CHAPTER 16

THE DISTRIBUTION SYSTEM

Contents

Figures and Tables

16.1 INTRODUCTION

The transmission of water from the source (or sources) to the various consumers is usually done in two stages, distribution and reticulation. The former term is generally used to describe the system of bigger (or trunk) mains, reservoirs and, in some situations, pumping systems. In bigger systems such as cities, the distribution function is well-defined and often operated separately. The term reticulation is normally used to describe the street mains and connections to properties.

The distribution system is designed to:

- reliably distribute bulk water supplies to the suburbs
- provide water at the correct elevation and/or pressure
- buffer the diurnal peaks in demand from the consumers.

To achieve these objectives, particular combinations of reservoir storage, ring mains and pumping are used, depending upon the system topography and size.

A distribution system is also made up of distribution zones. A distribution zone is a part of the distribution system in which all consumers receive drinking-water of identical quality, from the same sources, with the same treatment and usually at the same pressure and is usually clearly separated from other parts of the network, generally by location, but in some cases by the layout or composition of the pipe network. In these Guidelines the term distribution system is used to include specific zones.

Critical points in a distribution system
Are those points where procedures for equipment failure would lead to a public health hazard. Specific critical points are discussed in this chapter to highlight and differentiate the types of risk that are present in a distribution system. There are two types of critical points in the distribution system, those critical to continuity of supply and those critical to water contamination.

Water contamination is an obvious and direct risk to public health. It can occur directly by intrusion of contaminants into the system or by chemical reactions within the system (such as chemical reactions with the pipe structure). The contamination of water within the distribution system is discussed in detail in this chapter.

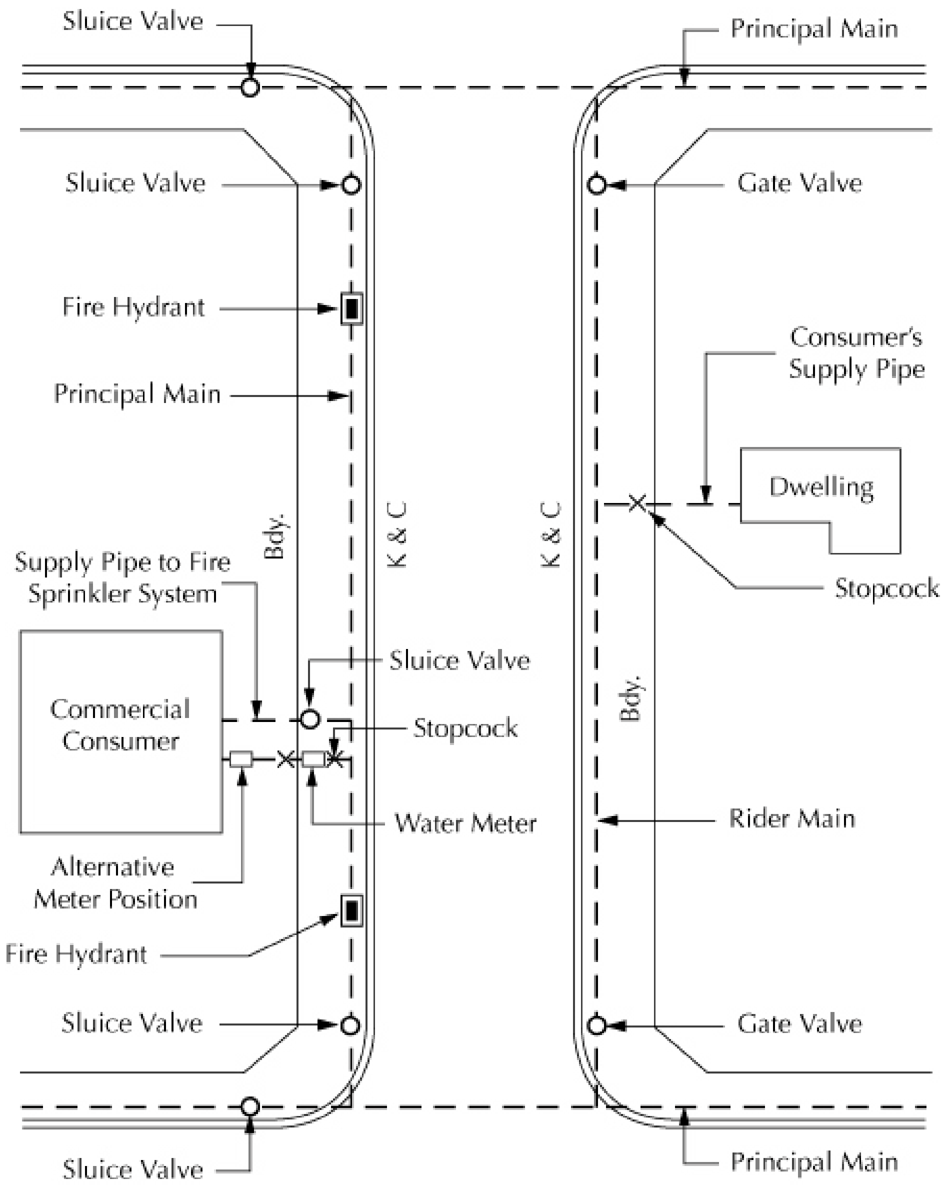
Supply loss is also a critical point for public health, but is not the subject of these Guidelines. For the initial time (say several hours), the risks to the community are not those of thirst, they are those of fire fighting and inadequacy of water for flushing away sewage, and for personal hygiene. The factors that could lead to supply loss include:

- treatment (or other upstream) failure
- supply main failure
- reservoir valve operation: inlet fails to open, drain fails to close
- water contamination, meaning supply must be stopped.

Emergency storage is required in order to continue supply when the inlet main is broken, during upstream system maintenance, or during some other loss of supply situation.

In practice, most supply losses involve a dual failure: a mechanical defect that occurs and an alarm system that fails to provide warning in time to take corrective action. Therefore the alarm system needs regular testing and valves need regular working and testing.

Figure 16.1: Typical reticulation system



Risk management issues related to the distribution system are discussed in the:

MoH Public Health Risk Management Plan Guide PHRMP Ref: P2: Treatment Processes – Water Transmission. Ministry of Health, Wellington.

MoH Public Health Risk Management Plan Guide PHRMP Ref: P10: Treatment Processes – Pump Operation. Ministry of Health, Wellington.

MoH Public Health Risk Management Plan Guide PHRMP Ref: D1: Distribution System – Post-Treatment Storage. Ministry of Health, Wellington.

MoH Public Health Risk Management Plan Guide PHRMP Ref: D2.1: Distribution System – Construction Materials. Ministry of Health, Wellington.

MoH Public Health Risk Management Plan Guide PHRMP Ref: D2.2: Distribution System – System Pressure. Ministry of Health, Wellington.

MoH Public Health Risk Management Plan Guide PHRMP Ref: D2.3: Distribution System – Operation. Ministry of Health, Wellington.

MoH Public Health Risk Management Plan Guide PHRMP Ref: D2.4: Distribution System – Backflow Prevention. Ministry of Health, Wellington.

16.2 COMPONENTS OF A DISTRIBUTION SYSTEM

The general components of a water distribution system and their influence on water quality are described in this section. A more detailed description of the components themselves can be found in other Ministry of Health resources such as the Water Assessor Training Notes, which are available on-line. Effective operation of the components to maintain water quality is discussed in Chapter 16.3.

16.2.1 SERVICE RESERVOIRS

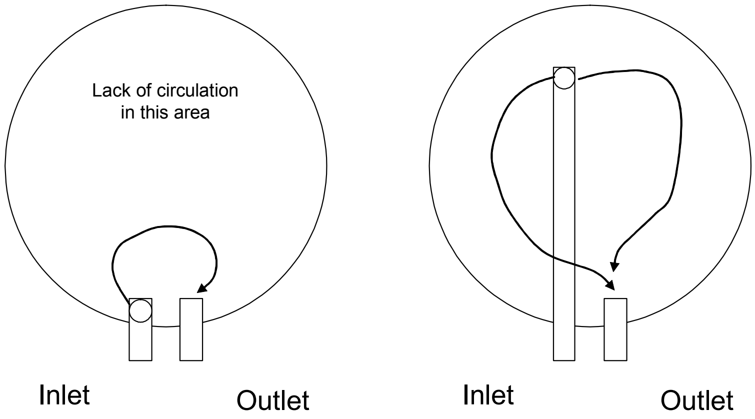
A water reservoir or tank is normally a structure that allows a different inflow and outflow at any given time. When inflow is greater than outflow, water is taken out of storage. Peak attenuation storage allows the treatment plant to produce water more consistently. Some reservoirs or tanks have a common inlet/outlet. Unless the reservoir volume is small in relation to the water flows, this is not good design because it can lead to stale water accumulating on the far side.

Important entry points to a reservoir for contaminants include wildlife access and human access. Reservoirs should also be designed to keep the water fresh and to prevent the carry-over of sediment. Features designed to maintain water cleanliness include:

- reservoirs must have a secure lid.
- access controls against non-authorised people gaining access. These may consist of security fences, locked manhole covers, and/or architectural constraints (tall walls with no footing/grips). Non-authorised access falls into two groups: casual/curious, and malicious. The former include children and casual passers-by; the latter may include vandals and, rarely but possibly, active saboteurs.
- constraints against environmental vectors. Reservoirs are required to allow air in and out as the water level changes so they must be ventilated to the atmosphere. However, the ingress of small animals, birds and mosquitoes should be prevented. Wind carried debris should be excluded, as should surface or underground natural water which may carry contaminants. Buried tanks present a potential problem if the water table is higher than the reservoir water level. If a buried reservoir is grassed, animals should not be allowed to graze above the roof.
- timber tanks should have an impermeable liner beneath the roof.
- circulation systems should be built into reservoirs. There is a natural tendency for water to rotate due to the spin of the earth but this should not be relied upon to stir and mix inflows. If the reservoir does not have internal partition walls to encourage plug flow, the inlets should be sited on the far side to the outlets, and the inlets should discharge at an angle to promote circulation, see Figure 16.2. Inlets are often placed above the water surface to provide an air gap to avert back flows. Outlets are obviously placed near the bottom.
- the outlet should be designed to avoid picking up any sediment that may settle out in the reservoir.
- if the outlet for draining the reservoir discharges to a sewer or stormwater system, an airgap or other suitable backflow prevention must be provided.

Figure 19.2 in Chapter 19: Small and Individual Supplies shows some design features aimed to prevent contamination of a water tank. These features apply to service reservoirs too.

Figure 16.2: Reservoir short-circuiting: severe (left) vs. moderate short-circuiting



16.2.2 DISTRIBUTION NETWORK

Water mains are broken down into a number of categories based on function:

- trunk mains: are those that connect treatment plants to reservoirs and, in some instances, reservoirs to demand areas. They are likely to have control valves and can often be taken out of service for several hours without interrupting general supply. Trunk mains rarely have customer connections and often do not have fire hydrants.
- reticulation mains: are used to supply consumers directly and thus have service connections made to them. They are usually fitted with fire hydrants at about 135 m spacing. Reticulation mains may be supplied from reticulation (or service) reservoirs or, in some systems, by control valves (often pressure reducing) from trunk mains.
- service connections: are where customers connect to the main. They fall into three categories: household services, multiple/commercial/industrial services and fire services.

One of the important factors influencing water quality is the effect of the various materials that come into contact with the water. The potential effect becomes more critical as the size of the system decreases from reticulation to plumbing systems, and the residence time in contact with these systems increases. AS/NZ Standard 4020 (2002) provides a means to test such materials in order that achieving the appropriate national recommended water quality values are not jeopardized. Materials used in potable waters should comply with AS/NZS 4020, and coatings and jointing compounds should be applied and cured correctly. In the UK there is a list of products and processes that have been approved for use in water supplies following testing (under DWI Regulation 31). Information is also available by contacting NSF (see references).

Water distribution system materials are required to have corrosion resistance to the water inside them, not only so they do not collapse, but so that problematic materials don't pass into the water. This is discussed further in Section 16.4.

Materials must also be resistant to adverse ground chemistry, the aggressiveness of the supply, and to breakages. A poor choice of materials can lead to deterioration in water quality as well as increased maintenance and early replacement.

Some pollutants such as hydrocarbons and phenols may diffuse through some plastic piping materials so attention should be given to the location of water mains in some cases. Intrusion is most likely to appear as a taste and odour issue.

16.2.3 PUMP STATIONS

A pump station is installed where water must be lifted from a low level to a high level. The flow may also be pressurised to a higher hydraulic grade instead of installing a high level reservoir. Virtually all pumps used to lift water more than a few metres are centrifugal pumps.

Most pump sets comprise two pumps: one set to duty and the other on standby. This arrangement means that if the duty pump fails to start, the standby can be used to avoid production loss. To avoid accumulation of very old water in the standby system, the allocation of the duty and standby pumps should be alternated from time to time. This will also ensure that the standby pump remains functional and will spread the wear over both (or all) pump sets. Where possible pumps should start up slowly to reduce the scouring effect of a sudden increase in water velocity that may lead to dirty water.

The lubricant used in water supply pumps should be suited to the application. Where there is any risk of contamination of the water supply, an oil designed for potable applications should be considered. There is no New Zealand standard for lubricants for use in potable applications. As a guide the lubricant should be listed under the New Zealand MAF Food Assurance Authority C15 or the United State Department of Agriculture Category H-1.

16.2.4 SYSTEM MONITORING AND CONTROL

SCADA (Supervisory, Control and Data Acquisition) systems are installed on many distribution systems to monitor and control the operation of the system. Chapter 17 provides further details on how these systems work.

Typical monitoring of a water reticulation system will include:

- reservoir levels
- pump operation
- system flows at key points (perhaps into and out of reservoirs).
- system pressure
- alarm systems set to warn when action is required.

A key requirement of monitoring is to set operator notification limits, there is no point in recording that a system is failing if no alarm rings!

SCADA provides a powerful tool for checking on design information and how well a section of the system is working. For example, monitoring how full a reservoir is and how often the pump starts/stops may reveal that the storage is too small or that the on/off probes are set too close together.

Instruments Used in the Distribution System

Flow Metering: metering in the reticulation can occur at several locations for different reasons. Reservoir outflow meters, or meters on large primary distribution mains are used to monitor the total demand over a significant area. They are usually installed as part of the system management concerned with supplying and treating enough water. Individual property meters are small and must detect all the water drawn by the customer.

Pressure: proper water line pressure ensures enough supply for customers and for fire fighting, while protecting treated water from ingress of untreated groundwater. For this reason pressure is usually measured at strategic points in the distribution system.

Level: is measured in reservoirs as a part of a level control system and to activate alarms if the water level strays beyond acceptable bounds.

Free Available Chlorine (FAC): is measured in the network to ensure that a residual is maintained under all flow conditions.

16.2.5 DESIGN ISSUES AFFECTING WATER QUALITY

Regulations covering design

Design of the distribution system should comply with current legislation for the protection of the quality of water. This is covered by the Water Supplies Protection Regulations 1961 (WSPR) enacted under the Health Act 1956, and by the Building Act 1991 (BA).

The First Schedule of the Building Regulations made under the BA is the New Zealand Building Code (NZBC). A building with a water supply designed to AS/NZS 3500 (2003) will meet the requirements of the Building Code. AS3500.1: Plumbing and Drainage. Part 1: Water Services is called up as a verification method in the New Zealand Building Code Clause G12/AS1, and this method includes individual protection, zone protection, and containment protection. Containment protection will meet the requirements of the water supplier if a backflow preventer is installed at the boundary.

Installation

Poor workmanship is a principal cause of watermain failure and recontamination. It is important to liaise with the personnel responsible for the laying and maintenance of the distribution system to minimise any likely sources of contamination due to defective installation methods. This includes ensuring that pipes are cleaned and the ends covered while in storage and being laid. This is described more fully in Section 16.3.2.

Service reservoirs

Common inlet/outlet pipes are not recommended because they tend to allow water to become stale. Inclusion of baffle or partition walls will help reduce short-circuiting. Collection of samples for *E. coli* testing through manholes may lead to contamination, so including sample taps at the design stage is advisable. Also refer to Section 16.2.1.

Reticulation

Dead end pipes are not recommended. In areas that experience persistent dirty water, it may be possible to join dead end pipes by using right-of-ways.

16.3 DISTRIBUTION SYSTEM OPERATIONS

As distribution is the final stage before the water is consumed, there are no further barriers between the entry of a contaminant and the consumer, so particular care is required.

Proper training and supervision of the maintenance workers responsible for the distribution system is essential. This includes sanitary training and clearance (refer Section 16.3.4).

Full and detailed documentation of the reticulation system and its components will be undertaken in a fully comprehensive manner by most operating authorities when asset management systems are put into operation. These can be used as a tool in identifying maintenance requirements and potential trouble spots.

Some general information is also available in the Ministry of Health's PHRMP Guide: Distribution System – Operation.

16.3.1 SERVICE RESERVOIR OPERATION

Water quality can be influenced by periods of storage. To minimise the effects, good operating practices and regular maintenance are required.

Mixing and turn-over

Reservoir operation should encourage turnover of water at least every few days. If a reservoir is filled and remains so, it is likely that fresh water is going directly to the users while the water in the reservoir sits for considerable time. This situation is common where the inlet and outlet mains are the same pipe, often supplied by a pump.

The reservoir should draw down to ensure mixing and renewal is occurring. The flow-balancing feature of a reservoir (allowing constant treatment plant operation, attenuation of peak flows, etc) requires the volume to change. The minimum operating level to allow for emergency storage should be assessed and the reservoir operated accordingly.

Quality will deteriorate rapidly if the water in a reservoir is not kept fresh. The chlorine will either combine with any residual organic material in the water to form mono-, di- and tri-chloramines, or dissipate into the atmosphere. The former may result in poor taste and odour (complaints will be received at about 0.05 mg/L of trichloramine). Dissipation will result in inadequate chlorine residual to prevent regrowth of micro-organisms.

Reservoir inspection

Reservoir inspection can be classified into the following categories:

- inspection of hydraulic controls
- inspection of cleanliness and security
- inspection of structural condition. The underside of the roof of buried reservoirs needs to be inspected for drips entering the reservoir through cracks in the roof material or breaks in the jointing material. The sound resulting from leaks tend to come from a consistent area, whereas the sound from condensation drips tends to be more random.

Hydraulic controls should be part of a routine maintenance programme. Typical frequency of inspection that valves are functioning correctly would be quarterly.

Cleanliness and security should also be checked routinely, typically at least quarterly depending upon both the access security risk and the testing programmes in place. The water surface should be examined for floating objects, even thistledown is an indicator that wind blown objects are able to get into the water. The clarity of the water should be adequate to examine the bottom of the reservoir with the aid of a reasonable torch or similar. In many situations, a clean piece of PVC pipe will be useful to stir the bottom to give an indication of sediment build-up. Divers may be used, provided cleanliness procedures are followed. They will provide a better picture of how much sediment is present, structural checks (floor displacement, joint sealant positions etc) than is possible from above the water surface. They may also be used without disruption to the supply.

A person experienced in detecting cracking, corrosion, and foundation stability should check structural integrity regularly. This may be the system operator or an engineer (who may further train the operator).

Reservoir maintenance cleaning

Water reservoirs can act as sedimentation tanks. Over time it is usual for sediment to accumulate on the floor of the reservoir. It is also possible that slimes, algae (if light can penetrate), or chemical deposits will accumulate on the interior walls. Eventually the accumulated material can adversely affect the quality of the water.

The initiation of a reservoir cleaning procedure may be due to any one of:

- customer complaints about taste, odour or appearance
- water quality testing showing quality degradation
- random checking showing a clean is due
- the sludge depth is reaching the height of the outlet
- planned maintenance procedures or design modifications.

If the procedure has been initiated by customer complaints, the problem is urgent and should be attended to directly.

Planned maintenance frequency requires the accumulation of experience of the particular reservoir, there is no golden rule for how often any particular reservoir should be cleaned. The frequency is likely to be around six months to four years, rather than some shorter time interval. A regular inspection programme, coupled with water quality testing, is the best way to assess this frequency. A key variable is the quality of the incoming water; if it is of low quality, more sediment will be trapped and more organic growths may be expected.

Reservoir cleaning will involve time and cost and may cause disruption of supply to customers. These factors make a lower frequency preferable to frequent cleaning. In assessing the frequency, the bottom line is minimising risk to public health. The free available chlorine content of the water after refilling should be at least 0.30 mg/L and ideally this residual should exceed 0.20 mg/L 24 hours later; any lower residual suggests that the reservoir was refilled while still dirty. Samples from different depths should be collected for *E. coli* testing. Supplementary chlorination will be required if the chlorine dissipates more rapidly than expected, or if *E. coli* are found. The procedure for reservoir cleaning and restoration to service should be documented in the PHRMP.

16.3.2 RETICULATION OPERATION

The main causes of recontamination of water in the distribution system are poor laying, the use of inappropriate types of distribution pipe, or poorly planned and coordinated maintenance systems. These can be overcome by good system design and a good asset management system.

Distribution systems are generally designed to ensure hydraulic reliability, which includes adequate water quantity and pressure for fire flow, as well as domestic and industrial demand. In order to meet these goals, large amounts of storage are usually incorporated into system design, resulting in long residence times, which in turn may contribute to water quality deterioration.

Should a main break require some significant time to repair, a temporary bridge between fire hydrants may provide some continuity of supply. This, coupled with public (e.g. radio) notices may provide some water, advising whether boiled water and conservation may be needed.

The most direct sources of contamination of reticulated water supplies arise from:

- older style ball hydrants that will open of their own accord under loss of system pressure
- open fire hydrants during mains repairs
- direct entry into broken mains or services
- backflows from individual properties.

Most authorities have replaced the old ball hydrants. The few that remain may be at points that are difficult to shut down to allow their replacement.

Fire hydrant contaminant entry after draining down for repair can be minimised by the use of standpipes on the hydrants. This restricts the level of the water drained from the main and is thus unpopular with service personnel. This is primarily a training and attitude matter - most service trucks carry a standpipe. Direct contamination entry during repair is also essentially a training and attitude issue.

Figure 16.3: Fire hydrant standpipe being used to flush a water main

During repairs, individual properties may be supplied from a neighbour's garden tap, often to the garden tap of the property without a supply. In such cases, the loss of integrity and use of non-disinfected piping may compromise the safety of the water. Suitable warnings should be issued about potability. Suppliers should have documented procedures for informing customers of interruption to supply and ensure that staff comply with these.

There is a natural tendency to stop the flow (completely!) and pump out a hole to see what is going on. To do otherwise requires training.

Backflow prevention

Backflows are defined as the flow of (possibly contaminated) water from the consumer's premises into the public supply.

Backflows are more common than most consumers realise. Overseas studies have indicated about 12,000 incidents per annum in a population of 1,200,000, a frequency of about 1 incident per year per hundred people served. Studies have not been reported in New Zealand but are probably similar. Not all of these events result in illness, but all represent a potential incident.

It is necessary for the water supplier to ensure that there is sufficient positive flow through the pipes to prevent any backflow or inflow that could contaminate the supply. The network must be monitored to ensure that this is so.

The network should also be modelled in some way to ensure that the necessary capacities and water pressure criteria are met under all conditions. This may be done by hand, or, more commonly, by computer modelling. The most powerful method for modelling distribution networks is by the use of purpose specific software packages.

For their part, the customer must also prevent backflow into the system by the installation of specific devices to prevent it.

Backflow prevention requirements are set out in the Water Supply Protection Regulations 1961, which are presently under review. The Building Act (2004) Approved Document for New Zealand Building Code Water Supplies Clause G12 Second Edition section 3.41 states that backflow protection shall be provided wherever it is possible for water or contaminants to backflow into potable water supply systems. The objective is to safeguard the health of people within the building by installing a backflow device at each source of possible contamination.

Approved methods are set out in this Act and include:

- air gaps reduced
- pressure zone devices
- double check valves
- vacuum breakers.

Figure 16.4: Commissioning a backflow prevention device

An appropriate device is required for the hazard level. G12 has definitions of the hazard levels, High, Medium and Low, and lists of possible examples for each. As well as protecting the internal water supply system, G12 section 3.1 requires that water drawn from the water main shall be prevented from returning by avoiding cross-connections or backflow.

Backflow prevention programmes are in place for new service connections but a high percentage of properties in New Zealand have supply connections predating the Building Act 1991.

The Backflow Special Interest Group of NZWWA, in consultation with the Building Industry Authority (BIA), produced The Backflow Code of Practice for Water Supplies (2003), specifically for Water Suppliers, in response to the Ministry of Health Public Health Risk Management Plan (PHRMP) Guide – Distribution System - Backflow Prevention.

Once a water supplier has undertaken the risk assessment as part of the PHRMP process, then the code of practice (CoP) provides a best practice approach to reducing the risk of backflow.

The primary focus of the CoP is on containment (boundary protection) and the protection of the public water supply. As a result, there is a need for the development of policies and the risk assessments in order to support this focus. The CoP can be incorporated into water suppliers' water bylaws.

The biggest question of concern for most water suppliers when developing a policy is that of the ownership of containment devices. Ownership in the CoP is primarily with the water supplier outside the boundary or upstream of the defined point of supply. Devices and testing is at customers' cost through connection charges and supply agreements.

There are benefits to the water supplier owning the containment devices in terms of better asset management and not coming into conflict with the Building Act (2004). If the water supplier chooses not to own the containment devices then a building consent is required. In both cases the water suppliers and customers' responsibilities are detailed including payments of costs, enforcement, change of use, record keeping etc.

Testable containment devices are recommended for all non-domestic connections. The device selection and specification is the responsibility of the water supplier regardless of ownership, and guidelines are provided in the CoP. All domestic connections should include at least a dual check device, under the hazard level of very low introduced in the PHRMP. Fire supplies are covered in detail. In consultation with fire industry specialists it was deemed best practice for fire sprinkler systems that the containment device is located in the valve house as per the G12.

The CoP states that the person undertaking the annual testing of containment devices shall have passed a 40 hour backflow testers course. Surveying of existing sites is covered in the CoP. Persons who survey existing buildings to assess the overall hazard level and if the current backflow prevention is adequate, must also have the appropriate qualifications.

Mains cleaning

Watermains gradually accumulate sediments and corrosion products, particularly where flow velocity is low. In some cases biofilms will form that must be cleaned off (biofilms are discussed in Section 16.4.1). There are two main methods for cleaning mains: flushing and pigging.

Flushing, by running the main at a high velocity (ideally 1.5 – 2 m/s) to waste, will generally control the rate of accumulation. Flushing must continue until satisfactory clarity is obtained. This is a routine task that may need to occur every few months, or only once every two or three years. Problem dead-end mains may require weekly flushing. Some water suppliers only flush their pipes on an as needed basis. Ideally, the procedure and programme should be documented.

The flushing water is typically disposed of to the stormwater drain. Water with significant chlorine levels has the potential to kill fish, and/or the organisms on which they feed. It may be necessary to neutralise the chlorine. When this is done with chemicals such as sodium thiosulphate or caustic soda, they should not be overdosed, as they will also damage the receiving environment.

Pigging involves passing a fluid-propelled object through an isolated section of the pipe. A foam plug is often used as the pig. It is normally the same diameter or slightly larger than the watermain and is shaped like a torpedo. Care should be taken to isolate the service connections so that poor quality water and pieces of pig are contained.

When foam pigs are used then the type of pig, the distance travelled, time used, and its efficiency should be recorded in order to appraise the cleaning operation. If a scraper is to be used then notice should be taken of the type and quality of the lining inside the pipes, so the integrity of the lining and joints is not compromised. This may lead to the reapplication of interior linings.

Asbestos cement mains and mains less than 150 mm diameter are not normally pigged.

CCTV pipe inspection may be needed before and after cleaning.

Reticulation System Records

Record plans: most community water supply plans start out with initial construction plans showing where and how the original mains were laid. These plans are still used as part of contract drawings for most construction work.

There is generally a requirement for as-built plans to be completed showing departures (if any) from the original design and position.

These construction plans, whilst giving key details of many items, are not suitable for the primary records purpose of what is buried where, and how the whole system is linked.

To provide this function, most communities have indexed records plans of underground services, including watermains, on a street basis, normally organised into sheets. The sheet will often list construction drawing numbers for detailed information if needed.

Many water suppliers are use Geographic Information Systems (GIS) to record the location and other attributes of their underground pipe networks. Further software is used for Assessment Management Systems (AMS) with the most common in current use called MIT-Hansen "PAMS" (Pipe AMS). These systems allow maintenance records and other relevant data to be stored as well as total asset evaluation for accounting purposes. Asset Management is described in detail in the International Infrastructure Asset Management Manual published by ALGENZ.

Fire flow records: most communities that have fire hydrants to provide fire protection also have a Fire Brigade. A routine brigade task is to flow test the hydrants in their area, partly for the flow information, but also to check markers are present etc. In some areas, this data is logged by the Council on the PAMS; in others it may be available as a paper copy of the Fire Brigade hydrant sheets. It is very useful data on the reticulation system performance and will highlight problem areas.

16.3.3 MAINTENANCE OF DISINFECTION RESIDUAL

Most water supply disinfection in New Zealand uses chlorine. This is generally acknowledged to offer a good initial kill of most bacteria and viruses, and a long-lasting residual able to continue disinfecting within the reticulation system, which helps limit regrowth, and to assist in countering any low level microbiological contamination. However, most contamination events in the distribution system will probably be too large for low levels of FAC to deal with; most ingress is likely to be as a result of a mains break. Therefore a major benefit of maintaining FAC is that it acts as an indicator of system security as large/sudden changes in FAC residuals would indicate ingress or contamination of some kind.

The DWSNZ (2005) specifies requirements for sampling of *E. coli* and free available chlorine levels within each distribution zone. In most cases there is only one point where chlorine is dosed, usually at the treatment plant. If the distribution zone covers an extensive area or is an area of elongated shape, a high chlorine residual may be needed near the plant in order to get the required residual at the most remote locations. Alternatively, supplementary chlorination can be installed to boost the residual at strategic points in the network.

Typically free available chlorine levels in the network are in the range 0.2 to 1.0 mg/L. Higher concentrations are resisted due to cost and taste and odour concerns. Free chlorine (FAC) has a noticeable flavour that increases with concentration. Most taste and odour complaints relate to the formation of inorganic and organic chlorine compounds, often in relation to pipes with biofilms, deposits, or corrosion products, particularly when the water temperature increases. Also refer to Chapter 18: Aesthetic Considerations.

In addition to biofilm, the rate of loss of the chlorine residual after the dosing point also depends on:

- contaminants remaining in the water following treatment
- contaminants entering the water in the reticulation system
- the state of the watermains
- water temperature.

This is why some *E. coli* monitoring is still required even when the water contains FAC.

The DWSNZ (sections 4.4.6 and 4.4.11) require that remedial action be taken in the case of *E. coli* contamination of a drinking-water supply distribution zone. These actions include doing an *E. coli* count, increasing disinfection, undertaking a sanitary survey, target sampling and informing the Medical Officer of Health or other Ministry of Health designated officer.

16.3.4 BARRIERS AGAINST RECONTAMINATION

Water leaving a well-designed and operated treatment plant will contain very few micro-organisms. Therefore, any microbiological contamination of the drinking-water received by the consumer will probably have occurred in the distribution system.

The main barrier against the recontamination of water supplies in the distribution system is a sound, well-designed maintenance regime. It is important that operational procedures cover all aspects of the maintenance of water quality from the treatment plant, through the distribution system, to the consumer's tap. These should be addressed in the PHRMPs, along with possible remedial actions for when problems have been identified.

Operational procedures (work instructions if part of a quality management system) should be produced covering:

- new mains disinfection mains cleaning and repairs
- backflow prevention (refer Section 16.3.2)
- overcoming quality problems induced by the distribution system, (e.g. dead ends, pressure variations, build-up of corrosion products)
- updating as-built drawings
- service reservoir maintenance and operation
- consumer complaints relating to the quantity and quality of drinking-water (details and action taken)
- leak detection, see NZWWA (2002).

Maintenance programmes should include the recording of the time and type of various repair and cleaning options used.

Staff working on water reticulation systems and their equipment offer potential sources of contamination. The following general guidelines are recommended most strongly to minimise these risks:

- operators and maintenance workers should work only on the water supply, and not alternate between water supply and sewerage
- staff and contractors need to be trained to use the appropriate hygienic practices at courses such as run by the Water ITO. Regular refresher courses are desirable
- vehicles and tools used on water supply work must be kept totally separate from those used in sewerage work
- a high standard of cleanliness must be adhered to in maintenance vehicle interiors
- ablution facilities must be available, and used
- operators and maintenance workers should report any gastrointestinal illness, have faecal specimens taken for analysis at the outbreak of such illness, and be placed on work not involving handling water supply system components until a medical certificate of clearance is obtained following such illness
- prior to employment on the water supply system, and on an annual basis thereafter, or following overseas travel to countries with a significant level of endemic waterborne disease, operators and maintenance workers should obtain a medical clearance from being carriers of potentially waterborne disease. The clearance required under this and the previous guideline is likely to be obtained from a laboratory evaluation of faecal specimens taken over three consecutive days and tested for the presence of *Shigella*, *Salmonella*, *Campylobacter*, hepatitis A virus, and *Giardia*, *Cryptosporidium* spp or antibodies
- the Water Supplies Protection Regulations (1961) require the disinfection of new mains and mains repairs to the satisfaction of the Medical Officer of Health in situations where significant contamination potential exists. This can be undertaken relatively simply. Check that the procedures used are to the satisfaction of the Drinking-Water Assessor.

Three cities in the Auckland region proposed a code of practice (Utting et al 1993). This has not eventuated yet. They used two main reports in preparing their paper: AWWA (1990) and WAA (1988).

They considered that the code should cover three situations, and they then offered some suggestions:

- new mains
- repairs maintained under positive pressure
- repairs where there is pressure loss or full draining of the line.

<u>New mains</u>

- chain of cleanliness established for all equipment and fittings prior to use
- thoroughly flush or swab mains to remove debris
- disinfect to achieve a minimum chlorine C.t value of 5000 mg/L.minutes
- flush chlorinated water to waste, with prior neutralisation and discharge approvals if required
- sample for *E. coli* at at least two locations

- commission mains when results <1 *E. coli* per 100 mL.

Repairs maintained under positive pressure
(generally limited to small diameter pipes and wrap-around clamps)

- chain of cleanliness applied to repair equipment and fittings
- good standard of work and equipment.

Repairs where pressure is lost or line drained

- chain of cleanliness applied for all equipment and fittings prior to use
- isolate the section of main and drain (or pump) the water from the break
- apply chlorine solution to trench walls, pipe and fittings
- if contaminated water is likely, apply chlorine to a C.t value of 500 mg/L.minutes, or notify consumers to boil water, or supply drinking-water
- thoroughly flush main and affected consumer connections before restoring service
- sample for *E. coli* randomly for low risk situations, and mandatory for all other cases.

16.4 AESTHETIC CONSIDERATIONS

There are many constituents that affect the taste, odour, colour, clarity or general appearance of the water. These are mostly listed in Appendix 2 of DWSNZ and Appendix 1 of the Guidelines. In some circumstances, the aesthetic quality of the water can deteriorate in the distribution system.

The impact and detection of aesthetic problems are detectable by consumers, whereas the more serious chemical and microbiological contaminants are not. Aesthetic considerations are covered in more detail in Chapter 18.

16.4.1 WHOLESOMENESS

Aesthetically poor water quality in the reticulation can be caused by a number of factors. In some cases the quality of the water in the network can deteriorate to the point where it affects compliance with the DWSNZ.

<u>Construction causes</u>
The installation of pipes should maintain cleanliness, particularly from plugs of mud or similar which will be detected by customers as cloudy water. Some construction materials can also impart taste and odour to water, such as solvent odours from some reservoir linings.

<u>Hydraulic causes</u>
Water that is retained in the reticulation network may go stale. The reasons for water standing in sections of water pipelines include: large-sized dead end mains for fire flows with very low flows, large-sized dead end mains for future supply, and dead spots in ring mains (a balance point of zero flow under most flow conditions). The most common solution to stale water is to flush the main regularly, weekly is normally adequate.

Stale water can affect water quality in the following ways:

- residual chlorine will dissipate with time, leading to the loss of consumer protection.
- chlorine may form chloramines with any organics or ammonia present. There is a link between water with elevated colour levels and trichloramine formation. Complaints relating to trichloramine will usually be of excessive chlorine smells because the trichloramine breaks down on release to air, giving off free chlorine. The remedies to these problems are to remove more of the organics in the treatment process and/or flush water to waste at frequent intervals, less than weekly
- harmful disinfection by-products such as THMs and HAAs can form with prolonged exposure of treated water to free chlorine. This issue is discussed separately in Chapters 10 and 15
- alkalinity and pH levels may increase due to the dissolving of cement based pipe lining. This is a particular problem with aggressive water and asbestos cement and concrete lined steel or ductile iron pipes. This problem eases with time (a few years) but initially can be very severe: pH levels may exceed pH 10. This can lead to reports of "green coffee".

Sediments, in some cases including precipitates of alum floc, iron, and manganese, or fine sand from groundwater, can collect in the system, only to be dislodged by higher flows (for example fire flows). Regular flushing will help to control this.

Chemical causes

Water quality may be affected by interactions with the reticulation pipework. These interactions may be divided into those with soft (aggressive) water and those with hard water. The chemistry of water is described in Chapter 10.

Soft, aggressive water

The most direct result of poor water chemistry is corrosion of the pipe materials, particularly the metal components. Consumers easily notice oxidised iron and copper products, but lead also corrodes out of some fittings. In severe cases the concentration of the corrosion products can exceed DWSNZ MAVs. This is discussed further in Chapter 10. Many corrosion issues in water supply are discussed in AWWA (1996).

Figure 16.5: Example of corroded water pipe

The problems will be worsened by unstable or inappropriate water pH. A stable pH is essential for developing and maintaining effective passivating layers on pipe surfaces. The pH of water leaving treatment will normally be controlled. The pH of the water can change in the distribution system, such as when carbon dioxide is evolved from some groundwaters, or if the water is rechlorinated.

Consumers detect corrosion products as follows:

- rust from cast iron watermains is normally dark red to black and may be any size from several millimetres to a very fine sediment. Iron typically appears as orange/brown rusty stains, streaks or spots on laundry. Stains from taps also appear on baths and sinks. Iron can clog pipes and damage the internal parts of appliances
- the concentration of copper in the water can increase to levels that cause a bitter metallic taste. Blue-green water or bluish cloudy water may discharge from cold taps. There may also be a build-up of crystals or blue stains on basins or the back of the toilet bowl. In some cases the corrosion will damage household plumbing, including hot water cylinders. Copper corrosion mechanisms can be complex and the causes (apart from simple dissolution due to carbon dioxide) are generally difficult to isolate. Copper materials (including brasses and bronzes) are affected by low pH water and/or water with high sulphate contents; as a general rule, the sulphate level should not exceed twice the bicarbonate level.

- asbestos cement pipe corrosion will lift the pH for many years and release fibres into the water. However the fibre release into drinking-water is not readily detectable by consumers, and is not a health problem. For further information, see NZWWA (2001).

Hard water

Hard water is not common in New Zealand. Examples of major (city) supplies with fairly hard water are the groundwater supplies to Napier, Hastings, Wanganui and Palmerston North. Hardness may lead to the build-up of calcium carbonate in pipelines. The deposition of scale in household kettles from temporary hardness is more common. Clothes washed in hard water may look dingy and feel harsh and scratchy. Dishes and glasses may be spotted when dry. Hard water may cause a film on glass shower doors, shower walls, bathtubs, sinks, faucets, etc. More soap is needed for cleaning and hair washed in hard water may feel sticky and look dull.

Hardness can be reduced by treatment but this is unusual on large New Zealand supplies. Hard water has few of the problems with corrosion by-products experienced in soft water supplies.

Silica

Silica is the second most abundant mineral on Earth. High silica levels may cause post treatment precipitates that may form plaque deposits inside pipework under certain conditions. Under certain conditions it can distil across in steam generators; its main problem is in boilers.

Biofilms

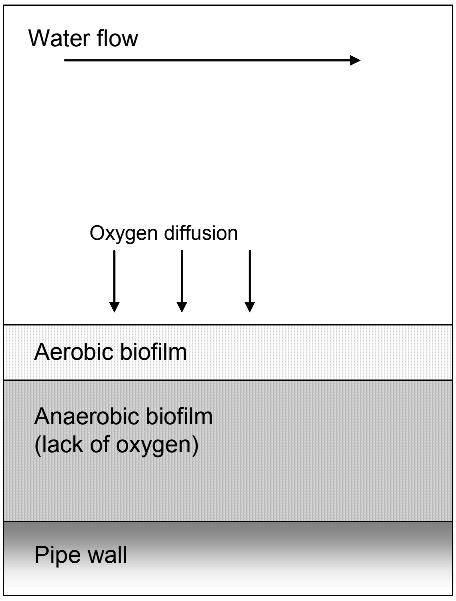
Biofilms, or slimes, can become established in static areas, sediments, corrosion tubercles and storage tanks. This may occur in the network or in the customer’s pipework and hoses. The biofilm may host pathogens, general heterotrophic micro-organisms (that can reach high population densities in the summer) with uncertain health-effects, and biologically oxidised precipitates of substances such as iron and manganese, and may lead to taste and odour. Where anaerobic activity develops, odorous sulphur compounds such as hydrogen sulphide can be produced. Biofilms are therefore very undesirable; they can even affect the flow.

Where nutrient levels are low and the water is chemically stable, biofilms should only occur as a result of inadequate chlorine residual. However, if significant biofilms develop on pipe walls, then even a high chlorine residual will not effectively penetrate the biofilm. In these cases it will be necessary to flush the lines regularly at high velocity to shear off the biofilm and apply chlorine at higher concentrations. The pH value also is important in dislodging biofilm as detachment can occur more rapidly at higher pH values.

In extreme cases, mechanical scouring (pigging) may be needed to remove the biofilm.

In the longer term, the growth of biofilms in corrosion tubercles etc can be reduced by the manipulation of water chemistry to reduce corrosivity. Microbial nutrients should be limited as far as possible. Ammonia can be a marked contributor to biofilms, partly due to its reaction with chlorine. Organic carbon, nitrogen, phosphorus, sulphur compounds, trace metals and salts can all contribute to biofilm growth.

Figure 16.6: Structure of a biofilm



Consumer complaints

Things can go wrong in any system. If they do, it is often customers who are the first to notice, so an effective way to capture information, respond to complaints, mitigate issues, and collect data so that overall service and reliability is improved should be a documented and monitored procedure. This should be covered in the water supplier's policy statement, and addressed where applicable in more detail in the PHRMP. See Chapter 18: Aesthetic Considerations.

The obligations of the water supplier to customers should be laid out in a customer charter, on the supplier website, or through a similar medium. These should include response times, prioritising complaints, and where the responsibility of the water supplier stops and starts.

Staff responsible for distribution will have to:

- investigate consumer complaints within an agreed timeframe. These typically relate to water pressure, volume, seepage, leakage, taste/odour and discolouration
- perform field tests as necessary
- advise the consumer of possible solutions to the problem
- fix the problem (where this is practical and within the terms of the customer contract)
- record the complaint and subsequent action on a register so performance measures and system reliability information can be assessed
- periodically examine and analyse the list of complaints for any discernible trends that may require remedy at the system/asset management level.

Performance measures include the general consumer complaint rate, frequency of repeat callouts, the justified consumer complaint rate, and the response time to consumer complaints.

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