



HUNTER WATER CORPORATION

**WATER AND SEWER
DESIGN MANUAL**

SECTION 4

**SMALL TO MEDIUM
SUBMERSIBLE SEWAGE
PUMPING STATIONS AND
SEWER RISING MAINS**

AMENDMENT HISTORY

Date	Clause	Amendment
August 2003	4.2.10	Hunter Water approval is required for new overflow structures. Designer to address in concept design report if an overflow is proposed.
April 2004	4.3.7	Amendment of requirements for de-rating of plastic pipe. Appendix 4E added. GRP added to list of rising main materials.
September 2004	4.6.2	Amendment to locking requirements for internal switchboard doors.
May 2005	4.2.11 4.8.1 / 4.8.2 4.8.4 4.8.5	New clause - revised emergency storage requirements. Amendments to ventilation requirements for pump stations. Amended requirements for vent height and location. New clause - requirements for vent colour.
December 2005	4.2.11 4.3.3 Appendix 4F 4.3.7 4.3.12 4.9.1 / 4.9.5 Appendix 4E	Rewording of emergency storage requirement. Deletion of separate phase relays requirement. Requirements for alignment of rising mains through intersections including new appendix. DICL K9 superseded by PN35. Table of allowable working heads for K9 and K12 deleted. Additional requirements for rising main connections to receiving discharge access chambers. Requirement for fall restraint anchor points added. Changes to derating factors for PVC-O.
May 2006	4.2.3 4.2.11	Correction of section reference Minor rewording – “shall”
September 2006	4.4.3, 4.4.4, 4.5.2, 4.5.3, 4.10.7	Replacement of references to Flygt and KSB with reference to Hunter Water’s Approved Products and Manufacturers list. Design to be suitable for installation of each of the approved pumps.
March 2007	4.6.2	Update of electrical requirements, including standard switchboard designs, acceptable method of pump starting and relevant electrical standards.
September 2007	4.3.2	ISG coordinates replaced by MGA.
September 2007	Appendix 4E	Minor revisions to derating methodology including amendments to derating factor for PVC-O.
February 2008	4.3.7 4.9.7	Requirements for thrust blocks added regarding factor of safety and rising mains $\geq$ DN300. Revision of requirements for access roads and turning areas.
July 2008	Appendix 4B	Added reference to Appendix 1A for electricity cost.

SMALL TO MEDIUM SUBMERSIBLE SEWAGE PUMPING STATIONS AND SEWER RISING MAINS

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4.1 INTRODUCTION

4.1.1 GENERAL

This manual has been produced as a guide to technical personnel concerned with the design of and the selection of components for small to medium submersible pumping stations generally in the size range DN 1800 to DN 4600 pump wells which are to be connected to the Hunter Water Corporation's sewerage system. The practices set out herein are those of the Hunter Water Corporation, NSW. They are applicable to the design of new schemes and extensions to or augmentations of existing schemes.

The pumping stations in a sewerage system may have a substantial effect on the successful operation of other reticulation components and many treatment elements in the system. The designer must, therefore, coordinate a design with the rest of the system. It is emphasised that this manual is intended to provide guidelines to the designer as to how to deal with the aspects presented. Engineering judgement should be applied at all times.

This manual has been based on the Public Works Department, NSW 1986 publication "Manual of Practice Sewage Pumping Station Design" and much of the information presented herein has been sourced from this PWD publication.

4.1.2 COST EFFECTIVE DESIGN

Development in pumping technology and the submersible motor sewage pump has provided the designer of a sewerage system with an opportunity to evaluate various combinations of pumping stations, rising mains and sewers to give the most economical scheme based on construction, operating and maintenance costs. For small schemes the most attractive combination can very often be assessed by a site inspection but for larger schemes reliable unit rates must be established for all the main variable items and alternatives examined and costed such that the final design is cost effective. Cost must, however, be subject to the engineering requirements of the scheme being satisfied.

4.1.3 PUMPING STATION TYPES

Single Well Station/Submersible Pumps

A centrifugal pump close coupled to a submersible electric motor is commonly referred to as a submersible pump. The pump and motor form an integral unit which operates fully submerged in the sewage collection well. The units automatically connect to and disconnect from the discharge pipework whenever they are raised or lowered from their supporting stands.

Due to the significant economy in construction of the single well for submersible pumps this type of station has largely superseded the wet well/dry well pumping station. Because of its low initial capital cost it has been economical to incorporate more pumping stations in schemes and thus restrict the depth of sewers. With the continuing rise in power costs and maintenance costs, however, greater importance must be placed on the conceptual design of schemes to ensure that running costs are minimised.

Commonly, duplicate pumps are installed in the wet well with control of flow achieved by means of valves normally located in a separate shallow valve pit which is easily accessible from ground level. The well and valve pit are normally finished close to ground level and the only above ground features will be a weatherproof cubicle to house electrical switchgear and a vent pipe. The electrical cubicle and vent pipe are normally mounted on the pump well roof slab.

Submersible pumps are generally suitable for flow rates ranging from 5 litres per second up to 200 litres per second within a head range up to 40 to 50 metres. However, pumps of greater capacity are now available and have been used selectively by the Corporation.

Where the total hydraulic head to be overcome is greater than the capability of a single submersible pump, two such pumps can be operated in series. The first pump is installed in the wet well in the conventional manner. The second pump should be installed along with the discharge valves in a shallow combined valve and pump pit. In this manner heads of approximately 80 to 100 metres may be achieved.

Where the total flow to be pumped is greater than the capability of a single submersible pump, two or more such pumps can be operated in parallel. A parallel pumping system may also be considered to achieve lower operating costs during dry weather flow or where some “flow matching” characteristic is required. The number of pumps operating will be automatically controlled by the well level.

Wet Well/Dry Well Stations

Design of wet well/dry well pumping stations and augmentation and /or conversion of existing wet well/dry well pumping stations is outside the scope of this manual. The following is for information only.

Wet well/dry well pumping stations were normal design practice until the development of the submersible motor driven pump. Because of the economy of civil works, when using submersible pumps in a single wet well these have largely replaced wet well/dry well pumping stations. Only in very large pumping stations, where the duty pump power requirements are in excess of 150 kW, are wet well/dry well stations considered. A number of pumping stations with submersible pumps considerably larger than this have been installed by the Corporation in recent years.

Most involvement with wet well/dry well pumping stations arises from the need to augment existing stations. This can be done by replacing the existing pumps with a similar type of unit, or by replacing with submersible pumps mounted as dry well units. The latter alternative may minimise the amount of modification required to existing ladders, openings etc., due to the more compact design of the submersible unit. In other cases augmentation by the installation of submersible pumps in either the existing wet well or in the dry well, after conversion to a wet well, may be considered. Wet well / dry well stations are less likely to be used in the future, due generally to the high cost of the structure.

4.2 DESIGN CONCEPTS FOR SEWAGE PUMPING STATIONS

4.2.1 GENERAL

Although not always possible, it would generally be of considerable advantage to have established the actual pumps to be used prior to the finalisation of civil designs for a pumping station. There is often considerable difference in the dimensions of pumps supplied by various manufacturers to handle similar duties. If designed before the actual pumps are selected, the well must be of sufficient size to allow the installation of the largest pump likely to be used and the roof slab openings only determined when the pumps to be supplied are confirmed. Inattention to these points can mean reconstruction works are necessary upon receipt of pumps on site. The acceptance of tenders for pumps prior to the calling of tenders for civil works is, therefore, highly recommended. The design of civil works may then be tailored to suit the pumps actually accepted and due allowance can be made for adequate hydraulic conditions for the pump and installation of satisfactory access, etc.

The Corporation has developed various standard design aids and procedures and standard construction practice drawings. The designer is urged to utilise these standards where possible. Sound engineering judgement should be applied at all times.

Some of these standards are:

1. HWC Sewage Pumping Station Standard Layouts - Figure 1 Section 4.2
2. HWC Standard Hatch Dimensions and Pump Spacings - Figure 1 Section 4.2
3. Typical Sewage Pumping Station Arrangements - Appendix 4D.
4. HWC Standard Construction Practice Drawings - Sewerage Standards
 - Part A - Gravity Sewers
 - Part B - Sewage Pumping Stations
 - Part C - Sewer Rising MainsA list of these drawings is included in Appendix 1E.
5. HWC Standard Electrical Switchboard Designs - Refer Section 4.6.2
6. HWC CAD Standards for Consultants, HWC Standard Borders, HWC “DXF CHECK” documentation and software.
7. HWC Standard Technical Specification for Construction of Submersible Sewage Pumping Stations - STS 402
8. HWC Standard Technical Specification for Construction of Sewer Rising Mains - STS 403

The design shall include but is not limited to:

- geotechnical investigation
- site layout including all weather vehicle access road and vehicle turning areas - Refer Figure 1 Section 4.2
- site drainage including access road drainage
- landscaping

- flood protection considerations
- retaining walls and embankments if required
- emergency flow relief provisions
- water supply
- incorporation of electrical conduits and cable trays
- hydraulic design
- mechanical design
- structural design
- electrical design
- environmental considerations

4.2.2 DOCUMENTATION AND DRAWINGS

Hunter Water Corporation has specific requirements for drawings and contract documentation. Refer Appendix 4A and Sections 1.4 and 1.5

It is also a requirement of the Corporation that the designer submits a design report. Refer Appendix 4A and Section 1.4.

4.2.3 SITING AND LAYOUT

General

The following factors should be considered when selecting the location of pumping stations:

- HWC Sewage Pumping Station Standard Layouts - Figure 1
- Proximity to rising main discharge point should be as close as possible to minimise the rising main length.
- Depth of incoming gravity sewer - this will influence the pumping station depth.
- Sites should be as unobtrusive as possible and kept away from houses and built up areas if possible.
- Sites should have available access and consideration should also be given to construction and maintenance requirements.
- The order of preference for land choice, is:
 - Land provided within the subdivision by the Developer (The Corporation to be given title or easement rights)
 - Council Land (Public Reserve)
 - Vacant Crown Land
 - Vacant Private Property
 - Established Crown Land
 - Established Private Property

- The Developer is to negotiate with the owner(s) and obtain easement rights or freehold title (vested in the Corporation) for any pumping station sites, access, services, and rising mains. The station should be contained within an easement if wholly within a public reserve or a designated lot if not within a public reserve. The easement or lot is to include batters, embankments, retaining walls and flow relief structures. Access, services, and rising mains should be contained within an easement. The Developer shall pay all costs associated with land or easement transfers.
- Consideration should also be given to the potential likelihood of development.

Given normal latitude the choice of site is usually determined by aesthetic conditions, but the location should allow for a suitable layout for the incoming gravity sewer and the rising main. The collecting access chamber for the gravity system should always be positioned approximately 5 m to 7 m clear of the pump well.

There should also be sufficient clearance from surface and subsurface obstructions to allow for construction. The clearance necessary will vary with the depth and diameter of the pump well and is also dependent on ground conditions. The site should never be located under power lines.

The average size of a pumping station site for a small to medium pumping station without superstructure is 12m x 12m with an increase in site size requirements for larger installations. If the pumping station is to be located within a road reserve, laneway etc., its position should be determined in conjunction with the local Council. If the pumping station is located within private land, crown land, etc, it should be so located that the site and any easements will have the least detrimental effect on the property with regard to existing, proposed or potential development including possible subdivision etc. ie. the site should not be isolated in the middle of a block so that complicated and long access and pipeline easements are required.

Access for Maintenance Vehicles

All pumping stations require adequate access and turning area for maintenance vehicles. Therefore, it will be necessary to provide or obtain suitable adequate land. Providing adequate attention is paid to the landscaping pumping stations can be blended to suit the surrounding environment. Access roads are discussed more fully in Section 4.9.7.

Emergency Flow Relief

As a pumping station may be subject to mechanical or electrical failure provision must be made to allow continuing sewage flows to be relieved from the sewer. This will take the form of a flow relief structure and should be considered together with the pumping station when determining location and layout of the station. Flow Relief Structures are discussed later in this section and more fully in Section 3.6.

Flooding

Where a pumping station is sited in a flood prone area the switchgear must in all cases be located above flood level. For small to medium pumping stations the finished surface of the top of the wet well roof slab should be placed 0.3 metres above 100 year flood level. The base of the electrical switchboard cabinet shall be mounted a minimum of 0.6 metres above 100 year flood level.

4.2.4 EASEMENTS

Easements are to be obtained for access road, rising main, water service and power supply. Site layout shall be arranged so as to minimise the number of easements. If possible, underground power supply shall not cross other services.

Approval of all relevant Statutory Authorities and bodies shall be obtained in relation to the proposed locations of access road, rising main including discharge access chamber vent stack, power supply and water service.

Minimum clear easement width for the access road shall be 4 metres. Minimum clear easement width for the rising main shall be 3 metres. Where it is intended to lay stormwater pipes as well as sewermain, rising main, water service and power supply within the access road easement, the easement width must be increased to accommodate the services. Refer to Section 4.2.5 for pipeline clearances.

4.2.5 PIPELINE CLEARANCES

Minimum horizontal clearances, where pipelines are laid parallel, between outside of pipe sockets or collars and clearance to property boundary are:

- Water service and power supply :
 - 300 mm clearance to each other
 - 500 mm clear of all other pipelines
 - 400 mm clear of boundary
- Watermain, rising main, sewermain, stormwater
 - 500 mm clear of water service and power supply
 - 600 mm clear of all other pipelines
 - 600 mm clear of boundary

Minimum vertical clearances between outside of pipe sockets or collars where pipelines cross are:

- 150 mm for pipelines up to 375 mm diameter
- 300 mm for pipelines greater than 375 mm diameter
- 225 mm for electricity power cables
- as required by Telstra for optic fibre cables
- as required by owner for high pressure gas mains

4.2.6 FENCING

Small pumping stations having only minor above ground features do not normally require fencing. However, the following guidelines should be considered:

- a) Fencing of stations should be to the requirements of the Corporation. Areas subject to vandalism may require security fencing.
- b) Sites adjacent to developed residential property may require fencing of the welded mesh type or timber paling type with galvanised posts.
- c) As fencing itself can have an adverse visual effect when security fencing is required the pumping station should be sited where the property is large enough to allow the fenced area to be adequately screened from general view; or in property

either previously owned or purchased specifically for the installation of the pumping station where screening may not be necessary.

4.2.7 ECONOMICS

Where technical constraints allow a choice in the type of pumping station arrangement, or type of pumping machinery, the final choice will normally be determined as the most cost-effective method. Cost effectiveness should be determined by a net present value analysis.

Factors to be considered are:

- a) Cost of pumping station structure, and its life.
- b) Energy cost over the life of the pumping station.
- c) Maintenance cost.
- d) Life and replacement cost of pumping machinery, including ancillary items such as switchgear, lifting gear and ventilation equipment.
- e) Rising main costs and life.
- f) Odour control costs if applicable.
- g) Net present values of alternatives. An example of the calculations necessary on a present value analysis is contained in Appendix 4B of this manual.

The net present value analysis shall include for the different efficiencies for each suitable pump, the variation in pump duty required for different pipe materials and class of pipe and the economic life of different pipe materials.

4.2.8 DESIGN LIFE

The design capacity of the civil structure should allow for future development, while for pumping machinery the design life varies with type of machinery used. Guidelines used by the Corporation are:

Civil Structures

For economic purposes, the serviceable design life of the civil structure should be considered to be 50 years.

Submersible Pumps

The life of submersible pumps is regarded as 15 years because most manufacturers do not hold spares for pumps that have been out of production for longer than this period.

Most schemes are augmented at intervals of approximately 15 years which makes it economical to augment submersible pumping stations by complete replacement of the pumping machinery. If staging is required at intervals of less than 15 years submersible pumps can be installed with reduced diameter impellers initially, and the full size impeller installed when increased output is required. This strategy requires that the motor be sized to suit the larger impeller. The use of the smaller impeller initially often incurs a reduction in efficiency which must be considered in the costing of alternatives.

Grinder Pumps

Grinder pumps may be allowed in certain low flow circumstances where present worth analysis including higher maintenance and shorter life of grinder pumps proved grinder pumps provided the lowest overall cost option. Operating experience has shown that this pumping machinery has a practical design life of 5 years or less. Cutting components are likely to require replacement every two (2) years or less. Grinder pumps enable the use of small bore rising mains down to a minimum of 50 mm.

Grinder pumps and/or rising mains under DN 100 mm must not be used for stations with design flows (PWWF) of five (5) litres per second and above. Where flows are below five (5) litres per second written approval of the Corporation must be obtained before designing stations with grinder pumps and/or rising mains under DN 100 mm.

4.2.9 DESIGN CAPACITY

The initial design capacity of the pumping station should be adequate to accept a minimum of 15 years of projected flows due to future development. Subsequent staging should involve upgrading of machinery only, with the civil structure being adequate for a minimum of 30 years.

The design flow to be pumped is the peak wet weather flow (PWWF) contributed by the catchment and is usually equivalent to 6 to 8 times the average dry weather flow (ADWF). Refer to Section 3.2 and Section 4.4 for design flow guidelines.

Where pumping stations are delivering to a treatment works, the design capacity and staging should be compatible to the treatment works staging strategy.

4.2.10 FLOW RELIEF / OVERFLOW STRUCTURES

A directed overflow structure shall not be designed or constructed without Hunter Water's approval.

Hunter Water shall decide whether a directed overflow structure is required based on an assessment of whether it is essential for the proper and efficient operation of the wastewater system. To facilitate this, the pump station concept design report must address as a minimum the following issues:

- The risk of harm to public health, environment or property if the proposed directed overflow structure is not constructed
- The risk of harm to public health and the receiving environment if an overflow from the directed overflow structure occurred
- The systems to be used to monitor overflows, power failures or mechanical failures of pumping or electrical equipment relating to or affecting the proposed directed overflow structure (consult with Hunter Water)
- Details of the proposed methodology for responding to overflows (consult with Hunter Water)

The design of overflow structures is covered in Section 3.6. Drawings of the Corporation's Standard Flow Relief Structures are contained in Part A of the Sewerage Standards.

The storage volume between Flood Alarm Level and Overflow Level to ensure available storage time as required by the Corporation is to be provided at both initial and ultimate stages, where applicable.

4.2.11 EMERGENCY STORAGE

Pump station failure may occur for a number of reasons including failure of power supply, switchboards, a number of pumps or failure of the pump station pipework or rising main. Emergency storage shall be provided to allow Hunter Water sufficient time to respond to such failures and to mitigate the potential for overflow to occur. Emergency storage is considered to include both wet well storage and storage in upstream gravity sewers. Emergency storage requirements for new and existing pump stations are discussed as follows:

New Pump Stations

For new pump stations a minimum of 4 hours storage at ADWF conditions shall be provided between Flood Alarm Level and overflow level. Systems draining to waters deemed sensitive by Hunter Water (eg: Hunter Water Special Catchment Areas, waters near oyster leases, waters classified “P”, “U”, or “S” as defined in the “An Atlas of Classified Waters in New South Wales”) require 8 hours storage. Consult with Hunter Water to confirm emergency storage requirements prior to commencing concept design.

Options to be considered for emergency storage in order of preference include:

1. Use of larger diameter wet wells;
2. Online storage in larger diameter gravity sewers;
3. Use of larger diameter manholes.

Where it is not proposed to include all the emergency storage in the wet well, justification should be provided in the design report. Offline storage structures shall not be used for new pump stations.

Existing Pump Stations

Where an existing pump station is to be upgraded (including the construction of a new pump station wet well to replace part or all of an existing pump station), the amount of storage required will be the same as for new stations. In the event that there are significant difficulties associated with providing additional storage (for example, site constraints) then this should be discussed with Hunter Water.

Options to be considered for emergency storage in order of preference include:

1. Use of larger diameter wet wells;
2. Inline storage in larger diameter gravity sewers;
3. Use of larger diameter manholes;
4. Offline gravity sewers;
5. Offline storage tanks.

Where it is not proposed to include all the emergency storage in the wet well, justification should be provided in the design report.

Due to the potential for odour generation, offline sewers or storages should contain allowance for washing down of the emergency storage after each use or other odour control measures should be implemented as part of the proposed storage option.

Other Measures to be Included For All New and Existing Pump Stations

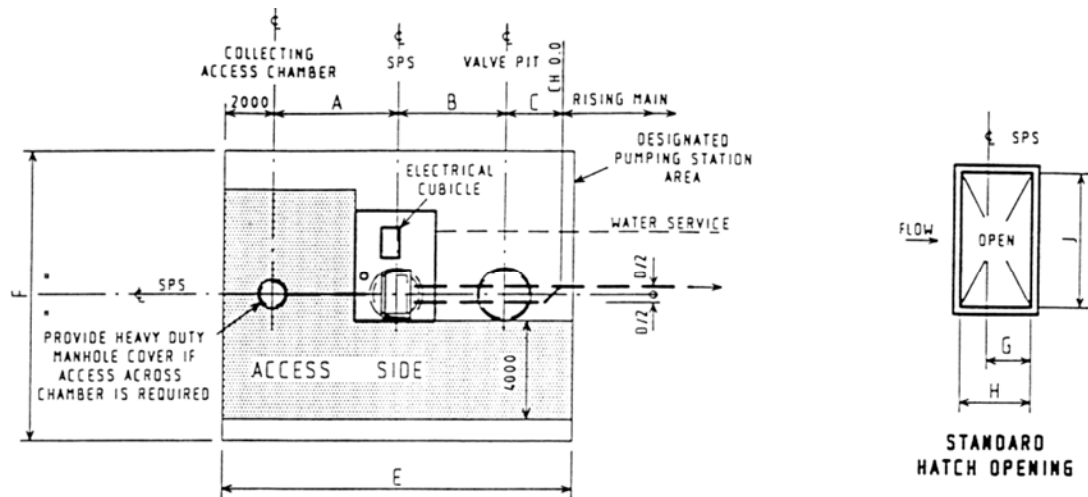
In addition to the provision of the required amount of emergency storage as discussed above, the following additional measures shall be provided for both new and existing pump stations to minimise potential wastewater overflows:

- A bypass pumping connection point on the rising main;
- A generator connection point to allow the connection of a portable generator. For pump stations with multiple duty pumps, the generator connection point only needs to be sized to run sufficient pumps to discharge the peak dry weather flow;
- For large critical new or existing pump stations it may also be necessary to provide on site permanent backup power supply and/or standby generators. The requirement for these additional items should be discussed with Hunter Water prior to commencing concept design;
- Access for tankering. Note that it is necessary to confirm that the tanker pumps will have sufficient suction (6m) to overcome the difference in head between the tanker and the water level in the tankering point (eg: wet well or collecting manhole). If sufficient suction is not available provide a 3-phase power outlet to allow the use of a drop-in submersible pump (note that mains power will not be available in the event of a power failure).

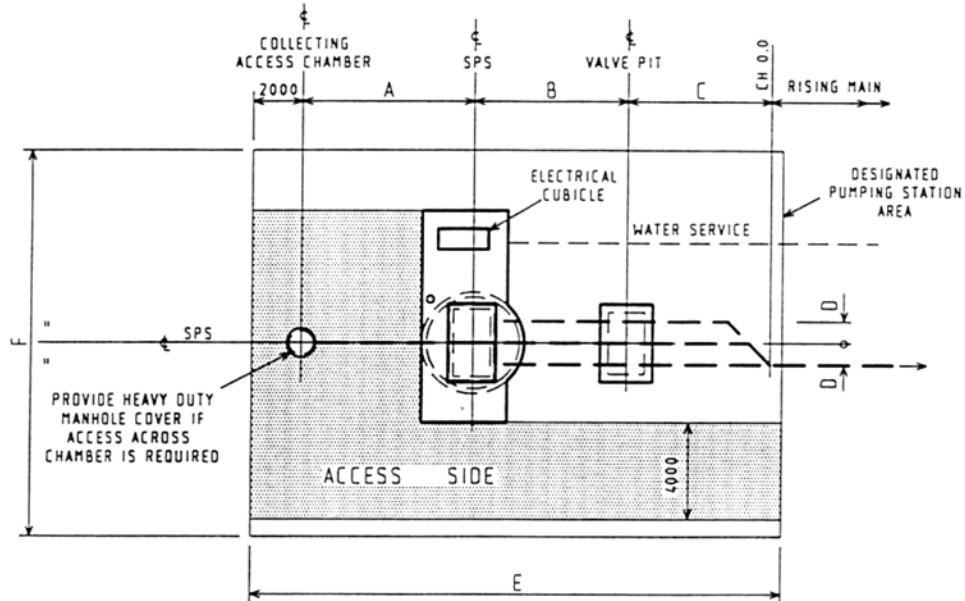
The designers report shall include discussion of the recommended mitigation measures and calculations of available storage time between Flood Alarm Level and Overflow Level at ADWF and PWWF for initial and ultimate flows.

4.2.12 SCREENING AND GRIT REMOVAL

It is no longer the practice to provide for screening or for removing of grit from raw sewage at pumping stations. It was once common to perform such operations in advance of the pumps to protect pumps from grit abrasion and blockages. Modern pump design and use of modern alloys has reduced the need for pump protection although unusually severe operating conditions may dictate that some pump protection is necessary.



PLAN ON DUPLEX PUMPING STATION



PLAN ON TRIPLEX PUMPING STATION

RECTANGULAR VALVE PIT	CIRCULAR VALVE PIT	PUMP STATION	A	B	C	D	E	F	G	HATCH OPENING H x J
—	DN 1800 RC PIPE	DN 1800 - DUPLEX	5000	4400	2300	660	14200	12000	450	900 x 1600
—	DN 2100 RC PIPE	DN 2100 - DUPLEX	5000	4400	3000	660	14900	12000	450	900 x 1600
—	DN 2100 RC PIPE	DN 2400 - DUPLEX	7000	6100	3400	700	19000	16000	635	1270 x 1800
—	DN 2100 RC PIPE	DN 2700 - DUPLEX	7000	6100	3400	950	19000	16000	635	1270 x 2000
2100 x 2700	—	DN 2700 - TRIPLEX	7000	6100	3400	615	19000	16000	780	1270 x 2000
—	DN 2100 RC PIPE	DN 3000 - DUPLEX	7000	6100	3400	950	19000	16000	780	1270 x 2000
2100 x 2700	—	DN 3000 - TRIPLEX	7000	6100	3400	615	19000	16000	750	1500 x 2000
2100 x 2700	—	DN 3800 - DUPLEX	7000	6100	3400	950	19000	16000	930	1500 x 2000
2100 x 3200	—	DN 3800 - TRIPLEX	7000	6100	5200	900	20800	16000	700	1500 x 2800
2100 x 2700	—	DN 4600 - DUPLEX	9000	7500	5200	1500	24200	18000	1100 1200	1800 x 3000
2100 x 3200	—	DN 4600 - TRIPLEX	9000	7500	5200	1000	24200	18000	1100 1200	1800 x 3000

HARDSTAND AREA - SHOWN THUS

- PROVIDE - 1. ADEQUATE TURNAROUND
2. CRANE PARKING AREA
3. 3000 WIDE ACCESS ROAD WITHIN
4000 WIDE EASEMENT TO SPS

SEWAGE PUMPING STATION STANDARD LAYOUT

FIG. 1

4.3 RISING MAIN DESIGN AND SELECTION

4.3.1 GENERAL

The following is covered in this Section:

- a) Survey and Alignment of Rising Mains;
- b) Crossings
- c) Velocities in (and diameter of) rising mains;
- d) Detention Time in rising mains;
- e) Septicity Control in rising mains;
- f) Waterhammer in rising mains and Pipe Selection;
- g) Pipe Size Selection and Hydraulic Head
- h) Air Vents on Rising Mains;
- i) Scours on Rising Mains;
- j) Emergency Isolating Valves on Rising Mains;
- k) Connection of Rising Mains;
- l) Sewer Rising Mains Pipe Materials.

The Designer shall also consider environmental impact (refer to Section 1.2)

4.3.2 SURVEY AND ALIGNMENT OF RISING MAINS

Location of Sewer Rising Mains

Rising mains should be located, consistent with other requirements, so as to keep gross head to a minimum, thereby minimising pump size and operating costs.

Where practicable, rising mains should be located in public thoroughfares to ensure ease of access for future maintenance and to obviate the need for easements. The preferred location for the rising main is in the footpath but not within the watermain allocation.

Where this is not possible, the location in private property should be adjacent to and parallel to boundaries and easements obtained to satisfy future operational requirements. Care shall be taken to avoid that area likely to be built on.

Rising mains shall be kept as short as possible to reduce the residence time of sewage in the main thereby aiding in the avoidance of septicity and its associated problems.

The survey for a sewer rising main shall normally commence at the valve pit at the pumping station and terminate at an access chamber on the receiving sewer.

Changes in direction or grade shall be made by the use of angle bends. Standard bends should be used where practicable eg, 45° , 22.5° , 11.25° , but 90° should be avoided if possible.

Bends shall be indicated on design plans either by line bearings or angles of deflection. Horizontal and vertical bends shall be indicated on longitudinal sections as deflections.

Rising mains shall be designed to provide at least the minimum cover for protection of the pipe as shown in the relevant Corporation Standards.

The longitudinal section profile should be generally rising with the discharge point higher than the pump. The profile may include some downhill length but should not be overly undulating. Simple manual air release valves shall be provided at all high points. Sags should be avoided in the grading. Where a sag is unavoidable, a scour shall be provided. Preferably use a gravity scour. Where the scour pipe cannot be drained to a suitable sewer access chamber a pump out pit is to be provided.

For more detailed information on survey requirements refer to Section 1.3 and Section 3.8.

Basic Marking and Recording of Rising Main Location

Benchmarks are to be established in accordance with Hunter Water procedure.

Pegs or other suitable marks (spikes, etc) are to be placed at all proposed structures, start and ends of mains, all changes of direction and at 50 metre intervals. These marks shall be tied in to property boundaries. Marks more than 2 metres square off a boundary shall be tied in by two (2) ties to the ends of a measured base.

The rising main is to be traversed and connected to local ties by bearing and distance. Datum line of traverses to be MGA where appropriate.

Origin of Levels

Origin of levels is to be a State Survey Mark, Permanent Mark or Hunter Water Bench Mark. Designers are to confirm the details, including level, of receiving sewers. All levels shall refer to AHD

4.3.3 CROSSINGS

Railway Crossings

The crossing of a railway should be as close as practicable to right angles to the track. The normal method of construction under a railway is by “thrust boring” an encasing pipe. The crossing must be to the requirements as set out in ROA code of the State Rail Authority whose prior approval for the crossing and the design must be obtained.

Road Crossings

The crossing of a roadway should be as close as practicable to right angles to the road alignment. Local roads, subject to Council approval may be crossed using conventional trenching methods. Major roads eg. RTA classified, Council Arterial, Sub-arterial, and Collector roads require encased thrust bore pipe crossings similar to railways and as agreed with the relevant Authority.

Where a rising main is to be constructed through an intersection or a single lane roundabout, the main shall be laid through the intersection in a straight line along the same alignment that would be used if the intersection was not present. In the case of two or more lane roundabouts the main should deviate around the roundabout on an alignment selected to

minimise the extent of construction within the road pavement. These arrangements are shown in Appendix 4F. Where possible, valves should be constructed in the footpath to reduce the potential for damage by traffic.

Drainage and Creek Crossings

Watercourses and stormwater pipes should be crossed at right angles, if possible.

Rising mains shall cross over stormwater pipes rather than under, if possible.

The type of creek crossing causing the least upset to the environment is below bed level. The use of aqueducts to cross waterways should be avoided as they could adversely affect the hydraulics of the drainage system and are aesthetically undesirable. Consideration should be given to utilising existing or proposed bridges.

Where below creek bed, the depth of the pipe below bed level is dictated by:

- a) Grading requirements
- b) Creek bed material (rock or OTR)
- c) The likelihood of scouring of the bed
- d) Future drainage works

In navigable waters, the prior approval of the Maritime Services Board shall be obtained.

Where the rising main is located within a drainage reserve, it should ideally be located parallel and adjacent to the reserve boundary.

Rising mains should be located clear of unlined waterways to minimise the effect of trenches on groundwater levels.

4.3.4 VELOCITIES IN RISING MAIN

A minimum velocity of 0.6 m/s has generally been accepted as necessary for satisfactory transport of solids through a rising main. However, if velocity is maintained constant throughout the range of pipe sizes it can be shown that as pipe size increases the shear stress exerted on the wall decreases. At lower shear stress levels slime growth on the wall may increase effectively causing high head losses in the system. In order to achieve reasonable control of slime growths, a velocity found by the formula hereunder is considered desirable under normal dry weather pumping rates:

$$V = -0.3 \log (0.1/D)$$

where V = Velocity (m/s)
 D = Pipe Internal Diameter (mm)

Providing this order of velocity is attained the boundary roughness (k) may be taken as 0.3 mm. Such velocity (0.9 m/s in 100 mm dia. to 1.13 m/s in 600 mm dia.) achieves a shear stress of 0.3 kg/m^2 on the pipe wall irrespective of pipe size.

Where such velocity leads to excessive head losses or discharge rates, the velocity may be reduced, subject to written approval by the Corporation, but the slime growth may be expected to increase the effective boundary roughness. It is expected that the effective boundary roughness may increase to 1.5 mm or more if the shear stress is reduced to 0.15 kg/m². Such shear stress is achieved at a velocity found by:

$$V = -0.215 \log (0.4/D)$$

Velocity here varies from 0.52 m/s in 100 mm dia. to 0.68 m/s in 600 mm dia. and solids transportation would be considered barely adequate. For lesser velocities settled material may not be picked up on the resumption of pumping thus allowing anaerobic fermentation and the production of odorous gases to occur.

For boundary roughness factors (k) for velocities in excess of the above, reference is made to “Tables for the Hydraulic Design of Pipes and Sewers” published by Hydraulics Research Station Ltd., Wallingford, where the following values for sewer rising mains in normal condition, regardless of pipe material, are recommended:

Mean velocity	1.0 m/s	k = 0.3 mm
Mean velocity	1.5 m/s	k = 0.15 mm
Mean velocity	2.0 m/s	k = 0.06 mm

Maximum velocities in rising mains are generally limited to approximately 3 m/s due to the high head losses occurring at higher velocities. Additionally at velocities above 4 m/s scour of the pipe material from entrained grit in the sewage may be a problem.

It can be seen that where it is intended to use a variable output pump that would pump sewage as it arrives at the pumping station the design of rising main is critical.

Essentially the fact remains that, in a single rising main, the lowest rate of pumping should not be less than approximately 25% of the maximum rate.

4.3.5 DETENTION TIME

Where the transfer of oxygen to sewage is prevented by the exclusion of air, sewage may ferment anaerobically allowing the production of odorous and hazardous gases, making the sewage more difficult to treat. It is, therefore, essential that the detention time of the sewage in the rising main and pumping station be kept to a minimum or that provision be made for treating the sewage in the rising main. Generally, the retention of fresh sewage in the rising main for a period of up to four hours should not be a problem. However, for stale sewage, sewage with low oxygen content or at elevated temperatures problems may be evident even with retentions of less than one hour.

Detention time is generally considered on the basis of the average dry weather flow (ADWF) and the volume of the rising main plus the volume of sewage contained in the wet well such that:

$$T = \frac{0.025 Q_p + 0.218 LD^2}{ADWF}$$

where	T	=	Detention Time (hours)
	Q _p	=	Pump Capacity (L/s)
	L	=	Rising Main Length (m)
	D	=	Internal Diameter of Pipe (m)
	ADWF	=	Average Dry Weather Flow (L/s)

Generally, as it is the largest factor in the system volume, careful selection of the rising main diameter is necessary to minimise detention times. If the volume of the rising main cannot be reduced sufficiently to overcome a detention time problem, the following solutions may be considered:

- (a) Where inflow to the station is expected to increase due to rapid development, lime dosing can overcome the problem until the detention time is reduced to an acceptable level. Alternatively a hose can be temporarily connected to the pumping station water service to provide a continuous flow of fresh water into the wet well to compensate for the lack of sewage inflow until sufficient development occurs.
- (b) Installation of a rising main to serve Stage 1 development only. The rising main would then be increased in capacity by duplication at the time of Stage 2 augmentation. This alternative incurs the following penalties:
 - (i) If the friction head with two mains is to remain the same as that with one main the volume in the two rising mains will only be increased by approximately 20% over one.
 - (ii) If the volume contained in two mains is to remain the same as that in one main the friction head in the two mains will be increased by approximately 60% over one.
 - (iii) Irrespective of whether detention remains constant or friction head remains constant there will be an increase in wall area when two pipes are used in lieu of one. The increase will be more than 50% in the case of the former and greater than 40% in the latter. As the major contributor to sulphide generation is the slimes on the wall of the pipe the amount of sulphide generated will be increased accordingly unless the design providing dual pipelines has overcome the problem.
- (c) Injection of air or oxygen into the rising main to keep the sewage in an aerobic state. This method incurs penalties of extra complexity, extra running cost and provision of gas extraction facilities from the rising main.
- (d) Injection of oxidising agents such as hydrogen peroxide, chloride or other proprietary lines. As these alternatives are generally costly they would not normally be considered for initial design but only for mains which in operation cause problems and due to the profile of the main, other solutions such as air injection are not applicable.
- (e) Injection of nitrate into the rising main to maintain the sewage in an anoxic state and prevent progression to an anaerobic state.

- (f) Injection of iron salts to bind up any dissolved sulphides and therefore prevent generation of H_2S gas.
- (g) Injection of biological reagents or enzymes to control pipe slimes and discourage the generation of H_2S producing bacteria.

4.3.6 SEPTICITY CONTROL

General

Sewage which has become septic will contain high levels of hydrogen sulphide (H_2S). H_2S will not damage a rising main which remains full except perhaps at high points. The H_2S remains in solution and is diluted by the sewage to such an extent that no corrosion of the carrying pipe will result. However at the receiving access chamber and in the sewer lines immediately downstream problems may occur.

With the reduced pressure at the top end of a rising main, H_2S will come out of solution and enter the air space in the gravity main. Any drops of moisture on the sewer crown will dissolve the H_2S which can then be oxidised by bacteria to form sulphuric acid. The latter is very corrosive particularly to cast iron, concrete and cement lining.

To control the formation of H_2S several methods may be used:

Use of Lime

Lime 'slug-dosed' into pumping station wet wells at intervals of two or three days will suppress sulphur reducing bacteria in the rising main wall slimes so that they are kept inactivated and do not develop strongly enough to produce significant quantities of H_2S .

This method has limitations in that it only controls the activity of the wall slimes; septicity can still occur in the sewage itself. However, it can be used in those cases where oxygen or air injection (ie. environment control) is not practised. It is particularly useful as a temporary or seasonal solution eg. used during summer months.

Use of Air

Air pumped in (at rising main pressures) at a rate of 0.011 m^3 free air/min/mm dia. of rising main will effectively suppress sulphur reducing bacteria and therefore the H_2S . It is necessary to keep injecting air continuously even between actual pumping cycles. The volume required may need to be varied depending on length of main, detention times, etc.

Since only the Oxygen from the air will be significantly dissolved, the undissolved Nitrogen will collect and travel up the crown of the pipe. If the rising main is not laid with a continuously rising gradient, the Nitrogen will accumulate at peaks and interfere with pumping, unless allowed to escape through an air-valve (see Section 4.3.9).

Another air injection point would probably have to be introduced further along the line where the rising main again is on a rising gradient.

Air injection, particularly where there are no peaks in the line, is simple and comparatively inexpensive.

Considerable splashing is experienced in the access chamber or other structure at the top end of the rising main, as excess gases are released. In an access chamber not properly

constructed this would be very noisy and make entry impossible whilst pumping. At Treatment Works inlets the rising main should curl over and down into a stilling basin to prevent the upwards jetting that occurs. A syphon breaking device should be fitted to prevent syphoning of inlet tanks back down the line in the event of a break in the rising main.

Use of Oxygen

Injection of pure oxygen has the advantage of eliminating the free nitrogen problem in rising mains which peak as well as allowing higher solubility of oxygen. Extensive work has been done in obtaining high solution rates with oxygen injection. The oxygen may also provide some treatment of the sewage.

Use of Hydrogen Peroxide (H_2O_2)

Because H_2O_2 is in a soluble form there is no problem with rising mains which peak, ie. no air lock caused. The H_2O_2 preferentially oxidises H_2S at high concentrations. However, H_2O_2 is unstable and may lose its oxidation potential with prolonged storage. It cannot compete with oxygen injection on a cost basis. Its main advantage is in correcting the effects of septicity.

It enables an attractive and possibly economic use of rising mains as partial anaerobic treatment devices. The sewage could be deliberately allowed to turn septic, (the pipeline is totally enclosed so that no odours would ensue), some thirty minutes travel from the pipe outlet, H_2O_2 could be injected in solution to oxidise any H_2S present. The sewage thus treated would have had its organic ammonia converted bio-chemically by the septic action into Ammonia (NH_4) which is easily treated in the usual sewage treatment works. However, this should be approached with caution as it may change the proportions of soluble and settleable loads in the treatment works causing overload to some treatment units.

Use of Water

As a temporary measure, whilst development is building up to the required design flow, water can be flushed into gravity mains leading to a pumping station. This will reduce detention time in the system and introduce some oxygen. This can be expensive if water from supply mains is used. Water not sourced from mains supply must be free of chlorides.

Use of Chlorine

The addition of sufficient chlorine destroys hydrogen sulphide present and at higher doses inhibit slimes. As chlorine is expensive and excessive residuals may introduce problems with respect to metallic corrosion and personnel safety, it is important that dosing rates closely follow actual requirements. May also have detrimental effects on sewage treatment plants.

Use of Nitrate

Sewage microbial populations will first consume all available dissolved oxygen, then nitrates then sulphates. If nitrate is introduced, progression to sulphate consumption can be prevented. Therefore the sewage goes from an aerobic state to an anoxic state but does not progress to an anaerobic state. Potential for adverse effects at the sewage treatment plant should first be investigated.

Use of Iron Salts

After sewage has become septic, iron salts can prevent the formation of H_2S gas. Iron salts bind with dissolved sulphides on contact forming a permanent precipitate thus removing dissolved sulphides from the sewage. Potential for adverse effects at the sewage treatment plant, particularly with regard to sludge, should first be investigated.

Use of Biological Reagents

There are many and varied biological reagents now being offered. It is usually claimed that they promote the dominance of non hydrogen sulphide producing bacteria. It is also claimed that they strip pipe slimes and break down fats and grease. Hunter Water Corporation experience indicates mixed results with the use of these products.

4.3.7 WATER HAMMER AND PIPE MATERIAL SELECTION

General

Water hammer occurs due to a rapid change in pressure in the rising main caused by a sudden variation in flow velocity. In a pumping system this occurs upon pump start and shut down, the latter usually causing the most severe water hammer. When a pumping station commences pumping there is a rapid increase in pressure in the rising main; this increase in pressure propagates along the rising main accelerating the flow until a steady state hydraulic grade line (or pressure head line) is established. Normally there will not be a severe problem, with increasing pressures, when a pump commences operation. Problems are most frequently encountered when a pump or pumps fail instantaneously due to, for example, a power failure. With a rapid cessation of flow through the pump(s) there will be a rapid decrease in the pressure head in the rising main. In some cases upon shut down the pressure in the main may fall below the vapour pressure of water and actual separation of the water column in the main occurs. Upon rejoining large positive pressure surges which may be very much greater than the normal operating pressure will occur. Water hammer analysis is necessary to ensure that the material and strength of pipe selected is adequate to sustain the surge pressures developed and determine requirements for thrust restraint design.

As different material types (even of the same nominal size and class) may cause differing surge pressures to develop it is recommended that water hammer analyses be carried out during preliminary design.

For a basic understanding of water hammer and its control the designer is referred to “Water Hammer Control in Pipelines” by T. H. Webb.

Methods of Analysis

The three methods by which analyses are generally carried out are:

- 1 Analytical
- 2 Computer
- 3 Graphical

The analytical method follows the basic principles and laws developed by Joukowsky and others. It is long and tedious even allowing for the assumptions generally made to simplify calculations.

The use of the computer allows the rapid analysis of water hammer in pipelines. “WATHAM”, a program developed by Hydraulic Computer Programming Pty Ltd is used by the Corporation for the majority of its water hammer analysis. This program can also provide graphical plotting of the HGL maximum envelope. An example of the “WATHAM” output is included at Appendix 4C.

Many other computer packages for the investigation of water hammer problems are available, with “LIQT” - developed by Stoner Associates Inc. and available through J L Lancaster and Associates Pty Ltd being another well known program.

Until recently, and even now in some computer programs, there have been difficulties with realistic stimulation of the sequence of events following column separation. Programs have generally overestimated the effect of the separation, this gives rise to the prediction of excessive positive internal pressures immediately following separation. This could lead to the installation, if based entirely on computer results, of some unnecessary surge mitigating devices. Computer results, therefore, should never be simply accepted without careful evaluation.

Graphical analysis uses the principles of the analytical method and the commonly used Bergeron method allows assumptions to be made which for most practical purposes give reasonably accurate results. The method may be used for preliminary design.

The flow chart at Figure 2 depicts the data required and the course of action followed in relation to the various methods of analysis. When assembling data for analysis, it is important that the data be modelled to resemble, as closely as possible, the intended pump operating and electrical control conditions of the rising main.

Water Hammer Control

Because of the content of sewage, pressure relief and other mechanical devices are generally not considered suitable for control. Surge tanks are sometimes used but require a supply of fresh water, often in copious quantities. Lowering the rate of approach of separated columns by the use of a bypass (eg a reflux valve with shaved flap) can also be useful in reducing the maximum pressure developed.

Often, however, the most satisfactory method of control is to ensure that the surge pressures which do occur are within the safe working pressure of the pipe selected. This may limit choice of pipe material and/or require adjustment of the pipe diameter to reduce the normal velocity.

Pipe Materials Selection

The pipe selected must be strong enough to withstand the maximum surge resulting from water hammer. In addition, it is necessary to assess whether adequate trench support is provided to protect against failure of the pipe as a result of water hammer. In ground, the pipeline is tested after installation with a pressure at least equal to the design maximum pressure maintained for four to twelve hours.

The following materials are used for sewer rising mains:

- Ductile Iron Cement Lined (DICT)
- Unplasticised, Modified and Oriented Polyvinyl Chloride (PVC)

- Glass Reinforced Plastic (GRP)
- Steel Cement lined (SCL) (special applications only)
- Polyethylene (PE) (Less than 100 mm internal diameter only)

Rising mains DN 100 to DN 300 may be DICL or PVC pressure pipe Series 2 (Cast Iron Outside diameters). PVC pipe to meet the following standards:

PVC-U	AS/NZS 1477 – 1999
PVC-M	4765 (int) – 2000
PVC-O	4441 (int) – 1996

Rising mains DN 375 to DN 600 shall be either DICL or GRP.

Where written approval has been granted to use small diameter rising mains (less than DN 100), either PVC to AS/NZS 1477 or polyethylene PE80 Type B to AS 4130 may be used.

a) Ductile Iron Cement Lined

Ductile Iron Cement Lined (DICL) pipe is used for sewer rising mains in sizes DN 100 to DN 750. Class PN35 is Hunter Water's standard and shall be used for rising main applications. Subject to approval from Hunter Water, PN20 may be used in above ground pipework in wastewater pump station dry wells and valve pits. The pipe is protected from external corrosion by the application of loose polyethylene sleeving. DICL pipes are jointed using elastomeric joint rings. Ductile iron cement lined fittings are to be used where required.

b) Polyvinyl Chloride

Polyvinyl Chloride (PVC) pressure pipe is used for sewer rising mains in sizes DN 50 to DN 300. Unplasticised (PVC-U), Modified (PVC-M) and Oriented Polyvinyl Chloride (PVC-O) pipes are available for use in sewer rising mains. Minimum Class 12 pipe is currently specified.

Series 2 (Outside diameter compatible with ductile iron and cast iron) is to be used for sizes DN 100 to DN 300. Series 1 may be used for sizes DN 50 and DN80. PVC to AS/NZS 1477 Series 1 is not to be used for mains DN 100 or larger. PVC pipes are jointed using elastomeric joint rings. Ductile iron fittings with a fusion bonded polymeric coating are to be used with PVC pipes DN 100 to DN 300. PVC fittings may be used for sizes DN 50 and DN 80 only.

c) Steel Cement lined

Steel Cement Lined (SCL) pipe is used for sewer rising mains typically in sizes larger than DN 300 and for special applications such as aqueducts. The pipe is protected from external corrosion by a polyethylene fusion bonded coating. The pipe can be jointed by elastomeric jointing rings in sizes greater than DN 300, which is the preferred system, or by welded joints. Welded joints require reinstatement of the internal and external protective coatings. Cathodic protection may also be required.

d) Polyethylene

Polyethylene pressure pipe is used for small diameter sewer rising mains in sizes DN 63 to DN 110. Minimum Class PN 12.5 PE 80 Type B pipe to AS/NZS 4130 is currently specified. Small diameter polyethylene pipes are jointed using mechanical compression fittings, electrofusion couplings or butt welded fusion. Polyethylene fittings to AS 1460 are to be used with small diameter polyethylene pipes.

e) Glass Reinforced Plastic

Glass Reinforced Plastic (GRP) pressure pipe is used for sewer rising mains in sizes DN 375 to DN 750. Minimum Class PN 16 pipe to AS 3571 is currently specified. GRP pipes are commonly jointed using elastomeric joint rings. GRP fittings designed in accordance with BS 7159 and manufactured in accordance with AS 2634 are to be used.

The following guidelines should be noted when considering the suitability of pipe with respect to strength.

a) Ductile Iron

Ductile Iron pipes are particularly strong in ring tension and sustain very high positive pressures resulting from water hammer. The maximum pressure should not exceed the allowable pressure for the pipe class as defined in AS 2280-2004.

Where it is intended to use flanged DI pipes the designer is reminded that the allowable pressures are limited to the pressure rating of the flanges used (refer AS 4087).

b) Plastic Pipe

Where plastic pipe (including Polyvinyl Chloride, Polyethylene or Glass Reinforced Plastic) are to be used for sewer rising mains, the selection of the pipe material and class shall take into account the potential for fatigue resulting from dynamic pressure loading from pump starts.

The de-rated fatigue capacity of the pipe is based on the number of pump cycles and shall be calculated and applied in accordance with the procedure in Appendix 4E. The number of cycles shall be determined, based on an operating life of 100 years. The number of cycles is determined by calculating the number of pump starts over the design life and multiplying this figure by two. Not less than 5,000,000 cycles shall be used for the purposes of calculating the de-rating factor. In addition to the above requirements, where GRP pipe is to be used the operating pressure range shall not exceed half the pressure class of the pipe.

Fittings and Thrust Restraint

Rising main fittings must be designed to be able to sustain the maximum surge pressures resulting from water hammer. Anchorages (including straps and puddle flanges) and thrust blocks must also be able to sustain those pressures. Field testing is often carried out with the rising main at least partially uncovered. Anchorages required to resist uplift should therefore, be designed without the soil load being taken into account or attention must be specially drawn to the fact that extra temporary anchorage is required. Design of thrust restraint shall incorporate a factor of safety of not less than 2 to account for variability in soil properties.

Restrained joints such as “Tyton-lok” gasket restrained joints should only be specified where the use of concrete anchor blocks is not practical, such as:

- in congested services areas where future interference with other services can be anticipated;
- when commissioning of the pipeline is urgent;
- where logistics of providing concrete blocks are difficult ie, poor soil conditions.

The details of the proposed restraint together with the design test pressure are to be clearly shown on the plan. Prior to designing any thrust restraint system the designer should be fully aware of the Acceptance Testing requirements of the specification.

Where it is proposed to upgrade the WWPS at a later date, the rising main fittings and thrust restraint shall be designed for the pressures that will result from the proposed upgrade.

For all rising mains DN300 and greater consult with Hunter Water to confirm whether further upgrades or increases in pressure are likely and therefore if a higher design pressure should be adopted.

4.3.8 PIPE SIZE SELECTION AND HYDRAULIC HEAD

As discussed in Sections 4.3.4, 4.3.5 and 4.2.7 consideration of the following is required when selecting the size of the rising main:

- a) self cleansing conditions;
- b) slime control conditions;
- c) detention times;
- d) maximum velocities
- e) minimum capital and operating cost of the pumping system.

The use of a single rising main may not be able to satisfy all criteria and in such cases the following may have to be considered:

- a) Variable or two speed pumping with two (or more) rising mains with dry weather flow through one rising main and wet weather flow through all mains simultaneously. With more than one main normal practice is for each to be used in turn in dry weather.
- b) Staging of rising mains and pumps particularly when inflows to the pumping station in the early years of operation are low compared with ultimate development. In such cases the rising mains for each stage should be designed to comply with the selection criteria.

Where the friction head of a selected rising main increases the total dynamic head beyond the normal range of centrifugal pumping units (approximately 40m), it may be necessary to increase the size of the rising main.

If it is not desirable to increase the size of the rising main and if the total head is greater than the value suitable for single stage pumping, series connected pumps may be considered. Series pumping, however, may incur higher cost and greater complexity and should not be adopted without thorough investigation including a present value analysis.

Discharge fittings in sewage pumping stations are normally made one size smaller than the rising main to create higher velocities to prevent silting in reflux and stop valves and minimise the cost of fittings. Special consideration is required where the rising main is short and the static head is small with the head loss in fittings a high proportion of the total head loss.

Friction loss in pipelines should be calculated using Colebrook - White formula:-

$$v = - (32gRS)^{0.5} \log [k/14.8R + 1.225 v / R (32gRS)^{0.5}]$$

Where

- v = velocity (metres / second)
- R = hydraulic radius (metres)
= A/P
- A = area of flow
- P = wetted perimeter
- S = slope (metres / metre) - ie. friction loss
- g = gravitational acceleration (metres / second²)
- ν = kinematic viscosity of water (metres² / second)
= 1.1425 x 10⁻⁶ m²/s at 15°C
- k = Colebrook-White roughness coefficient, linear measure of roughness, the Nikuradse equivalent sand roughness (metres)
- Q = A v

4.3.9 AIR VENTS ON RISING MAINS

Any entrained air or gases produced as the result of bacterial fermentation in the sewage will under the pressures in the pipeline either dissolve to a greater extent than at atmospheric pressure, or in the case of insoluble gases be compressed to small size bubbles.

As the pressure reduces along the length of the main such gases will tend to come out of solution (boil off) or if undissolved, the bubbles will enlarge and coalesce. At high peaks in the line these gases can collect and tend to reduce the carrying capacity by acting as an air lock and reducing the available waterway. This will increase velocity head at that point and with it the friction head. Any increase in head will reduce the quantity pumped.

Any sharp “peaks” in the line must therefore be provided with a device known as an air release valve through which accumulating gases can escape without an escape of the sewage being pumped. In water supply schemes which have the same problem, perhaps to a lesser degree, the familiar double-air-valve, which is automatic in operation can be used. Such a valve, without modification, is totally unsuitable for use with sewage since it would quickly choke with rags and paper.

Alternative designs which offer non clog holes have been developed. In general, however, the Corporation avoids the use of automatic air release valves on sewage rising mains.

Normal practice is to use manually operated taps (see Standard Drawing SCP-1004). These, if regularly used, are quite satisfactory and are simple and cheap. They will be useless if not properly maintained.

4.3.10 SCOURS ON RISING MAINS

With the choice of good self-cleansing velocities in rising mains the incidence of choked mains will be rare. There is always however the chance of break in the line due to waterhammer, cracked pipes, physical damage etc. When this occurs it is necessary to partially drain the line to enable repair work to be undertaken.

On short mains, without “peaks” in the line, it is possible to run the sewage back into the station wet well and even back into the supplying gravity sewers providing it does not come out through access chambers or house gullies.

Where peaks exist in the line it will not usually be possible to syphon the pipe contents back as the vacuum effect will be broken by the release of dissolved and entrained gases.

If it is a major break the pipe will have emptied through the break. But if, as is normally the case, it is only a leak the water level must be lowered and if this is not possible by relief at the station a scour must be used.

Scours should connect to, in order of preference:

- a) A separate sewer (gravity scour)
- b) A pump out chamber (discharge to be removed by sullage tanker)
- c) Emergency storage (not usually provided)

Refer to Standard Drawings SCP-1005 and SCP-1006 for typical details.

Provided slime control velocities are achieved, periodical scouring of sewage rising mains is generally unnecessary.

4.3.11 EMERGENCY ISOLATING VALVES ON RISING MAINS

On sewage rising mains, when bursts occur pumping can be stopped and the only back flow is from the main itself downstream of the burst, unless the main discharges below the surface of a tank which is not fitted with a syphon breaking device. Therefore emergency isolating valves are not normally required.

Isolating valves are necessary at the junction with another rising main where use is made of a length of rising main common to more than one station. They may also be required at railway crossings and crossings of features such as rivers with major pipelines.

The inclusion of isolation valves at every kilometre or two on large diameter and/or very long rising mains should also be considered. A rising main several kilometres in length with no way to isolate individual sections may present practical difficulties for testing during construction and for future maintenance requirements.

4.3.12 CONNECTION OF RISING MAINS TO ACCESS CHAMBERS

The entry of pumped sewage into an access chamber should be in such a fashion to eliminate splashing and reduce turbulence to a minimum. The inlet for the rising main in the receiving access chamber should be in line with the direction of flow in the outlet from the access chamber. Where this is not possible the rising main inlet shall be made at an angle of not more than 30 degrees to the direction of flow in the outlet. A rising main should not

terminate in a free fall from some height above the access chamber invert. The soffit of the rising main inlet should be at the same level as the soffit of the outgoing sewer gravity main, provided this gives a small drop in invert across the access chamber. Acceptable arrangements for entry into the discharge access chamber are shown in Standard Drawing SCP-1002. Where it is not proposed to adopt the preferred method where the rising main discharge point is the highest point on the rising main then:

- The reasons for doing so shall be discussed in the designers report;
- The impact on pump head and flow rate during pump startup shall be determined. The proposal will not be acceptable if it is likely that the pumps will “hunt” for a pump duty at startup;
- The distance from the high point to the upstream side of the discharge manhole shall not exceed 20 metres if the arrangements in SCP-1002 are to be used.
- Where it is proposed to place the rising main highpoint further than 20m from the connection point, a new receiving access chamber shall be constructed with connection arrangements in accordance with SCP-1002. Gravity sewer main design shall be adopted for the inter-connecting pipework between the “new” receiving access chamber and the original connection point.

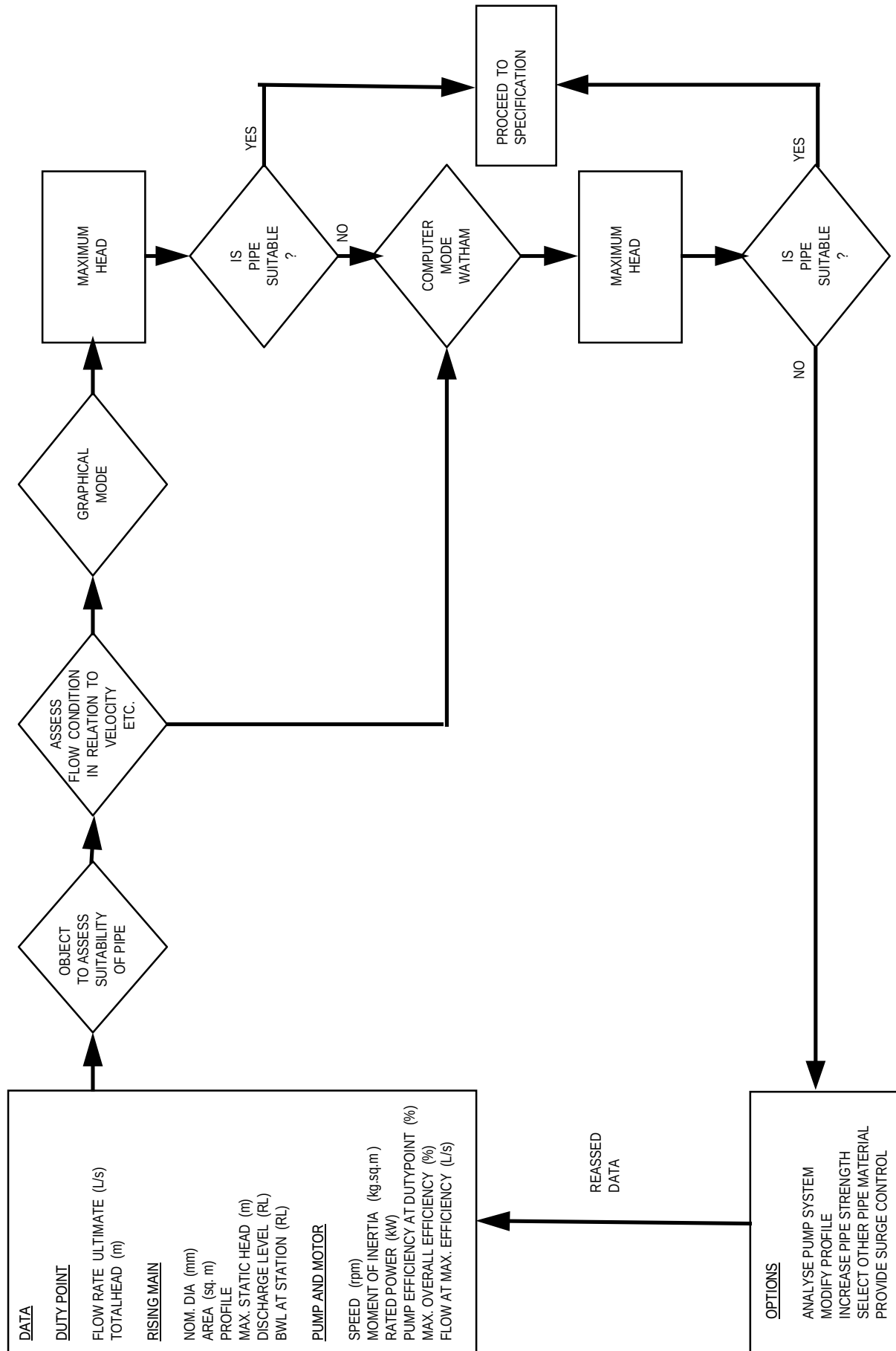


FIG 2

4.4 PUMP SELECTION

4.4.1 GENERAL

General

The pumping station in a reticulation system will generally have one of two functions. It will be used either to convey sewage to the treatment works or to convey sewage to another part of the reticulation system.

In general where it is proposed to pump to the treatment works there will be a limitation on the maximum rate of flow which can be accepted by the treatment facilities. If under storm conditions the hydraulic limitations of any treatment works units are exceeded by flows in the system, flow relief must be provided at the treatment works and due to dilution in receiving waters normally this would be considered acceptable. However, high rates of flow under dry weather conditions imposed by the pumping station and causing a bypass of the treatment facilities are unacceptable. It is necessary, therefore, to ensure that the treatment facilities can accept the flow rates allowed by the pumping station. Additionally many of the treatment units and in particular settling tanks (including those used for grit collection) operate optimally when there are not high rates of flow being imposed intermittently. This basically means that it may be unacceptable to have single rate pumping applied. In general it is preferable to allow flow to pass through the treatment process at a rate similar to that which it is applied to the reticulation system.

It may be possible to achieve this by passing flow through a balancing tank. The balance tank must be capable of balancing the total flow passed under normal dry weather conditions. This will generally be achieved by providing a volume in the balance tank equal to 90 times the pump output in litres/second. Where, however, friction losses in the rising main are high, dual or multi rate output from the pumping station will often be more appropriate. This may allow the increased capital outlay for extra pumps or dual speed pumps, more complex switchgear and perhaps overall increase in the size of the civil structure to be offset by reduced pumping costs over the life of the pumping station.

Where the pumping station is to pass flow to another part of the reticulation system, the pumping station may be required to pass flow at a rate that will provide self cleansing of the gravitational sewers downstream. Passing flow into the downstream section at a higher rate (ie. PWWF) will generally result in improved self cleansing and the ability to lay such sewers at flatter gradients. The improved self cleansing provided, however, only exists for relatively short distances into the gravity main due to attenuation of the wave created by the pumping station.

Where friction losses are high in the rising main, low rate output during normal dry weather conditions may allow sufficient savings in pumping cost to offset the additional capital outlay in the pumping station. However, the possible inability to flatten downstream sewers must also be taken into account.

Where pumping stations are receiving flow from other pumping stations, consideration must be given to the rate at which that flow is being received wherever other than single rate pumping is being proposed ie. each pumping station must be considered with regard to its overall effect on the system.

Single, Multi and Variable Speed Pumping

Generally, the peak wet weather flow rate (PWWF) which may arrive at a pumping station will be at least seven times the average dry weather flow rate (ADWF). Energy costs can sometimes be minimised by utilisation of two-speed, or variable speed driving motors. The major proportion of flow through a pumping station occurs at dry weather flow rates. Pumping at a rate lower than PWWF may significantly reduce the resistance due to friction in the rising main thus reducing the power used by the pump.

In the case of two-speed pumps, the pumps must be selected to suit maximum output requirements on high speed and pump a reduced flow on low speed. The reduced flow output would generally be in excess of any dry weather flow allowing the majority of flow to be pumped at the lower rate. Efficiency, therefore, should be as high as possible at that point to maximise energy cost savings. However, due regard should also be given to the efficiency at high speed duty point as this influences the pump and the electrical capital costs.

Even greater flexibility can be achieved by use of variable speed drives, however, the use of such cannot usually be justified on the basis of economics alone. They are occasionally used in large stations which pump to treatment works where large sudden changes of flow rate cannot be tolerated.

Single and Multiple Pump Installations

Analogous to the multiple or variable speed method of achieving energy savings, a similar result may be gained by the use of multiple pump installations. Instead of using one pump sized to handle PWWF, a number of smaller pumps are installed. With increasing flow rates extra pumps are brought on line until, with the maximum number of pumps operating in parallel, an output equal to the peak wet weather flow rate is achieved.

Besides the potential for energy savings, a lowering in cost of the civil structure can be achieved using the appropriate control procedures as described in Section 4.5.3. This method can also be used to cover present and future flow duties by installing say two pumps now to handle present flows and adding a third in the future without major downtime or refurbishing costs.

4.4.2 SEWERAGE RETICULATION NETWORKS

Consider a town of 4000 ET. If the reticulation system allowed total gravity flow to the treatment works, it would be expected that the average daily flow to the works would be approximately 3.8 megalitres (ie. $ADWF = 4000 \times 0.011 = 44$ litres/second) and the peak dry weather flow of the order of 85 litres/second. The treatment process employed would be expected to be capable of attaining the degree of treatment desired under these flow conditions. The works, however, must be hydraulically capable of accepting a peak wet weather flow rate of 317 litres/second under storm conditions.

Consider now a town of 4000 ET in which it has been necessary to employ pumping stations to convey flow to the treatment works. Figure 3 shows a diagrammatic layout of the system in which the pumping stations have the following loadings:

Pumping Station	Connected ET	Flow (litres/second)		
		ADWF	PDWF	PWWF
1	2500	27.5	56.3	201.3
2	900	9.9	23.1	75.3
3	500	5.5	13.9	42.9
4	700	7.7	18.6	59.2
5	1500	16.5	35.9	122.9
6	1200	13.2	29.6	99.2
7	500	5.5	13.9	42.9
8	300	3.3	9.0	26.4
9	400	4.4	11.5	34.7

Allowing that the pumps installed may deliver excess flow to the design requirements called for, the treatment works may be subjected to flow rates of up to say 230 litres/second from pumping station No. 1 and 140 litres/second from pumping station No.5. When both discharge concurrently the slug rate may total 370 litres/second even though the flow rate entering the system from the connected tenements may be at PDWF (85 litres/second) or even much lower.

The sewage treatment works must not only be capable of passing this flow rate, but would be expected to provide effective treatment while normal dry weather conditions prevailed. The Corporation normally achieves this by utilising balance tanks at the treatment works. With larger pumping stations, the best method of ensuring this very often is to set up the pumping stations with multiple output.

Combinations of submersible pumps are commonly considered as an alternative to the multiple flow output wet and dry well stations. If pumping station No.1 was set up with four submersible pumps of equal capacity - 3 duty and 1 standby - outputs might be expected to be 80, 150, 200 litres/second for 1, 2 and 3 pumps running respectively depending again on the actual system characteristics. Similarly, if pumping station No.5 was set up with three submersible pumps - 2 duty and 1 standby - outputs may be say 75 litres/second and 120 litres/second for 1 and 2 pumps running respectively.

It is normally less expensive to install single rate pumping. However, if the rest of the pumping stations in the example being considered were to be set up with single rate pumping, examine what effect this may have on pumping stations Nos.1 and 5.

Pumping stations Nos.3 and 4 contribute flow to pumping station No.1. However, the delivery from these stations is to a gravity main of considerable length. Under dry weather flow conditions when these stations are pumping intermittently, the flow from them will be attenuated to a greater extent as it travels down the gravity main and not more than 15 and 20 litres/second respectively will be the effective input to pumping station No.1.

On the other hand pumping station No.2 delivers flow almost directly to pumping station No.1 which would feel the full effect of the pump rate from pumping station No.2. Every time pumping station No.2 operated (assuming single rate pumping) it would cause overload of the low rate pumping stage in pumping station No.1 and thus cause higher rate output even though flow contribution to the system is at PDWF or below. Pumping station No.2, therefore, should also be set up with three pumps - 2 duty and 1 standby - output being say 40 and 75 litres/second for 1 and 2 pumps running respectively.

Similarly, pumping station No.6 would tend to overload the low rate output of pumping station No.5 and three pumps - 2 duty and 1 standby - giving say 60 and 100 litres/second should be used.

4.4.3 SELECTION CRITERIA

Selection of a type and size of pump will determine more than any other single factor, the final arrangement of the mechanical equipment within the pumping station, and the final dimensions of the pumping station.

The main criterion when selecting a pump is to ensure that there is a commercially available pump which satisfies the duty at, or close to, reasonable efficiency from at least one supplier. Refer to Hunter Water's Approved Products and Manufacturers list for details of pumps accepted by Hunter Water.

Pumps must be capable of passing a 75 mm sphere except where approval has been granted to use grinder pumps.

Especially in the case of some of the low flow applications it will be found that the intended duty point is close to the shut-off head of the pump. This is undesirable, because efficiencies will generally be poor and probably more importantly because this allows excessive internal turbulence in the pump causing the mechanical seal faces to chatter leading to premature seal failure. Generally, a pump should not be selected if the duty head is within 10% of the shut-off head. It should also be noted, that due to the normal flat characteristic curve of average pumps, any increase in system head for a pump operating within 20% of its shutoff head is likely to cause a drastic fall off in pump output.

In order to assess the design duty of the pump three pipeline resistance curves are calculated to give:

- (a) Maximum Head - based on normal maximum static head (ie. BWL) and friction head based on old pipe. The following values for the boundary roughness coefficient shall be used (refer Section 4.3.4):
 - $k = 1.5 \text{ mm}$ for $v = 0.6 \text{ m/s}$
 - $k = 0.6 \text{ mm}$ for $v = 1.0 \text{ m/s}$
 - $k = 0.3 \text{ mm}$ for $v = 1.5 \text{ m/s}$
 - $k = 0.15 \text{ mm}$ for $v = 2.0 \text{ m/s}$ or greater
- (b) Minimum Head - based on normal minimum static head (ie. cut-in level, normally TWL) and friction head based on new pipe. The following values for the boundary roughness coefficient shall be used (refer Section 4.3.4):

- $k = 0.6$ mm for $v = 0.6$ m/s
- $k = 0.3$ mm for $v = 1.0$ m/s
- $k = 0.15$ mm for $v = 1.5$ m/s
- $k = 0.06$ mm for $v = 2.0$ m/s or greater

(c) Flood Head - based on static head under flood conditions and friction head based on new pipe. The following values for the boundary roughness coefficient shall be used (refer Section 4.3.4):

- $k = 0.3$ mm for $v = 0.6$ m/s
- $k = 0.15$ mm for $v = 1.0$ m/s
- $k = 0.06$ mm for $v = 1.5$ m/s or greater

When determining Flood Head for the pumps it should be assumed that the incoming flow may exceed the pump capacity even with the reduced head on the pumps. Therefore the controlling level for determination of flood head will be the higher of 1 in 100 year flood level or the level at station overflow condition.

The pump duty point is actually specified on the minimum head curve as established above. This is desirable to ensure that excess flow from the pump is minimised under normal operating conditions. If inflow is above the pump output at lower operating levels in the wet well, the sewage level should simply rise back towards the normal top water level.

The pump motor is required to operate in air continuously over the full working range (maximum head down to flood head), and be capable of twelve starts per hour, with two starts in quick succession. This enables the wet well to be sized on the basis of 10 starts per hour (for which switchgear rated at 12 starts per hour is used).

The number of starts per hour may also be limited by the power supply authority depending on the authority's power reticulation system and motor start current. This must also be considered in the design.

Where pumping in parallel is required, the above criteria must be satisfied for each combination of operating pumps.

A maximum operating speed of 1500 r/min. is normally adopted for sewage pumps in order to limit wear to an acceptable rate. For larger units a lower speed will generally be offered but in the very smallest cases, such as grinder pumps, it may be necessary to accept 2900 r/min.

4.4.4 CORPORATION ACCEPTANCE OF INITIAL PUMP SELECTION

Details of the pump duty required together with mechanical design report (refer Appendix 4B) including water hammer analysis, pipeline characteristic curves, rising main selection, present worth analysis and initial pump selection report must be submitted to the Corporation who will verify the initial pump selection and review pump test results. Initial pump selection report should include a comparison between suitable pumps from all approved manufacturers with an NPV analysis (based on actual overall pump / motor efficiencies) and also include all relevant manufacturer's pump parameters for pumps such as model, impeller, duty, discharge outlet diameter, minimum pump spacing, minimum pump submergence, pump / motor efficiency, motor power, minimum throughlet.

4.4.5 PERFORMANCE TESTING AND COMMISSIONING

Inspections and Tests

Pumps are performance tested to AS 2417 Part 2 Class C with tolerances for non-mass produced pumps.

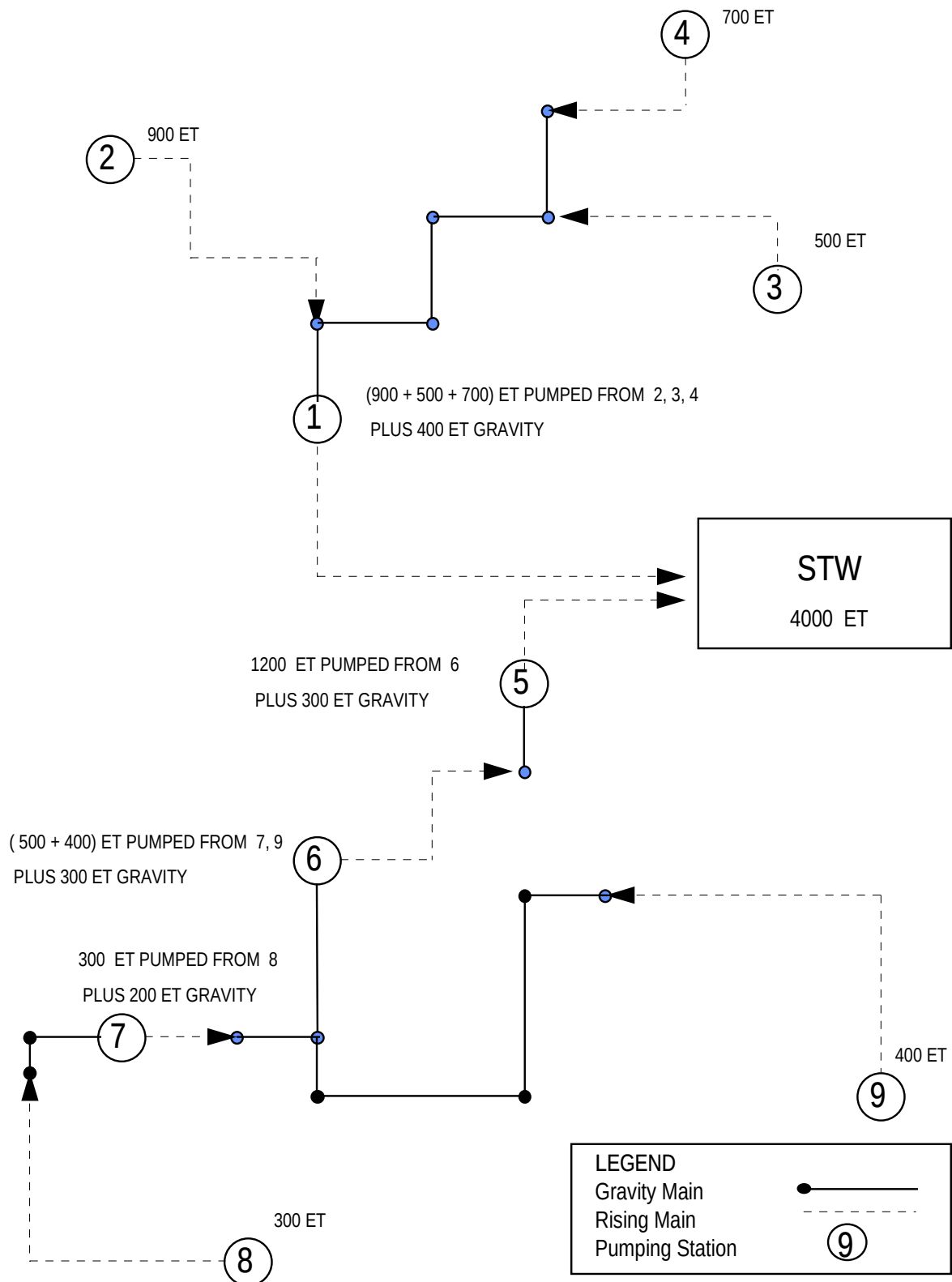
Pumps should not be accepted if the maximum delivery is substantially above the specified limits. Such excess flows can have adverse hydraulic effects at the treatment works or at other downstream elements in the system.

Commissioning and Site Tests

Upon completion of installation, the equipment is adjusted where necessary and placed into operation as near as possible in the manner, and under the conditions it will operate in practice. Tests are made to ensure all protective devices, and controls are fully operational.

Performance tests will also be made to verify the designed performance under operational conditions.

Refer to Technical Specification STS 402 for full details of commissioning and site tests.



MULTIPLE PUMPING STATION ARRANGEMENT

FIG 3

4.5 PUMP WELL LAYOUT

4.5.1 GENERAL

The number of pumps installed and their respective outputs will generally depend on the pumping strategy adopted. However, in all cases, standby is provided such that should any one pump in the station be inoperable 100% of output is still available, ie. in a station where a single pump provides the duty output, a second pump of equal capacity is mounted. Where three pumps of equal capacity are required to meet maximum flow conditions a fourth pump of similar capacity is provided. Where one pump handles dry weather flows and a larger pump is provided for wet weather flows, an extra pump similar in size to the larger is installed.

In cases where Protected Waters may be affected by discharge of sewage through an overflow at a pumping station an extra pump (not necessarily permanently mounted) may be provided for those cases where a pump is removed for maintenance. In special cases, where power loss could result in serious pollution of receiving waters, the following methods of improving the reliability of the power supply to the pumping station may be considered:

- a) Standby power generation
- b) Dual power feed - two separate electricity supplies from two separate sources. This could be from two different zone substations or from each half of one substation.

Remote monitoring is required of all pumping stations via the Corporation's telemetry system. The telemetry unit is to operate from 24 volt DC supply with battery backup. In the event of a pump failure or power supply failure the alarm signal is transmitted to the Corporation's Service Centre and displayed on the SCADA system which details the appropriate action and maintenance personnel to be notified.

4.5.2 HATCH OPENINGS AND PUMP SPACINGS

Standard hatch openings (Dimension H x J), pump spacing (Dimension D) and pump offsets (Dimension G) have been adopted by the Corporation - refer Figure 1 Section 4.2.

These dimensions essentially fix the hatch opening size and location relative to the wet well. The designer shall determine most suitable pump locations. Extended guide brackets may be required to optimise pump locations. The Corporation's standard safety screen details effectively reduce the available hatch opening and may require fabrication of special guide brackets. The designer is to ensure that pumps are positioned and guide rail brackets designed such that fouling does not occur when the pumps are raised and lowered through the hatch.

Pump offset (Dimension G) and pump spacing (Dimension D) may be altered to suit pumps provided that the dimensions are suitable for the equivalent pumps sized for ultimate duty for each of the approved pump suppliers.

4.5.3 WET WELL DESIGN

General

Wet wells should be arranged to have the minimum dead space where solids can accumulate, to provide smooth, even flow to the pump entrances and to adequately accommodate all pipework and pumping machinery. Flow should not have to travel past one pump inlet to reach another inlet.

Inlet design must be such that swirling does not occur in the wet well. In addition, the incoming flow should not impinge directly on submersible pump units. Excessive aeration of the incoming sewage must be avoided since entrained air may cause the pumps to lose prime altogether and in any case will prejudice the performance of the pump and may lead to air build up in the rising main.

In small stations with incoming design flows of 5 L/s or less a plain inlet will generally be sufficient, refer Figure 4.

In small stations with incoming design flows less than 60 L/s swirling and excessive aeration can generally be overcome by use of a drop tube attached to the incoming sewer, refer Figure 5. Drop tubes are to be fabricated from Grade 316 stainless steel and are designed as Tee sections with an open end at the top to facilitate cleaning out large debris which may lodge in the tube.

In larger stations with incoming flows of 60 L/s and greater, a baffle system is required, refer Figures 6 and 7. For further information on baffle systems and design criteria refer to Flygt Systems Engineering brochure entitled “Design Recommendations Pumping Stations With Large Submersible Pumps” and the Bibliography contained in this Flygt brochure.

The storage required in a wet well is a function of the sewage inflow and the chosen pump capacity. However, the following should also be considered:

- (a) Any storage area will act as a sedimentation tank and allow settling of sewage solids which if not directed to the pump suction may cause odour problems, etc. due to fermentation. The wet well should, therefore, be benched such as to direct flow to the pump suction. For typical benching arrangements refer to Figures 8 and 9. The plan area of the well should also be reduced to a minimum whilst still ensuring satisfactory storage volume is retained and adequate clearances to all pipework and pump machinery are maintained.
- (b) Pump life and efficiency would be improved if the frequency of pump start and stop are reduced. However, in the interests of limiting excessive detention times sewage pumping stations are subject to relatively high numbers of switching cycles. The rating of switchgear is related to the number of pump starts per hour. Accordingly, it is preferred to ensure there is sufficient storage between switching levels to limit the number of pump starts to 10 per hour (Refer Section 4.4.3).
- (c) It is not the function of a pumping station to provide storage of sewage for extended periods of power blackout, pump failure etc. Overflow under such circumstances is normally permitted except in the case of Protected Waters where EPA requirements will govern. It is desirable that suitable wet well capacity be provided at the minimum cost.

- (d) As the wet well is also the machinery well, the area must be sufficient to allow machinery to be installed with clearances required by the manufacturer. Sufficient space should also be allowed for level regulators.
- (e) To minimise dead storage volume the depth from the bottom water level to the floor level should be kept to a minimum. The depth will be dictated by pump manufacturers requirements on submergence for pump cooling and avoidance of air entrainment, Net Positive Suction Head (NPSH) and priming requirements.

Clearances for Pump Suction

With submersible pumps there is no suction pipe and sewage enters the pump directly through the pump inlet which is on the underside of the pump. There are minimum dimensional requirements for the distance from the floor to the underside of the pump, the distance from pump to front wall and side walls and the distance between pumps. These minimum distances are functions of pump inlet diameter, pump overall size, pump capacity and pump design and should comply with the minimum clearances required by pump manufacturers in order to obtain the desired performance.

Determination of Wet Well Control Levels

The well size and control levels will generally comply with the following:

- (a) **Bottom Water Level (BWL)** is set as low as possible (to minimise “dead” storage) but ensuring sufficient submergence to prevent vortexing and to provide sufficient suction head at the pump inlet. With the smaller submersible pumps both these criteria are easily satisfied by setting the bottom level approximately quarter way up the motor housing. This will ensure adequate motor cooling. When using larger submersible pumps the manufacturer will indicate a minimum BWL in relation to the pump. The duty pump is switched off at this level.

Minimum pump submergence shall be 200 mm above the top of the pump volute casing or in accordance with pump manufacturers recommendation whichever is the greater submergence.

Minimum pump submergence MUST allow for pumps from each of the approved manufacturers sized for ultimate duty.

- (b) **Top Water Level (TWL)** is set such that there is sufficient volume between this level and bottom water level to limit the number of pump starts per hour to an acceptable number (generally 10 per hour). The expression to determine this volume is -

$$V = \frac{900 Q_p}{S}$$

Where V = Control Volume (L)

Q_p = Pump Capacity (L/s)

S = Allowable number of starts per hour

Duty pump is switched on at this level. Figure 10 shows the manner of determining wet well volumes for simple switching arrangements.

The top water level for ultimate flow condition is set 150 mm below the invert of the incoming sewer to avoid the possibility of surcharging the sewer.

Maximum control depth (ie depth between TWL and BWL) is normally limited to approximately 1000 mm. Absolute maximum control depth for small to medium pumping stations is 1500 mm.

Minimum control depth is 300 mm.

Control depth should be rounded up to the nearest multiple of 100 or 150 mm to suit the multitrode level probe where these are used. The Corporation now specifies VEGAWELL pressure level controls.

- (c) **Maximum Top Water Level (MTWL)** is set at the invert of the incoming sewer and this level is usually only reached when the duty pump is unable to cope with incoming flow. The standby pump is switched on at this level.
- (d) **Flood Alarm Level** (High Level) is set 150 mm above MTWL.
- (e) **Switching Arrangement**

Figure 11 shows a simple pump switching arrangement which is satisfactory for smaller pumping stations.

Figure 12 shows a typical staged switching arrangement for larger pumping stations. In this arrangement the distance between each individual “pump on” and “pump off” would provide a control depth which limits the number of pump starts to the maximum allowable, usually ten (10), for the rated pump capacity for each pump. A minimum difference in levels of 150 mm will generally allow switching unaffected by turbulence.

When considering larger stations the pumping arrangement can affect downstream sewers and/or treatment works. By staging the pump-on switching the flow downstream will gradually build up. Similarly with staged pump-off switching the flow downstream will gradually decrease, thus avoiding the “all on” “all off” situation of smaller stations.

Clearances for pumps and pipework

Particular attention must be paid to sizing of wet wells to ensure, that as well as fitting pumps, pipework and proper dismantling provisions, there will be sufficient room to provide adequate access for maintenance purposes.

4.5.4 DRY MOUNTED SUBMERSIBLE PUMP WELL DESIGN

General

This type of installation may be used when series pumping is determined to be the least NPV option to achieve the pump head required. In general the immersible pump well (or pit) must be of sufficient size to allow personnel to move around the machinery as well as dismantle and assemble the machinery. In consideration of possible replacement of machinery with perhaps larger units in the future the designer, therefore, should be liberal with space provided. An attempt should be made to ensure pipework does not need to be totally rearranged to allow installation of larger machinery. Provision of make up pieces and dismantling joints in the appropriate locations may greatly simplify later augmentations.

Access for maintenance is of prime importance in immersible pump well installations. The space required to remove pump covers, suction bends, etc., should suit the largest machinery liable to be installed. Care needs to be taken with placement of valves to ensure adequate access for maintenance.

In order to minimise the plan area required for an immersible pump pit the pump delivery may be turned such that the delivery pipework is on the same side as the suction pipework. It should be noted here, however, that the delivery manifold connecting delivery pipework from each pump should not be vertically above the delivery pipework as this would allow solids to settle on and build up within the pipework from the standby pumps.

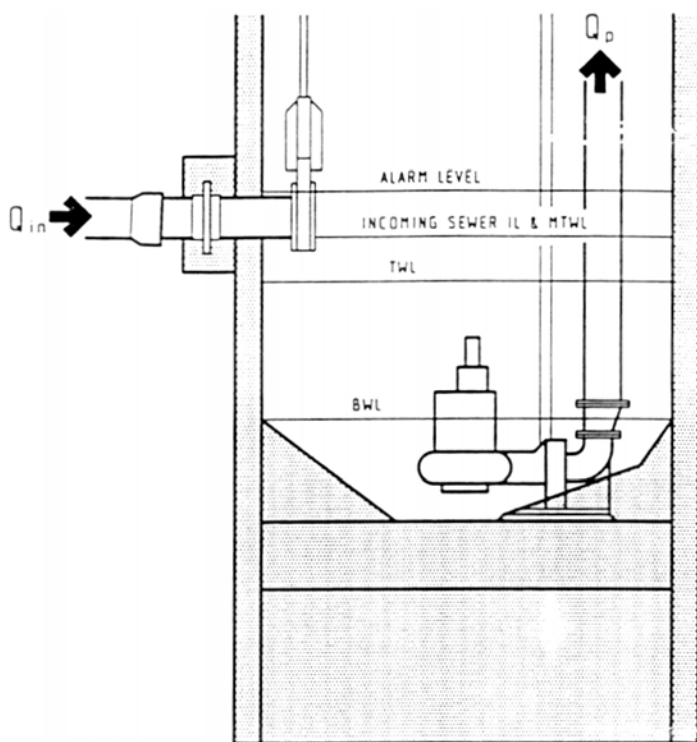
Draining Valve and Series Pumping Pits

Valve and series pumping pits are designed to remain in a dry condition. There are various sources from which moisture will enter the pits.

- (a) From ground water seeping through the concrete seals around the base and around pipes and conduits passing through the walls.
- (b) From entry of surface water, however a good design should preclude entry of surface water.
- (c) Sewage from pumps and reflux valves during maintenance.
- (d) Wash down water used during maintenance and cleaning.

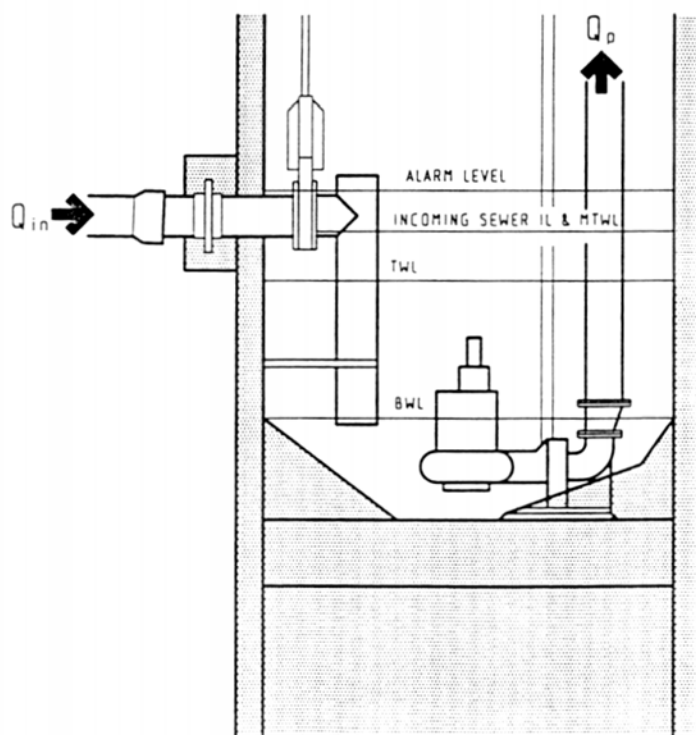
This water must be removed from the valve / pump pit. The pit floor therefore should be graded to an outlet pipeline which drains back into the wet well. The inlet to the wet well should be as high as possible, ideally above overflow level and 100 year flood level and above flood alarm level as a minimum. A flap or reflux valve is to be installed on the outlet. The minimum drain size is DN 100.

In isolated cases where it may not be possible to drain to the wet well a sump and a sump pump which will pump a moderate amount of raw sewage without blocking should be installed. Such an installation is quite small and is automatically controlled using float switches. The discharge from the sump pump shall be directed to the station wet well. However care must be taken to ensure that sewage cannot syphon back from the wet well to the pit at any time. In this regard a reflux valve should not be relied upon, the sump pump delivery discharge should be installed above pumping station overflow level and above 100 year flood level.



INLET DESIGN - PLAIN INLET
FOR $Q_{in} \leq 5 \text{ L/s}$

FIG. 4

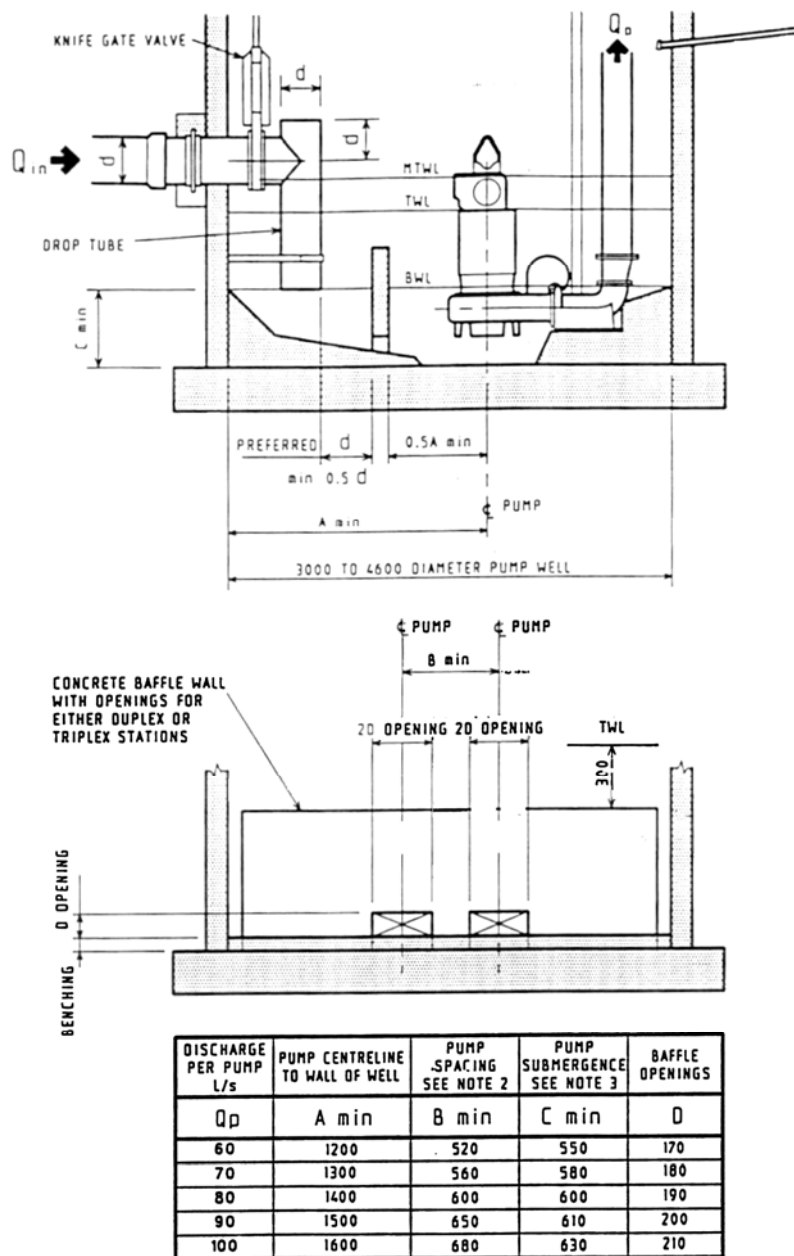


NOTE:

BOTTOM OF DROP TUBE TO BE LEVEL WITH BWL
OR MAXIMUM OF 50mm BELOW BWL.

INLET DESIGN - DROP TUBE INLET
FOR $Q_{in} > 5 \text{ L/s}$ AND $< 60 \text{ L/s}$

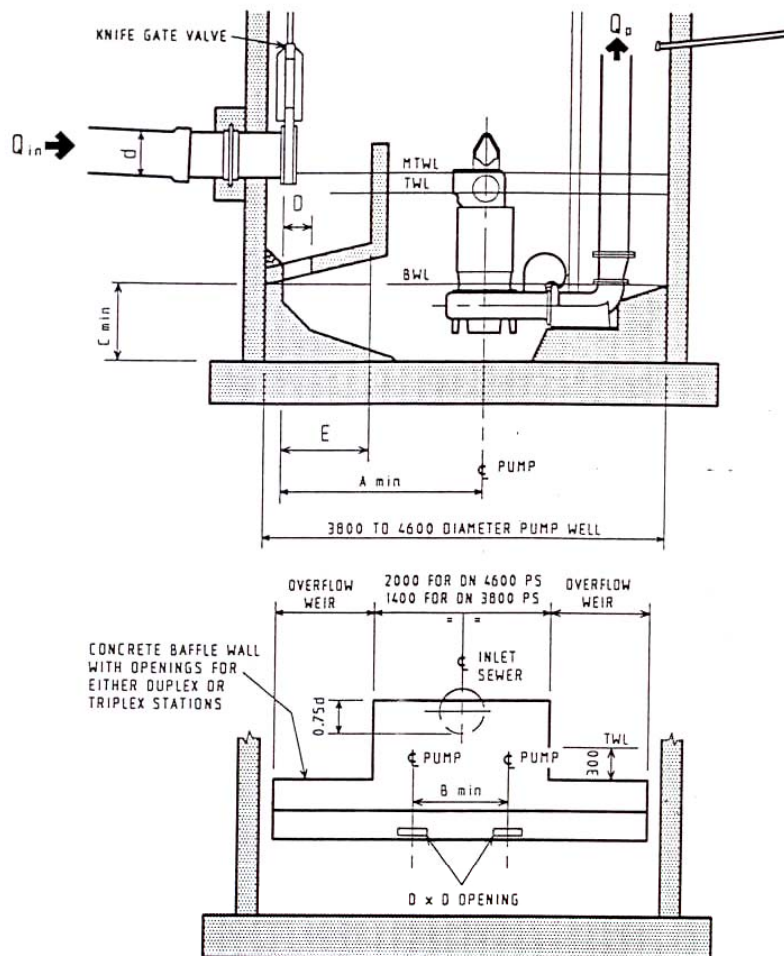
FIG. 5

**NOTES**

1. REFER FIGURE 7 FOR BAFFLE WALL INLET DESIGN TO BE USED WHEN MINIMUM CLEARANCE (0.5 d) BETWEEN DROP TUBE AND BAFFLE WALL IS NOT AVAILABLE.
2. PUMP SPACING MUST BE THE GREATER OF :
 - a) B MINIMUM.
 - b) MINIMUM DIMENSION AS RECOMMENDED BY PUMP MANUFACTURER.
 - c) 200 MINIMUM CLEARANCE BETWEEN PUMP CASINGS.
 - d) CORPORATION STANDARD PUMP SPACING REFER FIGURE 1
3. PUMP SUBMERGENCE MUST BE THE GREATER OF :
 - a) C MINIMUM.
 - b) MINIMUM DIMENSION AS RECOMMENDED BY PUMP MANUFACTURER.
 - c) 200mm ABOVE TOP OF PUMP VOLUTE CASING.
4. BOTTOM OF DROP TUBE TO BE LEVEL WITH BWL OR MAXIMUM OF 50mm BELOW BWL.

INLET DESIGN - BAFFLE WALL WITH DROP TUBE
 FOR Q_{in} = 60 L/s to 100 L/s Duplex, 180 L/s Triplex

FIG. 6



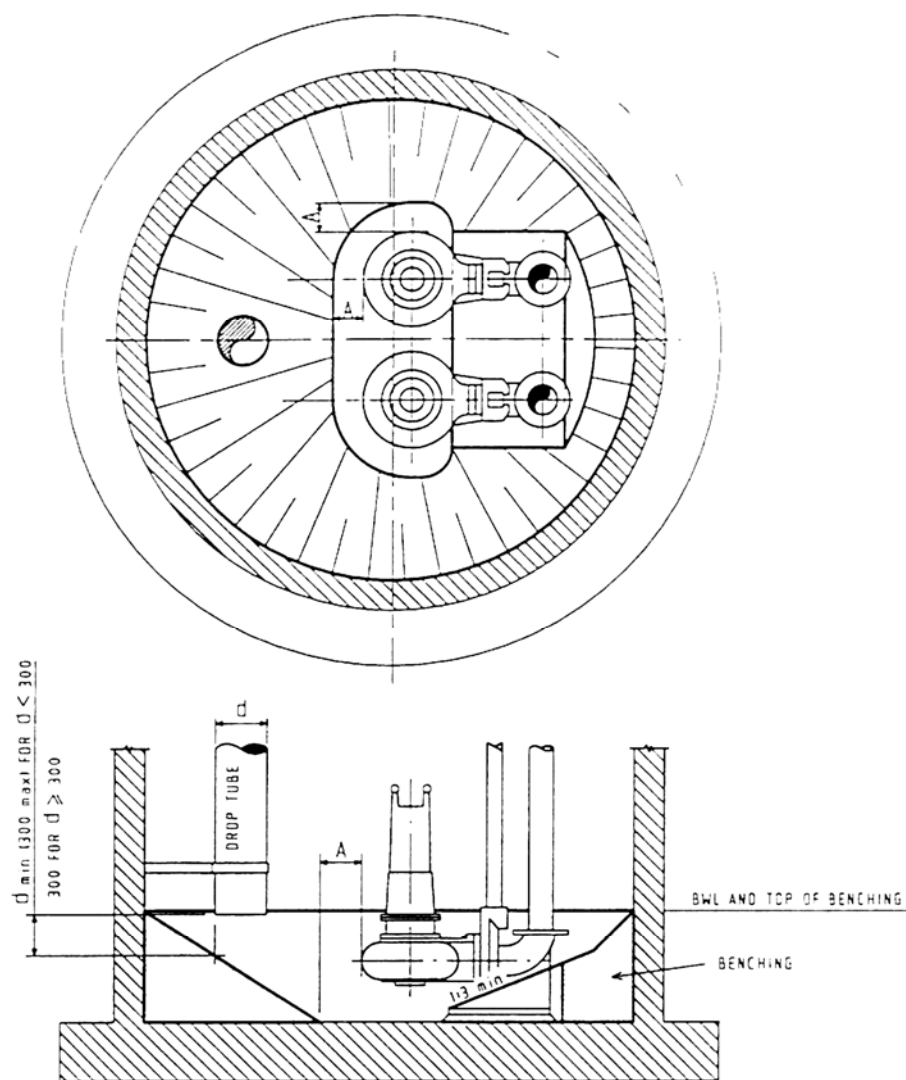
DISCHARGE PER PUMP L/s	PUMP CENTRELINE TO OPENING	PUMP SPACING SEE NOTE 2	PUMP SUBMERGENCE SEE NOTE 3	BAFFLE OPENINGS	BAFFLE WIDTH
Q_p	A min	B min	C min	D	E
100	1600	680	630	210	1100
110	1650	720	650	220	1130
120	1750	750	660	230	1150
130	1800	780	670	240	1180
140	1900	810	680	250	1200
150	1950	840	700	260	1230
160	2000	870	710	270	1250
170	2100	900	720	280	1270
180	2150	920	730	290	1290
190	2200	950	740	290	1310
200	2300	970	750	300	1330
220	2400	1030	760	320	1370
250	2500	1100	780	340	1420

NOTES

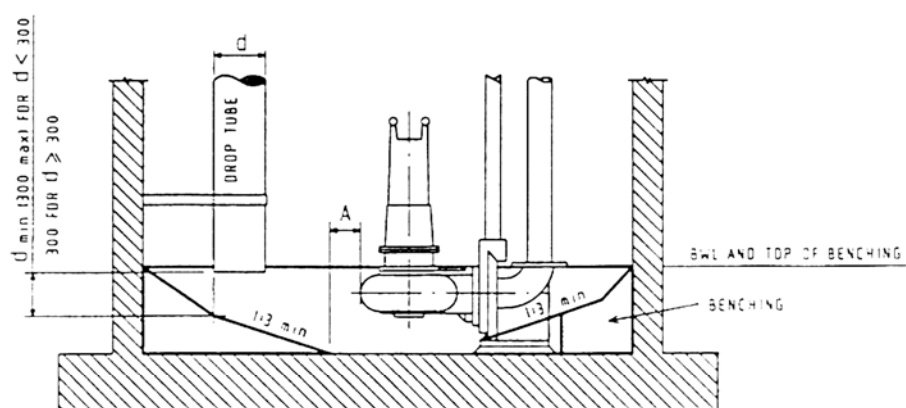
- THIS BAFFLE WALL INLET DESIGN IS TO BE USED:
 - WHEN MINIMUM CLEARANCE (0.5 d) BETWEEN DROP TUBE AND BAFFLE WALL IS NOT AVAILABLE or
 - $Q_{in} > 100$ L/s Duplex and > 180 L/s Triplex.
- PUMP SPACING MUST BE THE GREATER OF:
 - B MINIMUM.
 - MINIMUM DIMENSION AS RECOMMENDED BY PUMP MANUFACTURER.
 - 200 MINIMUM CLEARANCE BETWEEN PUMP CASINGS.
 - CORPORATION STANDARD PUMP SPACING REFER FIGURE 1
- PUMP SUBMERGENCE MUST BE THE GREATER OF:
 - C MINIMUM.
 - MINIMUM DIMENSION AS RECOMMENDED BY PUMP MANUFACTURER.
 - 200mm ABOVE TOP OF PUMP VOLUTE CASING.

INLET DESIGN - BAFFLE WALL WITHOUT DROP TUBE
FOR $Q_{in} > 100$ L/s Duplex and > 180 L/s Triplex

FIG. 7



PREFERRED BENCHING ARRANGEMENT

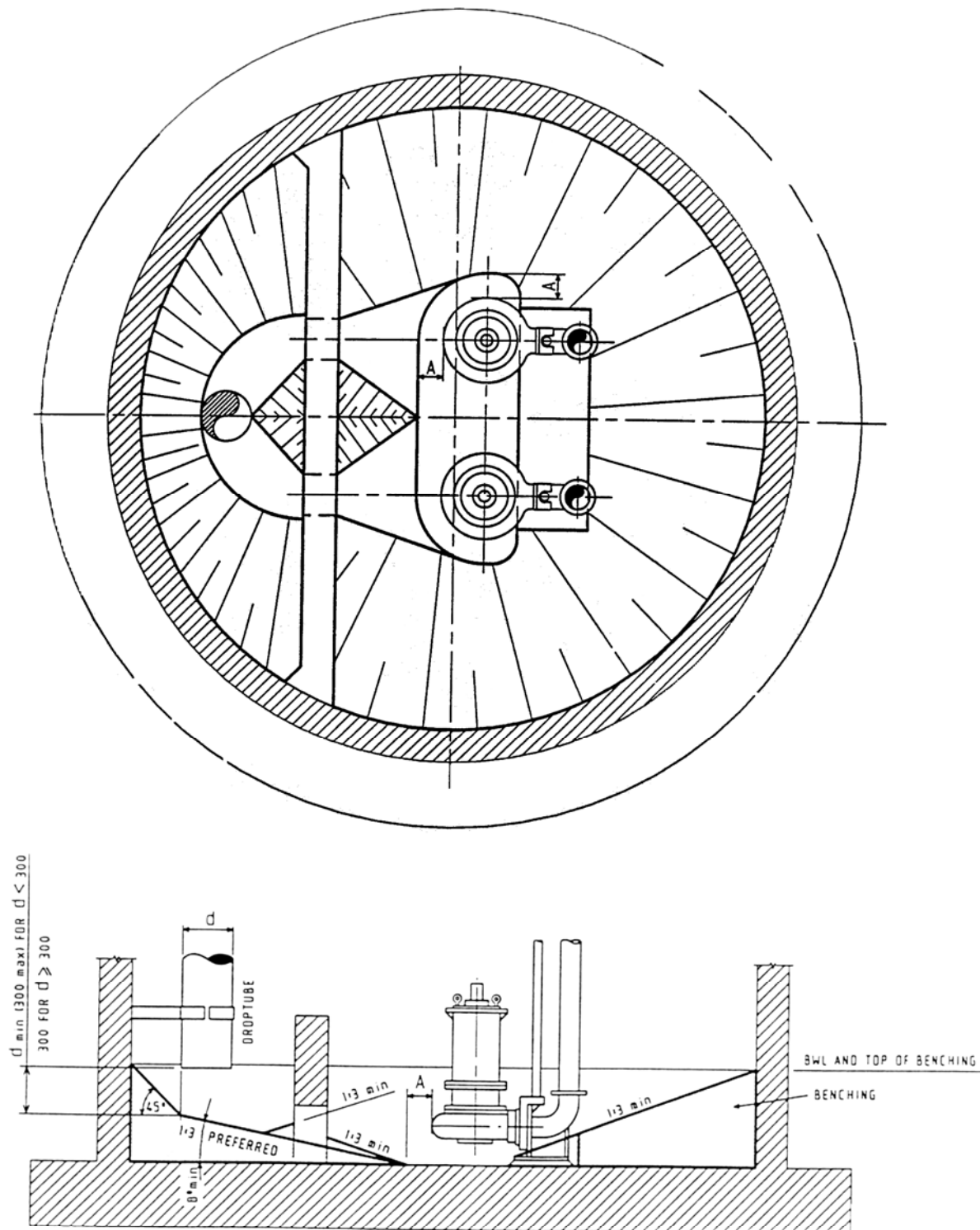


ALTERNATIVE BENCHING ARRANGEMENT

BENCHING DESIGN WITHOUT BAFFLE WALL

1. DIMENSION A = PUMP DISCHARGE DIAMETER.
2. DIMENSION d = DROP TUBE DIAMETER.
3. BOTTOM OF DROP TUBE TO BE LEVEL WITH BWL OR MAXIMUM OF 50mm BELOW BWL.

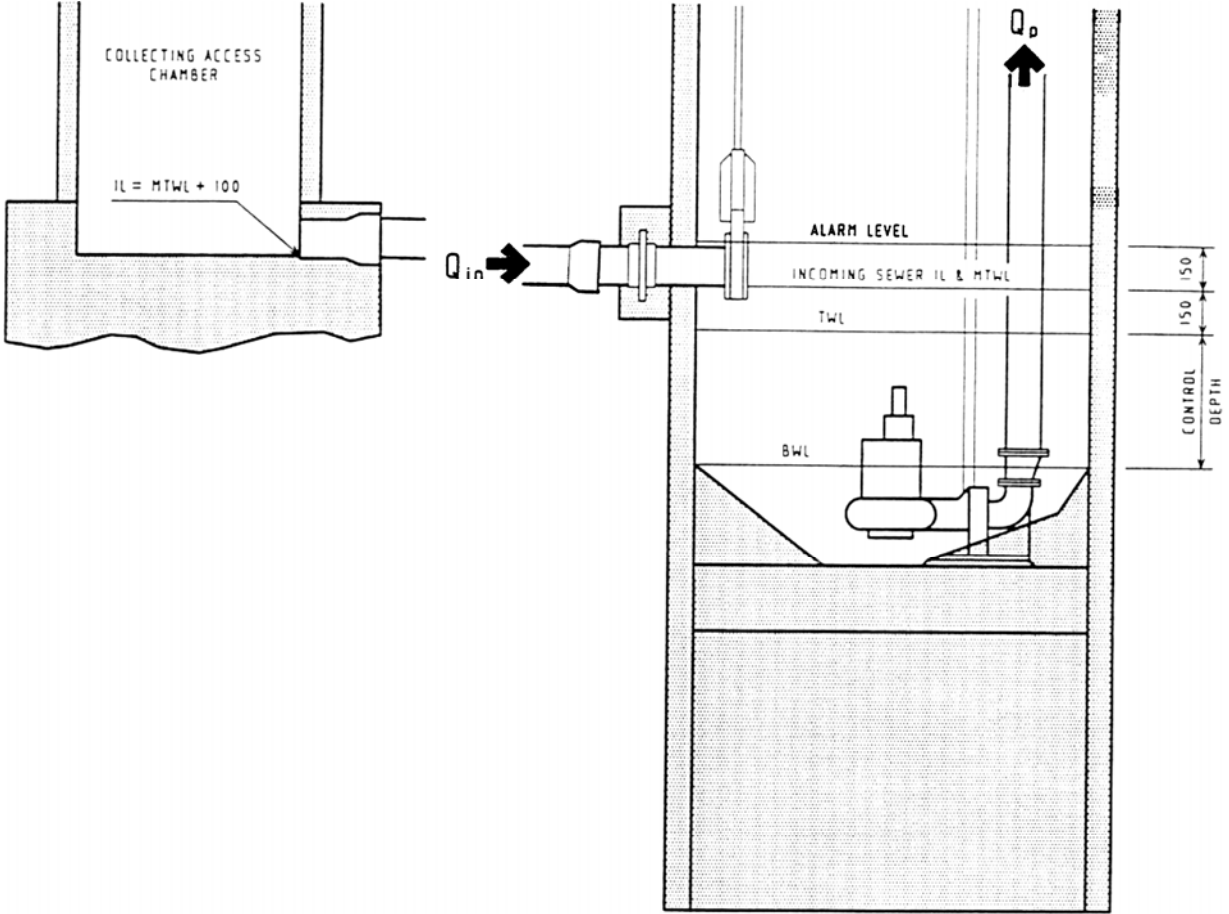
FIG. 8



BENCHING DESIGN WITH BAFFLE WALL

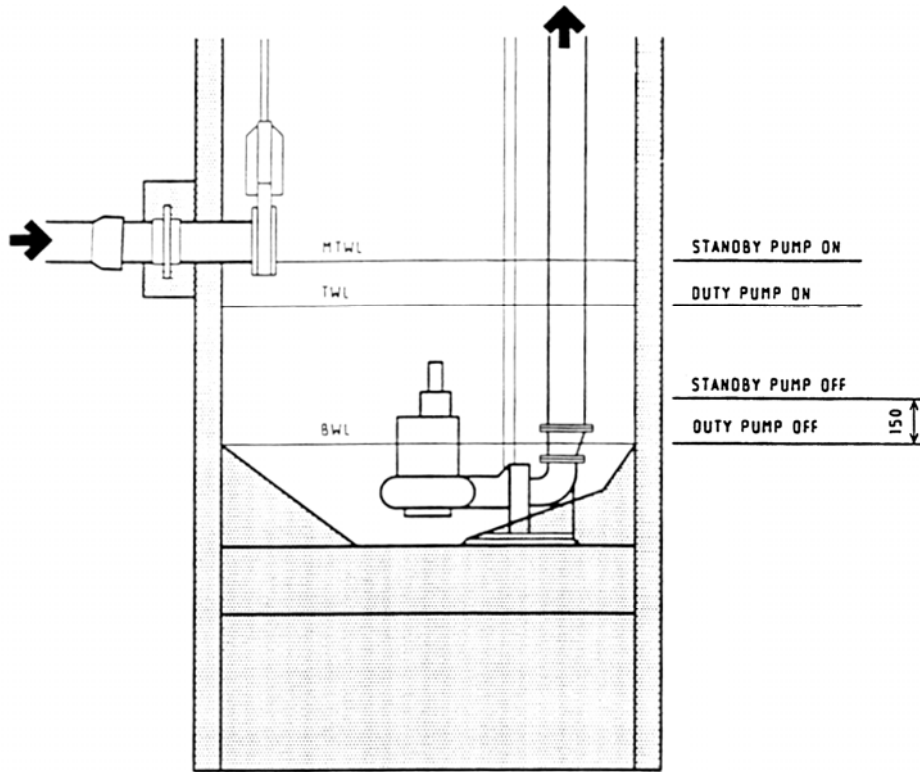
1. DIMENSION A - PUMP DISCHARGE DIAMETER.
2. DIMENSION d - DROP TUBE DIAMETER.
3. BOTTOM OF DROP TUBE TO BE LEVEL WITH BWL OR MAXIMUM OF 50mm BELOW BWL.

FIG. 9



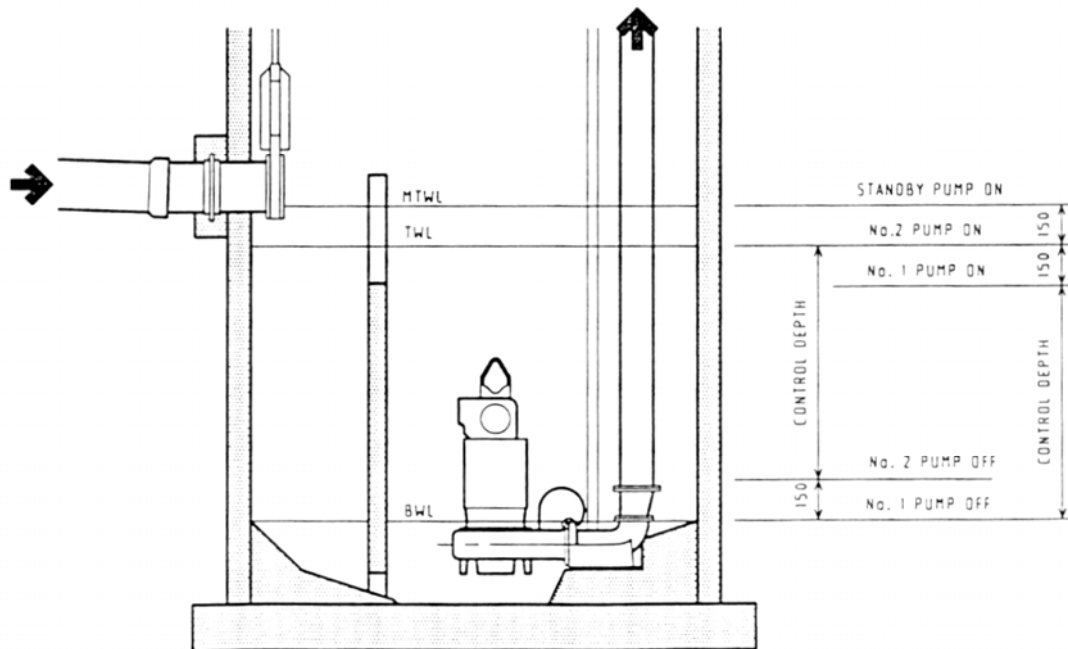
OPERATING CONTROL LEVELS

FIG. 10



SIMPLE SWITCHING ARRANGEMENT

FIG. 11



STAGED SWITCHING ARRANGEMENT

FIG. 12

4.6 PUMP CONTROL

4.6.1 WATER LEVEL REGULATION

General

Liquid level regulators have been developed over a long period and vary from simple mechanically actuated switches, through balanced mercury switches to pressure switches, resistance probes and various pressure sensitive or ultrasonic electronic types. These types may all be used with raw or treated water. However, the content of sewage often creates problems with some of these devices.

Turbulence within the wet well may cause problems with suspended type level regulators. These problems include entanglement of cables where multiple regulators are used, float switches held up with rags and also frequent inadvertent switching of pumps which may overload electrical systems. The incorporation of separate stilling areas is not recommended as they will inevitably be clogged with solids and fats.

As described in Section 4.5.3, inflow to the wet well should be directed such as to control swirling of the wet well contents.

The Corporation uses three (3) types of level regulators

Types of Level Regulators

(a) Tear Drop Float Regulator

Tear drop float type level regulators have been successfully used by the Corporation for a considerable period of time. They consist of a mercury tube switch and a counter weight contained in a fully sealed case shaped like a tear drop. The counterweight ensures that the tear drop always tips under flotation such that the mercury makes the required contact to activate the switch. The regulator is suspended by its own plastic coated, fully sealed control wires from the roof of the station. Care must be taken with the installation of these floats. Turbulence as well as fats and rags can be a problem. It is recommended that inlet conditions be properly designed to minimise turbulence and adequate attention be given to cleaning and maintenance to ensure continued satisfactory operation. The regulator is connected to 12 to 32 volts not 240 volts for safety and as required by Electricity Regulations.

(b) Multiple Resistance Probes

Multiple resistance probes which allow the completion of a circuit when covered by water allow the sensing of changes in water level and give good service in clean water. When used in sewage, fats, grease, etc., decrease their sensitivity and as such they could only be recommended where adequate attention to cleaning is ensured.

(c) Hydrostatic Pressure Probe

Hydrostatic pressure probes use a submersible type pressure transducer with a stainless steel cylindrical device supported by an electrical cable. These are of particular use where a number of pumps are installed. For example, where four pumps would require perhaps 9 or 10 tear drop regulators in a station the one transducer can provide the information required for all the pump operating positions. Further, subject to its calibrated range, it can continue monitoring well depth after MTWL has been exceeded.

The Corporation has recently been successfully using VEGA hydrostatic pressure probes to monitor well levels and this has now been adopted as a Corporation standard.

4.6.2 ELECTRICAL CONTROLS

General

Electrical design shall be in accordance with the requirements of Hunter Water Corporation's Standard Technical Specification STS402 and General Requirements for Electrical Installations EIS-91 as amended hereinafter and elsewhere in STS402.

Where EIS-91 describes more than one material or method of installation, that which is indicated in STS402 or on the Standard Drawings shall apply.

Should any part of STS402 or the Standard Drawings conflict with EIS-91 then the requirements of STS402 or the Standard Drawings shall take precedence over the corresponding requirement of EIS-91.

Except where EIS-91 or STS402 requires a higher standard, design in accordance with the current edition of AS/NZS 3000, the NSW Service Rules & the Supply Authority Regulations, the local requirements of Telstra and the requirements of all relevant Statutory Authorities.

References throughout this manual and STS402 to particular clauses of any standard shall not relieve the Designer of responsibility to comply with all clauses, where applicable.

Overhead electricity mains must not enter a public reserve by more than one (1) metre. Locate power poles to reduce their number and environmental impact.

Where a "lead-in pole" is required design to STS402 and Supply Authority requirements.

Locate the "lead-in pole" as close as possible to the front boundary of the property and as close as possible to the common boundary between two properties. Locate the "lead-in pole" so as to ensure that the service mains from the Supply Authority pole to this "lead-in pole" shall not cross any adjoining property boundary.

Where crossing or running parallel to other services, underground cabling shall be spaced as approved by the Authority responsible for the adjoining service. At no point shall these mains be located within 300 mm of any water service. This separation is a requirement of AS 3500.1 clause 5.3.1.2, (National Plumbing and Drainage Code – Water Supply).

Where a cable passes under a road or path, a marking plate is required at each side of the road or path to the concrete kerb or to a concrete block approximately 150 mm x 150 mm x 300 mm deep.

Standard Electrical Switchboard Designs

Electrical design shall be in accordance with Hunter Water Corporation Standard Electrical Switchboard Designs. These standard designs are not included in this document and may be obtained from the Corporation. :

An approved designer shall be engaged to provide the electrical design.

The standard drawings should be amended as required. When modifying drawings, the designer must ensure that electrical equipment is secured behind an internal door fitted with a lock than can be “81/3” keyed, similar to arrangements shown in the standard drawings. However, the electricity meters, station controls, and at least one 240V AC power outlet shall be accessible by opening an external door with padlockable handles. Electricity meters must have their own dedicated external door with padlockable handle ready to accept the network operators customer lock to ensure the network operator has access. All outer doors to have a 3 point locking system.

Equipment Selection and Cabinet Type

The pumps may be installed initially with small impellers which may be changed later for the ultimate rating of the pumps. The contactors and soft starters must therefore be rated for the ultimate size with protection suitable for the installed motor rating.

Advise the Supply Authority of the actual pump kilowatt ratings, including any proposed future upgrading of the pumps and confirm the method of starting and supply.

Acceptable starting methods are:-

1. Circuit breaker and Direct On Line contactor.
2. Circuit breaker and soft starter with starter bypass contactor.
3. Variable speed drive

Integral direct on line (DOL) type starters shall not be used.

Prepare a complete set of drawings for each switchboard based on the standard designs. Any item shown <> on these standard drawings is to be replaced by the details applicable to the respective pump, motor, consumers main, fault level, etc.

Provide power terminal blocks, of suitable rating, in the switchboard for the termination of the incoming field wiring. Provide control terminal blocks, minimum size 10 amps, in each cubicle for the termination of incoming field wiring. Provide a separate terminal for every field cable core including spare cores. Terminate each core within a cable in consecutive terminals.

Select equipment from Hunter Water Corporation Approved Products and Manufacturers - Electrical list.

Do not specify switchboard equipment unless spare parts are available from Newcastle distributors. Confirm that adequate stocks of replacement parts for proprietary equipment specified in the manufacture of the switchboards (eg contactors, starters, relays, timers, indicating lamps, fuses, etc) are readily available from Distributors in the Newcastle area.

An equipment schedule detailing all equipment required for each switchboard is to be issued as part of the specification – Refer STS402 – Tender Schedule – Switchgear and Control Gear Assemblies.

Service Conditions

Ambient conditions will be within the limits of 0°C to 45°C.

The switchboards will be connected to the Supply Authority Supply System.

Nominal system parameters:

415 Volt, 3-phase, 4-wire, 50 Hz, multiple earthed neutral (MEN) system

Prospective Fault Current for each installation is to be shown on the respective power circuit diagrams. Confirm these fault levels with the Supply Authority.

Pump Operation

For Duplex pumping stations the equipment is to be sized to enable both sewage pumps to operate together.

For pumping stations other than Duplex the equipment is to be sized to enable one (1) less than the installed number of pumps to operate together.

Where vacuum pumping stations are offered, design and size the electrical equipment to enable all vacuum producing pumps to operate together. Where only two discharge pumps are to be installed ultimately, size the equipment for both discharge pumps to operate together when all vacuum pumps are operating. Where more than two discharge pumps are to be installed ultimately, size the equipment for one less than the maximum number of final discharge pumps to operate together when all vacuum pumps are operating.

Specific Requirements for Soft Starters

Soft starters (electronic) where used, shall be rated as follows for the required kW output of the motor:

- | | | |
|-----|-----------------------------|--|
| (a) | By-pass operation | -12 starts per hour |
| (b) | Without By-pass operation | |
| | - ie under manual operation | -4 starts per hour with a 5 minute maximum run time following each start |

The above ratings shall apply to the installed situation with service conditions specified above.

The disturbance to the electrical supply system when using soft starters is not to exceed the limits set down in AS/NZS 61000.3.6:2001.. Radio interference external to the soft starters is not to exceed the limits set down in AS/NZS CISPR 11:2004.

To reduce the possibility of radio interference the soft starters chassis and cubicle shall be bonded to earth with a larger than normal earth conductor – minimum of 20% above normal size.

Provide space in the starter cubicle to allow for the retrofitting of a suitable R.F.I. filter network except where the consumers supply is from a substation dedicated to the installation. A suitable R.F.I. filter network may be required if, during commissioning of the station, the operation of the soft starters causes radio interference in excess of the limits set down in AS/NZS CISPR 11:2004.

Housing Switchgear

HWC Standard Outdoor Electrical Switchboard shall be mounted on a 300 mm high concrete upstand suitable for the particular standard switchboard cabinet dimensions and located adjacent to the hatch opening. The upstand shall be cast integrally with the roof slab. There are four (4) standard switchboard cabinet sizes. The approved electrical designer shall nominate the particular switchboard dimensions once pump motor kilowatts, method of starting and number of pumps are known and liaise with the civil designer to ensure that the civil works will be adequate for the switchboards. The cabinet base is to be 25 mm smaller than the concrete plinth on all sides.

Switchgear for pumping stations range from the very simple for small stations where it is all housed in a stainless steel or aluminium cabinet situated adjacent to the wet well to more complex installations for large stations where a switchroom must be provided. Generally a switchroom will not be required for small to medium pumping stations (up to 130 kW depending on starting methods). Design of larger stations which require switchrooms is outside the scope of this manual. For all designs, the pump motor starters are to be located inside their own individual lockable compartment.

The outdoor switchboard should be sited adjacent to the wet well, as shown on the Corporation's standard roof slab drawings, with the switchboard doors opening to enable the hatch opening to be visible to an operator when operating pump starters. Minimum clearance between any obstruction and the cabinet with doors open at 90 degrees is 600 mm.

Switchgear is often larger than the civil designer may anticipate. It is essential that early discussions are held with electrical designers such that ample room is made available to house switchgear and control gear assemblies. All electrical installations must be protected from inundation by flood and rainwater.

Electrical Conduits and Cable Trench

Electrical cables from switchboard to pump well must be laid in a cable trench formed in the top of the roof slab and not in conduits. The cable trench in the roof slab should be placed adjacent to cable holders (ie. immediately adjacent to fillets in roof slab opening) and is to have an aluminium cover which can be removed only when the hatch covers are opened. Refer cable trench in typical sewage pumping station standard roof slab drawings. A drawing list is included in Appendix 1E.

Electrical conduits are required under the roof slab between the switchboard and any remote equipment and incoming power supply. Early coordination of the position and entry of cables and conduits to the civil structures should be made.

Switchgear and Controlgear Assemblies

All pumping station assemblies are equipped with the following:

- Electricity Supply Meters
- Incoming Power Supply
- Station Control Unit
- Motor Starter Units
- Telemetry Unit (provision for)

The controls, switches and indicating lights contained in the switchboard include:

a) Electricity Supply Meters

These are the property of the Electricity Supply Authority. They record the energy consumption of the pumping station.

b) Incoming Power Supply

The incoming power supply distributes power to all the control and starter units. Power is 3 phase 415 volts supplied by the relevant Electricity Supply Authority. Features include:

- i) **Main Switch** - for control of the incoming power supply. When ON the SCA is “live”. When OFF the SCA is inoperative and the pumping station is off line.
- ii) **Voltmeter** - for measuring the voltage of the incoming power supply.
- iii) **Phase Failure Relay** - to detect the failure of one or more of the 3 phases, or phase reversal of the Electricity Supply Authorities power supply.
- iv) **Circuit Breakers** - for protection of equipment by limiting the current supplied to the various circuits.
- v) **General Purpose Outlet** - double 10 ampere general purpose outlet.

c) Station Control Unit

The station control unit houses all the control equipment for automatic operation of the station. This unit may include:

- i) **Duty Selector Switch** - selects the duty and standby pumps where a PLC is not used for station control.
- ii) **Programmable Logic Controller (PLC)** - The duty of the pumps is determined by the PLC software. All available pumps share the duty - ie the duty pump will alternate between available pumps whenever the cut-in level is reached.

The Corporation has standardised on PLC to control pump operations and monitor the pumping station levels and other parameters.

- iii) **Override Button** - can be used while the operation is in the automatic mode, to simulate that the sewage level has reached pump cut-in level at any time the sewage level is above BWL. Pressing this button will start the standby pump which will pump down to BWL and then automatically switch off.
- iv) **High Level Alarm** - if the wet well high level alarm float switch is reached both pumps shall operate for a predetermined time and a high level alarm is transmitted to the Corporation's Service Centre via the telemetry system.

d) **Motor Starter Units**

Each pump is controlled by a motor starter unit which houses all the motor protection equipment and alarm lights. For submersible pumps the equipment includes:

- i) **Control Selector Switch** - selects the control mode for the pump. It has three settings:
 - A. **ON** - manual operation. When selected the pump will operate independently of any automatic control and not shut down when sewage level drops below BWL. NOTE : dry running may damage the pumps. Care should be taken, therefore, not to allow the level of the wet well to drop too low.
 - B. **OFF** - the pump will not start
 - C. **AUTO** - automatic operation. When selected pump operating will be controlled by the level regulators.
- ii) **Thermal Overload (Motor Overcurrent)** - the overload will trip and cut out the pump when a predetermined current is exceeded for a predetermined time. The pump will remain inoperative until the fault has been rectified and overcurrent relay reset.
- iii) **Motor Overtemperature (Thermistor) Indication Light**- the indication light remains off while ever the motor operating temperature is below the pre-set thermistor temperature level. Once exceeded, the pump is cut out and the indication light turns on. The pump should not be started again until the fault has been rectified. The thermistor relay must also be reset, after the fault has been found.
- iv) **Seal Failure Relay** - pumped fluid is prevented from reaching the motor by mechanical seals on the pump drive shaft. The seals are located in an oil filled chamber. Any ingress of water to the oil is monitored through a water sensor to the seal failure relay which then illuminates the seal failure light. NOTE: The pump will continue to operate after the light has come on. The pump oil should be inspected as soon as possible.
- v) **Seal Failure Reset Button** - a reset button is located on the seal failure relay. Pressing this button will reset the seal failure relay. However, if the oil is contaminated with water, the relay will reactivate the light.

- vi) **Ammeter** - indicates the current drawn by the pump motor. If the indicated current is above that shown on the engraved pump details plate, the pump should be checked immediately for the cause of overloading.
- vii) **Drive Fault Indication Light** - used to indicate a fault condition which occurs when a pump is called to operate and does not start in a predetermined time.
- viii) **Level Display** - 4 digit loop powered digital level display to indicate the level in the wet well. The 4 - 20 mA signal for the level display comes from the level probe (24 VDC supply).

(e) Telemetry Units

The following functions are monitored at the pumping station via inputs to the PLC / telemetry units and transmitted to the Service Centre for display on the Corporation's SCADA screens:

- i) Position of pump control selector switch.
- ii) Pump available.
- iii) Pump operation.
- iv) Pump hours run.
- v) Pump running.
- vi) Well level (via analogue signal).
- vii) Seal Failure.
- viii) Phase / power supply failure.
- ix) Wet Well High Level Alarm.
- x) Motor overtemperature (if applicable).
- xi) Pumping station load current.
- xii) Drive fault.
- xiii) Pump current.
- xiv) Telemetry status
- xv) PLC status

4.7 VALVES AND PUMPING STATION PIPEWORK

4.7.1 ISOLATION OF PUMPING STATIONS FROM INCOMING FLOW

Sewage generally arrives at a pumping station via a gravity main. Irrespective of the type of pumping station, there are times when a pumping station must be wholly or partially closed down for maintenance or further works. This means that sewage must be prevented from entering the wet well. When only one wet well is provided in the pumping station, storage of sewage under shut down conditions must be considered. If shut down for an extended period is being proposed, tankering or bypassing with temporary pumping may be necessary.

4.7.2 ISOLATING PUMPING STATIONS WITH SUBMERSIBLE PUMPS

The arrangement used to cut off sewage flow to pumping stations with submersible pumps is shown in the Typical Sewage Pumping Station Arrangements contained in Appendix 4D. The knife gate valve is used as due to the small face-to-face dimensions it does not protrude greatly into the pumping station wet well itself and is suitable for use with raw sewage. An extension spindle allows operation of the valve from the top of the pumping station.

4.7.3 ISOLATION OF PUMPS FROM THE RISING MAIN AND WET WELL

Each pump is fitted with a reflux valve and a stop valve on the delivery side of the pump. The reflux valve ensures that backflow, from the rising main through the pump, does not occur when the pump is not operating. The stop valve is positioned beyond the reflux valve so that the rising main can be isolated when it is necessary to carry out maintenance on either the pump or the reflux valve. The stop valve should be in the fully open position when the pumps are operating to ensure minimum resistance to flow.

The stop valve does, however, allow the initial filling of the rising main from the pumping station. By opening the valve slowly, the initial lack of friction head, due to there being no sewage in the main, can be overcome thus ensuring that too great an electrical current is not drawn by the pump motor.

Submersible motor pumps do not usually require separate isolation as they may be simply withdrawn from the well for inspection, removal of chokes and maintenance.

In the case of single well pumping stations with submersible pumps, valves on the discharge pipework are to be mounted in a separate pit from the wet well. Generally this pit is small and shallow relative to the main wet well. This allows the designer to minimise the size of the wet well and makes operation and maintenance of valves easier to carry out. In the event of flooding of the wet well, solids would also tend to hang up around the valves. The separate valve pit also allows a suitable accessible point for the attachment of pressure gauges to check the performance of the pumps.

4.7.4 TYPES OF VALVES USED

Isolating Valves

Valves for isolating duties should be gate valves because they offer unobstructed full-way flow and are capable of shearing fibrous matter upon closure. Conventional gate valves to AS 2638 are used on the delivery side, however, stainless steel knife gate valves are required on the inlet.

Non-Return Valves

The preferred valve is a long body swing check type, again because they offer unobstructed full-way flow when open and they have the ability to shear fibrous matter upon closure. Only double hinged swing check valves are used as single hinged are more prone to stay partially open when any solids rest on the sealing face. By use of an extended spindle (hinge pin on the body), no-flow sensing can be achieved with a cam operated micro-switch or electronic sensor. Addition of a counterweight enables control of the closing characteristics for water hammer control purposes.

Swing check type non-return valves installed in the vertical up position should be avoided because deposition of sediment on the closed disc can prevent the valve from opening. It is also necessary that the gate does not open past the vertical position and thus stick open. A counterweight may be necessary to ensure closure and thus head losses will be increased.

Where it is necessary to install a non-return valve in the vertical up position, a sinking ball type valve should be used since this type of valve is able to shed sediment. Electromagnetic proximity switches are available with ball type valves for no-flow sensing. Care should be taken with the ordering of ball type non-return valves as they may be used in the vertical, horizontal or in between orientation. The design of the ball is, however, specific to each case (ie. the specific gravity is varied depending upon orientation) and will not operate satisfactorily unless the correct ball is selected.

Non-return valves are installed between the pump and its discharge isolating valve to facilitate maintenance of the non-return valve whilst operating other pumps in the pumping station.

Materials of Construction

Materials used are described in Hunter Water Corporation standard technical specifications STS 402 and STS 103.

4.7.5 VALVE PITS

Particular attention must be paid to sizing of valve pits to ensure, that as well as fitting valves and proper dismantling provisions, there will be sufficient room to attach pressure gauges and, where required, install monorail ladder.

As a guide to designers of small and medium submersible pumping stations Figures 13 and 14 show the minimum clearances and dimensions required for typical valve pits.

4.7.6 PIPEWORK

Inlet pipework from the collecting access chamber to station wet well shall be DICL. Nominal fall shall be 100 mm. The connecting pipework shall be sized for ultimate flow but shall not be less than the diameter of the largest sewer discharging into the collecting access chamber.

Discharge pipework from the pump discharge bend through the valve pit to rising main chainage 0.0 shall be DICL.

DICL pipes in ground shall be protected from external corrosion by a loose polyethylene sleeving

Two (2) flexible joints shall be provided for all pipes connected to structures to protect against differential settlement. The first joint shall be at the edge of the structure or as close as possible to the structure. The second joint shall be approximately 1500 mm from the first joint.

4.7.7 VELOCITIES IN DISCHARGE VALVES AND PIPEWORK

The discharge pipework is normally selected with a smaller diameter than the rising main with velocities above 2 m/s being preferable to ensure satisfactory operation of reflux valves and avoid sedimentation in the valves and vertical pipework, for example, in the case of a DN 150 rising main with velocity of 1.2 m/s, DN 100 valves and discharge pipework with a velocity of 3 m/s would be selected. The maximum velocity is limited to 4 m/s to avoid scouring of the pipework lining or material.

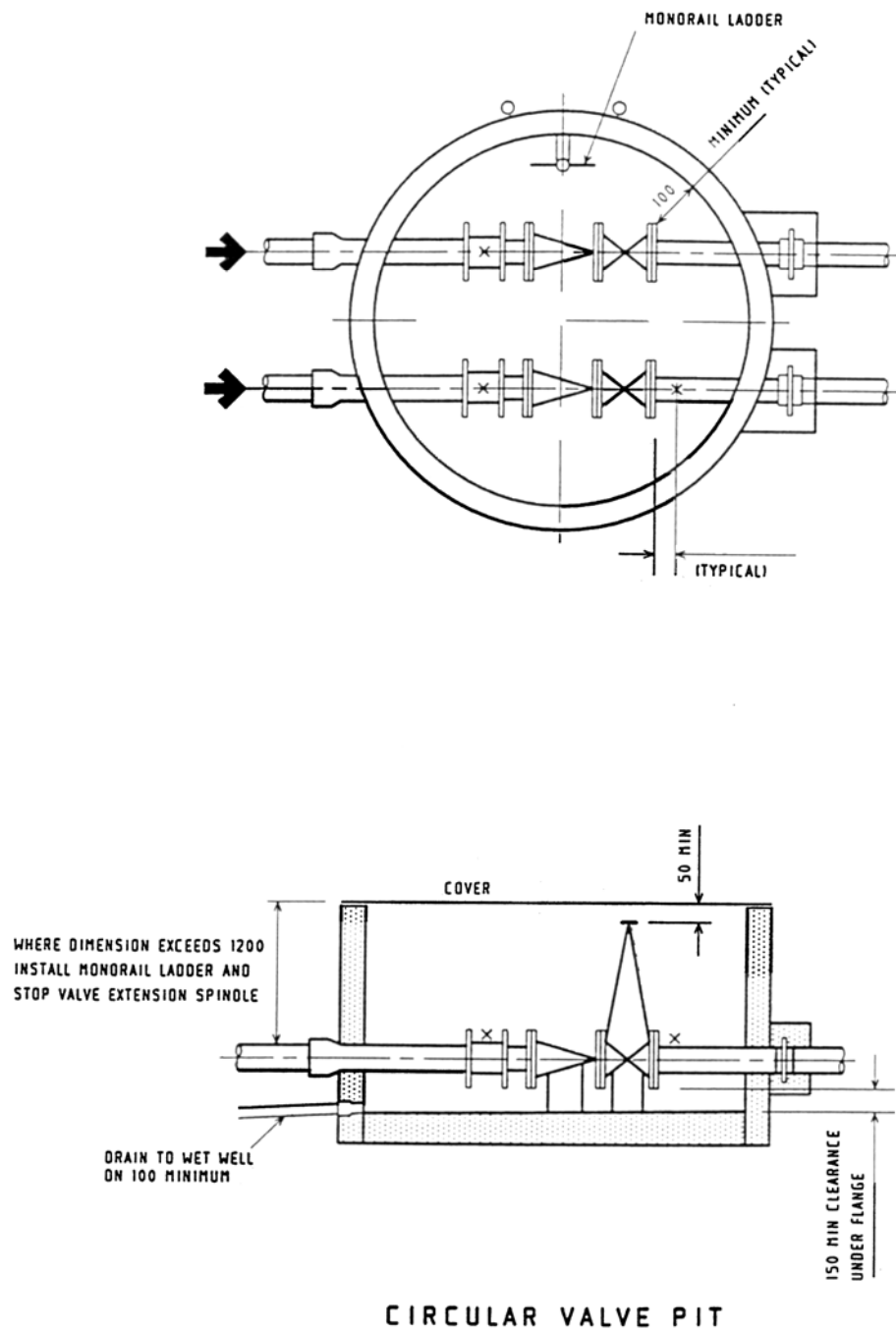


FIG. 13

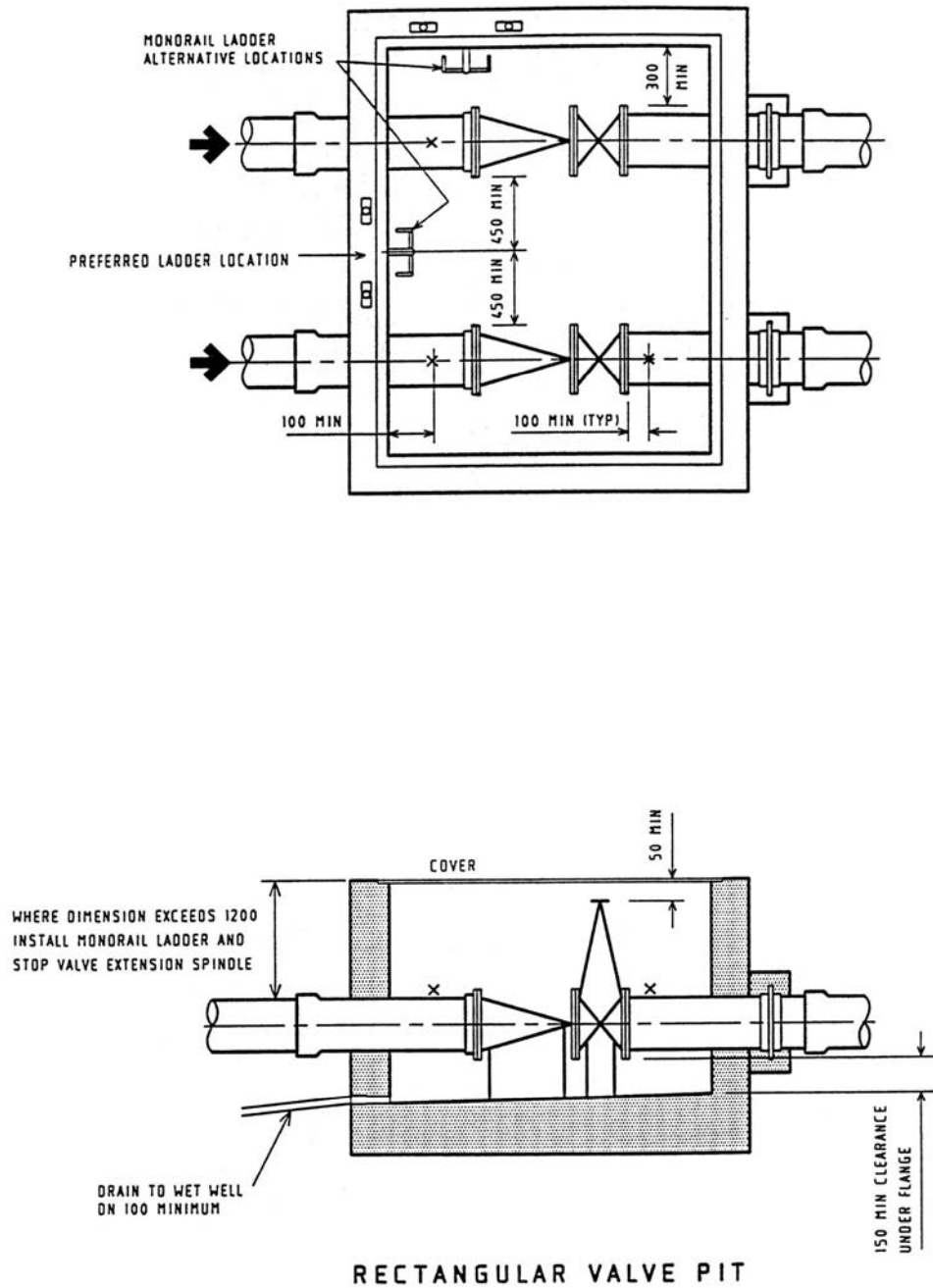


FIG. 14

4.8 VENTILATION

4.8.1 GENERAL

Sewer gases may be found in confined spaces such as pumping stations. These gases can be toxic to personnel entering the installation. The gases may arise due to the septicity of sewage or from chemical wastes that find their way into sewers.

Ventilation of the pumping station by natural air circulation is insufficient to remove the hazard of toxic gases. Some gases, being lighter than air, disperse with a minimum of ventilation whereas other gases which are denser than air do not readily disperse from confined spaces.

For this reason forced ventilation of pumping stations must be carried out if personnel are to enter the installation. This is to conform with the requirements of the Occupational Health and Safety Act, 1983 and AS 2865 - "Safe Working in a Confined Space".

The following practice is to be implemented for submersible pumping stations;

- a) All pump station wet wells shall be provided with natural ventilation only (refer Section 4.8.2).
- b) Appropriate portable appliances as carried by the Corporation's maintenance personnel are used to provide forced ventilation to wet wells should access be required (refer Section 4.8.2).
- c) For pump station dry wells a permanent extraction type forced ventilation system shall be installed.

Where existing pumping stations are being augmented, ventilation shall be in accordance with these requirements.

4.8.2 VENTILATION OF WELLS

Natural Ventilation of the Sewer Atmosphere

As the sewage is led to the pumping station through the sewer there is drag on the air space above the sewage such that the air travels to the pumping station.

In order to ensure the unrestricted passage of this air the natural ventilation which is normally provided must be reasonably sized. Wet wells shall be naturally ventilated using an induct and educt vent combination. The provision of an educt vent stack approximately half the diameter of the incoming sewer with a minimum diameter of 150 mm will generally satisfy the performance requirements. Standard N55 induct vents with DN 100 pipe are used by Hunter Water. Stations with wet wells diameters greater than 3000 mm shall have a minimum of two (2) N55 induct vents and associated DN 100 pipes.

The outlet of the induct vent pipe shall terminate 150 mm above the invert level of the incoming sewer ie, Flood Alarm Level, and shall be located away from the region where the sewage falling from the wet well inlet meets the surface of the sewage stored in the well. The distance between the outlet of the induct vent and the inlet of the educt vent shall be maximised with the educt vent inlet located as close as possible to the roof of the wet well.

It is normal practice to provide a galvanised powder coated mild steel educt vent pipe stack either bolted onto the roof of the wet well or located as near as possible to the pumping

station to suit the particular site. The vent stack shall be at least 9 metre in height and taller than the existing or expected surrounding buildings. Special designs above 12 metres would be required for vents located in low lying areas. When the educt vent stack is sited away from the roof slab consideration should be given to the guidelines in Section 4.8.4 paragraph c) below.

Portable Ventilation Equipment

For submersible type pump wells or pump wells without permanently installed ventilation equipment forced ventilation is provided by a portable blower appliance to which a flexible duct is attached to allow fresh air to be supplied directly to the area of work.

The portable blower unit is usually electrically powered (single phase, 240 volt) or petrol powered and light enough to be comfortably handled by 2 persons.

Electric power shall be provided from the adjacent switchboard.

The air flow rates for portable blower units are based on the following:

- a) for wells up to 7 metres deep an air flow rate equivalent to 20 air changes per hour in the bottom 3 metres is to be provided.
- b) Where wells are between 7 and 10 metres deep 25 air changes per hour in the bottom 3 metres are required.

Units are usually available in the following 2 sizes:

- a) to suit wells up to 2.7 m diameter
- b) to suit wells larger than 2.7m diameter and up to 4.6m diameter

The minimum diameters of flexible duct for (a) and (b) above is to be 150 mm and 200 mm respectively. Larger units will be required for wet wells greater than 4.6m in diameter.

Appropriate portable appliances as carried by Corporation's maintenance personnel are to be used.

Permanent Mechanical Ventilation Systems

Permanent mechanical ventilation systems are outside the scope of this manual.

Odour Control Equipment

Where natural venting is unacceptable, due to visual aesthetics or the likelihood of unacceptable levels of offensive odours, consideration should be given to the installation of odour control equipment such as soil absorption beds with forced air removal. Such units strip out the offensive odours and the remaining air may be vented to the atmosphere. This control is recommended wherever the size of incoming sewer exceeds 600 mm and may be justified in many smaller situations. The soil beds must be of sufficient size to deal with the expected air quantities and replacement of the soil bed media may be found necessary depending on the actual concentrations of hydrogen sulphide passed through the soil bed.

Odour control systems may be either a bypass to the wet well extraction system or a separate system. Odour control systems should have an air flowrate of 4 to 6 well volume air changes per hour and be controlled by a time switch.

4.8.3 VENTILATION OF PUMPING STATION SUPERSTRUCTURES

Ventilation of pumping station superstructures is not covered in this manual.

Where a superstructure (eg. switchroom) is required it should not be placed over the top of a wet well.

4.8.4 VENTILATION OF RISING MAINS

- a) Educt Vent stacks are required at all access chambers receiving pumped discharges. Sometimes it is not possible to prevent anaerobic and even septic conditions developing in rising mains. Foul gases which are produced under these conditions will be released under the reduced pressure near the outlet and further purged from the solution if splashing occurs in the access chamber. Since these gases are both poisonous and aggressive their quick removal and safe dispersion is essential.
- b) Vent stacks should have a diameter equal to the diameter of the rising main they ventilate, up to the maximum vent stack size, normally DN 300.
- c) Due to the many variables associated with changing weather conditions and different terrains and localities which affect natural ventilation no hard and fast rules can be applied to the location of vent stacks. However the following guidelines shall apply:
 - i) Whenever possible vent stacks shall be located on high ground above the level of adjacent inhabited areas.
 - ii) When high ground is not available vent stacks should be located at the most exposed site, or in places where full advantage can be taken of high wind velocities, eg narrow valleys, gullies, etc.
 - iii) Vents stacks should be located as far as practicable from houses, residential areas (including those not yet developed) and other habitable areas.
 - iv) Vents should be positioned to minimise their visual impact and be painted an appropriate colour (refer Section 4.8.5).
 - v) The vent stack should be tall enough to discharge and disperse any foul air above the roofs of surrounding buildings. The vent stack shall be at least 9m in height. Taller vent stacks are available if required.
 - vi) The vent stack shall be connected to the access chamber by a line of the same diameter as the stack having a minimum grade of 1 % draining toward the access chamber.
 - vii) The final location of all vent stacks shall be decided after consultation with Hunter Water.

4.8.5 VENT COLOUR

Vent stacks are considered aesthetically undesirable and consideration should be given to minimising their aesthetic impact.

Following galvanising, the stack should be painted an appropriate colour. This colour should be selected depending on the surrounding environment in which the vent is located. Where the vent is to be located in a bush setting a darkish green-brown colour (Colorbond Woodland Grey or similar) is suggested. Where the background behind the vent will consist mainly of sky, a pale grey colour may be more appropriate.

The Designer's report shall contain a mock-up photo showing the proposed appearance of the vent and surrounding areas.

4.8.6 TYPES AND HEIGHTS

For details of standard educt vents refer to relevant Standard Drawings.

4.9 ACCESS

4.9.1 GENERAL

Requirements for entry to pumping stations vary depending on whether they are wet well-dry well type or single well with submersible pumps.

The single well pumping station will normally be equipped with a valve pit. Where depth to the top of pipework in the valve pit exceeds 1200 mm, ladders are generally used for access. As space is limited monorail ladders to Hunter Water Corporation Standard Construction Practice Drawing SCP-909 are considered adequate up to a depth of 3 metres. For depths greater than 3 metres a sloped ladder is preferred.

For pumping station dry-wells, sloped ladders are considered essential.

Ladders are not to be provided in submersible pumping station wet wells

Entry to wet wells may be required for the following functions to be carried out:

- a) Cleaning (ie. hosing down).
- b) Removal of obstructions (eg. length of timber).
- c) Attention to level regulators
- d) Carry out inspections

Fall restraint anchor points must be provided for all structures (eg: dry wells, wet wells, valve pits) where it is possible to fall greater than 2 metres (refer Section 4.9.5).

Pumps and machinery are installed after the completion of the civil construction. Pumps and motors are frequently supplied as factory assembled units. Civil designers have occasionally failed to detail openings in the reinforced concrete roofs of pumping stations, of sufficient dimensions to allow installation of the pumping machinery. This requires either costly dismantling and re-assembly in the bottom of the well or adjustment of openings to enable proper installation. This oversight is of concern particularly when submersible pumping equipment is used as there is a frequent maintenance requirement to install and extract these units from the wet well. Pump dimensions must be checked before roofs are placed on the pumping station. Pumps considered by the designer may not be those that will be ultimately accepted under the pump supply contract.

4.9.2 WET WELL CLEANING - WATER SUPPLY

Cleaning of wet wells is a function required regularly and at relatively short intervals (recommended on a weekly basis). Ideally this function should be carried out from ground level by directing an adequate water jet at the walls of the well and entry would not, therefore, be necessary.

At all pumping stations an adequate water supply must be provided for cleaning purposes. Contamination of the reticulation system due to back syphonage must be prevented. The water service is provided with an air break or a vacuum breaker assembly such as the Reduced Pressure Zone Device (RPZD) arrangement detailed in HWC standard construction

practice drawing SCP-911. Often, particularly during the early life of the station, pumping stations must be provided with “make-up” water to lessen the effects of detention and septicity. All outlet taps are to be controlled by vandal proof lockable or removable handles. The size of the service main to be provided will depend on distance from the water main and the available pressure therein. A minimum available pressure of 20 metres at a flow rate of 0.70 L/s is required at the pumping station. Often, a 25 mm service will suffice for minor stations, whereas for larger stations a 50 mm service with a 20 mm outlet hose tap may be necessary.

The water supply service to the pumping station shall be designed and detailed on the drawings in accordance with the NSW Code of Practice - Plumbing and Drainage, AS 3500, HWC standard technical specification STS 402 and the following :-.

An approved testable reduced pressure zone device (RPZD) shall be installed at the meter stand in accordance with AS 3500.

Where the service crosses a road, the service pipe shall be laid within a Class 6 minimum suitably sized PVC conduit. Joints in the service pipe within the road crossing are to be avoided.

As the location of the meter stand is site specific, the designer shall determine a suitable location for the meter stand and obtain written approval from the Corporation for each individual site. The meter stand shall preferably be located one (1) metre inside the property boundary of the pumping station site. The service pipe from the main tap to the meter stand shall be laid at right angles to the watermain.

Where the meter stand including the RPZD could be subject to damage by maintenance vehicles it is to be protected by a galvanised pipe frame, to be indicated on the project drawings (refer SCP-911).

The service shall be sized in accordance with the following table:

LENGTH SERVICE metres	DIAMETER SERVICE mm	DIAMETER METER mm	DIAMETER RPZD mm	DIAMETER STANDPIPE mm	DIAMETER HOSE TAP mm
< = 30	25	20	20	25	20
30 to 130 *	32	25	25	25	20
> 130	Designed **	As required	As required	25	20
* The Corporation may permit use of DN 25 mm water service where the available pressure in the water main is sufficient. ** Designed to provide a minimum pressure of 20 metres head at the pumping station hose tap at a flow rate of 0.70 L/s					

A cast iron path box is required to be installed over the main tap in the watermain in accordance with Drawing SCP-911 where either of the following occur:-

- The meter stand is located more than 30 metres from the maintap.
- The service pipe from the main tap to the meter stand is not laid at right angles to the watermain.

The path box, if required, is to be shown on the Drawings.

Refer to Figure 15 for typical water service layout.

4.9.3 COVERS

The Corporation has standard designs for aluminium covers and safety screens for the pump well and valve pit. Wherever possible, these standard designs should be utilised by the designer. Sliding aluminium covers shall be used for pumping station wet well roof openings. Recessed aluminium covers shall generally be used for valve pits. Refer HWC standard construction practice drawings contained in Part 2 of HWC Sewerage Standards for typical standard sizes and designs. A drawing list is included in Appendix 1E. Gatic covers shall not be used for the wet wells.

The type of covers fitted to the valve pit may depend on the siting of the pumping station. Where the valve pit is subject to vehicular traffic Gatic cast iron covers may be used, however there has been considerable objection to the use of cast iron covers due to their mass and their use is restricted to trafficable valve pits and subject to written approval by the Corporation. The correct strength of cover is selected to withstand the likely loading application.

4.9.4 LADDERS

General

Ladders shall be designed in accordance with AS 1657 and the requirements of the NSW Workcover Authority.

Ladders are not to be provided in wet wells of submersible pumping stations.

Sloped Ladders

Sloped ladders should be rung type sloped at an angle between 70° - 75° to horizontal. Do not use tubular steel stiles for sloped ladders.

Vertical Ladders

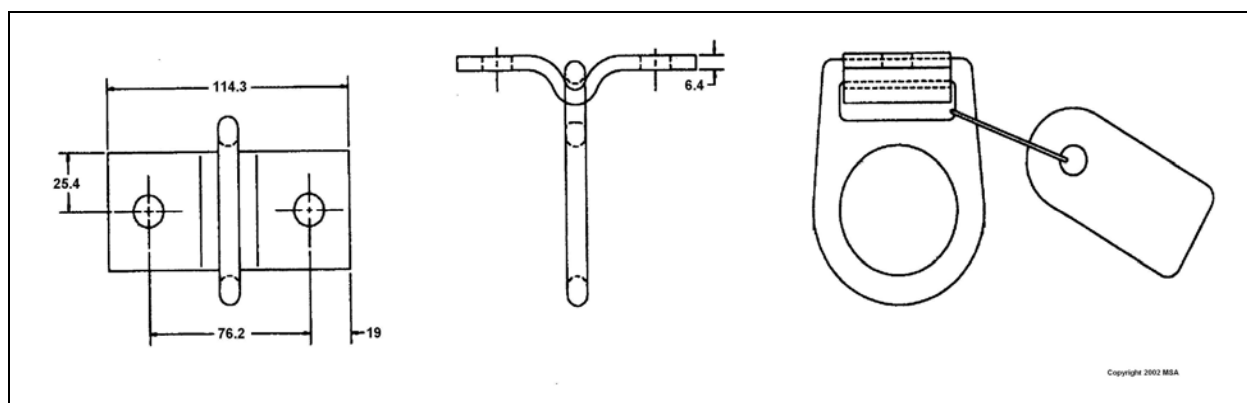
For dry wells, valve pits and other structures of pumping stations where it is impracticable to provide ladders at the desired slope, vertical ladders may be provided. For those cases where it is impracticable to provide intermediate landings to limit the vertical distance between landings to 3000 mm, an approved safety device must be provided. For valve pits vertical ladders will normally be galvanised steel monorail ladders to Hunter Water Corporation Standard Construction Practice Drawing SCP-909.

4.9.5 FALL RESTRAINT

Fall restraint anchor points shall consist of two grade 316 stainless steel “Trubolt” stud anchors (or equivalent) installed at 76mm separation of the bolts centre to centre. When undertaking works near openings maintenance personnel will attach anchor plates to the anchors. The stud anchors shall be 100mm x 12mm with an M12 thread with matching nuts and shall be installed in accordance with the manufacturer’s requirements with sufficient allowance for fastening of the anchor plates.

The anchor points shall be installed sufficiently far away from openings to allow adequate freedom of movement for personnel connected to the anchor points. It is anticipated that at most pump stations two separate anchor points on opposite sides of the hatch covers will be required. The anchor points shall be installed in a position (eg: the external side of the roof slab) that does not create a trip hazard. Provide sufficient clearance around the anchor points to allow installation and removal of the anchor plate.

A typical anchor plate detail is shown as follows:



4.9.6 LIFTING FACILITIES

Lifting arrangements for pumps and pipework during installation and later maintenance must not be overlooked. Adequate access is to be provided for mobile lifting equipment.

4.9.7 ACCESS ROADS AND HARDSTAND AREA

General

In all cases the access roads to the pumping station and the standing area at the site must be considered in the light of the necessary mobile lifting equipment, maintenance vehicles and tankers to be brought to the station. Access will be site specific. Roads shall be all weather and suitable for heavy vehicles.

Access and Turning Areas

Vehicle turning areas shall be provided where necessary to minimise any traffic hazard caused by vehicles entering and leaving the site. In general terms, vehicle turning areas are required where either:

- The pump station does not front an adjacent roadway, or,
- The adjacent roadway is a main road.

The Corporation and the relevant local council shall be consulted in determining requirements for access.

Minimum Access Road Requirements

- Minimum pavement width three (3) metres.
- Desirable maximum grade 12.5 %

- Absolute maximum grade 20 %
- Preferred and minimum crossfall 3 %
- Maximum crossfall 5 %

All proposals for access road grade steeper than 12.5 % must be submitted to the Corporation for written approval before proceeding with the design.

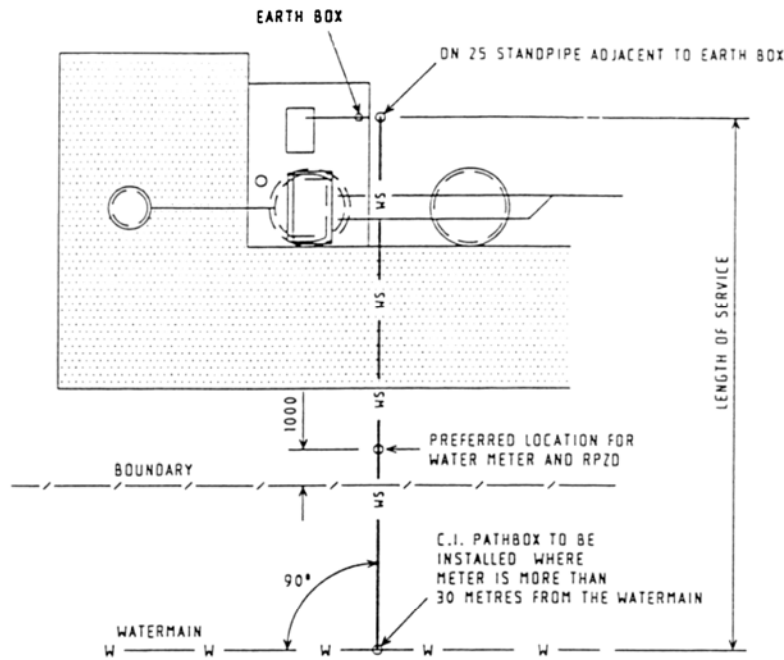
Design of Access Roads

Design access roads in accordance with the RTA Road Design Guide. Notwithstanding the requirements of the Road Design Guide, minimum requirements include:

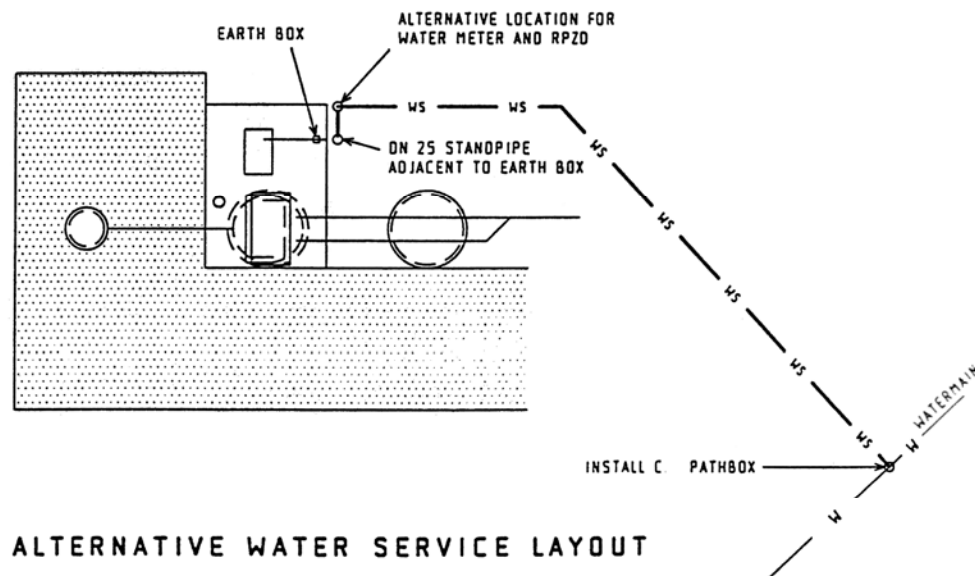
- Access roads and hardstand / turning areas shall be designed to accommodate a 25kL articulated tanker.
- Road base for access roads shall be not less than 200 mm thick road base.
- Access roads with grades steeper than 10 % and all hardstand areas shall be sealed. Seal shall be:
 - two (2) coat bitumen seal, or
 - 25 mm asphalt, or
 - reinforced concrete
- All vehicle turning areas shall be reinforced concrete.

Landscaping

The remainder of site including all cut and fill batters and any surface table drains shall be topsoiled and turfed. Undertake landscaping of the site to improve visual amenity.



PREFERRED WATER SERVICE LAYOUT



ALTERNATIVE WATER SERVICE LAYOUT

FIG. 15

4.10 CIVIL DESIGN

4.10.1 GENERAL

Sewage pumping stations are generally located in low-lying areas in order to maximise service to the area with gravity sewers.

Where soil conditions are favourable and open excavation is feasible, construction of a pumping station will proceed as for any normal tank. Under these circumstances the shape and design of the station will be governed by the requirements of fitting the equipment and the cost of construction. Sometimes a rectangular plan shape may be found to be the best.

In many cases it will be found that water charged sands, silts or clays exist for the full depth of the station. In these circumstances the method of construction frequently adopted is the open well caisson technique. A reinforced concrete shell, sometimes with a cutting edge on the lower perimeter, is formed above the groundwater level and is progressively sunk by excavating within the caisson wall. The caisson normally sinks under its own weight but where sinking difficulties are encountered, kentledge (temporarily superimposed dead weight) may be used to provide the additional weight. An alternate design using a lubricant, such as Bentonite, to reduce the resistance to sinking may also be considered.

In sinking the caisson due care must be taken to maintain acceptable verticality. The allowable tolerance on verticality of wells sunk as caissons will generally be related to the fixtures to be placed internally. As such, deep caissons out of vertical will generally be a greater problem than shallow caissons. Controlling features to be considered are:

- a) Pump guide rails must be vertical
- b) Internal walls which may be required to be vertical.

The following tolerances shall apply to the wet well:-

- a) In the final position, the centreline of the wet well shall not vary from plumb by more than 1 (horizontal) to 100 (vertical).
- b) In the final position, the trace of the centreline of the wet well at the surface must be contained within a circle centred in the design position and of radius 150 mm.

Whilst this is a relatively tight tolerance, it is difficult, due to the variable size of pumps and wells, to cover all situations. Any instance of greater misalignment can be assessed on an individual basis as to the effect and the need for any corrective measures.

The depth to which the caisson is sunk is generally governed by the level of the incoming sewer except where the geotechnical investigation suggests a very weak founding stratum. The latter would be rare as the bearing pressure imposed on the founding stratum by sewage pumping stations is generally small.

4.10.2 SOIL INVESTIGATION

At least one borehole should be drilled at the proposed pumping station site. The boreholes must be taken to at least 2 metres beyond the foundation level except where solid rock is encountered which would indicate that open excavation will be necessary. The foundation level may often be deeper than first envisaged. Points to be considered are:

- (a) Depth to Invert of the incoming gravity sewer
- (b) Sewage depth for control of pump (BWL to TWL).
- (c) Minimum pump submergence (Pump Floor to BWL)
- (d) Plug depth to avoid flotation.

A preliminary borehole depth may be found from the following approximation:

$$BD = 1.5 (DS + 0.1 T^{0.5})$$

where

BD	=	Borehole Depth (metres)
DS	=	Depth of Incoming Sewer (metres)
T	=	Approximate Number of Tenements for which the station is to be designed

A typical soil and groundwater analysis required from the boreholes is as follows:

- Classification properties
- Permeability
- Shear Strength
- Lateral Pressure
- Settlement
- Groundwater lowering
- Elastic Modules Profile
- Chemical Testing of soil and groundwater

4.10.3 DESIGN CRITERIA

General

The reinforced concrete walls internally and externally are designed as components of a water retaining structure in accordance with AS 3735 and appropriate sections of AS 3600.

The limit state design procedure is adopted for economical design of members. The stress in the reinforcement is not arbitrarily restricted as in the “alternative method” and therefore should result in thinner sections with less reinforcement.

For concrete water retaining structures, it is essential for durability to restrict the width of cracks in the concrete consistent with the design exposure condition. For sewage pumping stations, the concrete walls and slabs in a sewage environment are considered to be in Class A exposure condition, and are designed to limit the crack width to 0.1 mm at the surface. Where the wall or slab is less than 225 mm thick, the same exposure condition shall be used for both faces. Thicker sections may be designed for different exposure conditions on each face where appropriate.

The minimum reinforcement provided must satisfy the crack criteria for stresses due to flexural tension and direct tension in the mature concrete and direct tension due to restrained shrinkage and heat of hydration movement in the immature concrete. Small diameter reinforcing bars at close spacing are generally preferred to large diameter bars at wide spacing.

Analysis of precast sections for shrinkage reinforcement is not generally required as these units can be examined before installation, the governing criterion being that there be no crack

into which a test crack measuring gauge of 0.08 mm thickness conforming to the shape shown in Figure B4 of AS 4058 can be inserted to a depth of 2 mm.

Cover to Reinforcement

Chemical testing of soil and groundwater is essential to allow proper assessment of the required external cover to the reinforcement. Generally, for concrete cast in-situ, a minimum cover of 65 mm is required both internally and externally on all concrete faces in contact with ground, sewage or sewerage gases. Where the soil investigation reveals a corrosive environment, the cover externally may need to be increased. The extra thickness so obtained cannot be used to decrease the amount of reinforcement required in the member. Often increased reinforcement will be required to overcome shrinkage during curing.

For smaller pumping stations reinforced precast concrete rings are often used for the walls as an economic alternative to cast-in-situ walls. Concrete units precast under controlled factory conditions can be expected to offer more durable concrete and as such lesser covers to reinforcement may be permitted providing excessively corrosive conditions will not be encountered. Covers to reinforcement generally adopted for precast units are:

- (a) 30 mm internal
- (b) 50 mm external for ground conditions moderately aggressive to concrete. For highly aggressive ground conditions a greater cover to reinforcement will be necessary. Alternatively, the units may be coated with coal tar epoxy in which case they may only be placed in open excavation, because sinking as a caisson would damage the coating.

Concrete Mix

Generally the cement to be used shall be either:

- a) Fly Ash Blended Cement conforming to the requirements of Type SR to AS 3972 and containing 20% fly ash to AS 3582 Part 1, “fine grade” only, or
- b) Blended Cement, other than fly ash, conforming to the requirements of Type SR to AS 3972.

The fineness index of the cement should be not less than 280 m²/kg and not more than 420 m²/kg.

In the interests of producing high quality durable concrete, relatively high cement contents and low water/cement ratios are used. Minimum cement contents, water cement ratios, maximum aggregate sizes and grade designations of the various elements of pumping stations are as follows:

Element	Min. Cement Content (kg/m ³)	Max W/C Ratio (by mass)	Nom. Max. Aggregate (mm)	Grade Destination (MPa)
Precast Units	400	0.45	-	32 or higher
Reinforced In situ Concrete	380	0.45	20	32 or higher
Benching	330	0.50	20	32

Concrete				
Plug Concrete	240	0.60	75	20
Blinding Concrete	-		-	15

It should be noted that strength is not a criterion as the specified mix will give concrete strength in excess of the designated grade.

The concrete is placed and cured in accordance with HWC Technical Specifications STS 402 and AWAQAN National Specification - Water - Section TR10 - Concrete (Civil Works).

4.10.4 DESIGN OF PUMPING STATION WALLS

General

The design of walls will fall into one of two categories. Where a rectangular station is used, the wall is designed to resist the stresses induced by the external active earth pressure and hydrostatic pressure. (either internal or external). Internal walls of wet and dry well stations are designed similarly, assuming that water (or sewage) may rise to the top of the wall on the wet well side.

Where a circular station is used, the wall is again designed to resist the stresses induced by the external active earth pressure and hydrostatic pressure (either internal or external). In this case the wall is analysed as a cylindrical shell with various end conditions to be considered depending upon the fixity achieved under the load condition occurring from particular construction phases.

Design Loads

- a) If the wall is to be constructed in open cut excavation the maximum load will be an external triangular load increasing linearly at the rate of 15 kN/m^2 for each metre depth. The following end conditions should be considered:
 - i) Where the wall is positively fixed to the base slab with reinforcement, the structure is analysed as having a fixed base and free top.
 - ii) Where the wall is rested on the base slab and sealed with cement mortar, the structure is analysed as having a hinged base and free top.

Additionally, the wall should be checked for an internal triangular load increasing linearly at 10 kN/m^2 per metre depth imposed by the maximum liquid level. In this case, it is assumed that the external soil pressure is not effective. This condition can be alleviated by specifying progressive backfilling of the structure and designing accordingly.

- b) If the wall is to be constructed in caisson form the following conditions must be considered:
 - i) During sinking, the wall is analysed as a cylindrical shell with free top hinged base subject to a linearly increasing external triangular load imposed by soil pressure and where present groundwater.

Soil pressure only	10 kN/m^2 metre depth
Soil and groundwater	15 kN/m^2 per metre depth

- ii) With the caisson plugged at the base and dewatered, the wall is analysed as a cylindrical shell with a free top and fixed base, subject to linearly increasing external triangular load imposed by soil pressure ($K_a = 0.5$ for long term) and where present groundwater.
- iii) With the caisson plugged and no groundwater present, the wall is analysed as a cylindrical shell with a free top and fixed base subject to linearly increasing internal triangular load imposed by the minimum liquid level (10 kN/m^2 per metre depth) and the external load imposed by the soil neglecting the top 2-3m of the disturbed soil depth. See Figure 16.
- iv) Simultaneously with (i) or (ii), the caisson wall must withstand any surcharge loads imposed during and after construction. Stockpiling of excavated material near the caisson combined with heavy machinery can result in severe asymmetrical loads. This aspect can be minimised by specifying adequate construction procedures.

Precast Cylinders

The standard precast cylinder units as supplied by Humes and Rocla are suitable up to the following depths from the top of the roof slab to the top of the floor slab:

UNIT DIAMETER DN (mm)	MAXIMUM DEPTH mm
1800 to 2100	6000
2400 to 3000	8000

Humes will design and supply units with additional reinforcement which are suitable for depths up to 9000 mm.

Design of the Toe of Caisson Walls

The base of the caisson wall is often provided with a cutting edge sloped between 30 and 45 degrees to the vertical, with the steeper slope being preferred for clayey soils and the flatter slope for sandy soils. The underside of the cutting edge is projected beyond the face of the wall to act as a reamer reducing the skin friction resistance. The reduction may be significant in clayey soils but is generally much less effective in soft sandy soils which are quickly reconstituted against the face of the wall.

4.10.5 DESIGN TO RESIST HYDROSTATIC UPLIFT

In the case of pumping stations and valve pits constructed in open excavation, the base slab is generally extended outside the walls such that backfill placed on top of the slab protruding beyond the external face of the wall is utilised to counteract the pressures acting to float the structure. It must be appreciated that until such time as backfill is placed, the structure may float. The excavation must, therefore, be kept essentially dry. If water floods the excavation, a similar head of water inside the structure will ensure that flotation does not occur.

For pumping stations which are sunk as caissons, upon reaching the desired level, a concrete plug is placed to form a seal. The concrete plug will add sufficient mass to the walls to counteract the hydrostatic uplift pressure when the caisson is dewatered. The remainder of

the internal work can then be carried out in the dry. The depth of plug required is determined from the balance of forces. If skin friction is neglected the required depth is found simply by the equation:

$$d = \frac{2.4 D^2 H}{1.4(D+2t)^2} - H - \frac{W}{1.4}$$

where

- d = depth of plug (metres)
- D = internal diameter (metres)
- H = depth of caisson from top of wall to top of plug (metres)
- t = wall thickness (metres)
- W = depth of water table from top of wall (metres)

Skin friction may be utilised if sufficient soil information is available. Normally, the top 2 to 3 metres are neglected as the soil may not be reconstituted following sinking of the caisson. See Figure 16.

If skin friction is to be taken into account the required depth of plug will be found by:

$$d = \frac{1}{f\pi(D+2t) + 14A_o} [10A_o(H-W) - 24A_wH - f\pi(D+2t)(H-Y)]$$

where

- f = skin friction assessed from soil tests (kPa)
- Y = depth of caisson from top of wall not considered to be contributing to skin friction (metres) (minimum 2 metres)
- A_o = Plan view area of Caisson = $\pi/4(D+2t)^2$
- A_w = Cross sectional area of wall = $\pi/4[(D+2t)^2 - D^2]$

Note: Skin friction will depend on whether open cut or caisson construction is used. In the former, material used for backfill must be considered. In the latter, consideration must be given to soil type and whether a clearance ring is used in which case friction forces may be considerably reduced.

Since the plug itself will be under load, the minimum plug depth required is based on the flexural strength of the concrete such as to limit tensile stress to $0.13\sqrt{F'_c}$ MPa. Minimum plug depth, therefore, is found by the equation:

$$d_{\min} = S \sqrt{\frac{3PD^2}{8F_t}}$$

where

- S = Safety Factor to allow for the non-uniform depth of plug and likely poor quality of concrete on the under side of the plug. Normally a factor of 1.5 should be adequate. (Minimum 1.1)
- P = Contact soil pressure or hydrostatic pressure (MPa)
- D = Internal diameter (metres)

$$\begin{aligned}F_t &= \text{Allowable tensile stress for concrete (} 0.13\sqrt{F'_c}\text{)} \\F'_c &= \text{Compressive strength of concrete at 28 days.}\end{aligned}$$

4.10.6 DESIGN OF BASE SLAB

A base slab is generally placed on top of the plug in caissons to provide watertightness, good durable concrete and a solid base on which to mount equipment. The slab is designed to sustain the full hydrostatic pressure on the underside assuming that leakage past the plug occurs. For larger pumping stations, the design span may be reduced by anchoring the slab to the plug. The slab again is designed such as to limit cracking to a maximum width of 0.1 mm.

4.10.7 DESIGN OF ROOF SLAB

General

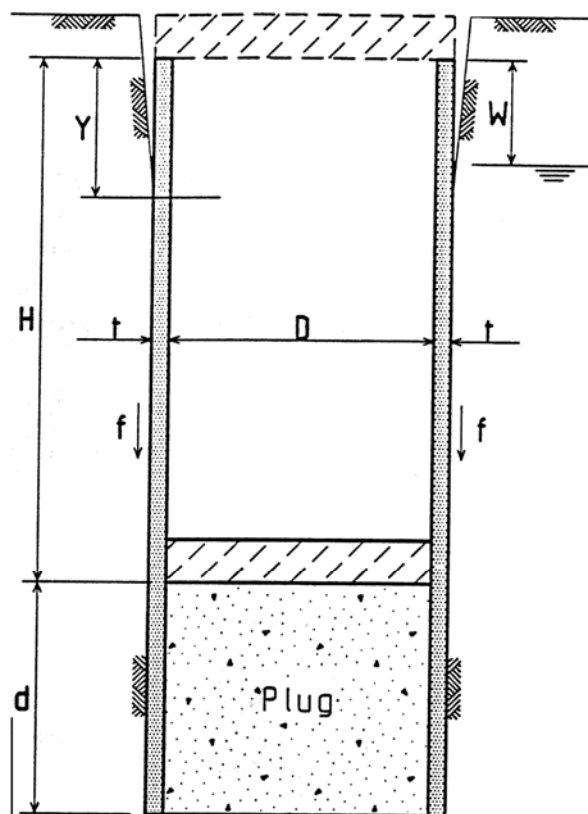
The roof slab is also designed to limit cracking to a maximum of 0.1 mm width. The location of the pumping station will determine whether vehicle loading should be considered. Roof openings require particular attention especially where removable beam recesses are to be provided.

Hatch Openings and pump spacings

Standard hatch openings (Dimension H x J), pump spacing (Dimension D) and pump offsets (Dimension G) have been adopted by the Corporation - refer Figure 1 Section 4.2.

These dimensions essentially fix the hatch opening size and location relative to the wet well.

Pump offset (Dimension G) and pump spacing (Dimension D) may be altered to suit pumps provided that the dimensions are suitable for the equivalent pumps from each of the approved manufacturers sized for ultimate duty.



d = depth of plug (metres)

D = internal diameter (metres)

H = depth of caisson from top of wall to top of plug (metres)

t = wall thickness (metres)

W = depth of water table from top of wall (metres)

Y = depth of caisson from top of wall not considered to be contributing to skin friction (metres) minimum 2 metres

f = skin friction assessed from soil test (kPa)

FIG. 16

4.11 MAINTENANCE AND SAFETY

4.11.1 GENERAL

For dependable, efficient operation and for safety reasons sewage pumping stations require an ongoing program of systematic inspection, testing, preventative maintenance and equipment overhaul.

4.11.2 MAINTENANCE

The systematic inspection of plant equipment to detect and correct problems before they develop into costly major repairs or replacements is recommended. The way in which the equipment is operated will increase or decrease the amount of maintenance required. The nature and age of the equipment and the number of hours operation are factors that will affect the maintenance requirements.

The Corporation has developed specific maintenance programs for its facilities and monitors all sewage pumping stations using a telemetry system which also allows operating history records for individual pumping stations to be kept.

The wet well of any pumping station may accumulate a build-up of grit and solids in the bottom of the well and grease and slime on the walls. If unchecked, this build-up may cause odour problems and generally impair operation.

The walls of wet wells, especially at sewage levels should be hosed down at least weekly. Particular attention should be paid to the cleaning (and untangling if necessary) of level regulators.

4.11.3 SAFETY

General

Hazards in pumping stations include exposure to physical injuries, body infections, oxygen deficiency, toxic gases or vapours and explosive or flammable gases. The wet or damp conditions of the working environment exacerbates the already high incidence of hazards. These occupational hazards can be largely avoided by the adoption and execution of safe practices and the use of approved safety equipment.

It is the responsibility of the designer to acquaint themselves with the hazards associated with pumping station operation and to take steps to mitigate them in the design.

Hazardous Atmospheres

Pumping station wells are a confined space. Only personnel who have undertaken approved training for entry and working in confined spaces are allowed to enter pumping station wells. Designers should be familiar with Hunter Water Corporation's "Procedures for the Safe Entry and Working in Confined Spaces".

GLOSSARY OF TERMS

ADWF	The average flow in sewers during a period of dry weather. An ADWF of 0.011 litres/second/tenement is to be assumed for areas for which more accurate information is not available. (Refer Section 3 “Sewerage Network”).
Alarm Level	Flood Alarm (High) Level. The sewage level in a wet well at which a warning will be transmitted to the Corporation’s Service Centre to alert attention. (Refer Section 4.6.2)
BWL	Bottom Water Level. The minimum automatic operational sewage level in a pumping station wet well. Pumps are switched off at this level. (Refer Section 4.5.3)
Corporation	Hunter Water Corporation
DI	Ductile Iron (Pipes and Fittings)
DICL	Ductile Iron Cement Lined(Pipes and Fittings)
Equivalent Tenement (ET)	The basic unit of measure adopted by the Corporation to describe flow from contributing sources as a ratio to that flow expected from a single average residential sewer.
GMS	Galvanised Mild Steel
GRP	Glass Reinforced Plastic (Pipes and Fittings)
HGL	Hydraulic Grade Line
HWC	Hunter Water Corporation
Invert	The lowest point of the internal surface of a pipeline or channel at any cross-section along its longitudinal section.
IL	Invert Level
k	Colebrook-White roughness coefficient, linear measure of roughness, the Nikuradse equivalent sand roughness.
MS	Steel Plate (Pipes and Fittings).

MTWL	Maximum Top Water Level. The maximum automatic operational sewage level in a wet well. Standby pumps are switched on at this level. (Refer Section 4.5.3).
NPSH	Net Positive Suction Head. The NPSH is the difference between the inlet total head (absolute) and the head corresponding to the vapour pressure (absolute) of the liquid.
PDWF	The expected peak flow in sewers during a period of dry weather. (Refer Section 3 “Sewerage Network”).
PWD	Public Works Department, NSW
PWWF	The expected peak flow in sewers during a period of wet weather. (Refer Section 3 “Sewerage Network”).
Qp	The rated capacity of a pump or group of pumps, expressed in litres per second.
Reticulation	The network of sewers and rising main(s) in a sewerage system
SCA	Switchgear and Controlgear Assemblies for pumping stations. (Refer Section 4.6.2).
Sewage	The waste (mainly water) produced by the community from residential, commercial and industrial services
Sewerage System	The complete system of sewers, access chambers, pumping stations, treatment facilities and associated disposal facilities, required to receive, transport and treat sewage to a certain standard and to dispose of the resultant effluent in an approved manner
TWL	Top Water Level. The sewage level in a wet well at which pumps for normal automatic operation are switched on. (Refer Section 4.5.3).
UPVC	Unplasticised Polyvinyl Chloride (Pipes)
V	Wet well Control Volume. The volume between TWL and BWL. (Refer Section 4.5.3).
v	The velocity of flow in a given size pipe, expressed in metres per second.

BIBLIOGRAPHY

1. Manual of Practice - "Sewer Pumping Station Design" PWD, NSW, 1986
2. Webb TH, Gould B.W., "Water Hammer Control in Pipelines" NSWU Press.
3. "Tables for the Hydraulic Design of Pipes and Sewers" Hydraulics Research Station Limited, Wallingford, Oxfordshire, 1983.
4. AMD 2337 CP 312 (British) "Unplasticised PVC pipework for the conveyance of liquids under pressure"
5. "Design Recommendations Pumping Stations With Large Submersible Pumps" Flygt Systems Engineering, ITT Flygt, Sweden, 1994

APPENDIX 4A

DRAWING AND DOCUMENTATION REQUIREMENTS

Drawings

Refer to Section 1.5 for Drawing Standards.

Contract Documentation

Designer shall ensure that all drawings required including relevant standard drawings are included in the contract documents.

Standard Construction Practice Drawings listed in Appendix 1E are subject to review. Before including any of these drawings in contract documents designer is to ensure that drawing has not been revised. Current drawings may be obtained from the Corporation.

Designer shall provide a completed technical specification for the pumping station. This specification shall be based the Hunter Water Corporation standard technical specification for Construction of Submersible Sewage Pumping Stations (STS 402) and accompanying standard volume and shall incorporate all amendments and / or additions as required for each particular pumping station. These amendments shall include:

- Nominating the required pumps, suitable alternative pumps, pumping station title and 'S' number on the Form E86;
- Specifying the required pump duty point, estimated annual pumped volume, minimum motor cable length, the pumping station title and 'S' number on the Schedule of Technical Data –Submersible Pump Sets;
- Specifying the required switchboard components, the pumping station title, 'S' number and relevant drawing numbers on the Schedule of Technical Data - Switchgear and Controlgear Assemblies;
- Incorporating the following Appendices:
 - APPENDIX F ASSET AND EQUIPMENT NUMBER LABELS LIST (Numbers to be obtained from the Corporation and list completed)
 - APPENDIX G DRAWING LIST (Complete list of contract drawings)
 - APPENDIX H PIPELINE CHARACTERIESTIC GRAPHS
 - APPENDIX I BORE LOGS
- Incorporating any other approved amendments and additions to the standard technical clauses as required for the particular pumping station.

Design Reports

Designers designing sewage pumping stations and rising mains to be incorporated into the Hunter Water Corporations' system shall submit Two (2) copies of the following documentation for review.

- o A Design report including any special assumptions or design details.
- o A Mechanical design report covering the following :-
 - Wet well diameters and structure levels (eg , floor level , roof level , overflow level , 1:100 year flood level).
 - Operating levels (TWL , BWL , etc) including any staged TWL's.
 - Discharge pipework and valves (diameters, materials).
 - Velocities in discharge pipework and rising mains.
 - Pump spacings and pump offsets in wet wells.
 - Detention times of system and any necessary septicity controls.
 - Overflow storage time at ADWF and PWWF
 - Incoming sewer invert levels and diameters.
 - Duty points.
 - Initial pump selection report (refer Section 4.4.4).
 - Electrical requirements (eg motor rating).
 - Present worth analysis of pumps and rising mains.
 - Rising main selection (diameters, materials).
 - Ventilation requirements.
 - Water hammer analysis details.
 - General comments (eg future upgrading by impeller change; triplex versus duplex station, special requirements).
 - Pumpout and / or gravity scours and air release valves if necessary.
 - Rising main characteristic curves.
- o An Electrical design report which covers the following:-
 - Supply options.
 - Voltage drop calculations for consumers mains for each pumping station.
 - Voltage drop calculations for each total installation
 - Fault level calculations for each installation.
 - Starting methods.
 - Switchboard type.
 - Ratings for contactors , T.O.L.'s , integral units , circuit breakers and main isolators for each installation.
- o Geotechnical report for the pumping station and rising main.
- o Copy of submission to EPA for overflow approval.
- o Copy of EPA approval for overflow.
- o Copy of Mine Subsidence Board approval if applicable.
- o Required amendments to technical specification.
- o Two (2) sets of fully detailed drawings (including civil, mechanical and electrical).

APPENDIX 4B

EXAMPLE OF PRESENT VALUE ANALYSIS

(Refer: Section 4.4.2.7)

Factors considered are:

- (a) Rising main costs and life
- (b) Pumping station structure costs and life
- (c) Pumping machinery (including switchgear and ancillary items) life and replacement and maintenance costs.
- (d) Pump running costs over the life of the station.

DATA

Base Year	1995
Rising Main	200 mm diameter UPVC Class 12 1500 m long - sized for ultimate flows. 30 years economic life. Cost \$210,000
Static Head	15 m
Pumping Station Structure including pipework	2700 mm diameter - sized to ultimate flows and pumps. 30 years economic life. Cost \$95,000.
Stage 1 Pumps including electrical	20 L/s, $v = 0.6$ m/s, 7.5 kW motors 15 years economic life. Cost \$35,000
Ultimate Pumps including electrical	45 L/s, $v = 1.5$ m/s, 30 kW motors 15 years economic life. Cost \$60,000
Maintenance costs	Small duplex pumping station
Pumping station and pumps	Cost \$8,500 pa.

CALCULATIONS

Determine annual pumping costs from:

$$\$/\text{year} = \frac{0.0098 \times Q \times H \times c \times t}{\text{eff}}$$

Where

- Q = pumping rate (L/s)
- H = total pumping head (m)
- c = cost of electricity kWh (\$) (refer Appendix 1A)
- t = duration of pumping per year (hrs.)
- eff = pump efficiency

Stage 1

$$\begin{aligned}
 H &= \text{Friction losses at 20 L/s + Static head} \\
 &= 0.0028 \times 1500 + 15 \\
 &= 19.2 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \text{Annual pumping cost} &= \frac{0.0098 \times 20 \times 19.2 \times 0.16 \times 4 \times 365}{0.6} \\
 &= \$1,465 \text{ pa.}
 \end{aligned}$$

Ultimate

$$\begin{aligned}
 H &= \text{Friction losses at 45 L/s + Static head} \\
 &= 0.014 \times 1500 + 15 \\
 &= 36 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \text{Annual pumping cost} &= \frac{0.0098 \times 45 \times 36 \times 0.16 \times 4 \times 365}{0.6} \\
 &= \$6,180 \text{ pa.}
 \end{aligned}$$

DETERMINE PRESENT VALUE

(i) Running Costs

The Present Value Factor (PVFA) of \$1 per annum for n years at interest rate r per annum is calculated from the formula:

$$PVFA = \frac{1 - (1 + r)^{-n}}{r}$$

$$\begin{aligned}
 \text{Running Costs 1995 - 2009} &= 1465 \times \frac{1 - (1 + 0.07)^{-15}}{0.07} \\
 &= \$13,343
 \end{aligned}$$

$$\begin{aligned}
 \text{Running Costs 2010 - 2024} &= 6180 \times \frac{1 - (1 + 0.07)^{-30}}{0.07} - 6180 \times \frac{1 - (1 + 0.07)^{-15}}{0.07} \\
 &= \$20,400
 \end{aligned}$$

(ii) Maintenance Costs

$$\begin{aligned}
 \text{Maintenance Costs 1995 - 2024} &= 8500 \times \frac{1 - (1 + 0.07)^{-30}}{0.07} \\
 &= \$105,477
 \end{aligned}$$

(iii) Replacement Costs

The present value (PV) of \$1, n years hence, which is discounted at interest rate r per annum is calculated from the formula:

$$PV = (1 + r)^{-n}$$

Present value of pump

$$\begin{aligned}
 \text{replacement 2010} &= 60000 \times (1 + 0.07)^{-15} \\
 &= \$21,747
 \end{aligned}$$

Item	Cost \$	Calculation of Present Value	Present Value \$		
			Capital	Running	Replacement
Pumping Station Civil Costs					
30 years life	95000		95000		
Rising Main					
30 years life	210000		210000		
Stage I Pumps & Electr'l					
15 years life	35000		35000		
Running Costs 1995-2009	1465 pa.	@ 7% over 15 years		13343	
Maintenance Costs 1995-2024	8500 pa.	@ 7% over 30 years		105447	
Ultimate Pumps & Electr'l 15 years life	65000	discounted @ 10% over 15 years			21747
Running Costs 2010 to 2024	4830 pa.	@ 7% over 15 years		20400	
			340000	139190	21747

TOTAL PRESENT VALUE = \$500,937

NOTE :

1. Present value analysis is to allow for different efficiency for each model of pump considered.
2. Present value analysis is to allow for variation in pump duty with each different rising main pipe type and class considered.
3. Present value analysis is to allow for variation in economic life for each different rising main pipe type considered.
4. Currently the Corporation adopts an interest rate (r) of 7 % for present value analysis. The analysis should also be carried out for interest rates of 4 % and 10 % in order to determine the effect of variations in the adopted rate.

APPENDIX 4C

AN EXAMPLE OF “WATHAM” WATERHAMMER
ANALYSIS COMPUTER OUTPUT

C:\WHAM\MA20-1.OUT
18-NOV-1995
18:28
C:\WHAM\MA20-1.DAT
C:\WHAM\MA20-1.TRC

ANALYSIS OF: MAITLAND No.20 DN150 UPVC (AS2977 CL12) SINGLE PUMP

POWER FAILURE

ANALYSIS TIMES

TOTAL TIME = 100.0 SECS
CALC. INTVL= 0.100 SEC
PRINT INTVL= 10.0 SECS

PIPE DATA									

LABEL	U/S NODE	D/S NODE	LENGTH M	DIAM MM	CELERITIES M/SEC INPUT USED	NO OF INTVLS	DARCY FRICT FACT INPUT USED	PIPE COUNTER	
RM1	5	6	732.	158.0	406. 406.7	18	0.0120 0.0210		

PIPE PROFILES

LABEL	U/S NODE	D/S NODE	1	10
RM1	5	6	6.20 7.57 8.93 10.30 12.78 14.95 14.73 14.50 17.02 18.30 19.58 20.86 22.14 23.42 24.69 25.97	15.75

SEPARATION IS TO BE TESTED AT ALL NODES AND PIPE SECTIONS
VAPOUR PRESSURE TO OCCUR 10.00 M BELOW OBVERT LEVEL
VAPOUR CELERITY FACTOR = 1.00 COALESCING FACTOR = 1.00
TIME FACTOR = 1.0000 PRESSURE FACTOR = 1.000
LIMIT ON RATE OF CHANGE OF CELERITY FACTOR = 1.00

MA20-1.OUT

Page

NODE DATA *****				ATTACHED CONTROLS TYPE LABEL	
NODE NO	HGL RL M	PIPE OL RL M			
1	4.00	4.00	RESERVOIR	WETWELL	
2	40.00	4.00			
3	39.90	6.20			
4	39.75	6.20			
5	39.65	6.20			
6	27.25	27.25	RESERVOIR	DISCHARGE	
PUMP DATA *****					
PUMPS TO LOSE POWER AT A NOMINATED TIME					
LABEL	U/S NODE	D/S NODE	FLOW L/S	PUMP HEAD M	SPEED RPM
PUMP1	1	2	31.000	36.00	1450
PUMP CHARACTERISTICS USED					
VEE/ALFA OR ALFAVEE					
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1					
GROUP 1 (NS= 1800 RPM)					
HAN = 1.290 1.280 1.280 1.270 1.250 1.230 1.200 1.170 1.130 1.070 1.000 0.920					
HVN = -0.690 -0.520 -0.380 -0.270 -0.170 -0.050 0.100 0.280 0.480 0.730 1.000 1.280					
HAD = 1.290 1.300 1.320 1.340 1.380 1.440 1.510 1.600 1.710 1.840 1.990 2.160					
HVD = 0.690 0.730 0.800 0.880 0.970 1.090 1.210 1.360 1.550 1.760 1.990 2.190					
HAT = 0.640 0.650 0.670 0.690 0.710 0.730 0.760 0.810 0.860 0.930 1.010 1.110					
HVT = 0.690 0.650 0.630 0.630 0.640 0.660 0.700 0.760 0.830 0.920 1.010 1.120					
BAN = 0.440 0.510 0.570 0.640 0.700 0.770 0.830 0.890 0.930 0.970 1.000 1.010					
BVN = -0.370 -0.280 -0.180 -0.070 0.070 0.200 0.340 0.490 0.650 0.820 1.000 1.170					
BAD = 0.440 0.390 0.360 0.350 0.370 0.420 0.480 0.580 0.710 0.860 1.040 1.250					
BVD = 0.870 0.890 0.920 0.940 0.960 0.970 0.980 1.000 1.020 1.030 1.040 1.060					
BAT = -0.680 -0.500 -0.340 -0.220 -0.110 -0.030 0.020 0.100 0.200 0.320 0.450 0.610					
BVT = 0.870 0.830 0.810 0.770 0.730 0.690 0.650 0.610 0.560 0.500 0.450 0.400					

VALVE DATA									

REFLUX VALVES									
LABEL	U/S NODE	D/S NODE	FLOW L/S	HEAD LOSS M	HEAD LOSS COEFFICIENTS M/(L/S)**2		REVERSE FLOW FACTOR	CLOSURE TIME SECS	
					INPUT	USED			
REFLUX1	3	4	31.000	0.15	0.0000E+00	0.1561E-03	1.0000		0.000
SIMPLE RESTRICTION DATA									

LABEL	U/S NODE	D/S NODE	FLOW L/S	HEAD LOSS M	HEAD LOSS COEFFICIENTS M/(L/S)**2		REVERSE FLOW FACTOR		
					INPUT	USED			
RISER1	2	3	31.000	0.10	0.0000E+00	0.1041E-03	1.0000		
SV&FTGS1	4	5	31.000	0.10	0.0000E+00	0.1041E-03	1.0000		
RESERVOIR DATA									

LABEL	NODE LOCATION	HGL RL M	OUTFLOW (INTO NODE) L/S	SURFACE WATER LEVEL RL M		WAVE AMPLITUDE M	(IF ANY) PERIOD SECS		PHASE SECS
WETWELL	1	4.00	31.000						
DISCHARGE	6	27.25	-31.000						

TIME = 0.00 SEC

PIPE CONDITIONS HGL'S (M) AND VELOCITIES (M/SEC) AT SECTIONS ALONG THE PIPE

LABEL	U/S NODE	D/S NODE										
			1	2	3	4	5	6	7	8	9	10
RM1	5	6	HGL=									
			39.65	38.96	38.27	37.58	36.89	36.21	35.52	34.83	34.14	33.45
			HGL=									
			32.76	32.07	31.38	30.69	30.01	29.32	28.63	27.94	27.25	
			V=									
			1.581	1.581	1.581	1.581	1.581	1.581	1.581	1.581	1.581	1.581
			V=									
			1.581	1.581	1.581	1.581	1.581	1.581	1.581	1.581	1.581	1.581

FLOW DEVICE CONDITIONS

LABEL	U/S NODE	D/S NODE	FLOW *****		TYPE	OTHER DETAILS	
			L/S	CU M/SEC			
PUMP1	1	2	31.000	0.031	FAILING PUMP	PUMP HEAD=	36.00 M
RISER1	2	3	31.000	0.031		HEAD LOSS=	0.10 M
REFLUX1	3	4	31.000	0.031	REFLUX VALVE	HEAD LOSS=	0.15 M
SV&FTGS1	4	5	31.000	0.031	MINOR HEAD LOSS	HEAD LOSS=	0.10 M

NODE CONDITIONS ASSOCIATED HEAD CONTROL DETAILS

NODE NO	HGL M	LABEL	TYPE	OUTFLOW RATE		INTERVAL OUTFLOW LITRES	AIR VOL CU M	AIR PRESS GAUGE M
				L/S	CU M/SEC			
1	4.00	WETWELL	RESERVOIR	31.00	0.03	0.0	0.000	
2	40.00							
3	39.90							
4	39.75							
5	39.65							
6	27.25	DISCHARGE	RESERVOIR	-31.00	-0.03	0.0	0.000	

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TIME = 10.00 SEC

PIPE CONDITIONS

HGL'S (M) AND VELOCITIES (M/SEC) AT SECTIONS ALONG THE PIPE

PIPE LABEL	SECT NO	U/S		D/S		EQUIVALENT		CELERITY		SECT		U/S		D/S		EQUIVALENT VOID LENGTH M	CELERITY FACTOR
		U/S NODE	VEL M/SEC	U/S NODE	VEL M/SEC	VOID LENGTH M	FACTOR	NO	NO	U/S VEL M/SEC	D/S VEL M/SEC	U/S VEL M/SEC	D/S VEL M/SEC	U/S VEL M/SEC	D/S VEL M/SEC		
RM1	6	5	6	1	2	25.03	26.08	23.27	25.76	24.75	28.00	18.08	9.42	8.33	8.33	1.000	1.000
RM1	6	5	6	1	2	25.03	26.08	23.27	25.76	24.75	28.00	18.08	9.42	8.33	8.33	1.000	1.000
RM1	6	5	6	1	2	25.03	26.08	23.27	25.76	24.75	28.00	18.08	9.42	8.33	8.33	1.000	1.000
RM1	6	5	6	1	2	25.03	26.08	23.27	25.76	24.75	28.00	18.08	9.42	8.33	8.33	1.000	1.000
RM1	6	5	6	1	2	25.03	26.08	23.27	25.76	24.75	28.00	18.08	9.42	8.33	8.33	1.000	1.000

FLOW DEVICE CONDITIONS

LABEL	U/S NODE	D/S NODE	FLOW *****		TYPE	OTHER DETAILS			
			U/S L/S	CUM/SEC		PUMP HEAD=	0.00 M	SPEED RATIO=	0.0000 (0 RPM)
PUMP1	1	2	0.000	0.000	FAILING PUMP	HEAD LOSS=	0.00 M		
RISER1	2	3	0.000	0.000	MINOR HEAD LOSS	HEAD LOSS=	-22.28 M		
REFLUX1	3	4	0.000	0.000	REFLUX VALVE	HEAD LOSS=	0.00 M		
SV&FTGS1	4	5	0.000	0.000	MINOR HEAD LOSS	HEAD LOSS=	0.00 M		

NODE CONDITIONS ASSOCIATED HEAD CONTROL DETAILS

NODE NO	HGL M	LABEL	TYPE	OUTFLOW RATE		INTERVAL OUTFLOW LITRES	AIR VOL CUM	AIR PRESS GAUGE M
				U/S	CUM/SEC			
1	4.00	WETWELL	RESERVOIR	0.00	0.00	56.7	0.057	
2	4.00							
3	4.00							
4	26.28							
5	26.28							
6	27.25	DISCHARGE	RESERVOIR	-4.61	0.00	-70.9	-0.071	

MA20-1.OUT

TIME = 30.00 SEC

PIPE CONDITIONS HGL'S (M) AND VELOCITIES (M/SEC) AT SECTIONS ALONG THE PIPE

PIPE LABEL	SECT NO	U/S VEL M/SEC	D/S VEL M/SEC	EQUIVALENT VOID LENGTH M	CELERITY FACTOR	SECT NO	U/S VEL M/SEC	D/S VEL M/SEC	EQUIVALENT VOID LENGTH M	CELERITY FACTOR
RM1	6			COMPACT	1.000	13			COMPACT	1.000
	7			COMPACT	1.000	14			COMPACT	1.000
	8			COMPACT	1.000	15			COMPACT	1.000
	9			COMPACT	1.000	16			COMPACT	1.000
	10			COMPACT	1.000	17			COMPACT	1.000
	11			COMPACT	1.000	18			COMPACT	1.000
	12			COMPACT	1.000					

FLOW DEVICE CONDITIONS

LABEL	U/S NODE	D/S NODE	FLOW L/S	CU M/SEC	TYPE	OTHER DETAILS
PUMP1		2	0.000	0.000	FAILING PUMP	PUMP HEAD= 0.00 M SPEED RATIO= 0.0000 (0 RPM)
RISER1	2	3	0.000	0.000	MINOR HEAD LOSS	HEAD LOSS= 0.00 M
REFLUX1	3	4	0.000	0.000	REFLUX VALVE	HEAD LOSS= -32.47 M
SV&FTGS1	4	5	0.000	0.000	MINOR HEAD LOSS	HEAD LOSS= 0.00 M

NODE CONDITIONS ASSOCIATED HEAD CONTROL DETAILS

NODE NO	HGL M	LABEL	TYPE	OUTFLOW RATE L/S	CU M/SEC	INTERVAL OUTFLOW LITRES	AIR VOL CU M	AIR PRESS GAUGE M
1	4.00	WETWELL	RESERVOIR	0.00	0.00	0.0	0.000	
2	4.00							
3	4.00							
4	36.47							
5	36.47							
6	27.25	DISCHARGE	RESERVOIR	-0.82	0.00	4.1	0.004	

HGL ENVELOPE

MAXIMUM AND MINIMUM HGL'S (M) AND TIMES OF OCCURRENCE (SECS) AT SECTIONS ALONG THE PIPES

U/S D/S	1	2	3	4	5	6	7	8	9	10
LABEL	5	6								
RM1	59.78	58.50	54.79	48.13	48.67	49.02	47.74	44.71	45.79	49.28
	MAX HGL=	48.57	45.25	42.67	41.60	40.69	39.51	39.52	39.71	27.25
	MAX HGL=	7.50	7.40	7.30	7.80	7.90	8.00	7.90	8.00	6.40
	TIME=	6.50	6.30	8.70	8.80	7.00	9.00	5.90	5.80	0.00
	TIME=									
RM1	5	6								
	MIN HGL=	2.05	1.95	1.54	2.33	3.27	4.95	4.73	4.50	4.47
	MIN HGL=	7.02	8.30	9.58	10.86	12.14	13.42	14.69	15.97	27.25
	TIME=	1.40	1.30	10.90	1.10	1.00	1.00	1.10	1.20	1.30
	TIME=	1.30	1.40	1.40	1.50	1.60	1.70	1.70	1.80	0.00

MAXIMUM AND MINIMUM NODE HGL'S

NO	MAXIMUM HGL RL M	TIME SECS	MINIMUM HGL RL M	TIME SECS	NO	MAXIMUM HGL RL M	TIME SECS	MINIMUM HGL RL M	TIME SECS
1	4.00	0.00	4.00	0.00	4	59.78	7.50	2.08	1.40
2	40.00	0.00	2.13	1.40	5	59.78	7.50	2.05	1.40
3	39.90	0.00	2.11	1.40	6	27.25	0.00	27.25	0.00

HEAD CONTROL MAXIMUM AND MINIMUM OUTFLOW RATES

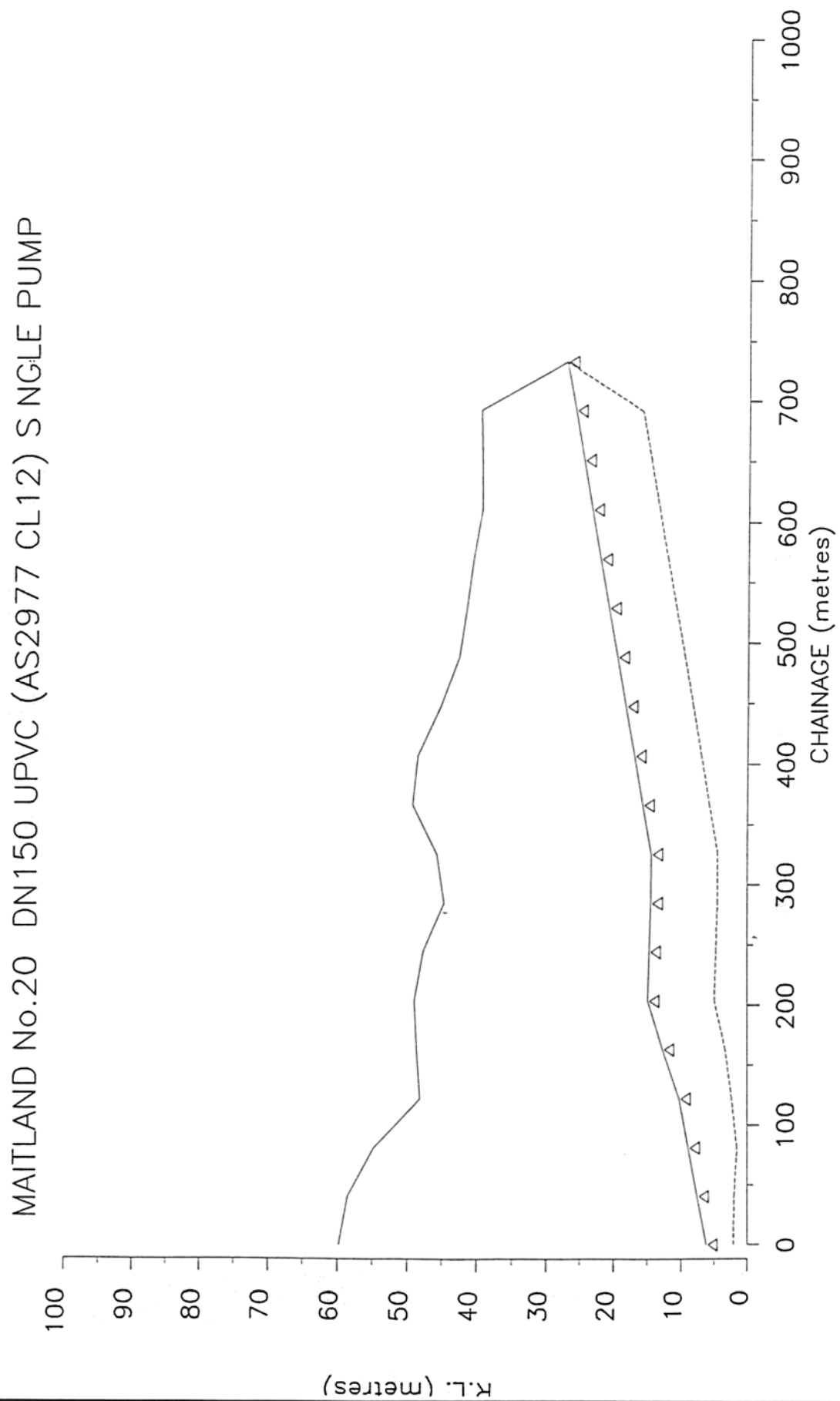
LABEL	TYPE	NODE	LOCATION	MAXIMUM				MINIMUM				ADDITIONAL AIR VESSEL VALUES			
				WATER OUTFLOW CU/M/SEC	TIME SECS	WATER OUTFLOW CU/M/SEC	TIME SECS	WATER OUTFLOW CU/M/SEC	TIME SECS	WATER LEVEL RL M	AIR PRESSURE GAUGE M	WATER LEVEL RL M	AIR PRESSURE GAUGE M	TIME SECS	TIME SECS
WETWELL	RESERVOIR		1	0.0310	0.00	0.0310	0.00	0.0000	5.00						
DISCHARGE	RESERVOIR		6	0.0159	5.70	-0.0310	0.00								

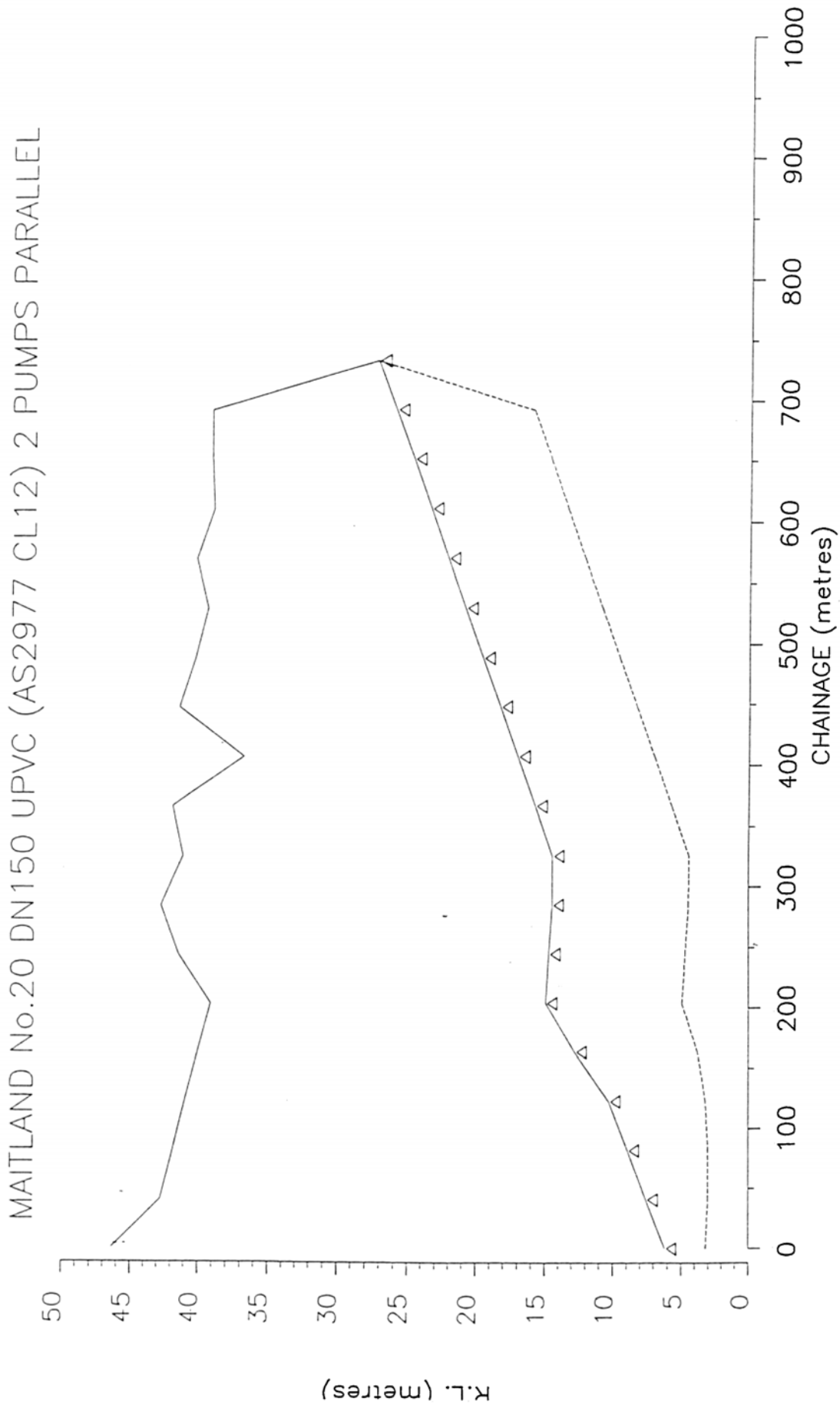
FLOW DEVICE MAXIMUM AND MINIMUM FLOW RATES

LABEL	U/S NODE	D/S NODE	MAX. FLOW CU/M/SEC	TIME SECS	MIN. FLOW CU/M/SEC	TIME SECS	TYPE
RISER1	2	3	0.0310	0.00	0.0000	5.00	MINOR HEAD LOSS
SV&FTGS1	4	5	0.0310	0.00	0.0000	5.00	MINOR HEAD LOSS
REFLUX1	3	4	0.0310	0.00	0.0000	5.00	REFLUX VALVE
PUMP1	1	2	0.0310	0.00	0.0000	5.00	FAILING PUMP

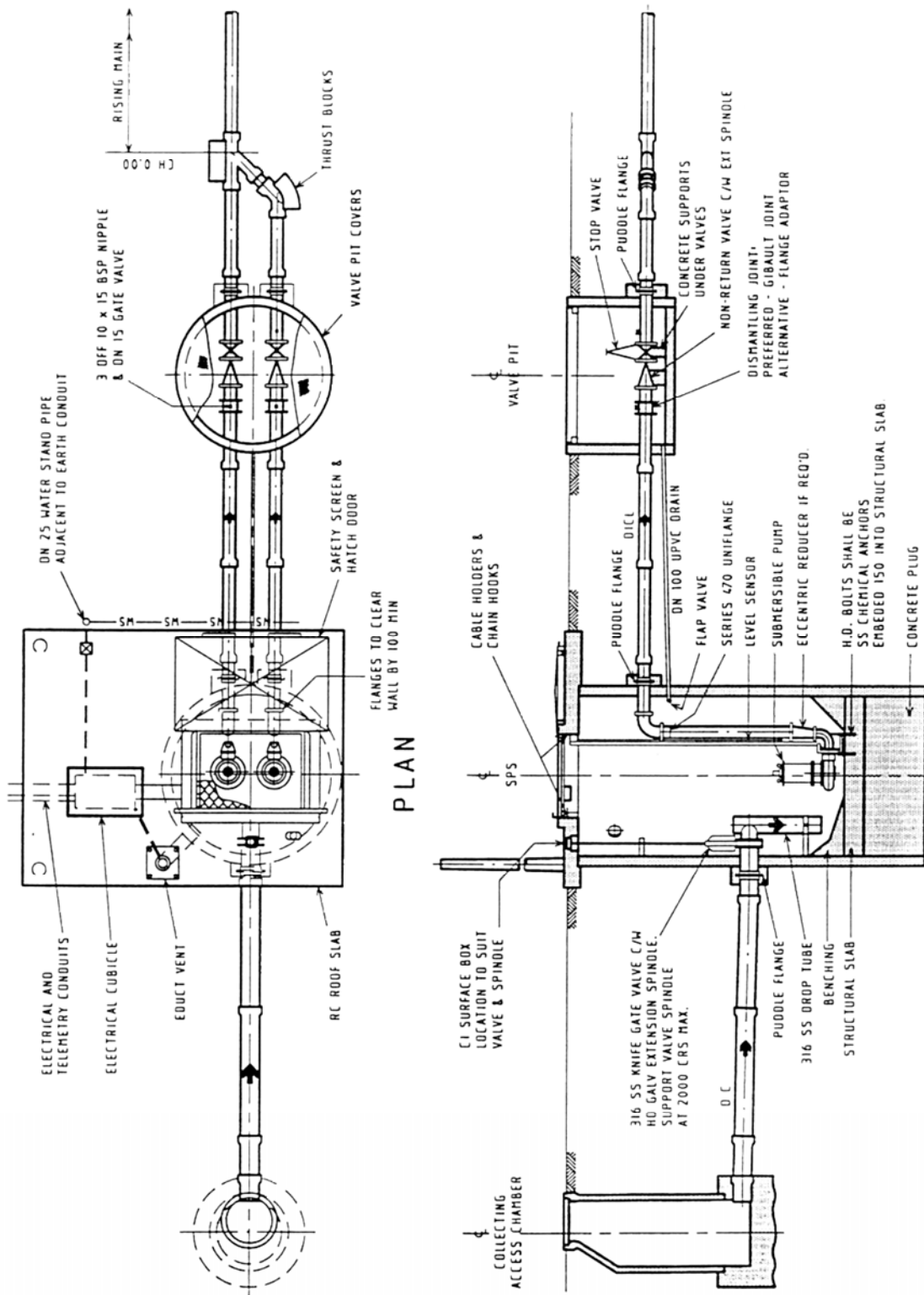
MA20-1.OUT

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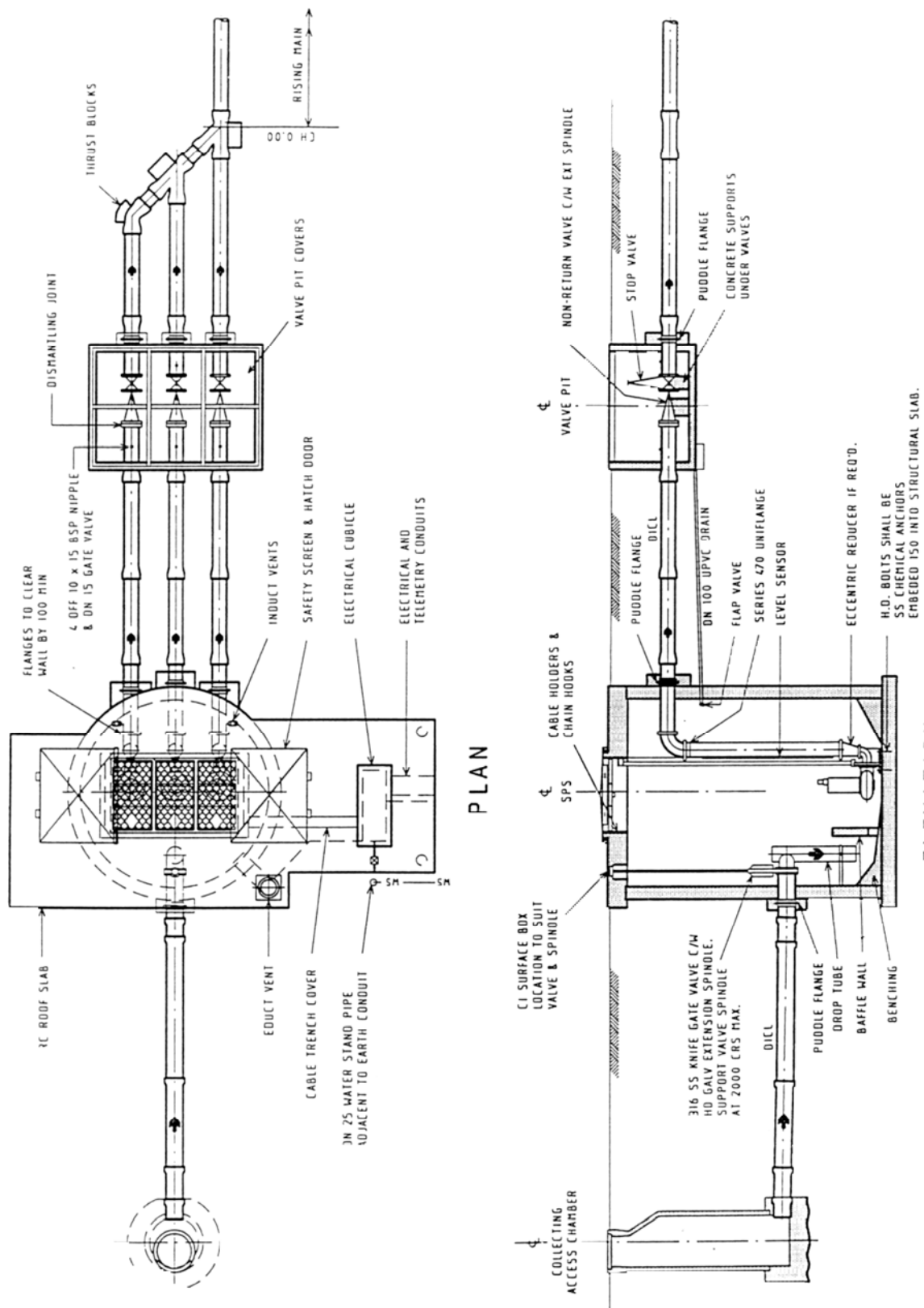




APPENDIX 4D



ELEVATION
TYPICAL SEWAGE PUMPING STATION ARRANGEMENT DUPLEX



TYPICAL SEWAGE PUMPING STATION ARRANGEMENT - TRIPLEX

APPENDIX 4E FATIGUE DERATING OF PLASTIC PRESSURE PIPE

PROCEDURE FOR SELECTING PIPE CLASS INCORPORATING FATIGUE

- 1) Determine the maximum operating pressure range by calculating the difference between the maximum pressure and the minimum pressure experienced during pump operation (including pressure surge effects from both pump startup and shutdown). It will be necessary to determine these pressures using the results of a waterhammer analysis to determine maximum pressure range at any point along the main.
- 2) Calculate the estimated number of pump starts per day and determine the number of pump starts over the design life. Multiply this number by two (to allow for primary and secondary pressure cycles on pump startup) to calculate the Total Number of Cycles over the design life (n).
- 3) Determine the Fatigue Derating Factor (f) from the following table based on the pipe material and total number of cycles.

Total Cycles	Approx No. Cycles/day for 100yr life	Fatigue De-rating Factor (f)			
		PVC-U	PVC-M	PVC-O	PE/GRP
5,000,000	137	0.31	0.21	0.36	0.74
10,000,000	274	0.25	0.17	0.32	0.68
15,000,000	411	0.22	0.15	0.29	0.65

De-rating factors for between these numbers of cycles may be approximated using the following relationships, where f is the de-rating factor and n is the total number of cycles:

$$f(\text{PVC-U}) = 31.491 n^{-0.2997}$$

$$f(\text{PVC-M}) = 22.814 n^{-0.3058}$$

$$f(\text{PVC-O}) = 6.57 n^{-0.1878}$$

$$f(\text{PE/GRP}) = 3.8627 n^{-0.1077}$$

- 4) Calculate the de-rated fatigue pressure capacity of the pipe by multiplying the pipe pressure rating (eg: PN 16 = 160m) by the De-rating Factor f.
- 5) The operating pressure range in 1) should not exceed the de-rated fatigue pressure capacity of the pipe. The maximum operating pressure should not exceed the pressure class of the pipe.

Example

Determine the suitability of PN 16 PVC-U pipe. The maximum and minimum pressures from waterhammer analysis are 40.0m and 10.0m respectively [Note: this is within the maximum allowed for PN 16 (160m)]. The minimum static pressure is 10m. Pumps start 8 times per hour.

- 1) Maximum operating pressure range = 40m – 10m = 30m.
- 2) Number of pump starts over 100 year design life = 8 x 24 x 365 x 100 = 7,008,000.
Multiplying by two gives a total of 14,016,000 Total Number of Pump Cycles.
- 3) Approximating from table, the De-rating factors are f(PVC-U) = 0.23.
- 4) De-rated pressure capacities as follows:
PVC-U = 160m x 0.23 = 36.8m (greater than operating pressure range 30m - acceptable)

APPENDIX 4F RISING MAIN CROSSINGS AT INTERSECTIONS

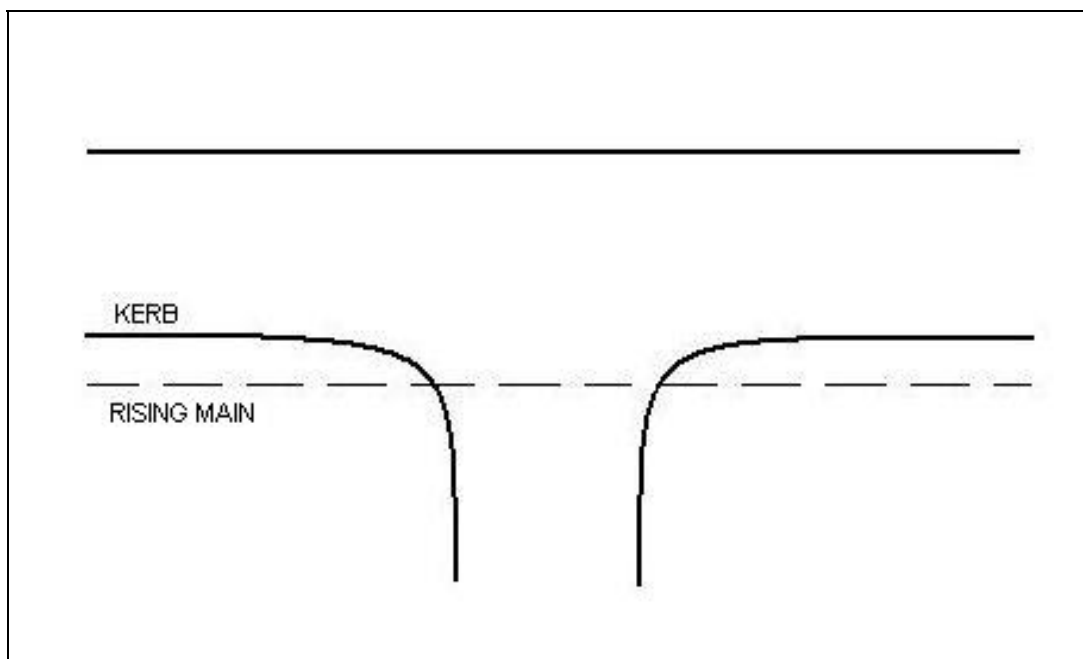


Figure 1 – Rising Main Crossing at Intersection

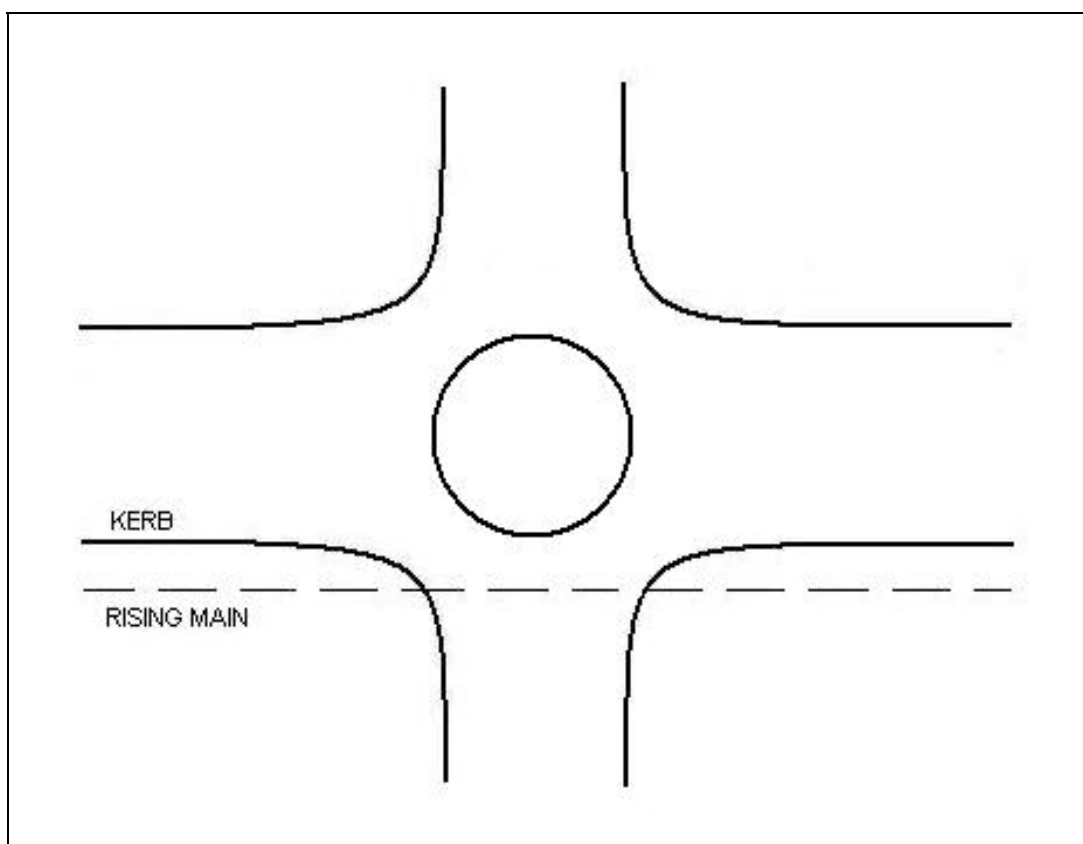


Figure 2 – Rising Main Crossing at Single Lane Roundabout

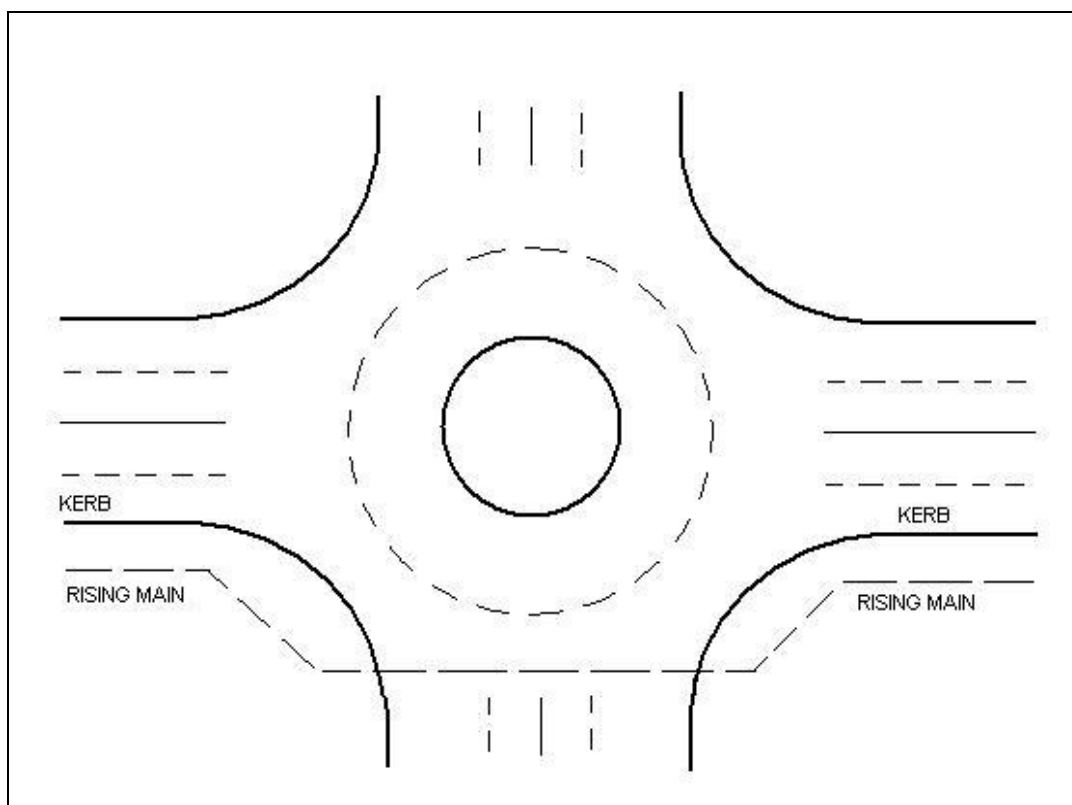


Figure 3 – Rising Main Crossing at Two Lane Roundabout