Settling Tank and Sediment Basin Decant Systems

Version 1, 2017

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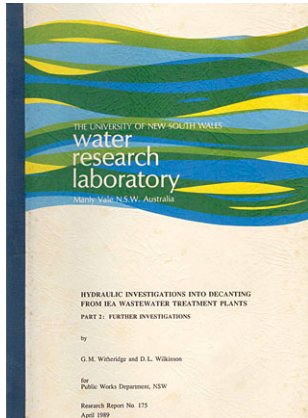
Version 1, April 2017

Disclaimer

Significant effort has been taken to ensure that this document is representative of current (2017) best practice erosion and sediment control; however, the author cannot and does not claim that the document is without error, or that the recommendations presented within this document will not be subject to future amendment.

The research work presented within this document on wastewater treatment tank decant systems dates from 1986–88 (the time of the author's university Masters research), and is representative of the knowledge base at that time. In preparing this publication the author has not investigated recent advances into the research of wastewater treatment systems, but instead has focused on how this 1980s research could be applied to the design and operation of construction site sediment basins.

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Principal reference documents:

Hydraulic Investigations into Decanting from IEA Wastewater Treatment Plants, Part 2: Further Investigations

G.M. Witheridge and D.L. Wilkinson, April 1989, Research Report No. 175, Water Research Laboratory, Manly Vale, NSW
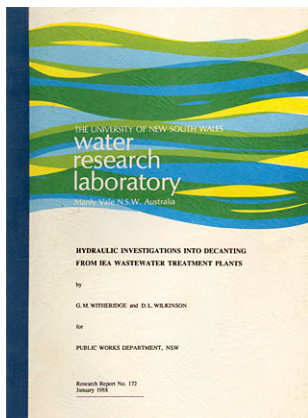
Witheridge & Wilkinson, 1989

Hydraulic Investigations into Decanting from IEA Wastewater Treatment Plants

G.M. Witheridge and D.L. Wilkinson, January 1988, Research Report No. 172, Water Research Laboratory, Manly Vale, NSW
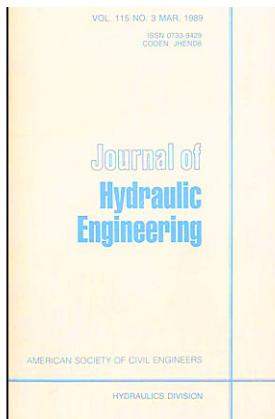
Witheridge & Wilkinson, 1988

Density Measurement of Particle and Floc Suspensions

Witheridge, G.M. and Wilkinson, D.L. 1989, Journal of Hydraulic Engineering, Vol. 115, No. 3, March 1989, American Society of Civil Engineers, pp. 403–408

Journal of Hydraulic Engineering, 1989
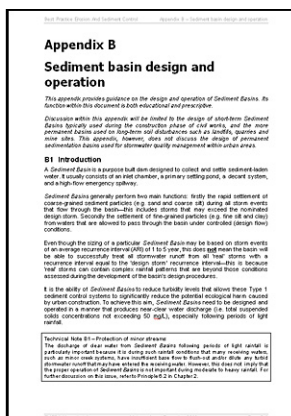
Appendix B – Sediment basin design and operation

Revised Appendix B (2017) associated with the 2008 IECA Best Practice Erosion and Sediment Control documents, (89 pages) International Erosion Control Association, Picton, NSW

IECA (2017) Appendix B - Sediment Basins

Contents   **Page**

Purpose of document

This publication has been prepared specifically to:

- provide background information on the 'science' and 'theory' used in the development of IECA Australasia's revised 2017 Appendix B – *Sediment basin design and operation*

- provide an overview of the research findings developed from the 1986–88 study into the decanting of intermittent activated sludge, wastewater treatment tanks located in Port Macquarie, NSW

- provide an overview of how the knowledge gained into fluid mechanics of settled sludge was used in the design of high efficiency sediment basins.

The photos presented within this document are intended to represent the current topic being discussed. The caption and/or associated discussion should **not** imply that the actual 'site' shown within the photograph represents either good or bad engineering practice.

About the author

Grant Witheridge is a civil engineer with both Bachelor and Masters degrees from the University of NSW (UNSW). He has 35 years experience in the fields of hydraulics, creek engineering and erosion & sediment control, during which time he has worked for a variety of federal, state, local government and private organisations.

Grant commenced his career at the UNSW Water Research Laboratory constructing and operating physical flood models of river floodplains. He next worked for the NSW Public Works Department in the field of wastewater treatment, with a focus on inlet works, including flow measurement and screening. He then returned to the UNSW Water Research Laboratory during which time he conducted this research work on the decanting of wastewater treatment tanks as part of this *Masters in Engineering Science* at the University of NSW.

Grant is the principal author of such publications as the revised *Queensland Urban Drainage Manual* (2007, 2013 & 2017), and IECA (Australasia) *Best Practice Erosion and Sediment Control (2008)* documents. In 2010 Grant was presented with the IECA (International) *Sustained Contributor Award*.

Acknowledgments

Officers who contributed to the wastewater research work included:
- Fred Cozma (NSW Public Works Department)
- Carmel Hayes (Hastings Municipal Council, Port Macquarie)
- Albert Jackson (NSW Public Works Department)
- Murray Thompson (Hastings Municipal Council, Port Macquarie)
- Dr. David Wilkinson (UNSW Water Research Laboratory)

Introduction

This publication provides and overview of the 1980s investigations into the mechanisms responsible for sludge carry-over during decant from intermittent aeration wastewater treatment tanks combined with recent (2016) research into the optimisation of construction site sediment basin operation.

The 1980s wastewater treatment studies identified several mechanisms that may result in sludge carry-over at decent weirs. An 'early failure' mode was identified, which may occur during the transient phase at the start of decant. It was concluded that this failure mode can be avoided by gradually increasing the rate of decent over a period of about five minutes.

Sludge carry-over can also occur when interfacial shear stresses between the supernatant and settled sludge exceed some critical value. This failure mode is considered to be a 'scour failure' analogous to the onset of erosion of a cohesive sediment. Experiments conducted in a variety of different types of extended aeration tanks indicated that the critical parameters governing failure are (i) the upstream velocity of supernatant, (ii) the settlement time, and (iii) the Stirred Sludge Volume Index (SSVI).

Introduction
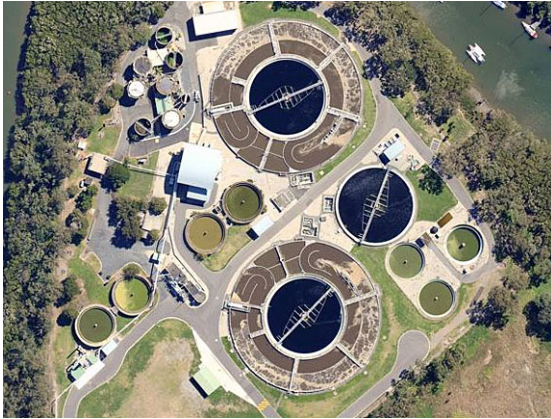
Carrousel treatment system
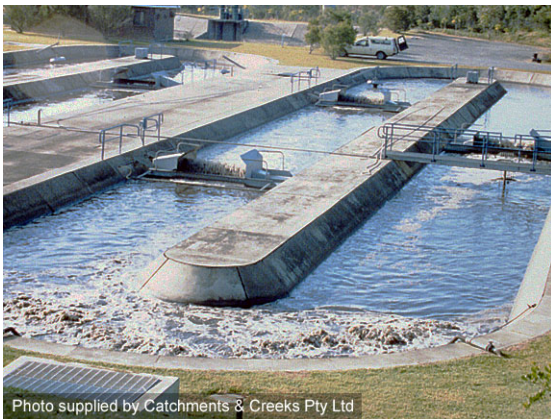
Wastewater Treatment

- Various wastewater treatment systems employ the activated sludge process.

- This process can either operate as a continuous system, which allows for aeration and settlement within separate tanks (e.g Carrousel tanks), or as an intermittent process with aeration and settlement occurring cyclically within a single tank.

- The latter process includes Pasveer Channels, Bathurst Boxes and Port Macquarie Tanks.

Pasveer Channel

Pasveer Channel

- The Pasveer Channel is an intermittent extended aeration wastewater treatment process that utilises a continuous loop (racetrack-like) configuration.

- The Pasveer Channel was originally developed by Dr A. Pasveer in the Netherlands.

- In NSW these channels have been developed to treat an equivalent population of typically 500, 1000 or 2000 persons, titled P500, P1000 and P2000.

Bathurst Box (empty)

Bathurst Box

- The Bathurst Box is a single rectangular tank designed for automatic sequential operation, incorporating the activated sludge, extended aeration process.

- The tank was first developed in the town of Bathurst, New South Wales.

- After the aeration and settling phases, a decant trough is lowered into the tank to drain the treated supernatant.

- Dimensions of the B4000 are 37 x 12.5 x 5 metres, with 3.27 m BWL & 4.33 m TWL.

Port Macquarie Tank

Port Macquarie Tank

- The Port Macquarie Tank is an expansion of the Bathurst Box developed for the purpose of treating larger populations, such as 15,000 equivalent persons (the original T15000 tank in Port Macquarie).

- Construction costs for the recessed tanks are significantly less than for the free-standing Bathurst Boxes.

- The decant mechanism is typically a floating weir, which operates from the end of the tank furthest from the inflow point.

Intermittent activated sludge process

Inflow mixing box (fully drained tank)
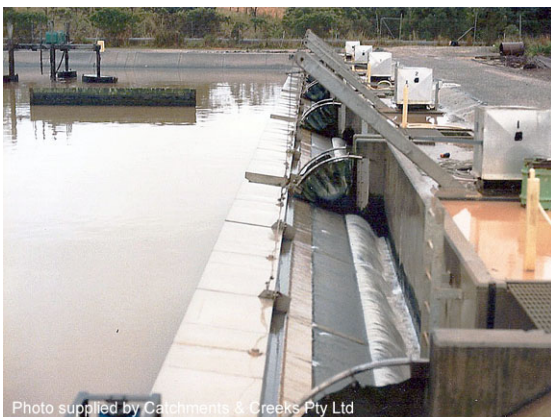
Continuous inflow and initial mixing

- The intermittent activated sludge process incorporates four phases (i) inflow and mixing, (ii) aeration, (iii) settlement, and (iv) decant.

- The Pasveer Channel, Bathurst Box and Port Macquarie Tanks all operate with continuous inflows.

- The Port Macquarie Tank (shown left) incorporated an inflow mixing chamber in response to the theory that an initial mixing zone would help to promote the growth of the preferred treatment 'bugs'.

Aeration phase

Aeration period

- Phases within the full treatment process can vary from system to system, but in a typical 4 hour cycle, the aeration phase operates for 2.5 hours, followed by 1 hour of settlement and 30 minutes for decanting.

Settlement phase

Settlement period

- The aeration period is followed by a quiescent period during which the sludge is allowed to settle with minimal external disturbance outside of:
  - continued inflow mixing
  - wind disturbance, which can create minor water circulation problems.

- A 1-hour settlement phase is typical for deep tanks.

- This photo (left) shows a decant weir modified (water drum) to allow variations in weir flows during the testing program.

Decant phase

Decant cycle

- Following the settlement period the 'clear' supernatant liquor is decanted into effluent ponds for either direct discharge or further tertiary treatment.

- A critical requirement of this decant phase is to ensure that the settled sludge layer is not disturbed, and that the settled sludge does not discharge from the tank, a process known as 'sludge carry-over'.

Initial experimentation, 1984 to 1986

Port Macquarie, 1984

Port Macquarie T15000 test, 1984

- In 1984, decant testing was conducted on the Port Macquarie T15000 Aeration Tank No.1 at Port Macquarie, NSW.

- During this testing the treatment plant experienced a heavy storm event, which caused excessive sludge carry-over.

- Study results were published in the NSW Public Works Department, Wastewater Engineering Research Bulletin No.7, 1986 (see reference documents on page 3).

Sawtell 'Bathurst Box', 1984

Sawtell B4000 test, 1984

- In 1984, decant testing was conducted on the trough decant system within the Bathurst Box B4000 treatment unit at Sawtell, NSW.

- This trough decant system lowers slowly into the supernatant through the use of a screw mechanism.

- This slow-decent decant system avoids some of the sludge carry-over problems experienced on tanks that incorporate a rapid-fall, floating-weir decant system.

Sludge scour test unit, 1986

North Richmond sludge flow testing, 1986

- At the North Richmond wastewater treatment plant a series of tests were conducted on a settled sludge subject to a known shear stress.

- A special tank was constructed with a variable outlet weir that could regulate the scour velocity passing over a settled sludge blanket—the sludge being obtained from the adjacent Pasveer Channel.

- Water die was used in some of the tests to identify movement within the settled sludge blanket.

Bundanoon 'Pasveer P2000', 1987

Pasveer tests, Bowral, Bundanoon and Huskisson, 1987

- In 1987, decant testing was conducted on the Pasveer P2000 channels at Bowral, Bundanoon and Huskisson in NSW.

- These tests involved manually over-riding the weir lowering mechanism at the start of the decant cycle in order to achieve higher decant rates; thus allowing the tests to encourage potential sludge carry-over conditions.

- Lock exchange and WRC settlement tests were performed concurrently.

Port Macquarie decant testing, 1986 & 1988

1986 Port Macquarie decant testing setup

Port Macquarie T15000 test, 1986

- A second series of decant tests were conducted on the T15000 Aeration Tank No.1 at Port Macquarie in 1986.

- During these tests the flow rate over the central decant weir could be increased by adding water (weight) to a drum attached to the floating weir (shown left).

- The weir flow rate was measured using a V-weir mounted within a suspended flume (shown below).

1988 Port Macquarie decant testing setup

Port Macquarie T18000 test, 1988

- Further decant testing was conducted on the new T18000 Aeration Tank No.2 at Port Macquarie in 1988.

- During these tests the flow rate over the central decant weir could be increased by adding water to several open bins attached to the main float.

- The weir flow rate was measured using the same V-weir mounted used in the 1986 tests (see below).
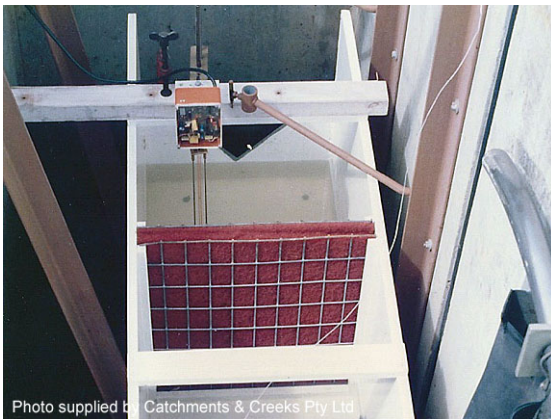
Flow measuring V-notch weir (1988)

Flow measurement system

- A V-weir was installed into the decant channel to measure the flow rate passing over a measured width the decant weir.

- This V-weir was calibrated at the University of NSW Water Research Laboratory (WRL).

- An electronic sensor was used to measure and record water levels within the flume during each decant test.

Weir flow measurement using a triangular-notch, thin-plate weir (1986)

Various failure modes causing sludge carry-over

Sludge passing over the decent weir
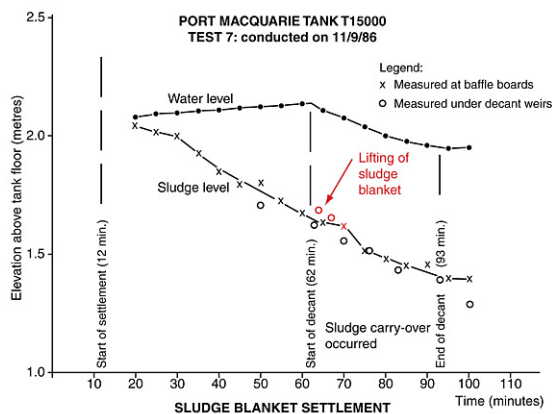
Lifting of sludge blanket at start of decent
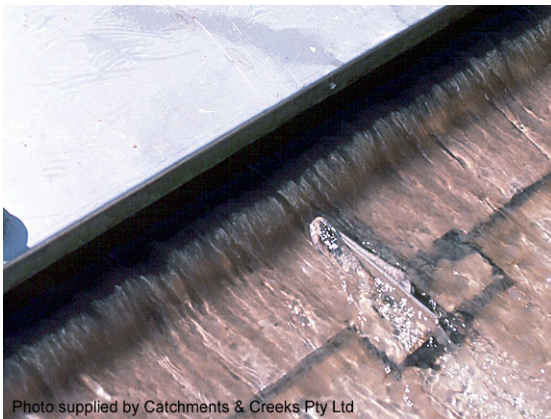
Severe sludge carry-over

Shear stress failure, North Richmond test

Introduction

- The visual occurrence of sludge carry-over during the tank decent phase was adopted as the 'point of failure', independent of the actual water quality.

- The study identified three different potential failure modes, those being:
  - (i) Early failure mode
  - (ii) Failure to selectively withdraw
  - (iii) Shear stress failure mode

Mode 1: Early failure

- The early failure mode results from the initial surge-like response of a settled sludge blanket.

- If the initial decant rate increases too swiftly, such as when a decant weir is 'dropped' into the tank, then the initial movement within the sludge blanket can fracture the floc bonds causing the settled sludge to flow towards the outlet weir.

- The study concluded that an early failure mode could be avoided by increasing the decant rate over a period of 5 minutes.

Mode 2: Failure to selectively decant

- A failure to 'selectively decant' the supernatant layer without disturbing the slightly heavier sludge blanket could potentially occur if the decant was initiated while the sludge blanket was still settling.

- During the early stages of the settlement phase, the bonds between the sludge floc particles are weak, and the floc can readily be carried by the surrounding water towards the outlet weir.

- This type of failure will likely occur only while the sludge blanket is still settling.

Mode 3: Shear stress failure

- A shear stress failure can occur when the velocity of the upper supernatant layer is sufficient to break the bonds between the settled floc particles.

- The primary variables appeared to be:
  - supernatant velocity
  - settlement time
  - stirred sludge volume index (SSVI)
  - wind speed (disturbance of settled floc).

Properties of settled sludge
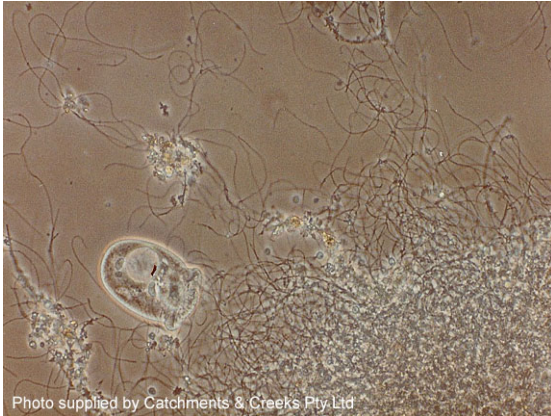
Filamentous sewage sludge floc

Sludge blanket disturbed by tank inflow

Blanket-like properties of settled sludge

Stirred sludge volume index (SSVI) test

Sewage sludge

- The biological properties of sewage sludge can vary significantly from location to location, and from time to time at any given location.

- Critical factors affecting its hydraulic properties include:
  - density of volatile matter
  - percentage content of non-volatile matter
  - relative density of settled sludge layer
  - fibre/filamentous structure.

Hydraulic properties of a sludge blanket during the settlement phase

- The flow characteristics of 'mixed liquor' (during settlement) and settled sludge (after settlement) are very different.

- Mixed liquor exhibits Newtonian properties with a density and viscosity slightly greater than clear water.

- While the sludge is settling, the water pressure within the sludge blanket is directly impacted upon by the weight of the sludge; however, once settled, the sludge rests on the tank floor.

Hydraulic properties of a sludge blanket near the end of the settlement phase

- As the sludge blanket begins to settle, the filaments interlock, and the fluid begins to exhibit Bingham characteristics–meaning, it can 'resist' minor shear stresses.

- The photo (left) shows water flow over a settled sludge—note the sludge is holding-together like a 'blanket' as it is slowly lifted from the plywood base of the shallow test tank by the passing flow.

- The green dye was used to help show the water movement over the sludge.

Settlement characteristics

- The settling velocity of a sludge floc is considered to depend on:
  - the degree of external disturbance (turbulence and water circulation) within the mixed liquor
  - the density of the particles relative to the water
  - the type of filaments within the floc
  - the degree of intertwining of the filament strands
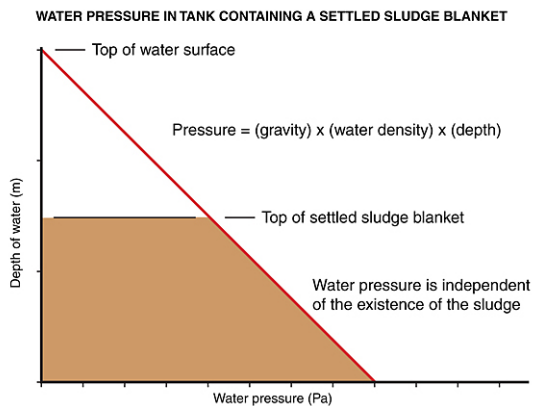 - stirred sludge volume index (SSVI).
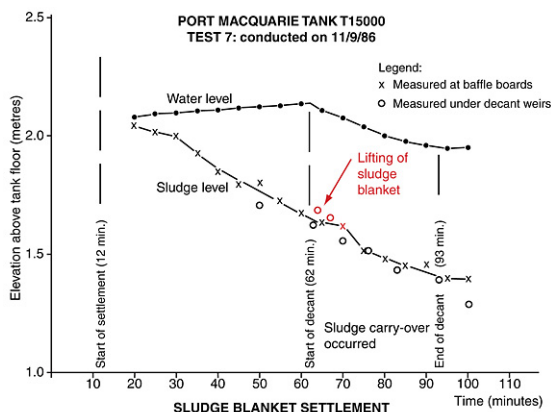
Cause of the 'early failure' mode

Undesirable floc carry-over

Photo supplied by Catchments & Creeks Pty Ltd

Early stage of sludge blanket settlement

Hydraulic pressure for settled sludge

Plot showing the 'surge' at start of decent

Early failure mode

- As previously discussed, the early failure mode results from the initial surge-like response of the settled sludge blanket.

- At the start of the decant phase, a pressure gradient is established within the liquor, which causes the water to flow towards the outlet.

- This pressure gradient exists throughout the tank, and throughout the full depth of the tank, including within the settled sludge blanket.

Pressure gradient during the settling phase

- While a sludge floc is still settling (i.e. yet to come to rest on the tank floor) the weight of the floc is indirectly 'carried' by the water through the forces of drag and turbulence.

- While the sludge floc is in this fully mixed stage, the liquor behaves like pure water, but with a slightly elevated density.

- Theoretically, water pressures down through the water column are reflective of this slightly-elevated mixed-liquor density.

Pressure gradient at end of settlement

- At the end of the settling phase, the sludge floc rests on the floor of the tank.

- This means that the water pressure **within** the settled sludge layer is independent of the weight of the floc.

- It also means that at the start of the decant phase, the water within the settled sludge layer will not register that the floc exists, and thus will initially try to move towards the decant weir.

- Only when the water tries to move will the floc begin to impede the water movement.

Cause of early decant failure

- If the decant rate increases too quickly at the start of the decant phase, then this initial movement of the water within the settled floc layer will shear the weak interlocking bonds of the sludge floc.

- If the interlocking bonds of the floc are fractured, then the floc's resistance to movement is decreased, and the floc can be dragged towards the decant weir initiating an 'early failure' mode.

- The plot (left) shows the settled sludge layer lifting at the start of the decant.

Hydraulic pressures in a tank filled with 'settled' particulate matter

Pebbles in a water container

- Under hydrostatic conditions, water pressure varies uniformly with depth.

- If the tank contains two, unmixed fluids of different densities, then there will be a change in the 'rate of pressure change' at the interface of the two fluids.

- If the tank contains particulate matter resting on the bottom of the tank, then the water pressure is independent of the weight of the particles.

- The pressure of water in a <u>settled</u> sludge mimics that of a resting/settled particulate matter.

Tank filled with pure water

WATER PRESSURE IN TANK FILLED WITH PURE WATER

Depth of water (m)

Top of water surface

Pressure = (gravity) x (water density) x (depth)
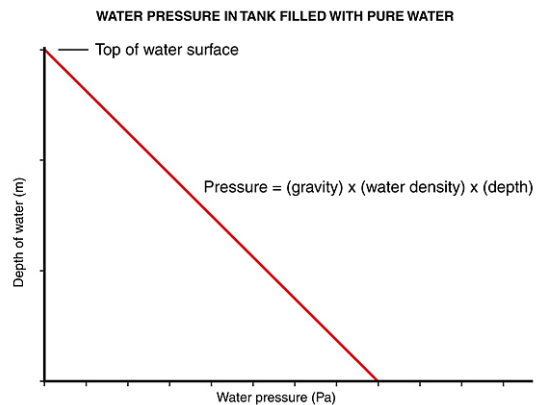
Water pressure (Pa)

Water pressures within a uniform fluid

Tank with two fluids of different densities

WATER PRESSURE IN TANK FILLED WITH TWO FLUIDS OF DIFFERENT DENSITY

Depth of water (m)

Top of water surface

Lighter fluid

Heavier fluid

Interface between the two fluids

Water pressure in uniform fluid

Water pressure in a two layer fluid
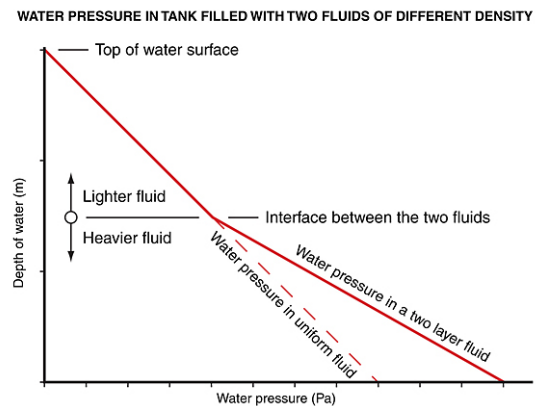
Water pressure (Pa)

Water pressures within a stratified tank

Tank filled with peddles

WATER PRESSURE IN TANK PARTIALLY FILLED WITH PEBBLES

Depth of water (m)

Top of water surface

Pressure = (gravity) x (water density) x (depth)

Top of pebbles

Water pressure is independent of the existence of the peddles
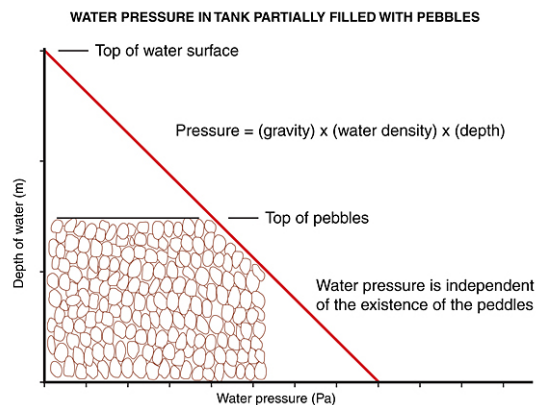
Water pressure (Pa)

Water pressures within the resting peddles

Shear stress failure mode

Undesirable sludge carry-over
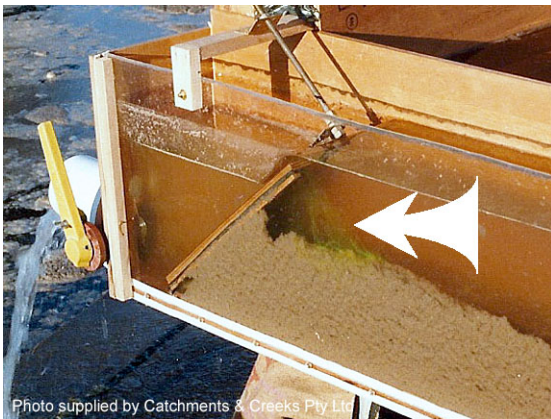
Green dye used to track water movement
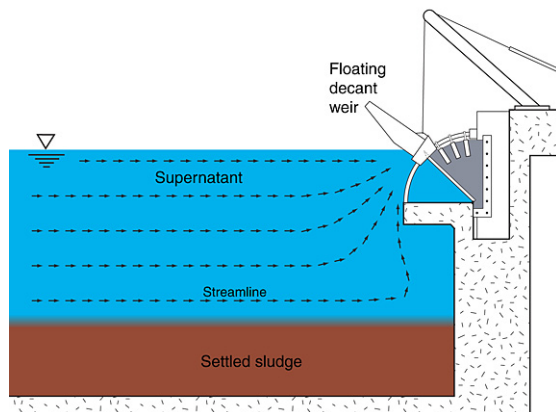
Typical decant streamlines

Velocity vs settlement time and SSVI

Shear stress failure

- A shear stress failure occurs when the velocity of the upper supernatant layer is sufficient to disturb the settled sludge blanket and cause sludge carry-over.

- Field tests indicate that the key sludge properties are:

  – supernatant decant velocity

  – settlement time

  – stirred sludge volume index (SSVI)

  – wind speed (disturbance of settled floc).

North Richmond critical shear stress experiments

- A special test unit was operated at the North Richmond Wastewater Treatment Plant to test the occurrence of a shear stress failure.
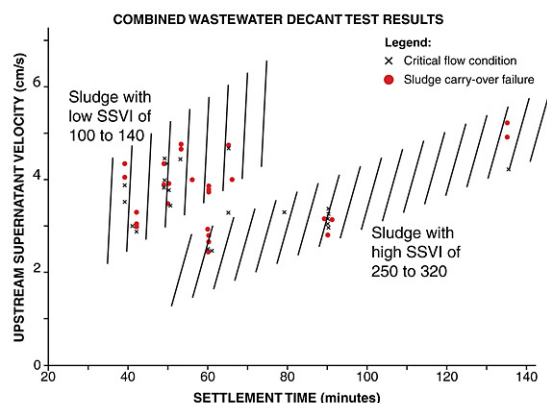
- These test results indicated a critical supernatant velocity of between 2.3 to 2.6 cm/s; however, one test achieved a velocity of 2.8 cm/s without sludge carry-over occurring.

The hydraulics of surface water decant weirs

- It is important to note that the use of a floating decant weir does **not** mean that only surface water will be drawn towards the outlet.

- Supernatant will flow towards the decant weir from the **full depth** of the supernatant layer, meaning that water can be drawn up towards the decant weir from a metre or more below the water surface.

Results from decant tests

- Based on a variety of test results, a correlation was found between the critical supernatant velocity, the sludge settlement time and the stirred sludge volume index (SSVI) as shown left (refer to Uni of NSW, Water Research Laboratory, Research Report No. 175)

- The minimal critical supernatant velocity was in the order of 2.4 cm/s.

Decant systems used on intermittent-aeration wastewater treatment tanks

Circular, 'Morning Glory' decant weir

Pasveer channels – Circular 'Morning Glory' decant weir

- The smaller P500 Pasveer channel can be decanted using a small circular (Morning Glory type) decant weir.

- The slow lowering of this system into the supernatant helps to reduce the occurrence of an early failure mode.

Pasveer decant trough

Pasveer channels – decant trough

- Pasveer channels are typically decanted through the use of a suspended trough that lowers slowly into the supernatant.

- The slow lowering of this system into the supernatant helps to reduce the occurrence of an early failure mode.

Bathurst Box decant trough

Bathurst Box

- A Bathurst Box tank is typically decanted through the use of a suspended trough that lowers slowly by a mechanical screw operation into the supernatant.

- The slow lowering of this system into the supernatant helps to reduce the occurrence of an early failure mode.

Floating decant system with slow fall

Port Macquarie tank floating decant system

- The Port Macquarie type treatment tanks typically use a floating decant weir, which uses the 'float chamber' as a scum barrier.

- In the later versions of this decant system, the weirs are lowered slowly into the supernatant to avoid the potential for an early failure mode.

- **To avoid an early failure mode, it is recommended that the flow rate over the weirs should increase slowly over a period of around 3 to 5 minutes.**

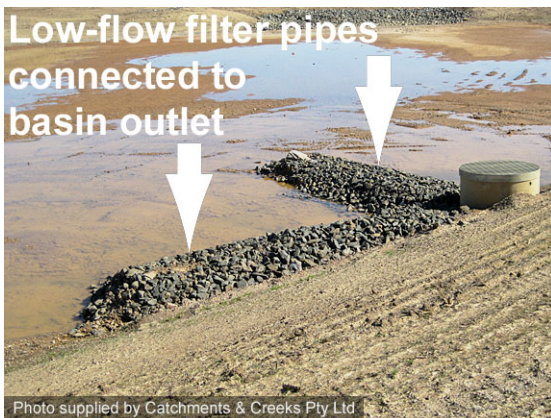# Decanting from Construction Site Sediment Basins

Types of sediment basin decant systems

Pumping system

Pumping systems

- Pumps have traditionally been used for the decanting of Type D (wet) sediment basins because these basins do not incorporate a piped decant system.

Low-flow Ag-pipe filters

Aggregate and geotextile filter outlets

- Aggregate and geotextile filter decant systems are typically associated with the older Type C (dry) sediment basins.

- The critical design feature of these decant systems is the design flow rate, which must be slow enough to allow the full settlement of the critical particle size.

- The aggregate and/or geotextile filter incorporated into the outlet is simply a secondary treatment process, which is subservient to the particle settlement process.

Sand filter under construction

Sand filters

- Sand filters are traditionally used as the low-flow decant system on permanent stormwater treatment ponds.

- These treatment ponds can be large ponds and wetlands, or small sand filters and bio-retention systems.

- These types of sand filters are generally not used as part of the decant system for temporary construction site sediment basins.


Riser pipe decant

Riser pipe decant system

- Continuous flow Type C sediment basins are most commonly decanted using some type of riser pipe system.

- The riser pipe normally incorporates either a geotextile or aggregate filter, which links it to the aggregate and geotextile filter outlets discussed above (*Aggregate and geotextile filter outlets*).
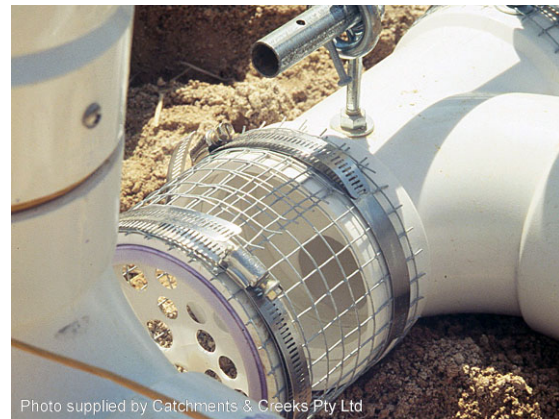
Types of sediment basin decant systems

Photo supplied by Warren Faircloth, USA
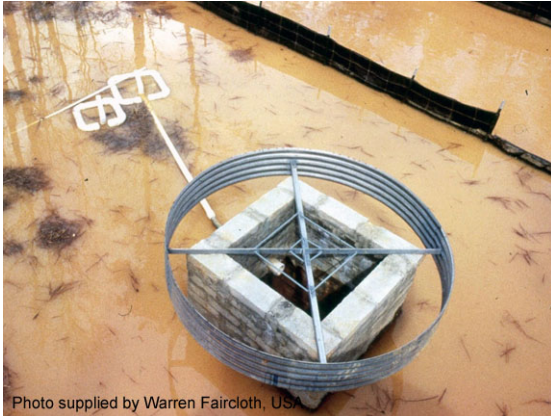
Early model of the Faircloth decant

Faircloth decant system

- Self-priming skimmer pipes are difficult to design and optimise.

- Commercial products, such as the Faircloth Skimmer, are available in the USA, and these systems have a discharge rate of around 1.7L/s.

- All floating decant systems incorporate moving components (connecting pipe work); therefore, it is essential for this pipe work to be protected from sediment deposition that may collect around the pipe.

Photo supplied by Catchments & Creeks Pty Ltd

Faircloth decant system (1995 version)

Photo supplied by Catchments & Creeks Pty Ltd

Faircloth decant system (1995)

Photo supplied by Turbid/O2 Environmental

Auckland-type floating decant system

Auckland-type decant system

- Floating siphon outlet systems are designed to self-prime when the basin's water exceeds a predetermined elevation.

- These decant systems attempt to drain the basin by siphoning water from the top of the pond, thus extracting the cleanest water.

- The decant process only begins when the pond level reaches the predetermined elevation, thus aiming to reduce the risk of an early discharge of poor-quality water.

Photo supplied by Turbid/O2 Environmental

Auckland-type floating decant system (photo sourced from Turbid/O2 Environmental)

Critical features of the Type A and Type B sediment basin designs

(a) Start of inflow, with basin in its designated 'empty' condition

Initial inflow

Forebay

Type-A basin

(b) Basin fills with automatic chemical dosing, and low-flow decanting

Forebay

Type-A basin

(c) Basin overflows with settled supernatant spilling over main spillway

Forebay

Increased settled sediment

Type-A basin

(d) Basin drains to its designated 'empty' condition

Sediment clean-out point

Forebay

Type-A basin

Typical stages of operation for a Type A sediment basin

Photo supplied by O2 Environmental

Type A basin decant system
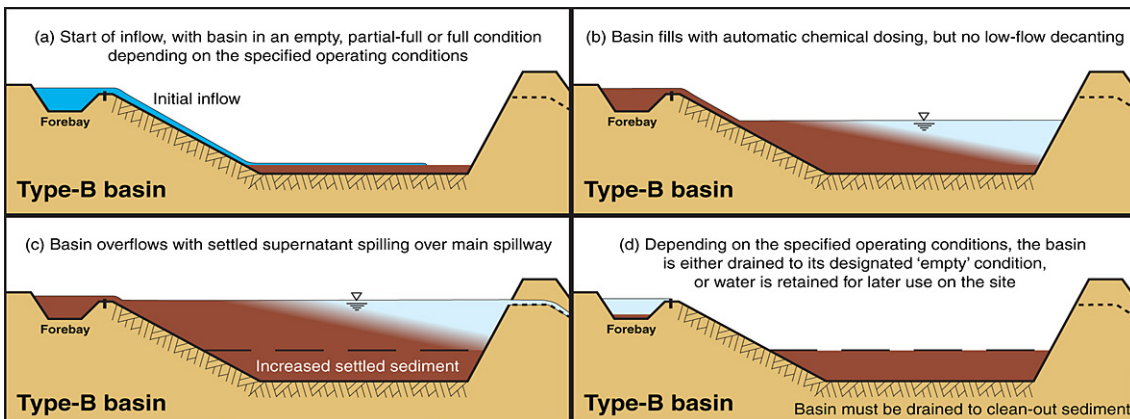
Type A sediment basin decant system

- The recommended design of a Type A sediment basin is based on:
  - a nominated 1 in 1 year design storm
  - achieving the full settlement of a nominal 0.01 mm sediment particle
  - achieving a maximum supernatant decant velocity of 1.5 cm/s (adopted from the wastewater decant study)
  - a low-flow decant rate within the range of 0.3 to 0.9 L/s/ha.

(a) Start of inflow, with basin in an empty, partial-full or full condition depending on the specified operating conditions

Initial inflow

Forebay

Type-B basin

(b) Basin fills with automatic chemical dosing, but no low-flow decanting

Forebay

Type-B basin

(c) Basin overflows with settled supernatant spilling over main spillway

Forebay

Increased settled sediment

Type-B basin

(d) Depending on the specified operating conditions, the basin is either drained to its designated 'empty' condition, or water is retained for later use on the site

Forebay

Type-B basin

Basin must be drained to clean-out sediment

Typical stages of operation for a Type B sediment basin

Photo supplied by Catchments & Creeks Pty Ltd

Type B basin overflow spillway

Type B sediment basin decant system

- Design option 1B is based on sizing the settling pond's surface area and depth such that the critical particle size has sufficient time to fully settle.

- Design option 2B is based on providing sufficient time to allow the sediment floc to settle at least 600 mm below the floating decant arms.

- Option 2B results in a basin with a greater depth, but smaller surface area, than design option 1B.

Density Measurement of Floc Suspensions

Background to test

Traditional density measurement
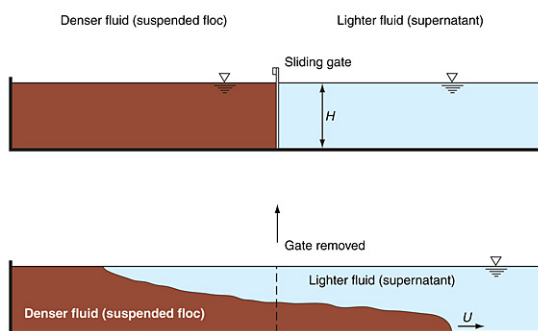
Lock exchange test

Shipping lock

Lock exchange test after gate removal

The problem

- The fluid mechanics within a settling tank can be linked to the density difference between the supernatant and the settled floc.

- Significant difference in the behaviour of the fluid motion can result from very small differences in the density of the supernatant compared to the settled floc.

- **The problem:** for a typical particle floc, the difference in the density of the two fluids is smaller than the error range of most density measuring systems.

The solution

- The solution to this dilemma can be found in the use of a Lock Exchange Test.

- Using the lock exchange test, density differences as small as one part in 1000 can be determined to better than 5%.

- The density of a floc suspension is determined by first measuring the density difference, then applying this to the theoretical density of water.

- The real advantage of this test is that the accuracy of the test <u>increases</u> with a decreasing density difference.

Lock exchange experiment

- The lock exchange experiment was originally used to study the effects of dangerous water movement in shipping locks following the opening of the gates.

- The lock exchange test used in this study was calibrated using a combination of fresh water as the 'lighter fluid', and various concentrations of a brine solution as the 'denser fluid'.

- The brine solution was diluted and retested until a density difference of one part in 1000 was reached.

Actual test chamber

- The lock exchange chamber used to in these tests had the following characteristics:

    - 1500 mm long

    - 150 mm deep

    - 100 mm wide

    - vertical slide gate in central location

    - overflow holes drilled through the gate at a height of 138 mm to ensure water levels were the same on each side of the gate prior to start of test.
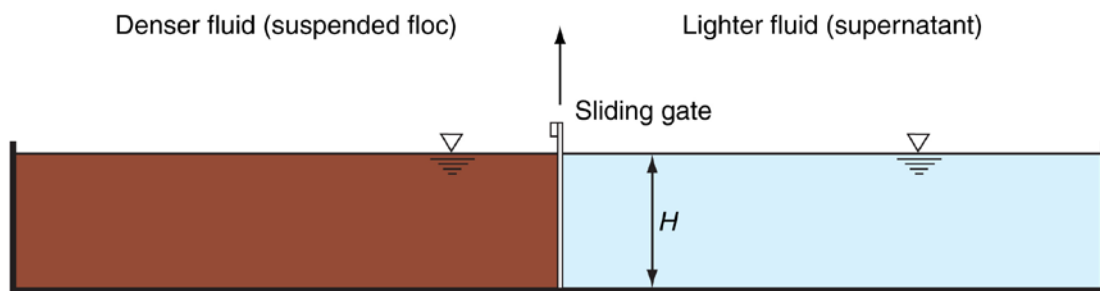
Lock exchange test
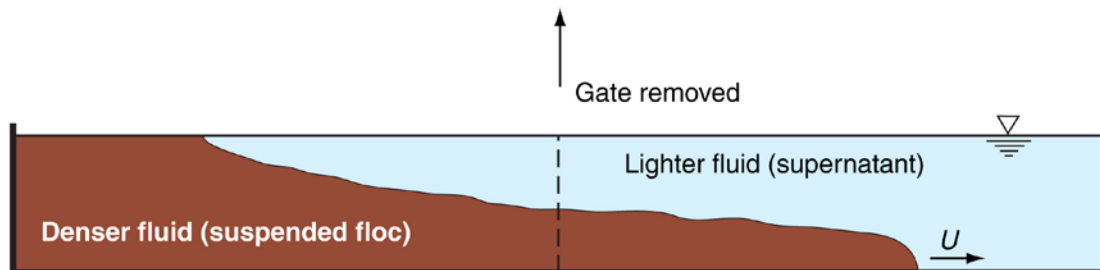

Photo supplied by Catchments & Creeks Pty Ltd

Lock exchange test prior to gate removal

Lock exchange test

- The speed of the advancing density intrusion (U) is related to the depth of the fluid (H) and the negative buoyancy (Δg) of the intrusion.

- The term (Δ) is the relative density difference of the two fluids, such that:

$$U = F(\Delta g H)^{1/2}$$

- The term (F) is a densimetric Froude number.

- It is noted that frictional effects can cause F to reduce in value over time.

Denser fluid (suspended floc)   Lighter fluid (supernatant)

Sliding gate

H

Lock exchange tank prior to removal of the dividing gate

Gate removed

Lighter fluid (supernatant)

Denser fluid (suspended floc)

U

Movement of the two fluids after removal of the dividing gate

Lock exchange tank used to measure density difference of wastewater floc