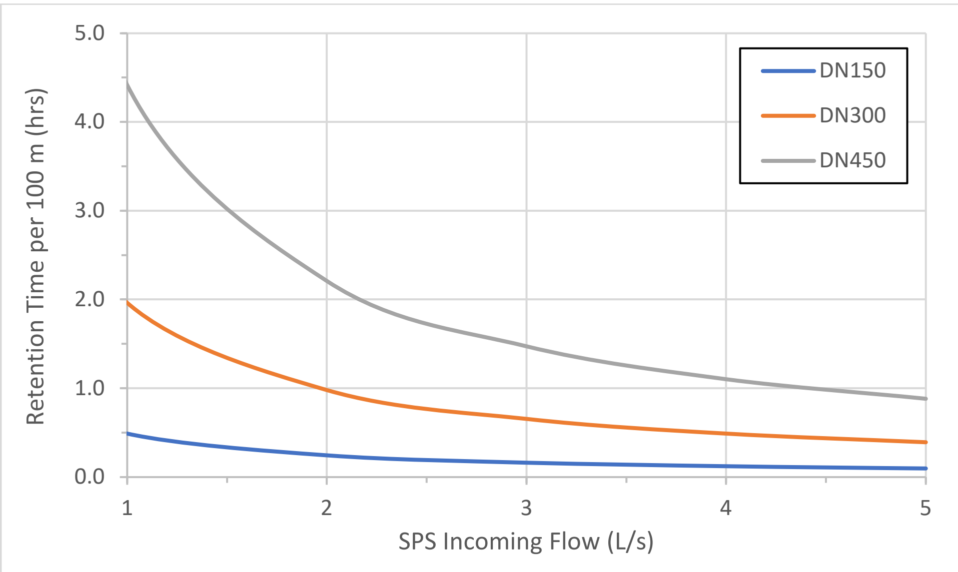



Figure 21: Hydraulic retention time per 100 m of pressure main

# 9 Pressure main discharge maintenance hole design

Pressure mains can generate a significant amount of sulphide which can cause substantial $H_2S$ release at the pressure main discharge maintenance hole. This is particularly relevant during the morning diurnal flush when the wastewater has been sitting in the pump station and pressure mains for longer overnight periods, and during the afternoon flow peak when turbulence becomes a significant factor for $H_2S$ release.

The following design features are recommended to decrease turbulence and reduce the risks of surcharging at pressure main discharge maintenance holes:

a. The pressure main connection to the receiving maintenance hole should be designed to minimise turbulence. This includes ensuring that the last 5 metres (or 10 times the pressure main diameter, whichever is greater) of the pressure main has a straight alignment with the gravity pipe and the invert of the pressure main with the invert of the gravity sewer pipe for a smooth transfer of flow. (refer WSA 04-2.1)

b. Pressure mains entering a gravity sewer should enter as close to the flow line of the receiving maintenance hole or at a point not more than 600mm above the flow line (liquid surface level) of the receiving maintenance hole (refer WSAS), and discharge should face downstream. Internal or external jump ups similar to Figure 6 or those used in wet wells can be considered to achieve this. An improvement on this arrangement is for the pressure mains entry to be submerged at the discharge maintenance hole to minimise turbulence and $H_2S$ gas release.

c. Discharge maintenance holes should be constructed from corrosion resistant material, lined or epoxy coated to minimise corrosion risk. The application of epoxy coating is not preferred. Where nominated, the Designer is to seek specific approval from SA Water.

d. Discharge maintenance hole and downstream sewer must be adequately sized to accommodate pressure main discharge and the flow from any gravity area.

e. Ensure that the discharge maintenance hole and receiving pipe are adequately sized to avoid surcharging when pumps start. Specifically, the system is to be designed such that the minimum sewage velocity in the downstream gravity sewer is 0.7 m/s when pumping (refer section 8.3.2).

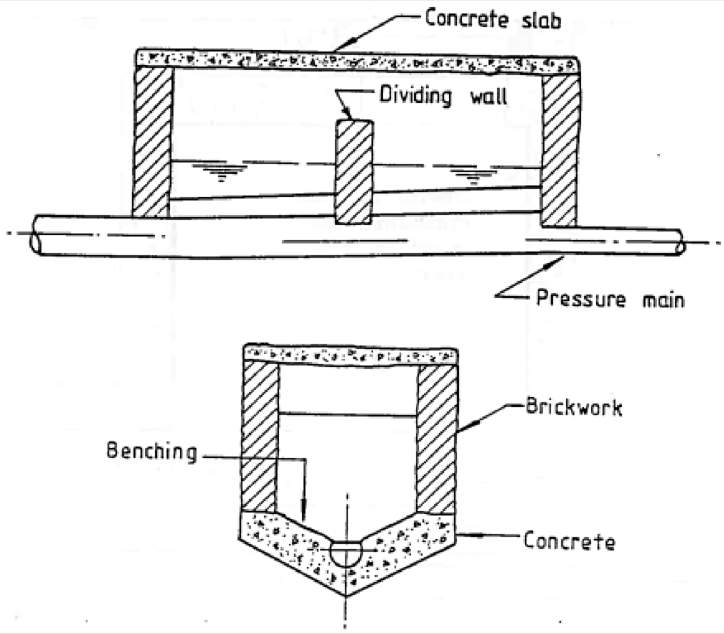
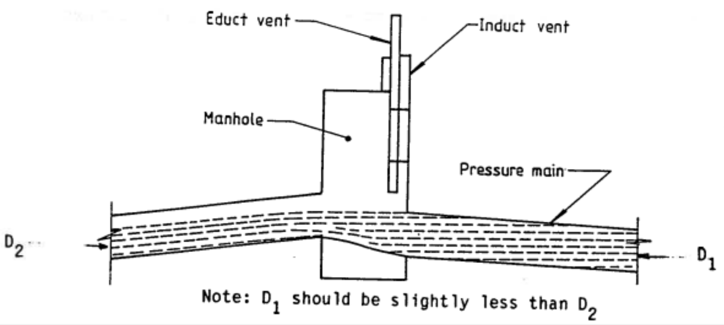
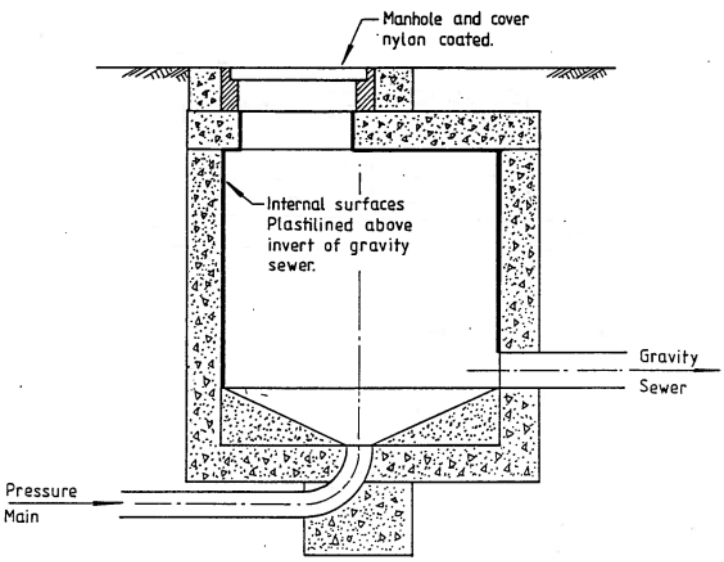
f. Pressure main discharge maintenance holes would normally have educt vents to depressurise a hydraulic surge during pump run times. For new sewers in sensitive locations, the maintenance hole should be well-sealed to avoid fugitive emissions, but the receiving sewer should be designed to mitigate the hydraulic surge so that the air can move downstream. If this is not possible, controls (forced ventilation with activated carbon vessel treatment) may be required to treat the air that needs to be released. Induct air vents, with non-return dampers, may also be warranted to promote fresh air dilution at the discharge maintenance hole, while avoiding odour risk.

g. Consider the need for additional ventilation or collection and treatment of the odorous air, based on the odour risk posed by the release.

h. Refer to SA Water Technical Guideline TG 0531 - Wastewater Network Ventilation Design for guidance on when to install vents such as educts and foul air treatment on pressure main discharges.

Three examples of discharge streamlined arrangements which minimise turbulence and therefore $H_2S$ release to different extents, are shown in Table 10. (refer MMBW-89) SA Water's standard design for a pressure main discharge maintenance hole is shown in Figure 22. As an improvement on this, to be implemented where practicable, the PM discharge MH should be a dedicated MH for receival of the PM flow. The PM discharge sewage would then flow from the dedicated receival MH via a short outlet gravity pipe to an adjacent MH where it connects with the main downstream gravity sewage flows.

Table 10: Pressure main discharge promoting non-turbulent conditions (refer MMBW-89)

| Type | Description | Figure |
|---|---|---|
| **A** | A dividing wall is arranged so that it does not quite reach the top of the chamber and partially obstructs the channel. When the pressure main discharges, the wastewater initially builds up behind the dividing wall due to the restriction. A stage is reached where the build-up produces an equilibrium between inflow and outflow and the level ceases to rise. The wastewater flow into the chamber is less turbulent because the discharge is submerged and the flow under the wall is streamlined. This type of discharge arrangement also requires minimal maintenance to keep the structure clean. |   |
| **B** | The most common streamlined form of discharge with operational experience proving them to be the least troublesome. However, this type can be subject to problems particularly where discharge velocities are high, resulting in wastewater being jetted across the structure creating considerable turbulence. One method of overcoming this problem is to use a larger diameter pipe for the section of pressure main immediately adjacent to the structure. |   |
| **C** | The standard configuration used in Brisbane. Similar to Type C, this type can be subject to problems particularly where discharge velocities are high, resulting in wastewater being jetted across the structure creating considerable turbulence. One method of overcoming this problem is to use a larger diameter pipe for the section of pressure main immediately adjacent to the structure. |   |

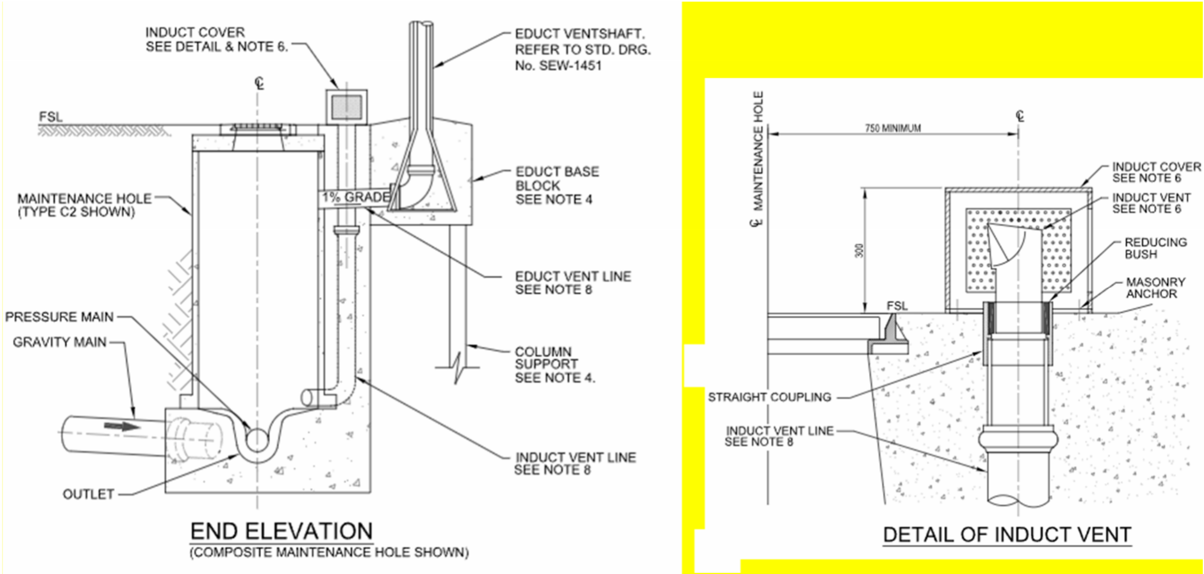



Figure 22: PM discharge MH with induct and educt vents (WSA 04-2022)

# 10 Sewage Pump Stations

## 10.1 Introduction

The design of SPSs is a critical element of sewer networks. Ideally, SPSs should be designed so as not to increase the total sulphide generation potential of the network. This is often difficult, however, due to the design practice for SPSs inherently including sewage retention time in both the wet well and the pressure main. When supplementary aeration is not provided, extended retention in the wet well and/or pressure main, and increasing the contact time of the wastewater with sulphide-generating slimes within the pressure main and the wet well surfaces, will tend to increase the potential for sulphide generation. Potential also exists for sulphide generation from solids deposition in the wet well if the wet well design does not contain adequate bottom slopes and suction piping arrangements for their continuous removal. (refer US-EPA-95)

This section sets out guidelines for SPS wet wells, inlet MHs and ventilation of SPS for the effective control of odour and corrosion risks.

## 10.2 SPS wet well and inlet MH arrangement

Pumping station wet wells shall be designed to achieve the following objectives:

a. Eliminate or minimise the deposition and accumulation of solids and scum to minimise maintenance and reduce septicity, odours, corrosion, and release of hazardous gases. (refer CoA-18)

b. In addition to design, management practices can also assist. SA Water has a daily automated pump down operation implemented as standard practice for new pump stations (or for switchboard and pump upgrade projects) to clear depositing material.

c. Minimise the potential for vortexing, swirling, and excessive turbulence from incoming flow to inlet maintenance hole and SPS wet well that can result in submerged and free surface vortices, entrainment of air, formation of rag balls, and pump reliability problems. (refer CoA-18)

d. Minimise drop where incoming sewer enters SPS with respect to bottom water level (BWL). Where this cannot be achieved, design shall include an inlet drop pipe to BWL to minimise turbulence in the SPS, thus decreasing potential for odour emissions.

e. Avoid frequent starting of pumps (refer CoA-18), i.e. ideally less than 6 starts per hour. This includes considering how the size of the wet well will impact the frequency the pumps run for the projected flow and seeking to minimise the number of starts as much as possible. Variable drives also decrease start times by allowing the pump to run longer at a slower rate and so less intensity. Wet wells should be as small as possible to minimise the wet well retention time and the potential for sulphide generation. (refer US-EPA-95) A summary of guidance consolidated from several sources in literature is that retention times based on ADWFs should be:

   - Less than 30 minutes in sensitive areas (refer US-EPA-95, WSAS, CoLA-1, and CoA-18); and
   - Less than 2 hrs (refer US-EPA-95) for less sensitive areas (i.e. nearest residents are distant to the SPS) or where shorter times are impractical.

f. Avoid storage or backup of wastewater into influent lines:

   - Constant-speed pump stations should be operated with start-stop cycles that are short enough to avoid backup of wastewater into influent lines. (refer US-EPA-95)
   - To prevent short-cycling of pumps, consider multiple pumps or multiple-speed pumps to reduce the incremental change in the pumping rate and therefore the required volume. (refer CoLA-1)

  - If it is not possible to avoid using the storage in the incoming sewers, ensure that adequate velocities are maintained in the sewers (refer CoLA-1) (refer to section 8.3.1 for velocities, particularly those related to sewer scouring).

g. Set the lowest liquid level in the well above the sloping portion of the wet well. This can be accomplished by making this level the stop point for the lead pump in the sequence. (refer CoLA-1)

h. Wet well interiors should be coated with an approved $H_2S$ resistant coating.

## 10.3 SPS wet well ventilation

The intermittent discharge of odorous air caused by rapid changes in the sewage level can be the source of odour complaints. The sewage level changes having the greatest odour risk impact are those occurring in the SPS wet wells and those that occur in and just downstream of a vented pressure main discharge maintenance hole. As sewage levels rise, air must be expelled from the sewerage asset at the same rate to avoid pressurisation of the sewer headspace. Pressurisation should be avoided, primarily because it can cause odorous air to be forced out into the environment through any gaps or weak seals. The most severe form of pressurisation due to increasing sewage levels can be avoided if the air is able to flow into other connected gas spaces. This could be achieved by having connected sewer gas space between the SPS wet well and the incoming gravity sewer(s), under all hydraulic operating conditions, though noting that all connected gas spaces need to be well sealed to avoid fugitive emissions.

Pressurisation can be avoided by implementation of the following features:

a. Installation of inducts and educts on wet wells for natural ventilation.

b. Extraction of air through an SPS forced ventilation system.

c. Keeping the level in the wet well steady by matching the pumping rate from the wet well to the rate of sewage inflow into the wet well by the use of variable speed pumps. (refer Hurse)

Of the above, installing vents at wet wells to facilitate ventilation is preferable. These vents will prevent foul air accumulation by accommodating air displacement due to the rise and fall of the water level in the wet well. Where there are elevated odour and corrosion risks at the SPS, forced ventilation with gas treatment may be required.

The design of vents to facilitate natural ventilation of the SPS should incorporate:

1. A vent line shall be provided from the inlet maintenance hole to the SPS educt vent shaft (refer WSA 04-2.1). While the design of the line may vary from case to case, some general standards are:
   a. A nominal diameter of 300 mm.
   b. Keep the line above the highwater mark so that it does not become a passage for wastewater in a surge event.
   c. If the distance from the inlet maintenance hole to the SPS educt is long (greater than 20 metres), consider a dedicated educt for the inlet maintenance hole.
2. In order to minimise accumulation of odorous air inside the wet well, there should be an educt vent to facilitate natural ventilation of the wet well and the inlet MH, as a minimum. The use of an induct vent can improve natural ventilation and reduce O&C risks by providing fresh air dilution in the wet well (reducing gas space $H_2S$ concentration and relative humidity). As set out in SAWS-ENG-0854, the use of a fresh air induct is to be discussed with SA Water.

   While an induct should not become a source of odour release when there is an educt connected to the same air space, if for any reason an induct becomes problematic, a non-return damper can be added to it.

3. Where both inducts and educts are required, the vents are to be adequately spaced to avoid short-circuiting of fresh air from the induct to the educt.
4. The educt vent should have a minimum diameter of one-half times the diameter of the incoming sewer. Where possible, the educt vent pipe can be connected to the nearest sewer maintenance hole.
5. Educts shall be sized to vent at a rate that is 25% greater than the maximum pumping rate.
6. Minimum vent diameter is 100mm, and gas velocity should not exceed 3 m/s through a vent pipe. (refer CoD-15)
7. Where the wet well is located away from any sensitive area, the educt could be extended above the roof line with a minimum of 3 metres from any potential air intake at the SPS building (for example, window or fresh air inlet). (refer CoLA-2)
8. Inducts and educts are to be fitted with screening to prevent entry of birds and insects to the wet well.
    a. Rain entering the wet well via the vents is not a major concern, as the volume of rain is minimal compared to the flow handled by the SPS. Rain covers can be added to the vents if desired.
    b. A typical rain cap over the induct is acceptable, but these should be avoided for the educt as they adversely affect the flow rate and dispersion of the emitted gas. Instead, a collar type or "no-loss" rain guard as shown in Figure 23 is recommended (if a rain guard is desired at all).


Figure 23: Collar-type rain guard for a stack

9. Should odour control be required at a SPS, consideration shall be given to extraction of air for treatment from the inlet maintenance hole, including potentially the incoming sewer and other areas of the SPS where there is common headspace, in addition to the wet well. It may be possible to extract air from one extraction point, or multiple extraction points may be required. Design of extraction systems shall be undertaken on a case-by-case basis.

a. Note well, the incoming gravity sewers can benefit becoming an air inlet to the wet well.

b. If an induct is added to the wet well, then the control of the fresh air ingress via this induct is to be designed to optimise ventilation of the incoming sewer and avoid short-circuiting of air from the induct to the educt. Consideration can be given to the induct located at the inlet maintenance hole if there is an air path to the wet well.

10. Guidance for sizing of odour control equipment at SPS is contained in the *SA Water Technical Guideline TG 0531- Wastewater Network Ventilation Design*.

# 11 Seals

## 11.1 Wet well and maintenance hole covers

A common problem with wet wells and maintenance hole covers and frames is the entry of surface water and escape of odours through holes in the lid, through spaces around the lid between the frame and the cover, and under the frame if it is poorly sealed. Seals on maintenance holes are quite often damaged by road work and heavy traffic.

EPDM or silicone rubber seals shall be installed on all wet wells and maintenance hole covers to minimise fugitive emissions. Where possible, the seals shall be attached to the covers to avoid them falling into the sewer when the covers are opened. Care should be taken when removing and reinstating covers to ensure that the seals sit flat, and a continuous seal is achieved around cover edges.

## 11.2 Water seals

Water seals are vital for preventing the flow of sewer gas into customers' homes. Water seals are found in the home in toilets and under sinks. Usually, these seals are sufficient when the home is directly connected to the sewer reticulation system.

When the nearest sewer available for connection is a trunk sewer, detailed planning and design must be undertaken. Direct connection to a trunk can impact customers with water seals being blown or sucked out either due to forced ventilation systems attached to the trunk sewer or the pulsing of air resulting from large changes in sewage flow in the trunk. Once water in seals is lost in a customer's home, sewer gas can enter the property unhindered.

To mitigate the risk of these problems, SA Water's preference is to avoid direct customer connections on trunk sewers. Instead, several homes on the street are connected to a reticulation (shallow) sewer, which then connects to a (deeper) trunk sewer with a water seal in between. This single water seal provides the barrier to the above problems for all homes upstream. This configuration is illustrated in Figure 24.

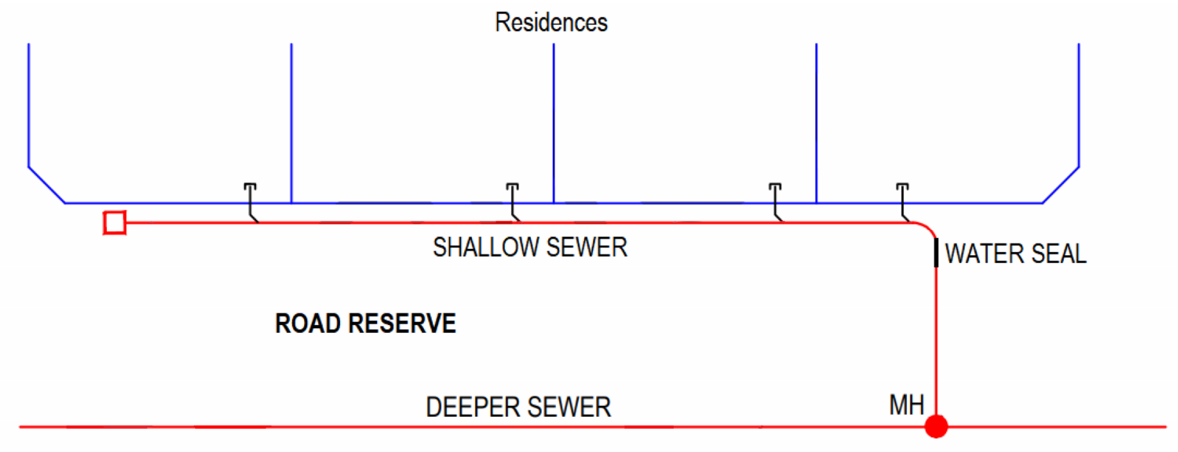



Figure 24: Connection of residences to a trunk sewer via reticulation sewer with water seal

## 11.3 Air curtains

Air curtains can be used in gravity sewers to control air flow in sewers with mechanical ventilation systems installed. Specifically, air curtains enable ventilation to target specific sewer sections and define the zone of influence to achieve target gas pressures and $H_2S$ gas concentrations (via dilution with fresh air). Advantages and disadvantages of air curtains are discussed in TG 0531 and their use requires consultation with SA Water.

# 12 Gravity sewer surcharging conditions and performance criteria

When sewers become surcharged, there is no opportunity for reaeration, resulting in anaerobic conditions, generation of $H_2S$, and often severe corrosion and odour complaints in the vicinity. Surcharging sewers restrict airflow by limiting headspace for air movement, which can lead to the accumulation of $H_2S$ in the gas space and an increase in gas pressure levels. Any turbulence in the area drives sulphides from the liquid to the vapour phase and could result in odour issues. Once the surcharge clears, air can once again flow, and $H_2S$ levels drop.

Unlike the conditions described above, shorter duration surcharged conditions caused by freshwater infiltration/inflow can have a positive impact on sewers. Freshwater infiltration surcharge conditions are often characterised by weaker (more dilute) sewage and colder temperatures that may result in reduced sulphide generation due to higher flow velocities, scouring of accumulated solids, and reduced biological activity. (refer US-EPA-95) These benefits of infiltration are not realised though for SA Water's networks, as infiltration often contains high salinity groundwater which is rich in sulphate and so encourages sulphide generation (in pressure mains), odour, and pipe corrosion. Infiltration in SA Water's network can be identified by high salinity in the wastewater.

Design of sewers which can potentially be surcharged should be avoided whenever possible. Where required, design velocities should be selected to avoid solids deposition and retention times should be minimised (refer MMBW-89).

To avoid surcharging, the following design standards should be followed:

a. Sewers should be sized to accommodate peak flow from upstream pressure mains and gravity sewers. Section 7.4 sets out pipe size guidelines for peak dry weather flow conditions, in alignment with WSA 02-3.3.

b. Sudden changes in sewer grade should be avoided