Reservoir Design for the Next Generation

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1 Introduction – The supply of safe drinking water

Drinking water storage tanks come in many shapes, sizes and construction materials. While the designing and building of tanks has been seen exclusively as an engineering discipline, the over-riding end-user requirement is often overlooked – the ability to store and supply drinking water in a safe and hygienic manner - water that will not make the consumers ill.

If a new tank is designed to last for 80 years plus, then we must 'second guess' what the maintenance implications will be throughout that corresponding time period. Maintenance items include regular inspections, cleaning of floor sediments and roof gutter areas, external and internal re-coating and the repairing and upgrading of pipe work, pumps and control equipment. Initial design must include the ability for all of these functions to be carried out safely and cost effectively.

Future labor sources must be considered when we have an aging workforce, combined with increased OH&S regulations and restrictions. If personnel are going to be restricted from performing necessary maintenance tasks, then designs must eliminate many of those manual practices currently required and robotics should be considered as one of the future options in the various maintenance practices that will occur throughout the life cycle of the asset.

Consider future labour needs, OH&S regulations and the use of robotics

2 Location - Plan for future site needs

An overview of the surrounding area should include future space requirements as they will arise, particularly encroaching urban development that will restrict vehicle access and waste disposal methods. The siting of additional tanks, along with pumping and chlorination stations which may need to be built or upgraded at a later date.

Location practicalities must not be compromised for aesthetics

Access roads should be able to accommodate tankers, trucks and work vehicles safely. Many tanks are situated adjacent to excavated earth banks, so all external wall areas should be accessible to scaffolding, ladders, cranes or mechanized digging and lifting equipment. Landscaping and natural vegetation must not encroach onto these work areas, as mature trees can damage foundations, pipe work, protective coatings, and create ongoing maintenance issues such as causing guttering systems to block up and overflow back into the tank.

Personnel carrying equipment can be injured from slipping or falling if required to traverse the steep slopes and landscaping that often surround tank perimeters. A level parking and working area with room to maneuver directly below the main roof access platform will enable equipment to be lifted up by the most direct route, thereby avoiding OH&S issues.

3 Naming and Identification

A key part of any inspection program is accurate naming of the asset and identification of specific areas. Most service reservoirs have been commissioned without any standardized method of achieving this.

Amalgamations of smaller Councils and water providers into larger, more efficient entities are becoming a reality. Tanks should therefore be named after the area or suburb location, as street names are too generalised and local knowledge is not always available within a larger organisation. The original, localised naming methods can lead to confusion of assets when viewed within a larger asset management system, as most towns have a Hill Rd, Reservoir Lane or High St.

Identify tanks by area location and a 'water storage' number

Tanks should also be allocated a WS number (Water Storage number) to enable asset management systems and field operators to accurately discriminate between often similar names. Tanks can be listed either by age or alphabetically and should be designated WS01, WS02 etc, with the numbering running sequentially to the newest asset. The WS number should be restricted to two or three digits for simplicity and should be independent of the larger alpha-numerical identification numbers that are often used for asset management purposes.

To reference inspection positions, the numbers of a clock face should be stenciled both inside and outside on circular tanks. To assist personnel carrying out inspections, numbers should be placed 500mm off the floor on the internal walls and also above the high water line. Corresponding numbers on the outside of the tank walls will reference external points of interest – these numbers should be above the 'normal graffiti line' area to avoid being covered over.

Clock face positioning provides standardised reference points

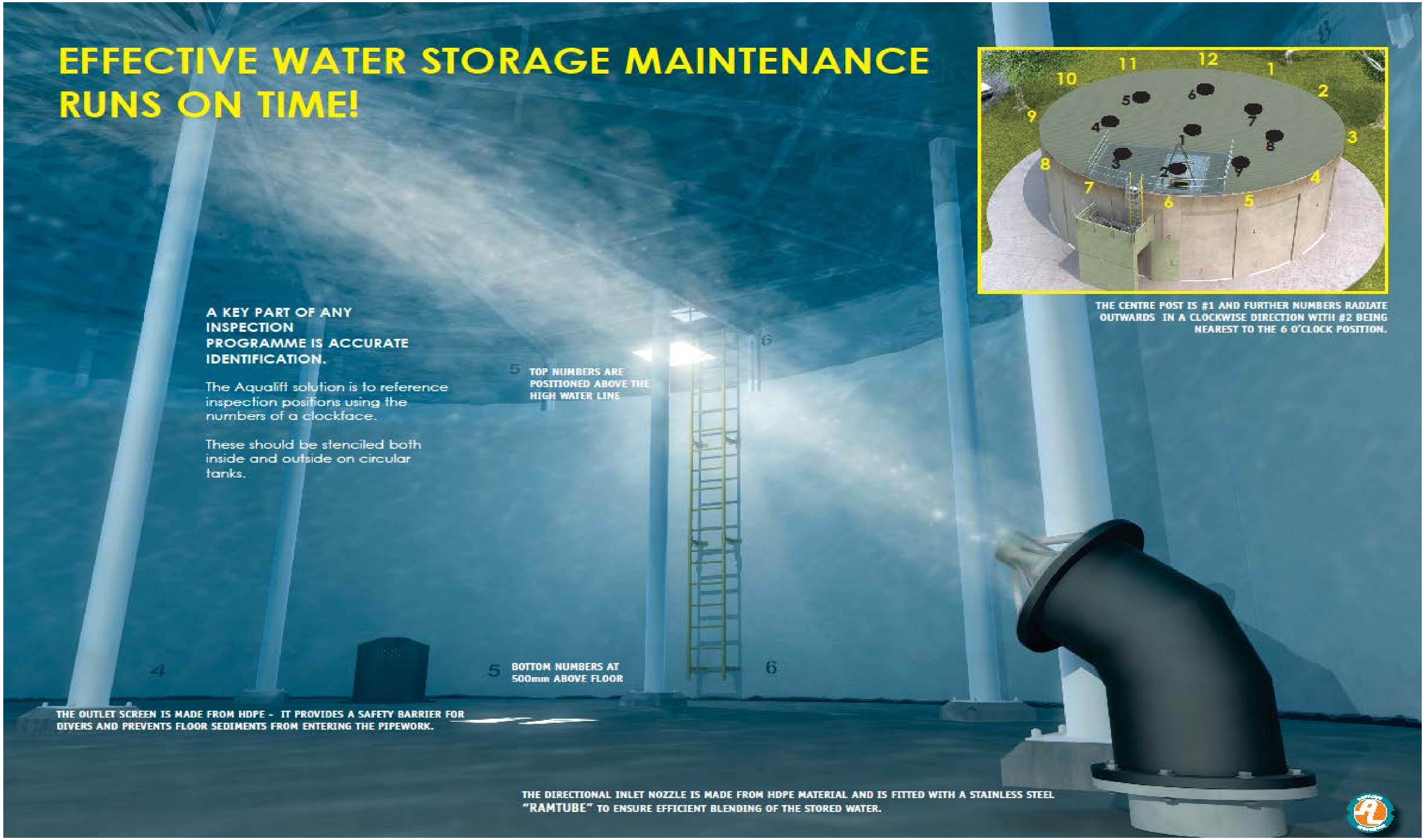
The main entry hatch is the 6 o'clock datum point and 180º to this is 12 o'clock, with the corresponding 90º points as 3 o'clock and 9 o'clock - the balance is divided up into remaining clock numbers (or half numbers if dealing with larger tanks). A simple method of allocating the clock face positions is achieved by measuring the tank circumference both inside and out using a tracking wheel and then dividing the total measurement by twelve. Another circuit is then carried out starting from directly below the entry hatch, using the divided measurement to accurately pin point the numbers of the clock face in sequence.

Roof support posts should also carry an ID number - the centre post is marked as No1 - the following numbers radiate out from there in a clockwise direction with No2 being nearest the 6 o'clock position.

Internal and external penetrations should be labeled with their intended function - INLET, OUTLET, SCOUR etc. and the external valve stems should be colour coded and the rotation direction recorded. A valve operations document should be compiled, laminated and stored onsite as a quick reference tool. Much experience has been lost during staff turnover and retirements, and this can lead to valves being operated incorrectly during emergencies or when regular staffs are not available.

Label all penetrations and valving, including operational directions

Refer to Appendix 1 – Identifying Safety.doc


EFFECTIVE WATER STORAGE MAINTENANCE RUNS ON TIME!
A KEY PART OF ANY INSPECTION PROGRAMME IS ACCURATE IDENTIFICATION.
The Aqualift solution is to reference inspection positions using the numbers of a clockface.
These should be stenciled both inside and outside on circular tanks.
TOP NUMBERS ARE POSITIONED ABOVE THE HIGH WATER LINE
BOTTOM NUMBERS AT 500mm ABOVE FLOOR
THE OUTLET SCREEN IS MADE FROM HDPE - IT PROVIDES A SAFETY BARRIER FOR DIVERS AND PREVENTS FLOOR SEDIMENTS FROM ENTERING THE PIPEWORK.
THE DIRECTIONAL INLET NOZZLE IS MADE FROM HDPE MATERIAL AND IS FITTED WITH A STAINLESS STEEL "RAMTUBE" TO ENSURE EFFICIENT BLENDING OF THE STORED WATER.
THE CENTRE POST IS #1 AND FURTHER NUMBERS RADIATE OUTWARDS IN A CLOCKWISE DIRECTION WITH #2 BEING NEAREST TO THE 6 O'CLOCK POSITION.

4 Roofing Systems

4.1 Roof sheets:

Roof sheets should be orientated to take advantage of prevailing winds and storms to sweep away any leaf debris that can build up around hatches and platforms. Sheet direction will also affect drainage when hatches and vents are fitted into the roof. Water can pond behind these fixtures if effective upstream drainage is not considered.

Consider local prevailing weather conditions and wind direction

Continuous roof sheets running parallel to each other should be used instead of 'centre pitched' roof designs, which have lots of ridge flashings running in towards the centre area. These flashings are labour intensive to construct and are not effective in sealing against wind born dust, leaves and faecal contamination.

Edge fixing areas need to be stronger than the rest of the roof structure as this is where wind damage will most likely occur.

4.2 Roof Gutters:

Roof edge gutters should be removed, as they require regular cleaning to be effective - OH&S issues often prohibit personnel from clearing blockages, which can then lead to back flow events occurring.

Box gutters running across the center roof area should be avoided as they are prone to vegetation and debris blockages of drainage points. Leaking joints or defective areas in box gutters are difficult to detect and any problems will lead to significant contamination of the reservoir.

Consider ongoing maintenance requirements and future defective areas to prevent ingress and contamination

Drainage spouts from box gutters inside the tank are often poorly connected, resulting in roof water missing the overflow bellmouth either partially or completely.

4.3 Roof framing:

Roof framing materials and roof sheet fixing screws should be suitable for use in moist, humid conditions – 'Stratco' type rolled steel purlins with a zincalume finish are not protected along the raw edges, resulting in premature corrosion developing – material product guides should be consulted for performance criteria under severe conditions.

Choose materials that are suitable for long term use in often warm, moist and corrosive environments

Only 'hot dipped galvanized' steel purlins or solid aluminum rolled framing should be considered in these severe environments, if roofing is to last past 30 years without incurring structural damage.

Stainless steel screws of good quality and insulated with suitable lubricating grease should be used to fix roof sheets to purlins. There have been a lot of recent failures involving poor quality steel roofing screws – many are showing significant corrosion and deterioration in less than 10 years.

There is a current OH&S trend of placing safety mesh on top of purlins, prior to installing the roof sheets, and this has created a significant failure rate in new tank roofing. While this installation method is OK in a dry industrial situation, it creates major corrosion issues to roof sheets placed in contact with the mesh in a warm, moist environment. More appropriate safety methods, such as temporary netting or filling the tank with water during the roof installation can be utilized.

4.4 Ventilation:

Think water quality first and roof framing life second! Ventilation to prolong the roof framing design life needs to be balanced with water quality issues. Wind born contamination needs to be considered - if the tank is in a dusty or otherwise contaminated environment, then ventilation needs to be limited at the expense of the roof design life. Larger hole size ventilation will also allow similar sized debris to enter the tank.

Ventilation should not compromise water quality

Ventilation (if selected) needs to be designed to encourage airflow across the total internal area – inlet vents must be included as well as exit vent points.

Inlet vents should be orientated away from sources of contamination. Fixed type ventilation points should be used in high wind areas instead of turbine type units that can be easily damaged.

Turbine vents of lower quality have a limited bearing and shaft life when operating over moist areas, so provision should be made to carry out replacements without damaging the roof sheets un-necessarily. Turbines are also more prone to vandal activity, so they should only be used in secure environments and be checked regularly for defects.

5 Access Systems

5.1 Platforms:

The platform can be made from aluminum or galvanized steel checker plate and a good sized working area is necessary for setting out cleaning, inspection and repair equipment. A good ‘fall’ to allow for effective drainage should be included in the design. Many platforms have a ‘negative fall’ and this creates ponding issues and resulting contamination events into the tank.

Platforms need to be designed to ensure that they are large enough, drain effectively and prevent debris build up

Platforms should be inserted under the roof sheets for effective drainage. The insertion method offers better sealing against backflow events and more effective drainage of leaf debris than roof sheets butting up to raised platform areas.

Platforms raised above the roof level create sealing issues around the bases of the mounting supports and the hatch frame areas - it is also difficult to remove leaf debris that accumulates under the structure.

On smaller tanks, the platform can be cantilevered off the wall area to create extra space and to simplify the roof plumbing.

Expanded mesh placed on top of adjacent roof sheets to prevent impact damage should be removable, so that accumulated leaf debris and dropped objects can be easily accessed to prevent accelerated corrosion points.

5.2 Guard Rails:

Guard rails should extend at least six metres either side of the platform area or any other section of roof edge used by personnel to operate or maintain the tank.

Guard rails are to extend around main working areas

Hinged gates (often adjacent to rescue systems) should be avoided as they are not necessary for rescue operations and merely increase the potential of personnel falling off the roof area.

External stanchions or handrails can be fitted adjacent to the entry hatch for orientation and balance when descending or ascending the internal ladder.

5.3 Entry Hatches:

The main entry hatch to be a minimum of 900mm wide by 900mm long. This allows easy entry and exit of personnel wearing diving or protective breathing equipment. It also allows the safe entry of robotic inspection and cleaning systems or the hoisting of emergency rescue equipment if needed.

Entry hatches should have a hinged cover system and not be of the sliding types (which are difficult to seal effectively).

Hatches need to be adequately sized and sealed against all forms of roof drainage

Hatches should have a continuous raised edge frame (75mm+ high) and a corresponding overlapped cover to prevent storm water and foreign matter from contaminating the tank. The overlapping sides also serve to stiffen the hatch cover against unauthorized entry or vandalism.

There should be no internal projections such as ladder stiles that prevent complete sealing of the hatch cover against debris or animal entry.

As more and more inspection personnel are being excluded from working at heights, hatches MUST be heavy duty and 100% secured against accidental opening, contamination ingress or structural damage caused by climatic events.

All hatch covers should be securely locked. Vertical lugs allow a padlock to lay flat and remain easy to operate. Many locking lugs are fitted horizontally and due to a lack of clearance, locks become inverted and their mechanisms are exposed to the weather, resulting in a failure of the padlock.

The cover should be easy to lift by one person. It should also have the ability to be secured into an open position, to prevent accidental closure by wind or human error whilst personnel are inside the tank.

5.4 Access Hatches:

Concrete tanks should be fitted with a sidewall hatch (similar to ones fitted into steel tanks) for safe access when the tank is empty. A minimum of 900mm diameter is required for safe access - this also places the structure into a lower category of confined space when empty.

A stainless steel pipe stub and flange can be cast into concrete tanks as they are built – if placed at the 6 o'clock position, the cover plate can incorporate a wall mounted auxiliary penetration used for vacuuming out the tank (more detail of this is supplied in 'Scour systems')

More than one roof access hatch should be fitted on tanks over 30 metres in diameter to allow for ventilation, light and the introduction of specialised equipment – e.g. inspection boats, robots and maintenance scaffolding.

5.5 Rescue Systems:

Most conventional davit systems are not effective in realistic rescue situations. They only give the 'appearance' of being safe and useful, so why install a mechanism that has no value for its intended purpose? Their fixed height makes it difficult to rig lifting equipment onto and the inability of a pivoting arm to effectively support side loadings makes it difficult to operate in complex lifting and lowering situations. A davit positioned above the entry hatch area also provides an attraction to roosting birds and the resulting accumulation of faecal material becomes a water quality issue.

Any rescue anchor system should have the ability to fold down onto the platform area when not in use, to reduce bird activity and the resulting contamination potentials incurred.

The anchor system should allow rescue rigging equipment to be fitted whilst in a lowered position, before being raised to its full working height.

It should be capable of sustaining sideways loadings for complex rescue situations down to 'safe ground'. Lifting an injured person out of the tank is only half of the rescue solution – lowering safely down to the ground is the final part of the operation, and this will generally involve multiple ropes and an abseiling type scenario with at least two persons being supported off the anchor system.

A single point of base fixing (as used in most pivoting davits) offers no back up if the material it is attached to (the wall concrete in most cases) or the fixing bolts themselves become defective - a multiple type base design offers more security against failure.

The base point fixings should be readily accessible for visual checking and testing prior to use. Yearly mandatory testing should not be accepted as 'foolproof' when a rescue situation is encountered – the rescue technician should always check the anchoring system prior to using it.

A 'Titan Arm' that is rated to over 200 kg SWL should be considered for serious confined space access and rescue situations. A vertical, un-caged Nextep FRP internal ladder should also be fitted below the entry hatch to compliment the access system.

Refer to Appendix 2 – Ladders into Confined Spaces doc

6 Internal Design Features

The most important factor is to store water in a high quality, hygienic environment - this cannot be achieved if internal fittings are heavily corroded or are causing contamination issues. While the internal fittings of steel tanks are generally fully coated, most items within concrete structures are neglected. Ductile iron pipe work, support brackets and metal ladders should all have a suitable protective coating before commissioning a concrete tank.

As cleaning is the most common water quality maintenance procedure carried out, all internal areas should be devoid of surfaces and fixtures that will gather or entrap sediments. Drain and sweep cleaning is being replaced with diver cleaning, and this will in turn be replaced by robotic cleaning, so all future tanks need to be designed to allow for effective sediment removal. This practical cleaning concept includes no wall/floor steps, no post base steps, minimal numbers of support posts, and all internal pipework and fixtures to have plenty of clearance to avoid entanglements of diver's airlines, robotic control cables and waste water discharge hoses.

Any horizontal fixtures such as platform landings and stairs should have perforated surfaces to prevent sediment build-up - ladder rungs and steps should be rounded instead of flat treads for the same reason.

Any reinforcement of the wall/floor area (where necessary) should be a flat, 90 degree step rather than a rounded or sloped type to allow for efficient vacuuming.

6.1 Materials:

Metal materials used in contact with water should be cathodically compatible to each other to minimize corrosion through electrolysis.

All metals should have a long life, protective coating suitable for immersion – most potable approved epoxies meet this requirement, but galvanizing is not suitable for submerged areas.

Stainless steel items should be coated to limit the cathodic potential difference to any adjacent metal fixtures, which will in turn corrode prematurely, due to the proximity of exposed stainless steel, if it is in sufficient volumes.

Aluminium is also subject to corrosion - during extrusion, carbon particles attach to the surface and cause severe electrolysis and corrosion unless removed by thorough surface preparation prior to installation. This process involves acid washing and/or polishing. (Refer to Appendix 3 – Internal Ladder Construction.doc).

6.2 Posts:

Aluminium posts fitted into concrete tanks have a documented failure rate if they are not cathodically insulated from both the floor fixings and the roof framing areas. Any electrical connection made will result in the aluminium post becoming an anode to protect the re-inforcing steel that is embedded within the concrete shell of the tank.

Roof support posts and other fixtures should be kept to a minimum to avoid entrapping sediments and interfering with water circulation. It is more cost effective to use larger roof framing members that can span greater distances, than to have multiple posts supporting smaller structural sections of roofing. Deeper tanks always have a minimum number of posts for this very reason.

Post support bases (if fitted) should be squared off, as sloping edges are hard to clean around. Remember that robots can only work on a flat, one dimensional surface and cannot climb up on top of things to access sediments.

6.3 Pipe work:

Pipes should be positioned under the floor where possible and only the penetrations should be exposed within the tank. All penetrations (with the exception of scours) should be flanged, so that the fitting of screens, nozzles and flow meters can be easily achieved at a later date. There should be adequate room below any flange to allow fixing bolts to be fitted and adjusted.

GRP or HDPE can be used for pipe penetrations, overflow risers and supports.

Overflow pipes need to be re-assessed. With telemetry and better pump controls, overflow events are less common, so overflow systems can be simplified. Rather than fitting internal risers (which corrode and create entanglement issues), the upper wall area can have an appropriate drainage area installed that leads out to an external riser pipe system. This external pipework is not subject to water pressure, so it can be lighter and of a lower pressure grade material. This installation method also allows for operational staff to hear an overflow event as it is occurring.

6.4 Outlets & Screens:

Outlets should extend to at least 150mm above the floor and have a flange fitted. – concrete steps cast around outlet pipe work penetrations should be avoided as they will allow sediments to accumulate around the edges and enter the reticulation system

Protective screens should be fitted onto outlets to prevent accidental diver, robotics or worker entanglement.

A sufficient ‘stand-off’ of the screen to increase cross sectional area of the penetration is required to avoid suction developing if the penetration were accidentally covered. Holes in the screen should not be too fine (15mm to 20mm diameter is ideal) and the holes should not total more than 120% of the penetration area. If the surface area is too large, the screen will become ‘passive’ and not ‘self-cleaning’ – this means sediments will accumulate during low flow periods and then be drawn into the reticulation system during high flow events. Screens under constant water pressure do not retard water movement, so ‘white water’ events caused by low flow restrictions are not an issue in this operational environment.

Screens should fit closely over penetrations to prevent sediments from accumulating internally within the screen, where they cannot be removed by regular cleaning processes.

Safety screens made from HDPE are ideal. In addition to providing strength and electrical isolation from adjacent metal materials, they can incorporate a solid raised edge area at the base (at least 150mm high) to keep sediments from entering the pipe-work, if existing penetrations are too close to the floor.

6.5 Inlets:

Water circulation within the tank should be designed to eliminate stale areas, promote efficient disinfection diffusion and avoid disturbing sediments already settled out on the floor area during the filling cycle.

Excessive circumferential water movement should be avoided as strong currents create entrapped areas of unmixed water and sediments in-towards the center area of the tank. This leads to 'water aging' and the disinfection product losing its effectiveness.

Incoming water energy can be harnessed at no cost to improve water quality. Inlet penetrations in the wall or floor should have an HDPE directional nozzle fitted to move the water flow upwards at 30 degrees plus and at 90 degrees to the wall.

Common inlet outlets should have a two way nozzle system fitted to avoid short circuiting of the incoming and the stored water.

Extra penetrations should be incorporated into the tank design to allow for future usage as surrounding areas develop. They can be blanked off and then brought into use as required – this is far better from a structural perspective than retro-fitting penetrations years after the tank is commissioned.

6.6 Scour Systems:

Cleaning is the most commonly performed water quality maintenance function on a tank. It depends on a properly designed waste water disposal system to effect compliance with environmental guidelines. Sediments cannot be deposited directly into storm water systems without treatment to reduce total solids loading, so the following features will be of assistance:

No scour trench to be included in the floor. The extra structural expense is not necessary, if diver or robotic cleaning is used.

Scour penetrations to be minimum of 150-200mm diameter and level with the floor for easy coverage with a vacuum suction plate. This cleaning method is not possible when roof posts straddle a center scour or if trenches or pits have close sides or irregular shaped penetration holes.

The scour penetration should be close to the main entry point for quick set up of vacuum suction plates without disturbing sediment. Vacuuming normally commences in this area, so extra hoses and equipment can be dropped onto the cleaned floor area without disturbing any sediments.

On tanks over 50 metres in diameter, a second scour in the center of the floor will allow vacuum equipment to be re-positioned to finish off to the far wall area without adding additional lengths of hose. Large steel tanks should have 75mm wall penetrations at 3, 6 and 9 o'clock positions to achieve a similar vacuum pattern - these penetrations should be mounted 1 meter off the floor and can be incorporated into personnel entry hatches or drilled through the wall using 'under pressure tapping' techniques.

'Through the wall' scour points can be directly coupled to a discharge hose or pump for transfer to a sewer, tanker or irrigation area. When considering any hook-up situation, backflow events must be eliminated to prevent contamination of the potable water.

'Through the wall' penetrations also serve a secondary purpose for the quick filling of fire tankers during emergencies.

The external scour exit point must remain within the client property to avoid disputes with run-off water flooding through neighboring areas.

6.7 Sediment disposal:

Levee banks to direct run-off water into settling-out areas are desirable - an earth dam with 4% of the reservoir capacity would allow turbid waste to settle out and be de-chlorinated if necessary. Clean water can then pass on at a later date, via a siphon system over the bank.

Surrounding urban development should include a sewer point adjacent to the tank for responsible waste disposal.

The scour can be connected into a 2000+ litre, in-ground sump - several options are now possible:

1. The sump can drain to storm water for normal overflow conditions. The addition of a simple penstock valve or inflatable ball plug at the base, can close off the lower area of the sump and allow another penetration at the top of the wall to gravity feed into a nearby sewer if it is available.
2. Alternatively, the sump could be fully isolated and its contents pumped directly into a mobile tanker or be irrigated onto suitable surrounding ground.

6.8 Floating Roof Tanks

When considering the installation of a floating roof, confined space issues must be addressed. Can personnel be safely introduced under a cover held up by air pressure alone? Any failure could lead to a drowning in shallow water if personnel were crushed underneath. Diver cleaning offers many advantages, but good preparation before the roof installation is necessary.

Multiple entry points allow the tank to be vacuumed in sections and permit the diver a quick means of escape in emergencies - the diver should not have to work under the roof area for more than 50 metres from an access opening.

Entry areas should be reinforced for at least four metres around the hatch and contain extra buoyancy to allow maintenance equipment to stay dry.

Sloping walls are hard to grip when being vacuumed and it is normal on an open basin for the dive tender to tow the diver parallel along the wall and work slowly down to the floor. With a floating roof this is not possible, so a sliding lanyard system can to be fitted. Stainless steel eyebolts with no sharp surfaces can be installed at 10-15 metre intervals above the top sediment level area. A 5mm stainless steel cable is then passed through these eyes and tensioned up - this allows the diver to attach a sliding lanyard to the cable and to vacuum sweeping areas of the wall before moving onto the adjacent floor area.

Identifying Safety

Prior to commencing any diving operation or tank cleaning operation, a series of hazard identification procedures need to be addressed - some of the main issues are the type and position of pipe-work penetrations.

A ‘clock face’ system was devised to divide the tank into identifiable areas of interest - this system is only accurate if markings are stenciled onto the exterior and interior areas of the tank. On the hazard identification ‘walk-around’, pipe work and valve positions can be noted accurately and the divers briefed accordingly.

The outside markings are of equal importance to the internal identification, because it is not possible to view any external pipe work relevant to its position, when standing on the roof at the entry hatch. If the diver is aware a particular penetration is located at say 9 o’clock for example, it can then be visualized and referenced against skylights, posts or fixed objects within the tank.

An internal numbering system is useful for inspection and safety purposes but it is not as easily achieved, unless the tank is empty for repairs or under construction - external numbering can be done at any time or included into anti-graffiti coating projects.

Many clients have implemented the numbering system and they have benefited from more accurate asset inspections, whilst at the same time improving safety issues.

8 Appendix 2 Ladders into Confined Spaces

Ladders into Confined Spaces

Risk assessment and compliance with Australian Standards will always be an important step in managing water quality and safety issues within water storage tanks. However applying appropriate Standards can be ambiguous unless an experienced risk analysis is undertaken – designers, regulatory authorities and clients need to consider all of the hazards involved (to both water quality and operations personnel) if sensible outcomes are to be achieved.

Access systems into most tanks have been poorly designed to date – they haven't considered the confined space implications to the personnel involved, let alone how they will affect water quality within the tank. Water storage tanks have one main purpose in life - to store water in a secure, high quality environment for the consumers. This has often been overlooked by the asset owners and OH&S regulators, in an attempt to satisfy workplace compliance issues and safety to the various personnel operating the asset. By applying an experienced, commonsense approach to all of the relevant issues, water quality can also be improved.

Hatch and platform areas must be protected against natural and deliberate contaminants that can enter the tank – this can be as simple as designing the hatch frames and covers to fully seal the tank, rather than trying to address several low importance issues such as 'trip hazards' and 'hand contact' requirements on access ladders.

Designers and clients have neglected the fact that personnel qualified to enter a confined space should be quite capable of stepping over a raised hatch frame without the assistance of a continuous protruding ladder stile to guide them – perceptions of a 'trip hazard' that may be encountered once or twice a year have overtaken the fact that contamination to the tank will occur continuously 365 days of the year if the hatch area is defective.

Water security has been compromised by not accurately assessing the 'risk and likelihood' guidelines designed to ensure safe, holistic outcomes - there are plenty of better options to assist personnel into the hatch area and onto the ladder safely, including the ergonomics of ladder placement and positioning, to favor safety when climbing **down** rather than **up.**

Consider an example of climbing up a ladder and onto the platform area – it is relatively easy to climb upwards as the body is comfortable and all the hazards can be viewed. However the experience of 'feeling' for that first rung with your foot as you move down the ladder is quite different – this is a critical point that has often been overlooked and it serves to illustrate that ladder safety is not equally balanced when travelling both up and down.

Ladders **must** be positioned into a tank to favor the decent rather than the ascent – this is achieved by placing the ladder parallel to the wall where it can be stepped onto while facing straight ahead, rather than having to turn 180 degrees and step backwards onto the rungs, as in a '90 degrees' to the wall' type installation.

Ladders fitted into confined spaces also have different functional requirements than those addressed in the Australian Standard 1657-1992 (Fixed platforms, walkways, stairways and ladders). The traditional ladder system of sloping stiles, enclosed cages and fixed platforms is not suitable for safe entry and exit using a harness and fall arrest system. AS/NZS 2865:2001 (Safe working in a confined space) 6.4 states: Any modification to a confined space shall not detrimentally affect the safe means of entry to, exit from, or work in a confined space.

Confined Space access ladders should be designed as a vertical structure system to allow for clear entry and exit when personnel are being lifted or lowered in a harness (cages and platforms will not assist in this situation – they actually increase the risk of an accident occurring)

A vertical ladder system will prevent 'Harness Trauma', by allowing personnel to climb under control and not be fully suspended throughout the confined space access operation - vertical ladders also allow the climber to maintain balance and to avoid any 'swing and rotation' throughout the access operation.

Some designers are incorporating twin access systems – a traditional 'caged, angled and platformed' ladder system under one hatch, and a separate rescue hatch without a ladder fitted. This concept should be avoided in favor of a single access area with all the combined resources placed into the one location - it also prevents the unnecessary added surface area where sediments can accumulate.

A Nextep FRP vertical ladder and a Titan Arm combination provides the ideal system for safe access and rescue capability – it places the safety component (the ladder) inside the confined space environment and the rescue system (the Titan Arm) outside the hazard area where it can be operated effectively by the confined space support team.

It is possible to achieve all outcomes simply and cost effectively, by assessing all of the risks involved, and not just making assumptions of the probabilities that may occur – there needs to be a strong practical input into all projects at the designer level, to make sure that past mistakes are not continued and that proven ideas, good practices and new materials are given the recognition and credit that they deserve.

9 Appendix 3 Internal Ladder Construction

Internal Ladder Construction

Most ladder systems in tanks and immersed structures are constructed from unsuitable materials, and their design does not meet confined space requirements.

Corrosion within a tank reduces water quality by direct contamination and reduced oxygen levels - both galvanized mild steel and fabricated aluminum will corrode heavily when immersed in potable or raw water.

Stainless steel is more corrosion resistant, but it can cause cathodic corrosion to adjacent tank structures when immersed - reinforcing fabric in concrete tanks is subject to corrosion attack if an electrical connection is made when attaching a stainless steel ladder system to the wall. Steel tanks are likewise subject to cathodic corrosion unless effective insulation procedures are carried out. Most stainless steel ladders also have round bar rungs that are difficult to grip when wet, so safety is often compromised for corrosion resistance.

Nextep FRP ladder systems have a 50-year life projection when immersed, and many have been in service for over 25 years with no signs of deterioration. FRP is lightweight, easy to install and remains neutral to cathodic corrosion. The rung design is ergonomic, non-slip, and the yellow coloring is safe to use in low light conditions.

Divers can remove most existing ladder systems while a tank or structure remains online, and the refitting of an FRP vertical ladder system can be carried out at the same time. A dedicated rescue frame such as the DBS Titan Arm, rated at 200+ kg provides the external safety component of the system and provides a high level of safety to any confined space access operation.

Confined Space compliance within enclosed and immersed structures cannot be ignored, and older ladder systems do not meet this requirement. An ergonomically, safe to climb, FRP vertical ladder system used in conjunction with personnel protective equipment and operator training is the only reality in today's workplace.