COST EFFECTIVE TECHNOLOGIES FOR TREATING INTERMITTENT WET WEATHER OVERFLOWS

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ABSTRACT

As part of the Central Interceptor Programme Watercare has engaged AECOM to assess treatment technologies for addressing overflows which occur during wet weather events. Internationally these technologies are generally referred to as "wet weather treatment systems", but can consist of a range of processes which provide various degrees of treatment for overflows. A common element to all of these technologies is the ability to provide intermittent treatment during wet weather events, usually done with a form of physical/chemical treatment that can be turned on and off when needed. This is in contrast to a conventional biological treatment system which must run continuously and generally is not appropriate or capable of treating intermittent high peak flows associated with wet weather overflows and bypasses. It is also important to note that some forms of wet weather treatment technology can also be configured to include a disinfection process, including the use of UV disinfection. This paper explores various technologies and options for treating intermittent wet weather overflows and provides an assessment of the cost effectiveness relative to other more conventional options.

KEYWORDS

Wet Weather Treatment, combined sewer overflows, ballasted flocculation, vortex separation, UV disinfection

1 INTRODUCTION

Watercare Services Limited (Watercare) are in the process of developing a consent application and concept level design for the Central Interceptor – a proposed tunnel that addresses the key drivers of asset duplication for risk, capacity for growth and mitigation of targeted combined sewer overflows. Figure 1 below provides an illustration of one potential alignment option being considered for the Central Interceptor.

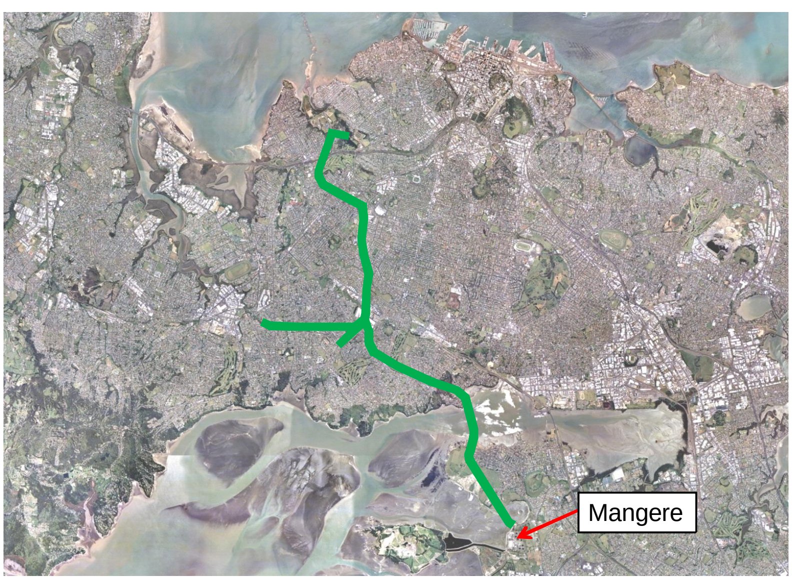


Figure 1 – One Option for Central Interceptor Alignment

This tunnel will connect to Watercare's existing Mangere Waste Water Treatment Plant (WWTP) and extend approximately 15kms into the existing network to address these key drivers. The tunnel will likely provide both a conveyance and storage function, with peak flows to the Mangere WWTP limited by available plant consented capacity at any given time. In parallel to the assessment of the Central Interceptor, Watercare are evaluating the technology of the Mangere WWTP to ensure optimised treatment capacity exists now and into the future.

A crucial aspect of the Central Interceptor Programme is optimising the balance of conveyance, storage and treatment capacities to ensure the least whole-of-life cost. Identifying the optimal balance of treatment, storage and conveyance requires a careful understanding of the inter-relationship between these three technologies in providing a regionally acceptable level of Combined Sewer Overflow (CSO) control. The Central Interceptor tunnel could provide both conveyance and storage to address control of CSOs, but any captured overflow volume, which in a combined system is significant, must receive an appropriate form of treatment. As the Central Interceptor will be connected to the Mangere WWTP the available capacity to treat flows will have a substantial impact on how big the tunnel must be, which in turn has a direct impact on the cost of the tunnel. Consideration of wet weather treatment technologies as a means to provide an enhanced capacity to treat wet weather flows is an important part of developing the least whole-of-life cost solution.

As stated above, Watercare are currently focused on options to reduce targeted (larger) CSOs, but are in the process of assuming control of the entire combined sewer system and as such will need to possibly address many other CSOs which are currently operated by Auckland City Council. The required timing, extents and degree of CSO control are uncertain. Watercare will be carefully evaluating this as they refine the concept of the Central Interceptor. Options to address CSO control include use of the Central Interceptor either for conveyance, storage or both, as well as other options such a strategic partial separation and/or local storage tanks. An additional option of utilising wet weather treatment technologies has been identified as a potentially cost-effective alternative which could be applied as a local/satellite scheme or as a regional scheme in the form of a parallel treatment train at the existing plant.

The purpose of this study was to evaluate process technologies for treatment of wet weather flows at either Mangere treatment plant or at a satellite location. To assess a satellite option Watercare chose their two largest overflows which are located within the Meola Catchment as shown in Figure 2. These two CSOs are located within approximately 500 meters of each other and options were assessed for treating both in combination.

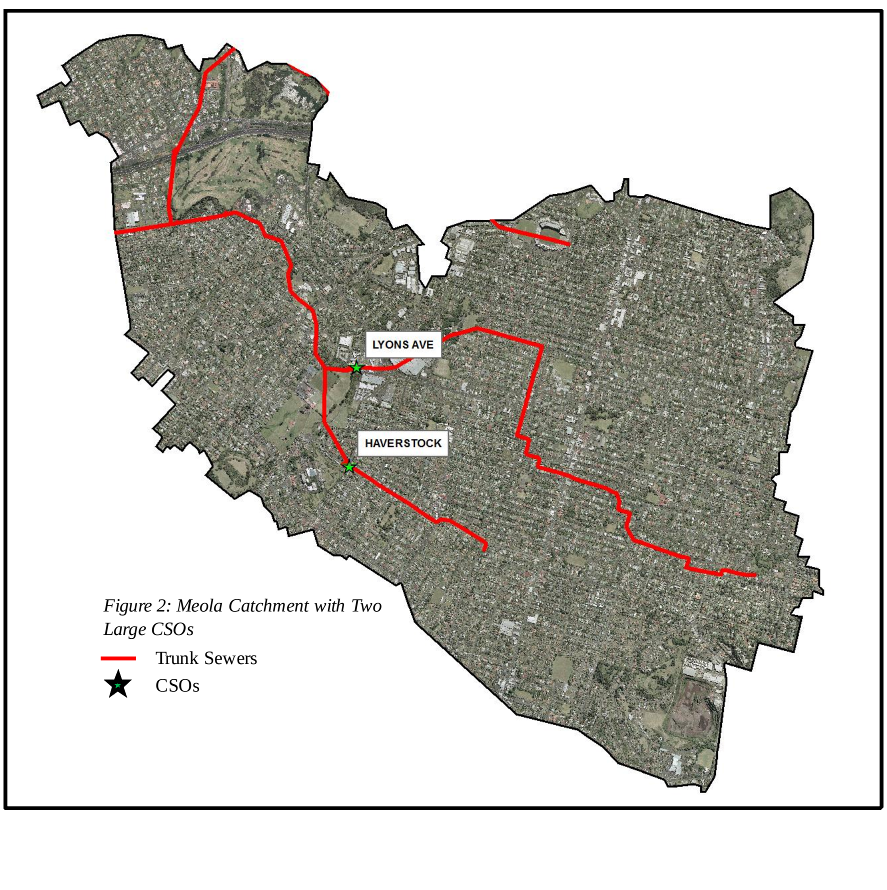


Figure 2: Meola Catchment with Two Large CSOs

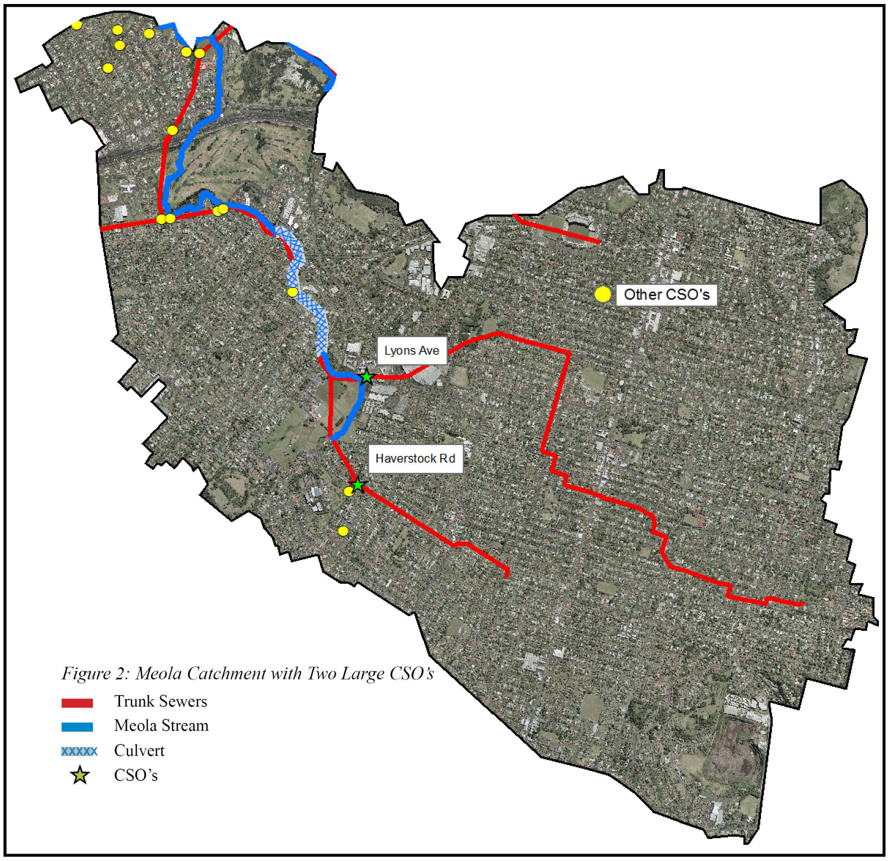


Figure 2: Meola Catchment with Two Large CSO's

This paper will guide the reader through CSO treatment by undertaking an assessment of applied and proven technologies for CSO treatment, and will show how options of satellite and regional wet weather treatment compared.

High rate treatment technologies would allow for currently untreated CSO flows to be treated to varying levels for such constituents as gross solids/visible floatables, TSS, biological oxygen demand (BOD), total phosphorus (TP), metals, and disinfection targets prior to discharging into public waterways. Depending on the treatment and disinfection types, a range of treatment options are available to lower capital and operational cost to the Mangere WWTP upgrade pathways with regards to processing peak flow and loads.

The wet weather technologies evaluated for this report are as follows:

- Ballasted flocculation (BF) – Using either microsand or recycled sludge
- Compressed media filtration (e.g. "Fuzzy Filter") (CMF) – varying particle size removal depending on filter interstitial void spacing in the media based on level of compression
- Chemically enhanced primary treatment (CEPT) – primary treatment using a metal salt (ex: Alum) and polymer (ex: anionic)
- Primary treatment (PT) – similar to the Mangere WWTP's current primary sedimentation process
- Detention treatment (DT)– This technology is considered as it provides good treatment over a range of performance conditions and is simple to operate, reliable, and rugged in its construction. Settling chemical application is uncommon and rare; however, it is being discussed in the USA as of late. The technology can also be readily blended into the community. This technology has a 'footprint' smaller than most conventional primary sedimentation tanks as the disinfection can be achieved in 10 to 12 minutes with rapid dispersion of sodium hypochlorite. UV disinfection with this technology would not be appropriate

- Vortex swirl separator (Vortex) – with no disinfection – uses flow velocity into unit and results in a centrifugal force pushing solids to the bottom of unit and discharging to sewer while treated water discharges
- Continual deflection separation (CDS)– using flow velocity to create centrifugal force and removal of gross particle constituents with a screen

2 PROJECT BACKGROUND AND OPTIONS EVALUATION CRITERIA

For purposes of the Central Interceptor Programme, Watercare are focusing options for controlling targeted large CSOs which are part of the current Watercare trunk sewer system. As part of the ongoing regionalisation of water and wastewater services in the Auckland region, Watercare will soon take ownership of the complete combined sewer system and as such will be considering how to address other CSOs that are presently owned by Auckland City. Watercare will be going through a process of understanding the location, size, magnitude and effects of these CSOs, and subsequently developing targeted levels of service which provide an adequate level of control. Through this process Watercare will analyse various options, and associated cost, including utilisation of the proposed Central Interceptor and locally based solutions such as storage tanks and strategic partial separation.

Watercare are considering utilisation of various wet weather treatment technologies which can be applied either locally or regionally, such as an additional treatment train at Mangere to handle high peak wet weather flows. This paper presents the results of an assessment of currently used wet weather treatment technologies including existing applications, ongoing performance and cost. Also presented are hypothetical examples of how this technology might be applied within the Auckland combined sewer system, using examples of a satellite application in the Meola Catchment targeting Watercare's two largest CSOs and a regional application as a parallel treatment train at Mangere. These examples have not been explored for purposes of developing recommended detailed solutions, but rather to assess the general viability of wet weather treatment and a high level understanding of cost and probable treatment performance. Further work is required to assess detailed specific options of utilising of wet weather treatment either in a satellite/local or regional form. This assessment will be largely dependent on key drivers for controlling CSOs, and the timing for achieving targeted levels of service. In evaluating these options it is important to consider the following issues with regards to satellite or regional applications:

Issues of satellite wet weather treatment applications:

- Operational complexity and control
- Distinction from conventional treatment plants in terms of not introducing a new discharge load to the environment (rather would be reducing an existing load) and only operating during wet weather conditions
- Proximity to residential areas
- Robustness of technology
- Reliability of technology including disinfection
- Treatment performance track record
- Required levels of treatment based on targeted levels of service
- Simplicity of operations and maintenance requirements
- Limitation of addressing multiple overflows and providing effects based benefits given the presence of other untreated overflows
- Management of solids and screenings
- Odour management
- Ability to consent
- Cost relative to other options
- Potential use as an interim measure

Issues of regional wet weather treatment application as parallel train at Mangere:

- Operational complexity and control
- Ability to enhance operational robustness including protection of secondary biological processes during peak wet weather flows
- Robustness of technology
- Treatment performance track record
- Ability to reduce required amount of tunnel storage and associated cost
- Enhancement of effluent quality and UV disinfection during high peak flow events

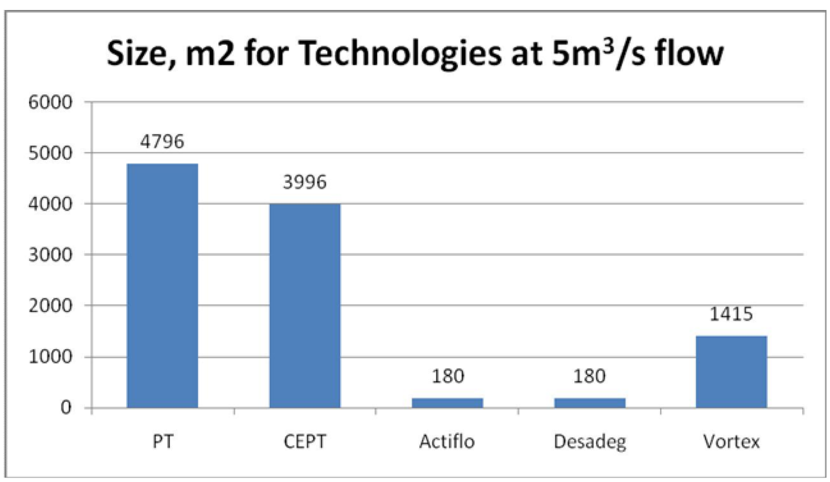
- Potential use as a redundancy and protection for primary and secondary clarifiers
- Required levels of treatment to meet overall effluent quality requirements
- Cost relative to other options for regional control of CSOs

For purposes of evaluating CSO treatment requirements a primary focused was placed on the ability to remove undesirable solids and floatables and utilisation of UV to disinfect to an appropriate level. Due to the short-term intermittent nature of wet weather CSO events and information about known impacts from CSOs, less emphasis was placed on the need to remove soluble constituents such as ammonia which are more important for treatment of normal base flow condition sewage. This is consistent with known applications of wet weather treatment in the United States and Europe.

3 OVERVIEW OF WET WEATHER TECHNOLOGIES ASSESSED

As described above, several technologies were assessed to provide wet weather treatment in either a regional form at the Mangere WWTP, or as a satellite facility in the Meola Catchment. To conduct an initial evaluation of wet weather treatment options an assumption of a required peak flow treatment rate of 5 m³/s was established based on a cursory assessment of peak flows observed at the Lyons and Haverstock CSOs, and an evaluation of additional peak flows likely to occur at Mangere In some cases certain technologies were dismissed from detailed evaluation as a specific option due the current state of the technology (i.e. limited full scale applications and/or relatively unproven), or constraints regarding space requirements and treatment limitations. Regarding site space constraints Figure 3 is presented below, taken from Metcalf & Eddy 4th Edition, which shows required facility footprint sizes for various technologies evaluated based on an assumed design flow of 5 m³/s. Based on this initial review, and an assumption that UV disinfection would be required, a decision was made to place emphasis on a detailed assessment of the ballasted flocculation technologies which is presented below. Other technologies such as vortex separation and detention tanks were assessed at a high level, but are not presented in this paper.

Figure 3 – Estimated Facility Footprint Sizes Based on 5 m3/s Design Flow



Ballasted flocculation is a general class of high rate wet weather treatment technologies which involves rapid mixing of chemicals to enhance settling, rapid flocullation, addition of a ballast material to add weight to the flocculants, and rapid settling using such technologies as a lamella plate system. This approach allows for very high loading rates, small facility footprints and utilisation as a temporary treatment system which can be brought on and off line during interim wet weather periods. The following provides an overview of the two most common ballasted flocculation technologies, Actiflo and DensaDeg, as they are typically applied to address wet weather treatment requirements.

Ballasted Flocculation (BF)

Objective

Treatment of excess wet weather flow via a physical and chemical process in either a regional or satellite location. The effluent from this process is also be disinfected utilising a UV system. The effluent from a satellite facility would be discharged directly to the environment at an appropriate location. A regional process located at Mangere could have a separate outfall or be blended with the plant liquids stream in a variety of pathways prior to UV disinfection.

Product Description

Ballasted flocculation, also known as high rate clarification, is a physical-chemical treatment process that uses continuously recycled media (microsand or recycled sludge) and a variety of additives (metal salt and polymer) to improve settling properties of suspended solids through improved floc bridging. Ballasted flocculation can also achieve pollutant removal through chemical precipitation of certain dissolved constituents.

The objective of this process is to form microfloc particles with a higher specific gravity. Faster floc formation and increased particle settling time allow clarification to occur up to ten times faster than with conventional clarification. Both Actiflo and DensaDeg use lamella settling components in the clarification area to further assist settlement. The result is a very small "footprint" in regards to land area.

Actiflo and DensaDeg are two industry standard processes and are considered suitable for either a stand alone, satellite wet weather system or as a parallel wet weather treatment train at a WWTP.

Disinfection would most likely be with UV. While chlorination and de-chlorination is widely used in North America, UV is the preferred disinfection method for wastewater in NZ. UV in series with ballasted flocculation is being used at installations in the USA and the UK. One constraint that must be imposed in order to use UV disinfection is the use of aluminium-based coagulants as iron-based coagulants interfere with the UV disinfection. While both Actiflo and DensaDeg both perform better in wet weather applications with iron-based coagulants, aluminium-based coagulants have been successfully used.

Comparisons between Actiflo and DensaDeg give the Actiflo system a slight edge in overall comparisons between the two based on the literature and information gathered for the report.

Actiflo can process flows between 10 and 100 percent of its nominal design capacity which allows the system to handle a wide range of wet weather events. Screening is required upstream of both processes. Actiflo requires 6mm screens while DensaDeg requires 12mm screens (Actiflo requires finer screens to avoid blocking the hydrocyclone for sand removal from sludge). The requirement for grit removal is typically a function of annual activations. For higher activation frequency (say >10 to 12 per year) grit removal would be required.

This technology provides the highest level of TSS and BOD removal of those considered in this paper and it also requires the highest level of operator involvement in terms of monitoring and control, however, this is minimal if located at an existing wastewater treatment plant.

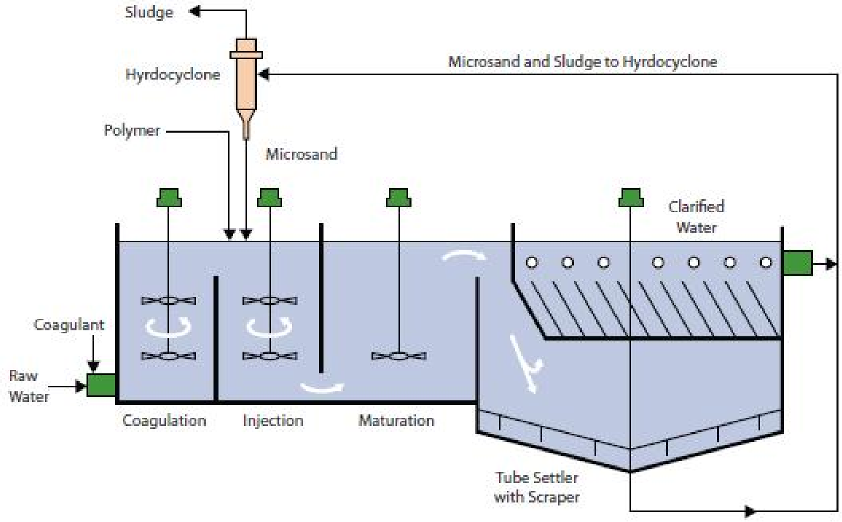
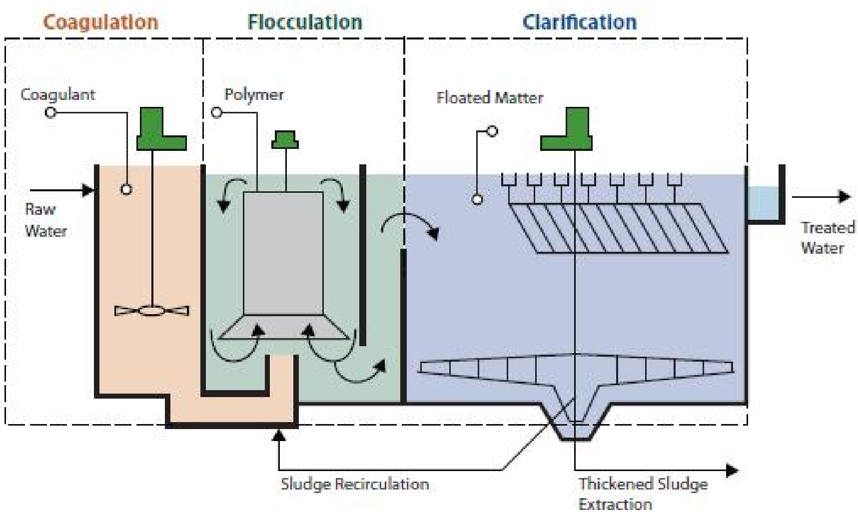
Operation and Maintenance

- BF with microsand (Actiflo) has a quick start up time compared to a dense sludge type BF (DensaDeg)
- Requires more optimization and control as compared to other CSO technologies
- Simple technology if compared to some WWTP unit processes
- Manned 4-8 hours per event on average

Key Product Points

- High treatment efficiency
- Good technology coupled with UV disinfection

- Small footprint compared with conventional clarifiers
- High loading rates 2400 $m^3/m^2/d$ or 100 m/h rise rate
- Short start-up time (10 to 20mins Actiflo, <30-45 min DensaDeg)
- Can be entirely automated and with local and remote monitoring and operational capability depending on degree desired

Actiflo

About the Manufacturer Veolia Environmental Services is one of the world's leading providers of waste management and cleaning services and is represented locally in NZ. Examples of Actiflo facilities in New Zealand can be found in Gore and Warkworth.
DensaDeg


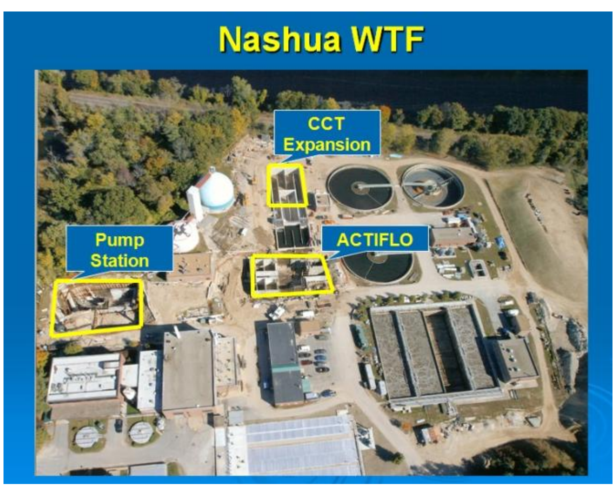
4 EXAMPLE APPLICATIONS AND PERFORMANCE OF BALLASTED FLOCCULATION

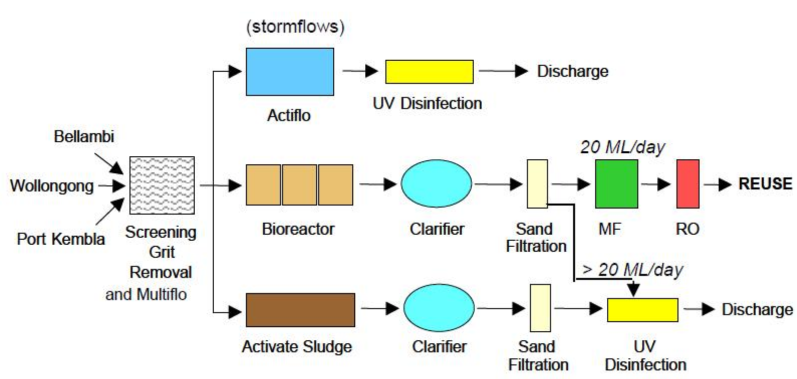
This section focuses on the Actiflo ballasted flocculation process due to the lack of presence with DensaDeg in New Zealand and concerns over required facility start-up times.

4.1 EXAMPLE FACILITY OVERVIEWS

The following presents summary fact sheets for example applications of ballasted flocculation facilities applied for treatment of wet weather flows. This includes examples of satellite (remote locations at specific overflows sites) and regional (located in parallel with existing wastewater treatment plants) facilities.

Treatment Technology	**Ballasted Flocculation – Regional Facility at Existing WWTP**
Project Name	**Nashua, New Hampshire**
Treatable flow rate	2.6m^3/s
Cost	$US27.5m (includes new pumping station and expanded disinfection facility)
Description	AECOM conducted a re-evaluation of Nashua's long-term CSO control plan, which will save the city nearly $US200 million compared to a previous plan. As part of this revised plan, AECOM designed the high-rate CSO treatment facility with a capacity of 2.6m^3/s that will discharge treated wet weather flow blended with existing plant effluent. The facility includes screening and grit removal, a 2.6 m^3/s pump station, ballasted flocculation treatment and chlorine disinfection. It is activated very little during the year with total activations to date of less than 10 times. The wet weather treatment facility controls have been incorporated into the wastewater treatment plant’s existing SCADA system. The plant uses sodium hypochlorite disinfection. Construction of the wet-weather facility was completed in January 2009, and preliminary performance and acceptance testing has been satisfactorily completed. The facility has a construction cost of $US27.5m. Testing results (shown in the following section) indicate consistently high TSS removals up to 90%+.
Photo	



Treatment Technology	Ballasted Flocculation – Regional Facility at Existing WWTP
Project Name	**Illawarra, Wollongong -NSW, Australia**
Treatable flow rate	1.7m^3/s
Cost	Cost unavailable
Description	Sydney Water supplies more than 1.7 billion litres of water to more than 1.6 million homes and businesses each day. It provides drinking water, wastewater services, and some stormwater services to customers in the communities of Sydney, the Blue Mountains and the Illawarra. Veolia Water Systems was contracted by Sydney Water Corporation to design, build and provide operational advice for upgrading three wastewater treatment plants south of Sydney (Bellambi, Port Kembla, Wollongong) to serve 300,000 residents. As part of the upgrade was the conversion of existing Bellambi and Port Kembla STPs to storm sewage treatment plants to store and treat wastewater. As a result of this upgrade, the city of Wollongong now has one of the most advanced coastal treatment plants in the world. The system is currently providing benefits such as: Improving water quality at Illawarra beaches, particularly those near sewage treatment plants. Protecting coastal water sand reducing impact on sensitive marine ecosystems. Minimising the effluents negative impacts when effluent from BF is released to the environment. Supply high-quality recycled water for industrial reuse. The upgraded facility at Wollongong will provide biological treatment to flows of up to 2.1 m³/s (three times ADWF). Flows in excess of this, up to maximum of 3.7 m³/s, will be treated using the high rate ballasted flocculation process, Actiflo®, followed by UV disinfection.
Schematic	

Treatment Technology	Ballasted Flocculation – Satellite Facility at CSO Location
Project Name	**East Bremerton Satellite CSO Treatment Facility, Bremerton, Washington USA**
Treatable flow rate	1 m^3/s
Cost	US $4.1m (includes cost of UV disinfection system)
Description	Bounded by the Puget Sound and divided by the Port Washington Narrows, the city of Bremerton, Washington, is also home to the Puget Sound Naval Shipyard. In its early development, the city combined its sewer and stormwater into one system that conveyed the water directly into the Puget Sound, untreated. As the city continued to develop during the 1940s, primary sewage treatment plants were built, into which combined sewer flows were redirected for treatment. By design, CSOs occurred during storm events. The city decided to build a satellite CSO treatment facility in East Bremerton adjacent to the Port Washington Narrows. The facility needed to have rapid start-up capability and be equipped to quickly meet peak removal efficiencies. As a result, chemical feed and ultra-violet (UV) disinfection equipment, coupled with a high-rate clarification system, were recommended. The Actiflo process has consistently exceeded state performance requirements for CSO treatment plants at the 20-mgd (1 m^3/s) East Bremerton CSO treatment facility in the US state of Washington, according to John Poppe, wastewater manager at Bremerton's Public Works and Utilities. The process is at the heart of the 10-mgd East Bremerton CSO treatment facility, which has complied with state and federal CSO rules since coming online in December 2001. Consequently, the improved water quality has increased the potential for shellfish harvesting in Puget Sound. The Bremerton facility can start up and achieve excellent performance in only 15 minutes. The process is removing between 90 percent to 95 percent of TSS, 80 percent of BOD, and 85 percent of total phosphorous. Effluent turbidity levels are less than 3 NTU. Post-clarification, the treated effluent passes through medium-pressure, high-output UV disinfection before it is discharged into the Puget Sound.
Photo	

4.2 SUMMARY OF EXAMPLE BALLASTED FLOCCULATION PERFORMANCE RESULTS

Table 1 presents performance data summaries for various supplemental treatment technologies including ballasted flocculation.

Table 1 – Performance Data for Selected Wet Weather Treatment Technologies

Technology	Sources	Hydraulic Capacities and Removals			
		Hydraulic Capacity ($m^3/m^2/d$)	Hydraulic Capacity ($m^3/m^2/d$)	BOD Removal (Percent)	TSS Removal (Percent)
		Lower	Upper		
Primary Clarification / Detention Treatment	Metcalf and Eddy 1991: NEIWPCC 1998 WEF 1996	28	141	25-40	50-70
Chemically Enhanced Primary Treatment	US EPA: In Plant Flow WW Management 2007	140	165	40-50	75-85
Screening	Metcalf and Eddy 1991:				
Coarse (5mm-25mm)		987	4042	NA	15-30
Fine (0.1mm-5mm)		7.05	65.8	NA	40-50
Micro(<0.1mm)		7.05	65.8	NA	40-70
Vortex Separation/CDS	EPA 1996 Boner et al 1995 WERF 2002	NA	4700	Up to 55	5 to 60
Ballasted Flocculation	Raddick et al. 2001 Scruggs et al. 2001 Vick 2000 Poppe et al 2001	NA	4230	65-80	70-95
Chemical Flocculation	Metcalf and Eddy 1991; Moffa 1997	NA	940	40-80	60-90

The following present performance results of Actiflo wet weather treatment facilities including pilot studies and full scale plants. In all cases reviewed the Actiflo system consistently met removal performance targets, and using the appropriate chemicals produced an effluent quality acceptable for UV disinfection to meet typical standards.

United Utilities Millom Works Pilot Test

In the UK, a 200m3/h Actiflo pilot plant was operated for 12 months at United Utilities' Millom works on the Cumbrian coast in the Lake District National Park. Some 90 trials were carried out on the pilot plant over the 12-month period; 50 under storm conditions and the remainder taking stored storm water from the works' storm-water tank. In every case, the effluent UV transmissivity was consistently high

enough (greater than 50 per cent) for an ultraviolet disinfection unit downstream of the clarifier to meet the microbiological consent for discharge to a bathing beach or shellfish water. Both ferric and aluminium coagulants were trialled, and both gave suspended solids reduction in excess of 90 percent, producing effluent suspended solids below 25mg/l; a figure that was reached within 10 minutes of start-up. COD reduction was generally 60-70 percent and total phosphorus removal was in excess of 80 percent.

Berlin CSO Pilot Facility Test

A shorter-term trial was carried out, this time over 52 days, in Germany starting in mid-January 2008. A mobile pilot plant was located in the car park of the Berliner WasserBetriebe office building in Bellermannstrasse, Berlin. It was situated approximately 5m away from, and running parallel to the CSO chamber installed at this location. A temporary submersible pump was installed to take water from the chamber and deliver it to the inlet of the Actiflo unit. Clarified water from the Actiflo unit was discharged under gravity to the adjacent sewer, together with the sludge from the hydrocyclone. During the trial period, 10 runs were carried out: the first with simulated raw water produced by diluting raw sewage with mains water in the CSO chamber, the rest of the runs were conducted during actual storm-overflow conditions. The pilot plant results from the Berlin trial confirmed the results from the Millom trial, namely a better than 60 percent removal of COD, more than 80 percent reduction in total suspended solids and more than 80 percent reduction in total phosphorous. They also confirmed that this performance can be achieved within 10 minutes of start-up.

Lawrence Wastewater Treatment Plant Full Scale (2m³/s) Wet Weather Facility Performance

The Lawrence Wastewater Treatment Plant (WWTP) was expanded and improved to accommodate the City of Lawrence, Kansas, future growth, maintain compliance with new regulatory requirements, and meet facility needs up through the design year 2020. To accommodate future projected storm flows or sanitary sewer overflows (SSO), a wet weather facility consisting of 40 million gallons per day (mgd) ballasted flocculation system was constructed to direct discharge with the main WWTP effluent to the Kansas River. The Actiflo® system, which has been in service for over a year and half, has been operated during ten peak flow storm events that lasted anywhere from four hours to 47 hours. The disinfection and dechlorination system selected for the Lawrence WWTP wet weather treatment facilities was sodium hypochlorite and sodium bisulfite, respectively. A separate contact basin was provided for the wet weather facilities flow. The wet weather facility effluent is blended with the main plant effluent to meet the combined chlorine residual as indicated in the plant's NPDES permit. During the first year of operation, the Actiflo® unit encountered a variety of influent flow characteristics and operating conditions. Real-time operating experience has been obtained. For each storm event, the polymer and ferric chloride dosages were optimized to enable the effluent to meet the plant's permit. Over the operating period the Actiflo system has consistently removed 80 percent of the turbidity. The TSS percent removal is around 88 percent. As a result of the removed solids, the City of Lawrence is able to meet the plant's NPDES for BOD, TSS, and chlorine residual.

East Bremerton Full Scale Satellite CSO Treatment Facility, Bremerton, Washington USA

The Actiflo process has consistently exceeded state performance requirements for CSO treatment plants at the 20-mgd (1 m3/s) East Bremerton CSO treatment facility in the US state of Washington, according to John Poppe, wastewater manager at Bremerton's Public Works and Utilities. The process is at the heart of the 20-mgd East Bremerton CSO treatment facility, which has complied with state and federal CSO rules since coming online in December 2001. Consequently, the improved water quality has increased the potential for shellfish harvesting in Puget Sound. The Bremerton facility can start up and achieving excellent performance in only 15 minutes. The process is removing between 90 percent to 95 percent of TSS, 80 percent of BOD, and 85 percent of total phosphorous. Effluent turbidity levels are less than 3 NTU. Post-clarification, the treated effluent passes through medium-pressure, high-output UV disinfection before it is discharged into the Puget Sound.

5 OVERVIEW OF OPTIONS AND COST DEVELOPED FOR SATELLITE AND REGIONAL WET WEATHER TREATMENT

The following presents a summary of options and cost estimates developed for applications of a satellite ballasted flocculation treatment system, using the Actiflo technology, in the Meola Catchment and a regional ballasted flocculation treatment system at Mangere. In both cases it was assumed that UV disinfection treatment would need to be included and a peak design flow rate of 5 m³/s would be used.

5.1 MEOLA SATELLITE WET WEATHER TREATMENT CONCEPT OPTION AND COST

Figure 4 below provides a concept process flow diagram schematic for a satellite ballasted flocculation in the Meola Catchment which would treat two of the largest CSOs in Auckland up to a maximum peak flow of 5 m³/s.

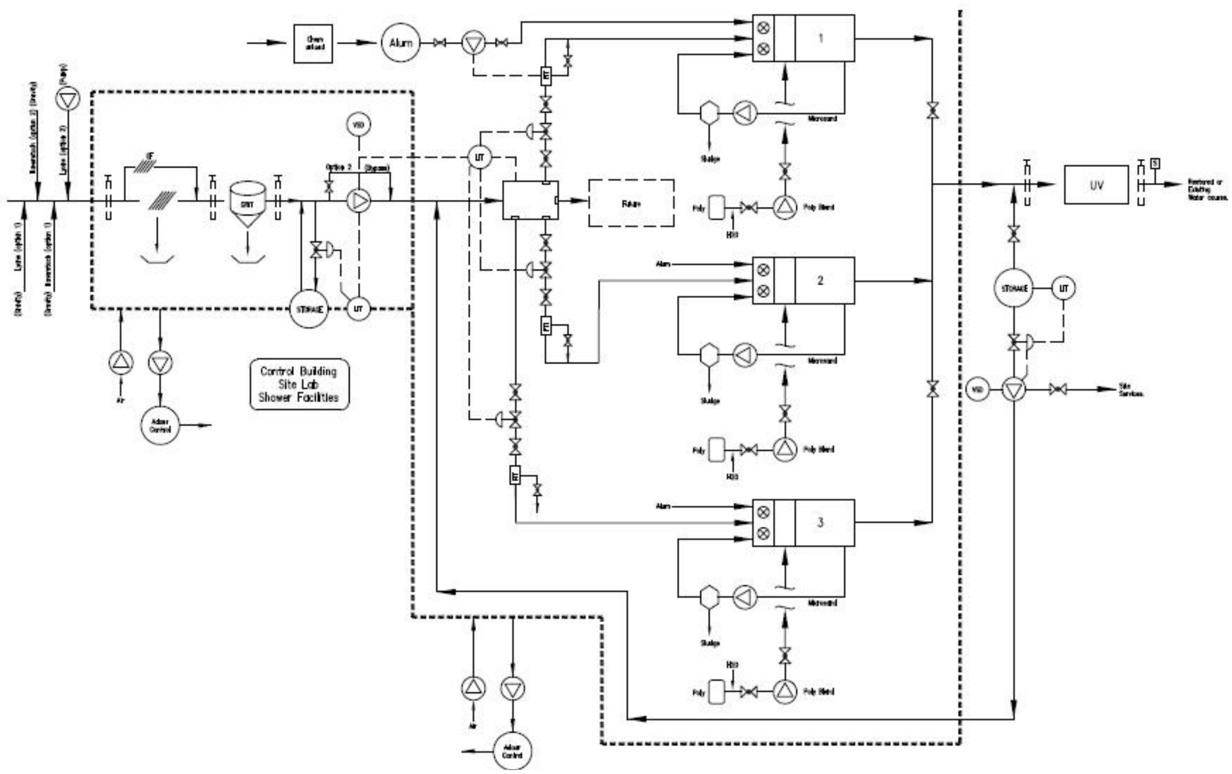


Figure 4 – Concept Process Flow Diagram for Meola Satellite Ballasted Flocculation System

Overflow from Haverstock and Lyons would be conveyed to a centralised location for initial screening and grit removal. Smaller overflow events would be stored within a small, storage tank prior to being pumped back into the trunk sewer. Larger events would use the stored overflow to prime the ballasted flocculation facility before activating to treat flows to a peak of approximately 5 m³/s. Overflows in excess of this would bypass the treatment device. Treated effluent would then pass through UV disinfection prior to discharge into the Meola Creek. Two concepts were developed for the configuration of Actiflo at this location as shown in Figure 5 on the next page.

Sludge from the Actiflo would discharge into the trunk sewer downstream of the overflows for treatment at Mangere.

Key points about this option are:

- A high capacity pump station would be required for the design to work hydraulically

- The facility would be located within a residential area and would therefore require potential extensive public consultation. Considerable effort may be required with regard to the aesthetics and odour control of the facility. There are numerous examples of satellite wet weather facilities which have been placed in residential areas, but typically require additional cost to address aesthetic, odour and noise issues

- Start-up and operation of this facility would need careful consideration. Key issues to address would include operational complexity, use of telemetry, chemical handling and storage, and regular maintenance requirements. Facility operations would require on site personnel prior to and during wet weather events. This would include required procedures to prep the facility for start-up in anticipation of a CSO activation, perhaps facilitated through the use of remote monitoring telemetry

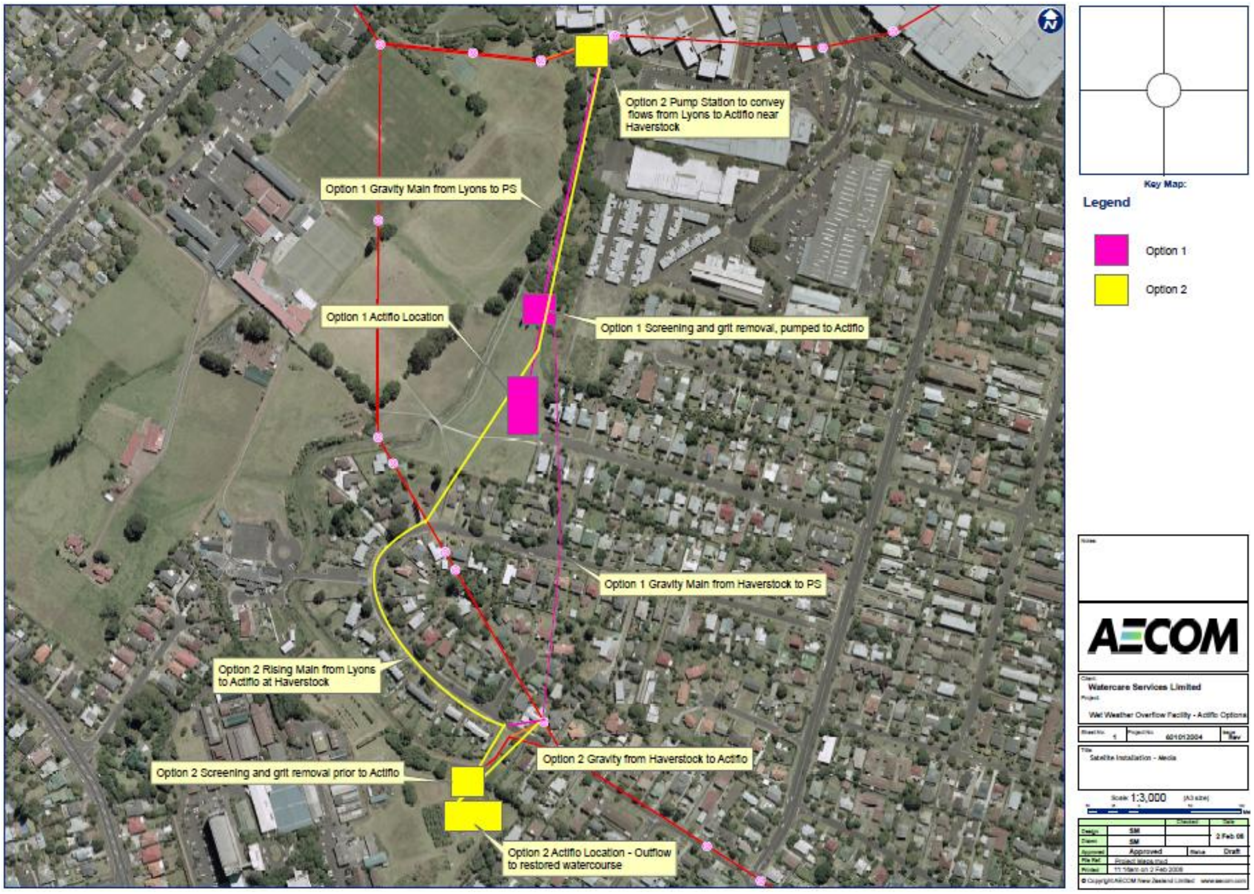


Figure 5 – Concept Options for Satellite Wet Weather Treatment in the Meola Catchment

Capital cost for this option have been estimated at approximately $38m which includes the wet weather treatment system, pumping station, buffer storage tank, UV system, enclosure buildings to address visual/noise/odour issues and a 30 percent contingency to address unknowns and risk. Annual operating cost, based on monitoring data from the CSOs, are estimated at $0.8m/year – resulting in a 20 whole-of-life cost $43m.

5.2 MANGERE REGIONAL WET WEATHER TREATMENT CONCEPT OPTION AND COST

Figure 6 below provides a concept process flow diagram schematic for a regional ballasted flocculation system at Mangere which would treat intermittent wet weather peak flows up to 5 m^3/s that exceed the biological treatment system.

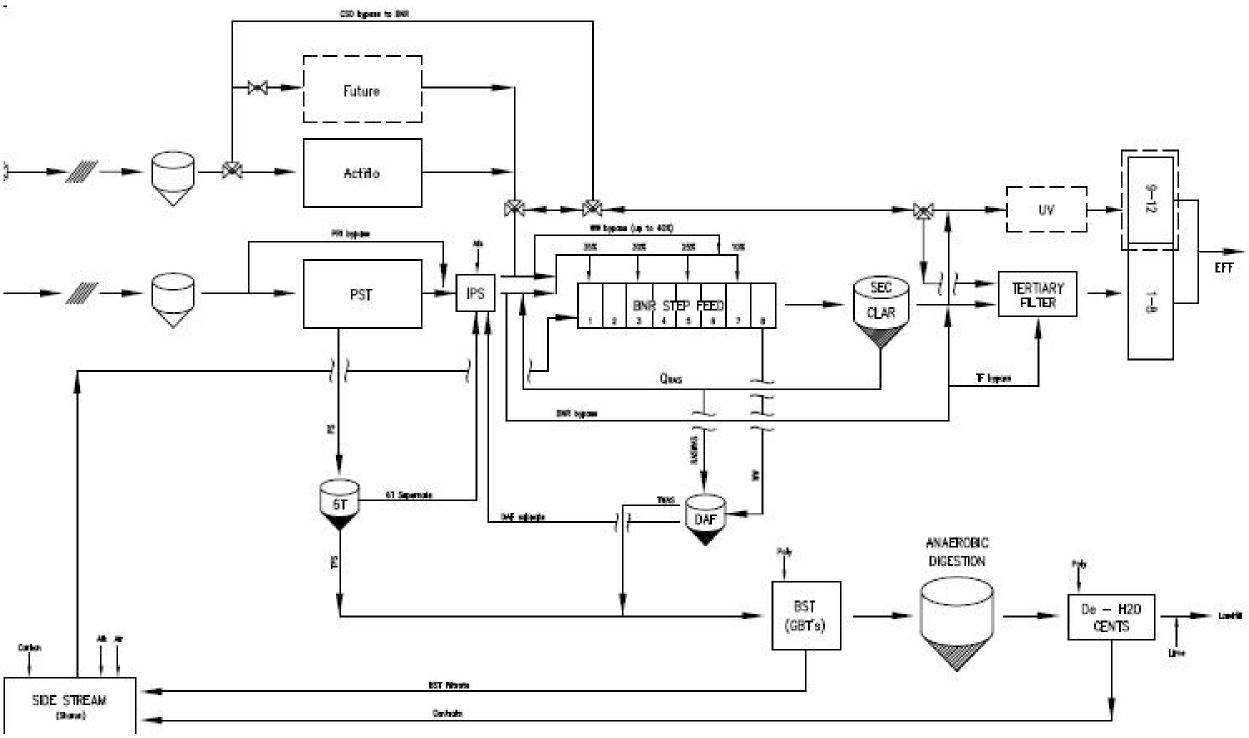


Figure 6 – Concept Process Flow Diagram for Regional Wet Weather Treatment at Mangere

An Actiflo ballasted flocculation system could be placed at Mangere as a parallel treatment train to the existing biological nutrient removal (BNR) system. In concept, this wet weather treatment system would accommodate flows in excess of the BNR system for up to 5 m^3/s, including wet weather flows delivered by the Central Interceptor tunnel system. The effluent from the ballasted flocculation system would be treated either with a new independent UV disinfection system or more likely would be blended with the BNR effluent and treated with the existing UV disinfection system which has sufficient capacity.

Sludge from the Actiflo facility would be processed in the plant and the effluent could be blended at multiple points depending on the degree of treatment and process consent condition at time of year.

Key points about this option are:

- Issues of operational complexity and start-up requirements are somewhat alleviated by placing the wet weather treatment facility at an existing plant which is manned 24 hours a day.

- Ballasted flocculation could possibly be used to enhance the overall performance of Mangere during interim peak wet weather flow conditions by de-stressing the existing BNR system. Detailed monitoring and process modelling may show that the effluent quality will be enhanced by utilising wet weather treatment at Mangere during high flow events.

Capital cost for this option have been estimated at approximately $30m which includes the wet weather treatment system, new parallel wet weather UV system, and a 30% contingency to address unknowns and risk. Annual operating cost, based on network hydraulic models, are estimated at $0.8m/year – resulting in a 20 whole of life cost $35m.

6 CONCLUSIONS

Wet weather treatment technologies have developed dramatically over the past 20 years. There are many different technologies to consider which provide varying degrees of treatment. Site specific conditions and local treatment

requirements for wet weather overflows and intermittent high peak flows must be carefully considered in assessing options and cost. Many full scale examples of satellite and regional wet weather treatment facilities exist, and detailed performance shows that these technologies can achieve targeted wet weather treatment requirements when applied appropriately.

As part of the Central Interceptor Programme options for wet weather treatment have been assessed for both a satellite application in the Meola Catchment to address two of the largest CSOs, and as a regional treatment facility operating at Mangere in parallel with the existing BNR system. Concepts for these options have been developed, including estimates of cost and performance ability.

Results of the analysis completed for the Central Interceptor Programme indicate that a regional wet weather treatment facility at Mangere would be the preferred option over satellite treatment facilities in the targeted combined sewer area. This conclusion only applies to the targeted service area for the Central Interceptor as there are other overflows which will not be directly addressed by this tunnel. For overflows outside of the Central Interceptor service area local solutions such as storage, targeted separation and satellite wet weather treatment will likely prove to be highly cost effective depending on targeted levels of service and performance criteria.

Regional wet weather treatment at Mangere appears to provide a highly cost effective solution to addressing targeted CSOs for the Central Interceptor Programme. The following provides key reasons which indicate that regional wet weather treatment should be assessed in more detail as viable solution for the Central Interceptor Programme:

- The cost of a regional wet weather facility at Mangere is less than a satellite facility due to issues of local site requirements and the ability to utilise existing systems at Mangere. Both facility cost, ranging in total from \$35m to \$48m on a 20-year NPV basis, provide a highly cost effective means to address intermittent wet weather flows.

- Issues of operational complexity, visual impacts, odours, noise, etc are far more easily addressed by placing a facility at Mangere than within a highly developed residential area which is remote from existing Watercare operational facilities.

- Wet weather treatment technologies are proven to provide a highly cost effective means for addressing intermittent peak wet weather flows that cannot be addressed through conventional biological treatment systems. Many full scale facilities exist which have been proven to work and to meet targeted performance criteria.

- Wet weather treatment in the form of ballasted flocculation will likely address required treatment needs at Mangere during intermittent peak flow conditions. This technology has been shown to produce a high quality effluent in terms of low turbidity which is amenable to UV disinfection – arguably the primary focus during short term wet weather periods. It has also been shown to be quite effective in removing BOD, TSS, metals, phosphorus and other constituents of concern. This includes additional flow which will be conveyed by the Central Interceptor system, providing a facility that can address multiple CSOs from one location.

- Initial assessments of wet weather treatment at Mangere show a cost effective means of optimising conveyance, storage and treatment cost for the Central Interceptor Programme. Utilisation of wet weather treatment allows the size of the Central Interceptor tunnel to be reduced to an optimal point which still addresses all targeted drivers including control and treatment of CSOs. One comparison shows that wet weather treatment could potentially reduce the cost of the Central Interceptor system by as much as \$100m in whole-of-life cost – and perhaps deliver better total annual pollution load reductions to the environment.

- Additional work required to assess the concept of wet weather treatment for the Central Interceptor Programme includes detailed wet weather sampling at Mangere, process modelling and trunk sewer modelling including representation of the Central Interceptor tunnel. This work is moving forward as part

of the development of the Mangere Wastewater Treatment Master Plan and the Central Interceptor concept design.

- Consideration of wet weather treatment technologies to address overflows and intermittent high peak flows at other locations needs to carefully assess site specific conditions and treatment needs. In many cases this technology has proven to be highly cost effective in lieu or more traditional solutions such as local storage, conventional treatment, separation and inflow/infiltration reduction programmes. Quite often the technology has been shown to produce better overall results for reducing pollution loads associated with wet weather impacts.

ACKNOWLEDGEMENTS

This paper was made possible by Watercare Services Ltd as part of the ongoing Central Interceptor Programme. The authors also wish to thank other programmes that provided information and data which could be referenced.

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COST EFFECTIVE TECHNOLOGIES FOR TREATING INTERMITTENT WET WEATHER OVERFLOWS

Clint Cantrell – AECOM, Myles Lind – Watercare, Matthew Mates - AECOM

ABSTRACT

As part of the Central Interceptor Programme Watercare has engaged AECOM to assess treatment technologies for addressing overflows which occur during wet weather events. Internationally these technologies are generally referred to as "wet weather treatment systems", but can consist of a range of processes which provide various degrees of treatment for overflows. A common element to all of these technologies is the ability to provide intermittent treatment during wet weather events, usually done with a form of physical/chemical treatment that can be turned on and off when needed. This is in contrast to a conventional biological treatment system which must run continuously and generally is not appropriate or capable of treating intermittent high peak flows associated with wet weather overflows and bypasses. It is also important to note that some forms of wet weather treatment technology can also be configured to include a disinfection process, including the use of UV disinfection. This paper explores various technologies and options for treating intermittent wet weather overflows and provides an assessment of the cost effectiveness relative to other more conventional options.

KEYWORDS

Wet Weather Treatment, combined sewer overflows, ballasted flocculation, vortex separation, UV disinfection

1 INTRODUCTION

Watercare Services Limited (Watercare) are in the process of developing a consent application and concept level design for the Central Interceptor – a proposed tunnel that addresses the key drivers of asset duplication for risk, capacity for growth and mitigation of targeted combined sewer overflows. Figure 1 below provides an illustration of one potential alignment option being considered for the Central Interceptor.

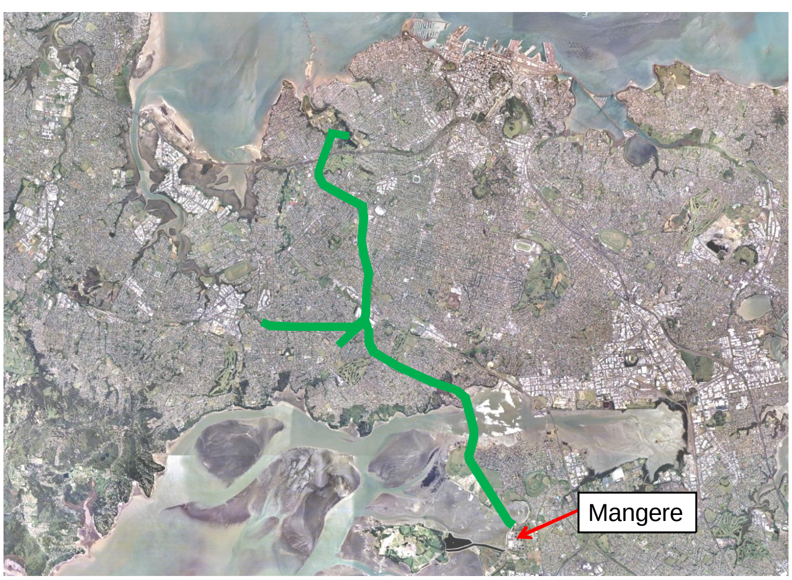


Figure 1 – One Option for Central Interceptor Alignment

This tunnel will connect to Watercare's existing Mangere Waste Water Treatment Plant (WWTP) and extend approximately 15kms into the existing network to address these key drivers. The tunnel will likely provide both a conveyance and storage function, with peak flows to the Mangere WWTP limited by available plant consented capacity at any given time. In parallel to the assessment of the Central Interceptor, Watercare are evaluating the technology of the Mangere WWTP to ensure optimised treatment capacity exists now and into the future.

A crucial aspect of the Central Interceptor Programme is optimising the balance of conveyance, storage and treatment capacities to ensure the least whole-of-life cost. Identifying the optimal balance of treatment, storage and conveyance requires a careful understanding of the inter-relationship between these three technologies in providing a regionally acceptable level of Combined Sewer Overflow (CSO) control. The Central Interceptor tunnel could provide both conveyance and storage to address control of CSOs, but any captured overflow volume, which in a combined system is significant, must receive an appropriate form of treatment. As the Central Interceptor will be connected to the Mangere WWTP the available capacity to treat flows will have a substantial impact on how big the tunnel must be, which in turn has a direct impact on the cost of the tunnel. Consideration of wet weather treatment technologies as a means to provide an enhanced capacity to treat wet weather flows is an important part of developing the least whole-of-life cost solution.

As stated above, Watercare are currently focused on options to reduce targeted (larger) CSOs, but are in the process of assuming control of the entire combined sewer system and as such will need to possibly address many other CSOs which are currently operated by Auckland City Council. The required timing, extents and degree of CSO control are uncertain. Watercare will be carefully evaluating this as they refine the concept of the Central Interceptor. Options to address CSO control include use of the Central Interceptor either for conveyance, storage or both, as well as other options such a strategic partial separation and/or local storage tanks. An additional option of utilising wet weather treatment technologies has been identified as a potentially cost-effective alternative which could be applied as a local/satellite scheme or as a regional scheme in the form of a parallel treatment train at the existing plant.

The purpose of this study was to evaluate process technologies for treatment of wet weather flows at either Mangere treatment plant or at a satellite location. To assess a satellite option Watercare chose their two largest overflows which are located within the Meola Catchment as shown in Figure 2. These two CSOs are located within approximately 500 meters of each other and options were assessed for treating both in combination.

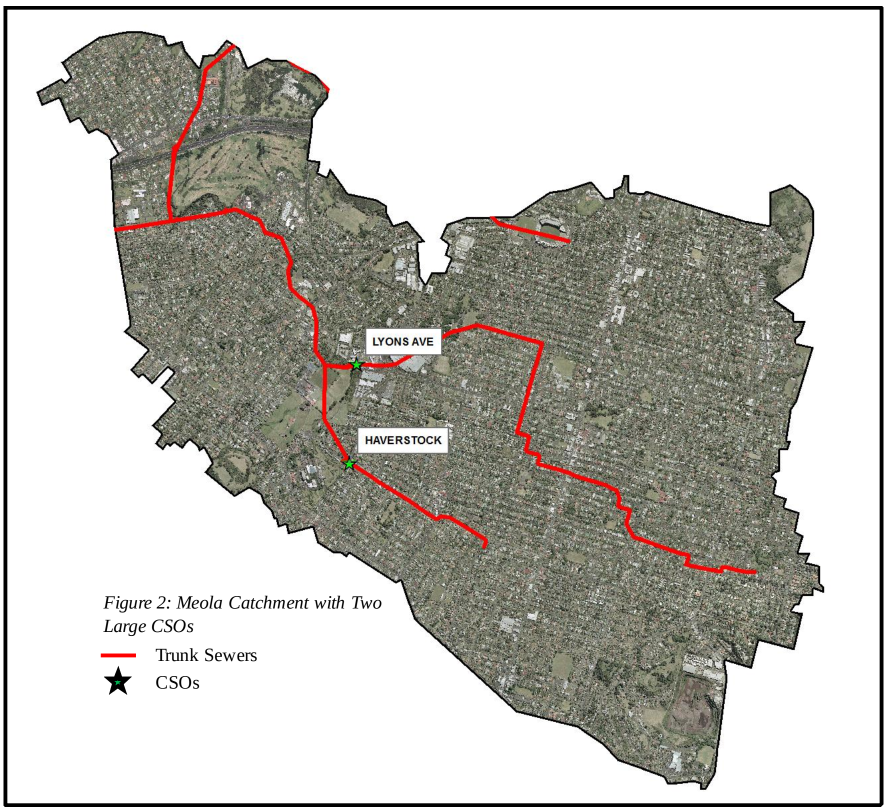


Figure 2: Meola Catchment with Two Large CSOs

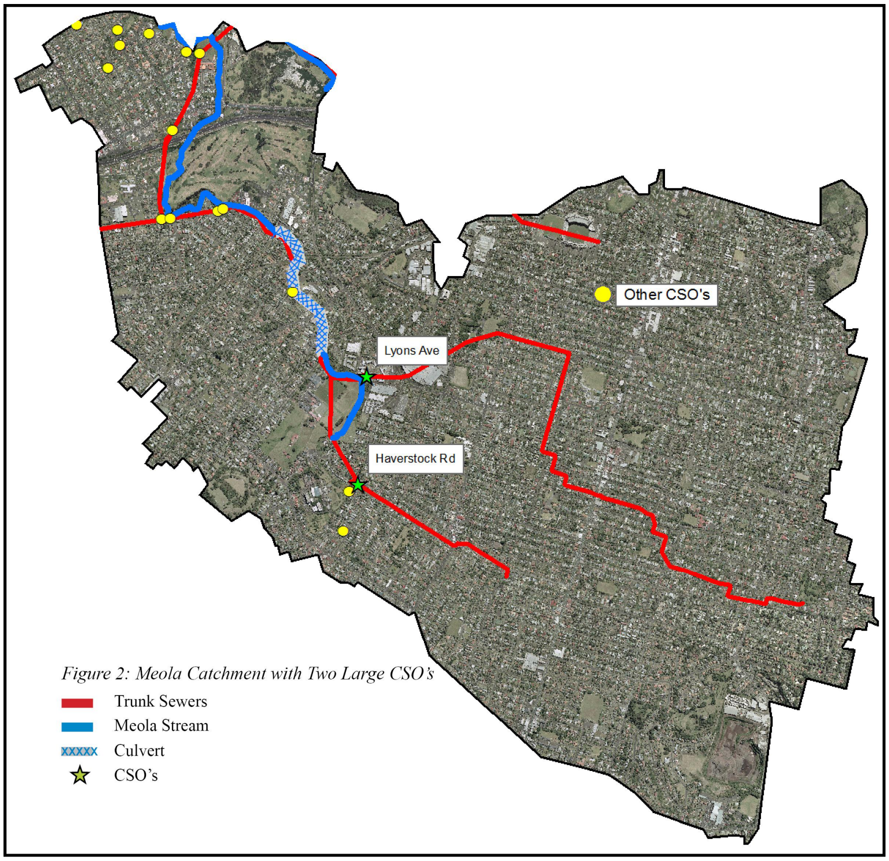


Figure 2: Meola Catchment with Two Large CSO's

This paper will guide the reader through CSO treatment by undertaking an assessment of applied and proven technologies for CSO treatment, and will show how options of satellite and regional wet weather treatment compared.

High rate treatment technologies would allow for currently untreated CSO flows to be treated to varying levels for such constituents as gross solids/visible floatables, TSS, biological oxygen demand (BOD), total phosphorus (TP), metals, and disinfection targets prior to discharging into public waterways. Depending on the treatment and disinfection types, a range of treatment options are available to lower capital and operational cost to the Mangere WWTP upgrade pathways with regards to processing peak flow and loads.

The wet weather technologies evaluated for this report are as follows:

- Ballasted flocculation (BF) – Using either microsand or recycled sludge
- Compressed media filtration (e.g. "Fuzzy Filter") (CMF) – varying particle size removal depending on filter interstitial void spacing in the media based on level of compression
- Chemically enhanced primary treatment (CEPT) – primary treatment using a metal salt (ex: Alum) and polymer (ex: anionic)
- Primary treatment (PT) – similar to the Mangere WWTP's current primary sedimentation process
- Detention treatment (DT)– This technology is considered as it provides good treatment over a range of performance conditions and is simple to operate, reliable, and rugged in its construction. Settling chemical application is uncommon and rare; however, it is being discussed in the USA as of late. The technology can also be readily blended into the community. This technology has a 'footprint' smaller than most conventional primary sedimentation tanks as the disinfection can be achieved in 10 to 12 minutes with rapid dispersion of sodium hypochlorite. UV disinfection with this technology would not be appropriate

- Vortex swirl separator (Vortex) – with no disinfection – uses flow velocity into unit and results in a centrifugal force pushing solids to the bottom of unit and discharging to sewer while treated water discharges
- Continual deflection separation (CDS)– using flow velocity to create centrifugal force and removal of gross particle constituents with a screen

2 PROJECT BACKGROUND AND OPTIONS EVALUATION CRITERIA

For purposes of the Central Interceptor Programme, Watercare are focusing options for controlling targeted large CSOs which are part of the current Watercare trunk sewer system. As part of the ongoing regionalisation of water and wastewater services in the Auckland region, Watercare will soon take ownership of the complete combined sewer system and as such will be considering how to address other CSOs that are presently owned by Auckland City. Watercare will be going through a process of understanding the location, size, magnitude and effects of these CSOs, and subsequently developing targeted levels of service which provide an adequate level of control. Through this process Watercare will analyse various options, and associated cost, including utilisation of the proposed Central Interceptor and locally based solutions such as storage tanks and strategic partial separation.

Watercare are considering utilisation of various wet weather treatment technologies which can be applied either locally or regionally, such as an additional treatment train at Mangere to handle high peak wet weather flows. This paper presents the results of an assessment of currently used wet weather treatment technologies including existing applications, ongoing performance and cost. Also presented are hypothetical examples of how this technology might be applied within the Auckland combined sewer system, using examples of a satellite application in the Meola Catchment targeting Watercare's two largest CSOs and a regional application as a parallel treatment train at Mangere. These examples have not been explored for purposes of developing recommended detailed solutions, but rather to assess the general viability of wet weather treatment and a high level understanding of cost and probable treatment performance. Further work is required to assess detailed specific options of utilising of wet weather treatment either in a satellite/local or regional form. This assessment will be largely dependent on key drivers for controlling CSOs, and the timing for achieving targeted levels of service. In evaluating these options it is important to consider the following issues with regards to satellite or regional applications:

Issues of satellite wet weather treatment applications:

- Operational complexity and control
- Distinction from conventional treatment plants in terms of not introducing a new discharge load to the environment (rather would be reducing an existing load) and only operating during wet weather conditions
- Proximity to residential areas
- Robustness of technology
- Reliability of technology including disinfection
- Treatment performance track record
- Required levels of treatment based on targeted levels of service
- Simplicity of operations and maintenance requirements
- Limitation of addressing multiple overflows and providing effects based benefits given the presence of other untreated overflows
- Management of solids and screenings
- Odour management
- Ability to consent
- Cost relative to other options
- Potential use as an interim measure

Issues of regional wet weather treatment application as parallel train at Mangere:

- Operational complexity and control
- Ability to enhance operational robustness including protection of secondary biological processes during peak wet weather flows
- Robustness of technology
- Treatment performance track record
- Ability to reduce required amount of tunnel storage and associated cost
- Enhancement of effluent quality and UV disinfection during high peak flow events

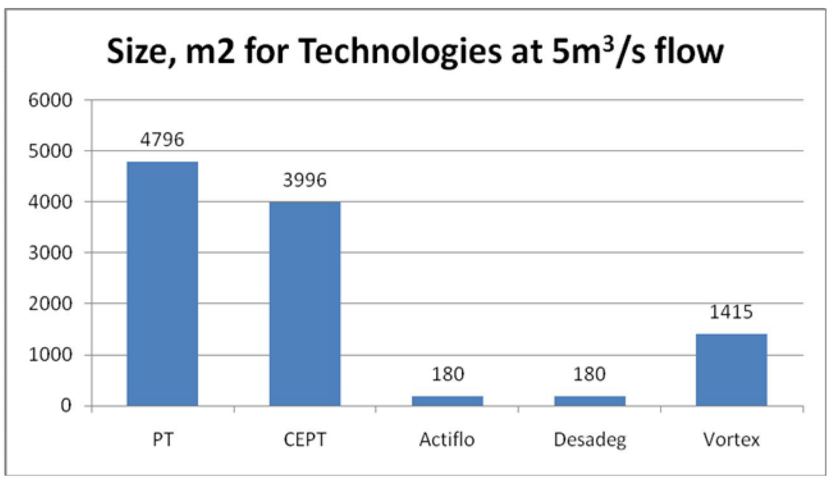
- Potential use as a redundancy and protection for primary and secondary clarifiers
- Required levels of treatment to meet overall effluent quality requirements
- Cost relative to other options for regional control of CSOs

For purposes of evaluating CSO treatment requirements a primary focused was placed on the ability to remove undesirable solids and floatables and utilisation of UV to disinfect to an appropriate level. Due to the short-term intermittent nature of wet weather CSO events and information about known impacts from CSOs, less emphasis was placed on the need to remove soluble constituents such as ammonia which are more important for treatment of normal base flow condition sewage. This is consistent with known applications of wet weather treatment in the United States and Europe.

3 OVERVIEW OF WET WEATHER TECHNOLOGIES ASSESSED

As described above, several technologies were assessed to provide wet weather treatment in either a regional form at the Mangere WWTP, or as a satellite facility in the Meola Catchment. To conduct an initial evaluation of wet weather treatment options an assumption of a required peak flow treatment rate of 5 m^3/s was established based on a cursory assessment of peak flows observed at the Lyons and Haverstock CSOs, and an evaluation of additional peak flows likely to occur at Mangere In some cases certain technologies were dismissed from detailed evaluation as a specific option due the current state of the technology (i.e. limited full scale applications and/or relatively unproven), or constraints regarding space requirements and treatment limitations. Regarding site space constraints Figure 3 is presented below, taken from Metcalf & Eddy 4th Edition, which shows required facility footprint sizes for various technologies evaluated based on an assumed design flow of 5 m^3/s. Based on this initial review, and an assumption that UV disinfection would be required, a decision was made to place emphasis on a detailed assessment of the ballasted flocculation technologies which is presented below. Other technologies such as vortex separation and detention tanks were assessed at a high level, but are not presented in this paper.

Figure 3 – Estimated Facility Footprint Sizes Based on 5 m3/s Design Flow



Ballasted flocculation is a general class of high rate wet weather treatment technologies which involves rapid mixing of chemicals to enhance settling, rapid flocullation, addition of a ballast material to add weight to the flocculants, and rapid settling using such technologies as a lamella plate system. This approach allows for very high loading rates, small facility footprints and utilisation as a temporary treatment system which can be brought on and off line during interim wet weather periods. The following provides an overview of the two most common ballasted flocculation technologies, Actiflo and DensaDeg, as they are typically applied to address wet weather treatment requirements.

Ballasted Flocculation (BF)

Objective

Treatment of excess wet weather flow via a physical and chemical process in either a regional or satellite location. The effluent from this process is also be disinfected utilising a UV system. The effluent from a satellite facility would be discharged directly to the environment at an appropriate location. A regional process located at Mangere could have a separate outfall or be blended with the plant liquids stream in a variety of pathways prior to UV disinfection.

Product Description

Ballasted flocculation, also known as high rate clarification, is a physical-chemical treatment process that uses continuously recycled media (microsand or recycled sludge) and a variety of additives (metal salt and polymer) to improve settling properties of suspended solids through improved floc bridging. Ballasted flocculation can also achieve pollutant removal through chemical precipitation of certain dissolved constituents.

The objective of this process is to form microfloc particles with a higher specific gravity. Faster floc formation and increased particle settling time allow clarification to occur up to ten times faster than with conventional clarification. Both Actiflo and DensaDeg use lamella settling components in the clarification area to further assist settlement. The result is a very small "footprint" in regards to land area.

Actiflo and DensaDeg are two industry standard processes and are considered suitable for either a stand alone, satellite wet weather system or as a parallel wet weather treatment train at a WWTP.

Disinfection would most likely be with UV. While chlorination and de-chlorination is widely used in North America, UV is the preferred disinfection method for wastewater in NZ. UV in series with ballasted flocculation is being used at installations in the USA and the UK. One constraint that must be imposed in order to use UV disinfection is the use of aluminium-based coagulants as iron-based coagulants interfere with the UV disinfection. While both Actiflo and DensaDeg both perform better in wet weather applications with iron-based coagulants, aluminium-based coagulants have been successfully used.

Comparisons between Actiflo and DensaDeg give the Actiflo system a slight edge in overall comparisons between the two based on the literature and information gathered for the report.

Actiflo can process flows between 10 and 100 percent of its nominal design capacity which allows the system to handle a wide range of wet weather events. Screening is required upstream of both processes. Actiflo requires 6mm screens while DensaDeg requires 12mm screens (Actiflo requires finer screens to avoid blocking the hydrocyclone for sand removal from sludge). The requirement for grit removal is typically a function of annual activations. For higher activation frequency (say >10 to 12 per year) grit removal would be required.

This technology provides the highest level of TSS and BOD removal of those considered in this paper and it also requires the highest level of operator involvement in terms of monitoring and control, however, this is minimal if located at an existing wastewater treatment plant.

Operation and Maintenance

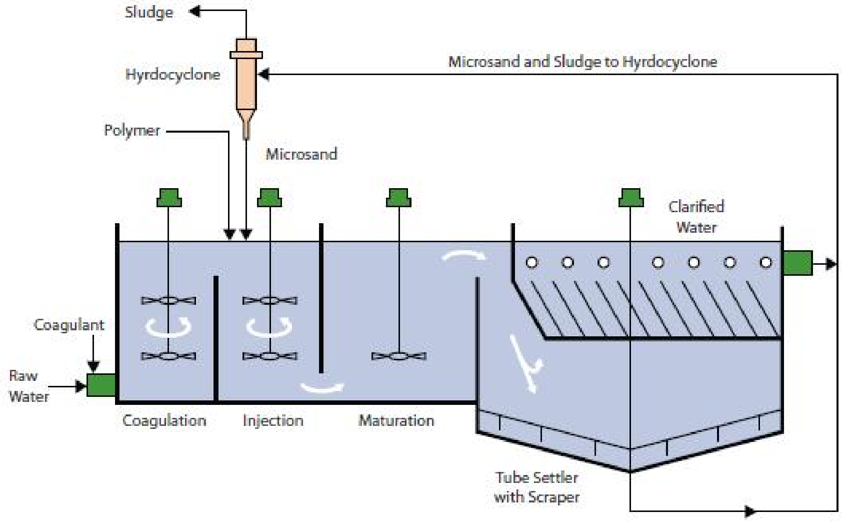
- BF with microsand (Actiflo) has a quick start up time compared to a dense sludge type BF (DensaDeg)
- Requires more optimization and control as compared to other CSO technologies
- Simple technology if compared to some WWTP unit processes
- Manned 4-8 hours per event on average

Key Product Points

- High treatment efficiency
- Good technology coupled with UV disinfection

- Small footprint compared with conventional clarifiers
- High loading rates 2400 $m^3/m^2/d$ or 100 m/h rise rate
- Short start-up time (10 to 20mins Actiflo, <30-45 min DensaDeg)
- Can be entirely automated and with local and remote monitoring and operational capability depending on degree desired

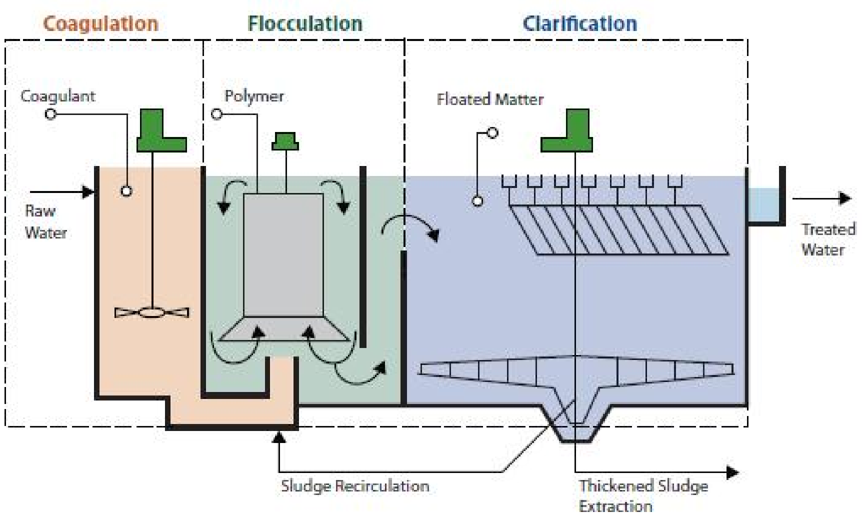
Actiflo



About the Manufacturer

Veolia Environmental Services is one of the world's leading providers of waste management and cleaning services and is represented locally in NZ. Examples of Actiflo facilities in New Zealand can be found in Gore and Warkworth.

DensaDeg



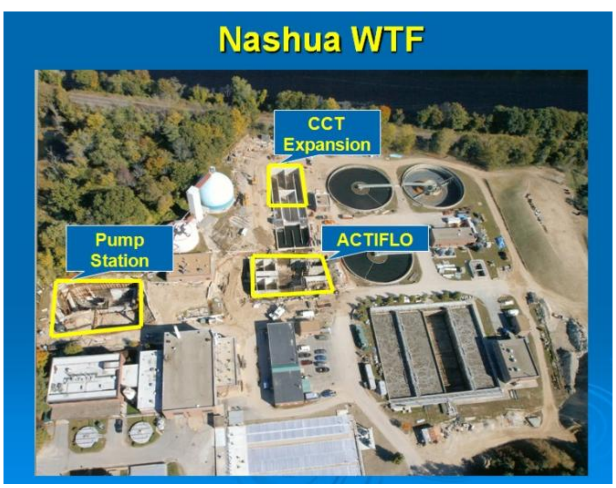
4 EXAMPLE APPLICATIONS AND PERFORMANCE OF BALLASTED FLOCCULATION

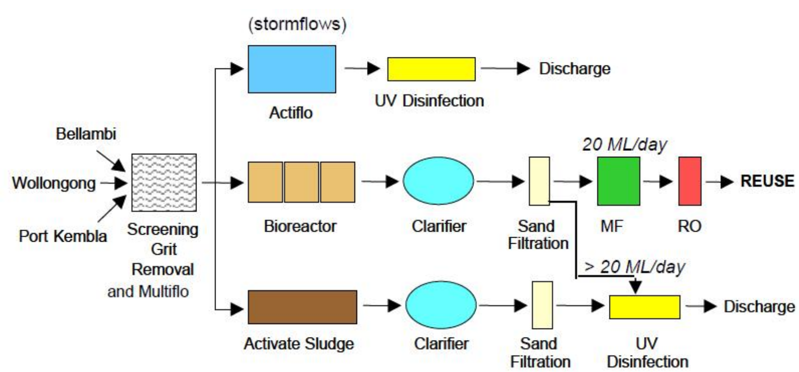
This section focuses on the Actiflo ballasted flocculation process due to the lack of presence with DensaDeg in New Zealand and concerns over required facility start-up times.

4.1 EXAMPLE FACILITY OVERVIEWS

The following presents summary fact sheets for example applications of ballasted flocculation facilities applied for treatment of wet weather flows. This includes examples of satellite (remote locations at specific overflows sites) and regional (located in parallel with existing wastewater treatment plants) facilities.

Treatment Technology	**Ballasted Flocculation – Regional Facility at Existing WWTP**
Project Name	**Nashua, New Hampshire**
Treatable flow rate	2.6m^3/s
Cost	$US27.5m (includes new pumping station and expanded disinfection facility)
Description	AECOM conducted a re-evaluation of Nashua's long-term CSO control plan, which will save the city nearly $US200 million compared to a previous plan. As part of this revised plan, AECOM designed the high-rate CSO treatment facility with a capacity of 2.6m^3/s that will discharge treated wet weather flow blended with existing plant effluent. The facility includes screening and grit removal, a 2.6 m^3/s pump station, ballasted flocculation treatment and chlorine disinfection. It is activated very little during the year with total activations to date of less than 10 times. The wet weather treatment facility controls have been incorporated into the wastewater treatment plant's existing SCADA system. The plant uses sodium hypochlorite disinfection. Construction of the wet-weather facility was completed in January 2009, and preliminary performance and acceptance testing has been satisfactorily completed. The facility has a construction cost of $US27.5m. Testing results (shown in the following section) indicate consistently high TSS removals up to 90%+.
Photo	



Treatment Technology	Ballasted Flocculation – Regional Facility at Existing WWTP
Project Name	**Illawarra, Wollongong -NSW, Australia**
Treatable flow rate	1.7m^3/s
Cost	Cost unavailable
Description	Sydney Water supplies more than 1.7 billion litres of water to more than 1.6 million homes and businesses each day. It provides drinking water, wastewater services, and some stormwater services to customers in the communities of Sydney, the Blue Mountains and the Illawarra. Veolia Water Systems was contracted by Sydney Water Corporation to design, build and provide operational advice for upgrading three wastewater treatment plants south of Sydney (Bellambi, Port Kembla, Wollongong) to serve 300,000 residents. As part of the upgrade was the conversion of existing Bellambi and Port Kembla STPs to storm sewage treatment plants to store and treat wastewater. As a result of this upgrade, the city of Wollongong now has one of the most advanced coastal treatment plants in the world. The system is currently providing benefits such as: Improving water quality at Illawarra beaches, particularly those near sewage treatment plants. Protecting coastal water sand reducing impact on sensitive marine ecosystems. Minimising the effluents negative impacts when effluent from BF is released to the environment. Supply high-quality recycled water for industrial reuse. The upgraded facility at Wollongong will provide biological treatment to flows of up to 2.1 m^3/s (three times ADWF). Flows in excess of this, up to maximum of 3.7 m^3/s, will be treated using the high rate ballasted flocculation process, Actiflo®, followed by UV disinfection.
Schematic	

Treatment Technology	Ballasted Flocculation – Satellite Facility at CSO Location
Project Name	**East Bremerton Satellite CSO Treatment Facility, Bremerton, Washington USA**
Treatable flow rate	1 m^3/s
Cost	US $4.1m (includes cost of UV disinfection system)
Description	Bounded by the Puget Sound and divided by the Port Washington Narrows, the city of Bremerton, Washington, is also home to the Puget Sound Naval Shipyard. In its early development, the city combined its sewer and stormwater into one system that conveyed the water directly into the Puget Sound, untreated. As the city continued to develop during the 1940s, primary sewage treatment plants were built, into which combined sewer flows were redirected for treatment. By design, CSOs occurred during storm events. The city decided to build a satellite CSO treatment facility in East Bremerton adjacent to the Port Washington Narrows. The facility needed to have rapid start-up capability and be equipped to quickly meet peak removal efficiencies. As a result, chemical feed and ultra-violet (UV) disinfection equipment, coupled with a high-rate clarification system, were recommended. The Actiflo process has consistently exceeded state performance requirements for CSO treatment plants at the 20-mgd (1 m^3/s) East Bremerton CSO treatment facility in the US state of Washington, according to John Poppe, wastewater manager at Bremerton's Public Works and Utilities. The process is at the heart of the 10-mgd East Bremerton CSO treatment facility, which has complied with state and federal CSO rules since coming online in December 2001. Consequently, the improved water quality has increased the potential for shellfish harvesting in Puget Sound. The Bremerton facility can start up and achieve excellent performance in only 15 minutes. The process is removing between 90 percent to 95 percent of TSS, 80 percent of BOD, and 85 percent of total phosphorous. Effluent turbidity levels are less than 3 NTU. Post-clarification, the treated effluent passes through medium-pressure, high-output UV disinfection before it is discharged into the Puget Sound.
Photo	

4.2 SUMMARY OF EXAMPLE BALLASTED FLOCCULATION PERFORMANCE RESULTS

Table 1 presents performance data summaries for various supplemental treatment technologies including ballasted flocculation.

Table 1 – Performance Data for Selected Wet Weather Treatment Technologies

Technology	Sources	Hydraulic Capacities and Removals			
		Hydraulic Capacity ($m^3/m^2/d$)	Hydraulic Capacity ($m^3/m^2/d$)	BOD Removal (Percent)	TSS Removal (Percent)
		Lower	Upper		
Primary Clarification / Detention Treatment	Metcalf and Eddy 1991: NEIWPCC 1998 WEF 1996	28	141	25-40	50-70
Chemically Enhanced Primary Treatment	US EPA: In Plant Flow WW Management 2007	140	165	40-50	75-85
Screening	Metcalf and Eddy 1991:				
Coarse (5mm-25mm)		987	4042	NA	15-30
Fine (0.1mm-5mm)		7.05	65.8	NA	40-50
Micro(<0.1mm)		7.05	65.8	NA	40-70
Vortex Separation/CDS	EPA 1996 Boner et al 1995 WERF 2002	NA	4700	Up to 55	5 to 60
Ballasted Flocculation	Raddick et al. 2001 Scruggs et al. 2001 Vick 2000 Poppe et al 2001	NA	4230	65-80	70-95
Chemical Flocculation	Metcalf and Eddy 1991; Moffa 1997	NA	940	40-80	60-90

The following present performance results of Actiflo wet weather treatment facilities including pilot studies and full scale plants. In all cases reviewed the Actiflo system consistently met removal performance targets, and using the appropriate chemicals produced an effluent quality acceptable for UV disinfection to meet typical standards.

United Utilities Millom Works Pilot Test

In the UK, a 200m3/h Actiflo pilot plant was operated for 12 months at United Utilities' Millom works on the Cumbrian coast in the Lake District National Park. Some 90 trials were carried out on the pilot plant over the 12-month period; 50 under storm conditions and the remainder taking stored storm water from the works' storm-water tank. In every case, the effluent UV transmissivity was consistently high

enough (greater than 50 per cent) for an ultraviolet disinfection unit downstream of the clarifier to meet the microbiological consent for discharge to a bathing beach or shellfish water. Both ferric and aluminium coagulants were trialled, and both gave suspended solids reduction in excess of 90 percent, producing effluent suspended solids below 25mg/l; a figure that was reached within 10 minutes of start-up. COD reduction was generally 60-70 percent and total phosphorus removal was in excess of 80 percent.

Berlin CSO Pilot Facility Test

A shorter-term trial was carried out, this time over 52 days, in Germany starting in mid-January 2008. A mobile pilot plant was located in the car park of the Berliner WasserBetriebe office building in Bellermannstrasse, Berlin. It was situated approximately 5m away from, and running parallel to the CSO chamber installed at this location. A temporary submersible pump was installed to take water from the chamber and deliver it to the inlet of the Actiflo unit. Clarified water from the Actiflo unit was discharged under gravity to the adjacent sewer, together with the sludge from the hydrocyclone. During the trial period, 10 runs were carried out: the first with simulated raw water produced by diluting raw sewage with mains water in the CSO chamber, the rest of the runs were conducted during actual storm-overflow conditions. The pilot plant results from the Berlin trial confirmed the results from the Millom trial, namely a better than 60 percent removal of COD, more than 80 percent reduction in total suspended solids and more than 80 percent reduction in total phosphorous. They also confirmed that this performance can be achieved within 10 minutes of start-up.

Lawrence Wastewater Treatment Plant Full Scale (2m^3/s) Wet Weather Facility Performance

The Lawrence Wastewater Treatment Plant (WWTP) was expanded and improved to accommodate the City of Lawrence, Kansas, future growth, maintain compliance with new regulatory requirements, and meet facility needs up through the design year 2020. To accommodate future projected storm flows or sanitary sewer overflows (SSO), a wet weather facility consisting of 40 million gallons per day (mgd) ballasted flocculation system was constructed to direct discharge with the main WWTP effluent to the Kansas River. The Actiflo® system, which has been in service for over a year and half, has been operated during ten peak flow storm events that lasted anywhere from four hours to 47 hours. The disinfection and dechlorination system selected for the Lawrence WWTP wet weather treatment facilities was sodium hypochlorite and sodium bisulfite, respectively. A separate contact basin was provided for the wet weather facilities flow. The wet weather facility effluent is blended with the main plant effluent to meet the combined chlorine residual as indicated in the plant's NPDES permit. During the first year of operation, the Actiflo® unit encountered a variety of influent flow characteristics and operating conditions. Real-time operating experience has been obtained. For each storm event, the polymer and ferric chloride dosages were optimized to enable the effluent to meet the plant's permit. Over the operating period the Actiflo system has consistently removed 80 percent of the turbidity. The TSS percent removal is around 88 percent. As a result of the removed solids, the City of Lawrence is able to meet the plant's NPDES for BOD, TSS, and chlorine residual.

East Bremerton Full Scale Satellite CSO Treatment Facility, Bremerton, Washington USA

The Actiflo process has consistently exceeded state performance requirements for CSO treatment plants at the 20-mgd (1 m3/s) East Bremerton CSO treatment facility in the US state of Washington, according to John Poppe, wastewater manager at Bremerton's Public Works and Utilities. The process is at the heart of the 20-mgd East Bremerton CSO treatment facility, which has complied with state and federal CSO rules since coming online in December 2001. Consequently, the improved water quality has increased the potential for shellfish harvesting in Puget Sound. The Bremerton facility can start up and achieving excellent performance in only 15 minutes. The process is removing between 90 percent to 95 percent of TSS, 80 percent of BOD, and 85 percent of total phosphorous. Effluent turbidity levels are less than 3 NTU. Post-clarification, the treated effluent passes through medium-pressure, high-output UV disinfection before it is discharged into the Puget Sound.

5 OVERVIEW OF OPTIONS AND COST DEVELOPED FOR SATELLITE AND REGIONAL WET WEATHER TREATMENT

The following presents a summary of options and cost estimates developed for applications of a satellite ballasted flocculation treatment system, using the Actiflo technology, in the Meola Catchment and a regional ballasted flocculation treatment system at Mangere. In both cases it was assumed that UV disinfection treatment would need to be included and a peak design flow rate of 5 m³/s would be used.

5.1 MEOLA SATELLITE WET WEATHER TREATMENT CONCEPT OPTION AND COST

Figure 4 below provides a concept process flow diagram schematic for a satellite ballasted flocculation in the Meola Catchment which would treat two of the largest CSOs in Auckland up to a maximum peak flow of 5 m³/s.

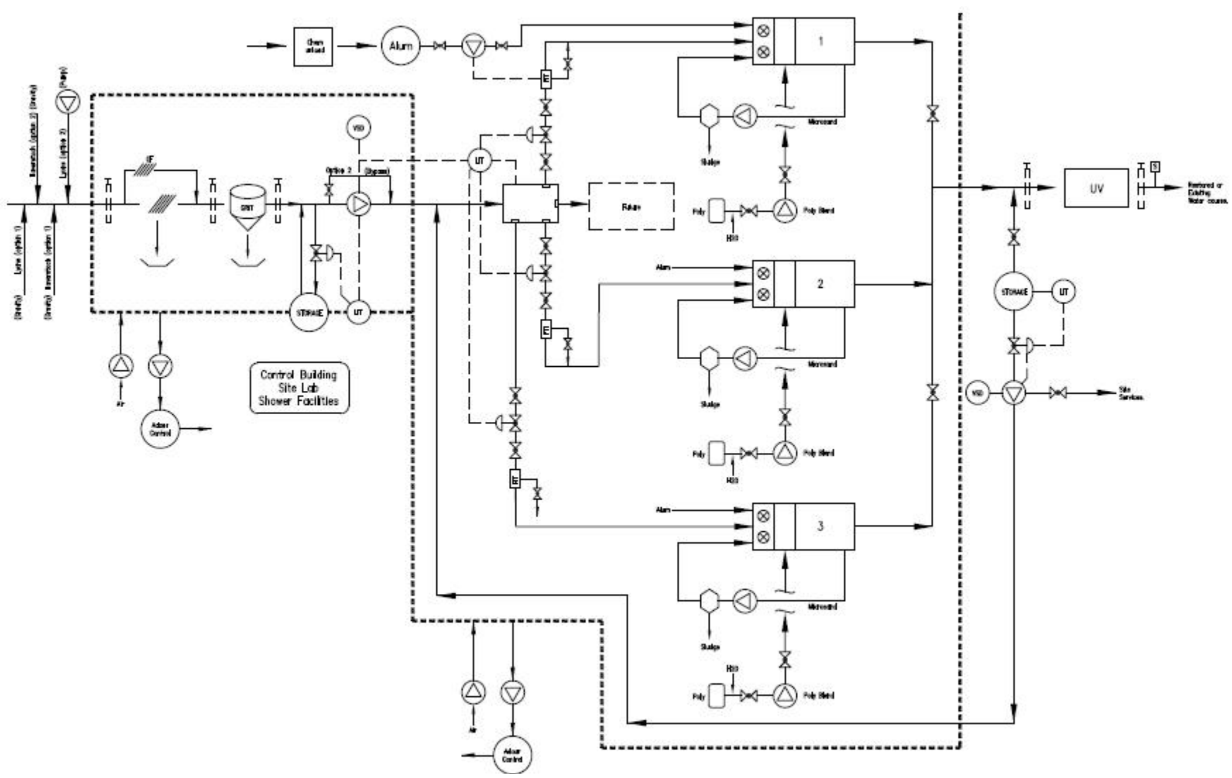


Figure 4 – Concept Process Flow Diagram for Meola Satellite Ballasted Flocculation System

Overflow from Haverstock and Lyons would be conveyed to a centralised location for initial screening and grit removal. Smaller overflow events would be stored within a small, storage tank prior to being pumped back into the trunk sewer. Larger events would use the stored overflow to prime the ballasted flocculation facility before activating to treat flows to a peak of approximately 5 m³/s. Overflows in excess of this would bypass the treatment device. Treated effluent would then pass through UV disinfection prior to discharge into the Meola Creek. Two concepts were developed for the configuration of Actiflo at this location as shown in Figure 5 on the next page.

Sludge from the Actiflo would discharge into the trunk sewer downstream of the overflows for treatment at Mangere.

Key points about this option are:

- A high capacity pump station would be required for the design to work hydraulically

- The facility would be located within a residential area and would therefore require potential extensive public consultation. Considerable effort may be required with regard to the aesthetics and odour control of the facility. There are numerous examples of satellite wet weather facilities which have been placed in residential areas, but typically require additional cost to address aesthetic, odour and noise issues

- Start-up and operation of this facility would need careful consideration. Key issues to address would include operational complexity, use of telemetry, chemical handling and storage, and regular maintenance requirements. Facility operations would require on site personnel prior to and during wet weather events. This would include required procedures to prep the facility for start-up in anticipation of a CSO activation, perhaps facilitated through the use of remote monitoring telemetry

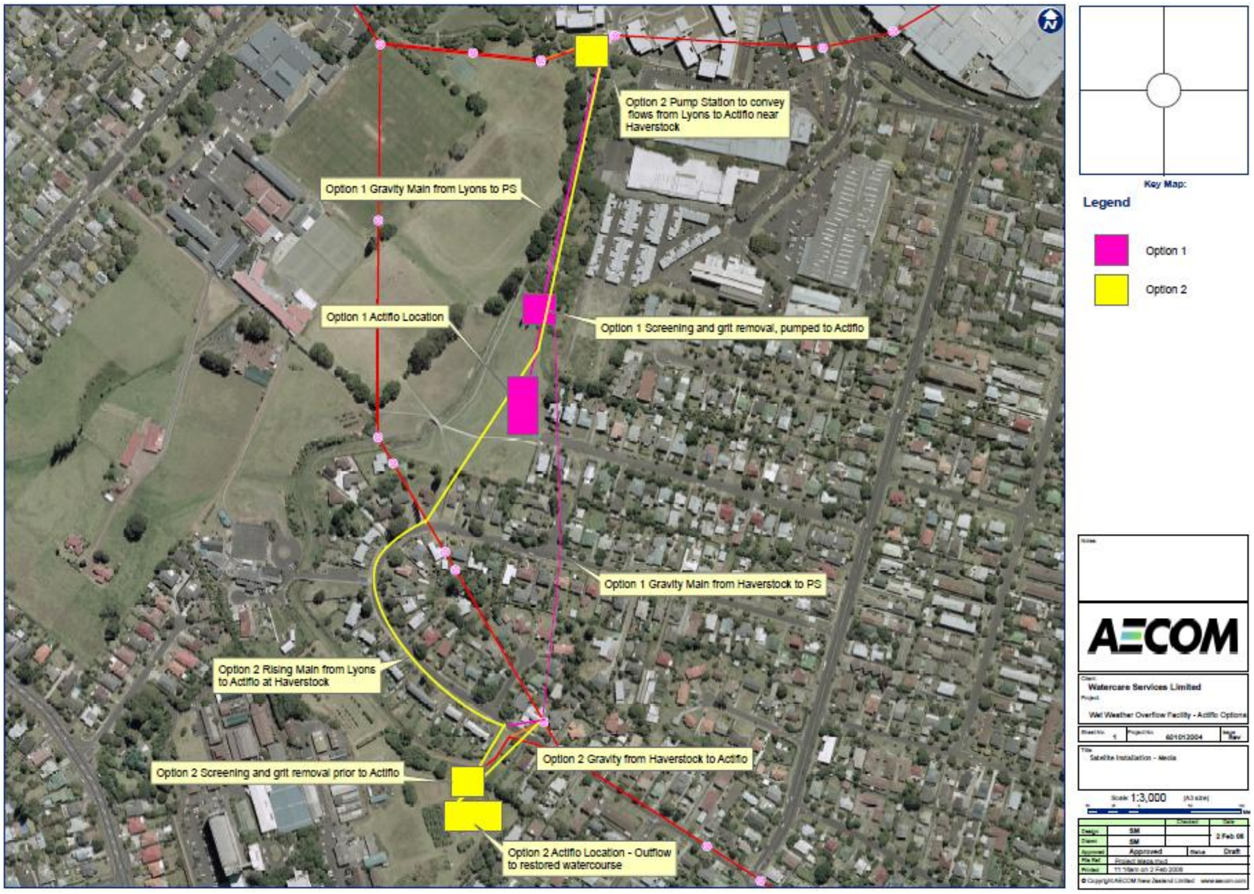


Figure 5 – Concept Options for Satellite Wet Weather Treatment in the Meola Catchment

Capital cost for this option have been estimated at approximately $38m which includes the wet weather treatment system, pumping station, buffer storage tank, UV system, enclosure buildings to address visual/noise/odour issues and a 30 percent contingency to address unknowns and risk. Annual operating cost, based on monitoring data from the CSOs, are estimated at $0.8m/year – resulting in a 20 whole-of-life cost $43m.

5.2 MANGERE REGIONAL WET WEATHER TREATMENT CONCEPT OPTION AND COST

Figure 6 below provides a concept process flow diagram schematic for a regional ballasted flocculation system at Mangere which would treat intermittent wet weather peak flows up to 5 m^3/s that exceed the biological treatment system.

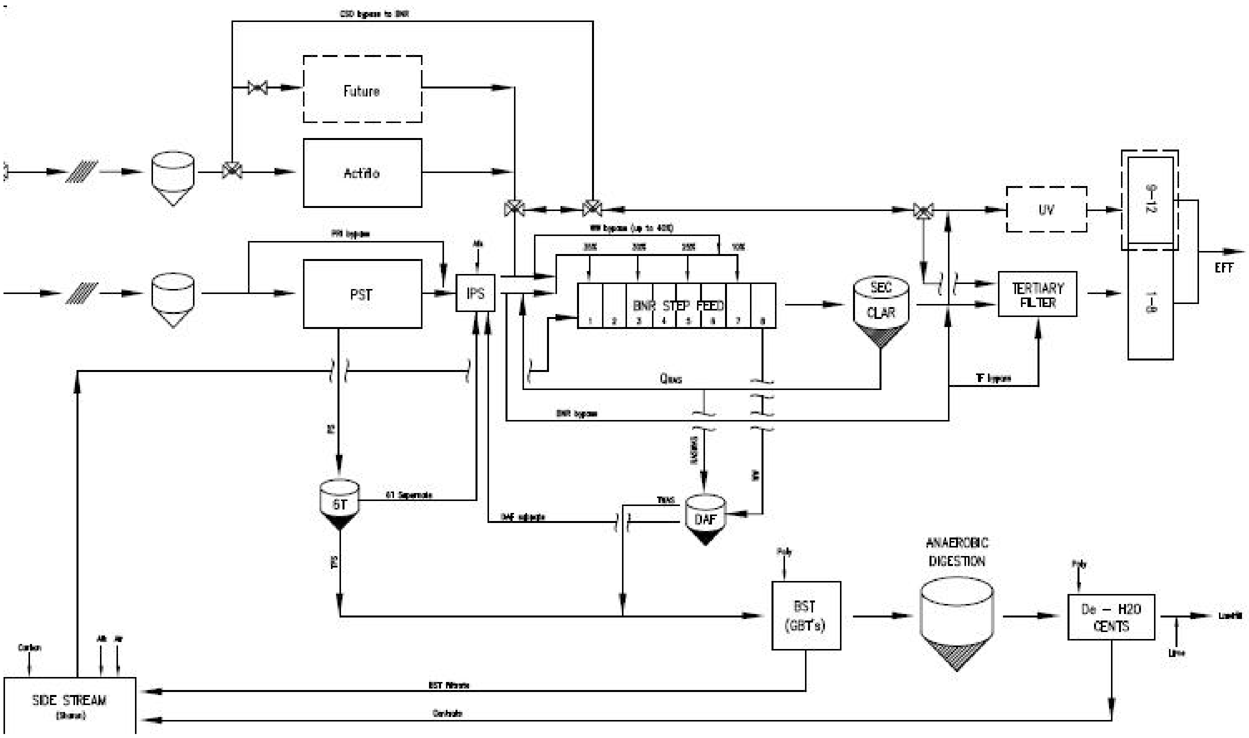


Figure 6 – Concept Process Flow Diagram for Regional Wet Weather Treatment at Mangere

An Actiflo ballasted flocculation system could be placed at Mangere as a parallel treatment train to the existing biological nutrient removal (BNR) system. In concept, this wet weather treatment system would accommodate flows in excess of the BNR system for up to 5 m³/s, including wet weather flows delivered by the Central Interceptor tunnel system. The effluent from the ballasted flocculation system would be treated either with a new independent UV disinfection system or more likely would be blended with the BNR effluent and treated with the existing UV disinfection system which has sufficient capacity.

Sludge from the Actiflo facility would be processed in the plant and the effluent could be blended at multiple points depending on the degree of treatment and process consent condition at time of year.

Key points about this option are:

- Issues of operational complexity and start-up requirements are somewhat alleviated by placing the wet weather treatment facility at an existing plant which is manned 24 hours a day.
- Ballasted flocculation could possibly be used to enhance the overall performance of Mangere during interim peak wet weather flow conditions by de-stressing the existing BNR system. Detailed monitoring and process modelling may show that the effluent quality will be enhanced by utilising wet weather treatment at Mangere during high flow events.

Capital cost for this option have been estimated at approximately $30m which includes the wet weather treatment system, new parallel wet weather UV system, and a 30% contingency to address unknowns and risk. Annual operating cost, based on network hydraulic models, are estimated at $0.8m/year – resulting in a 20 whole of life cost $35m.

6 CONCLUSIONS

Wet weather treatment technologies have developed dramatically over the past 20 years. There are many different technologies to consider which provide varying degrees of treatment. Site specific conditions and local treatment

requirements for wet weather overflows and intermittent high peak flows must be carefully considered in assessing options and cost. Many full scale examples of satellite and regional wet weather treatment facilities exist, and detailed performance shows that these technologies can achieve targeted wet weather treatment requirements when applied appropriately.

As part of the Central Interceptor Programme options for wet weather treatment have been assessed for both a satellite application in the Meola Catchment to address two of the largest CSOs, and as a regional treatment facility operating at Mangere in parallel with the existing BNR system. Concepts for these options have been developed, including estimates of cost and performance ability.

Results of the analysis completed for the Central Interceptor Programme indicate that a regional wet weather treatment facility at Mangere would be the preferred option over satellite treatment facilities in the targeted combined sewer area. This conclusion only applies to the targeted service area for the Central Interceptor as there are other overflows which will not be directly addressed by this tunnel. For overflows outside of the Central Interceptor service area local solutions such as storage, targeted separation and satellite wet weather treatment will likely prove to be highly cost effective depending on targeted levels of service and performance criteria.

Regional wet weather treatment at Mangere appears to provide a highly cost effective solution to addressing targeted CSOs for the Central Interceptor Programme. The following provides key reasons which indicate that regional wet weather treatment should be assessed in more detail as viable solution for the Central Interceptor Programme:

- The cost of a regional wet weather facility at Mangere is less than a satellite facility due to issues of local site requirements and the ability to utilise existing systems at Mangere. Both facility cost, ranging in total from \$35m to \$48m on a 20-year NPV basis, provide a highly cost effective means to address intermittent wet weather flows.

- Issues of operational complexity, visual impacts, odours, noise, etc are far more easily addressed by placing a facility at Mangere than within a highly developed residential area which is remote from existing Watercare operational facilities.

- Wet weather treatment technologies are proven to provide a highly cost effective means for addressing intermittent peak wet weather flows that cannot be addressed through conventional biological treatment systems. Many full scale facilities exist which have been proven to work and to meet targeted performance criteria.

- Wet weather treatment in the form of ballasted flocculation will likely address required treatment needs at Mangere during intermittent peak flow conditions. This technology has been shown to produce a high quality effluent in terms of low turbidity which is amenable to UV disinfection – arguably the primary focus during short term wet weather periods. It has also been shown to be quite effective in removing BOD, TSS, metals, phosphorus and other constituents of concern. This includes additional flow which will be conveyed by the Central Interceptor system, providing a facility that can address multiple CSOs from one location.

- Initial assessments of wet weather treatment at Mangere show a cost effective means of optimising conveyance, storage and treatment cost for the Central Interceptor Programme. Utilisation of wet weather treatment allows the size of the Central Interceptor tunnel to be reduced to an optimal point which still addresses all targeted drivers including control and treatment of CSOs. One comparison shows that wet weather treatment could potentially reduce the cost of the Central Interceptor system by as much as \$100m in whole-of-life cost – and perhaps deliver better total annual pollution load reductions to the environment.

- Additional work required to assess the concept of wet weather treatment for the Central Interceptor Programme includes detailed wet weather sampling at Mangere, process modelling and trunk sewer modelling including representation of the Central Interceptor tunnel. This work is moving forward as part

of the development of the Mangere Wastewater Treatment Master Plan and the Central Interceptor concept design.

- Consideration of wet weather treatment technologies to address overflows and intermittent high peak flows at other locations needs to carefully assess site specific conditions and treatment needs. In many cases this technology has proven to be highly cost effective in lieu or more traditional solutions such as local storage, conventional treatment, separation and inflow/infiltration reduction programmes. Quite often the technology has been shown to produce better overall results for reducing pollution loads associated with wet weather impacts.

ACKNOWLEDGEMENTS

This paper was made possible by Watercare Services Ltd as part of the ongoing Central Interceptor Programme. The authors also wish to thank other programmes that provided information and data which could be referenced.

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COST EFFECTIVE TECHNOLOGIES FOR TREATING INTERMITTENT WET WEATHER OVERFLOWS

Clint Cantrell – AECOM, Myles Lind – Watercare, Matthew Mates - AECOM

ABSTRACT

As part of the Central Interceptor Programme Watercare has engaged AECOM to assess treatment technologies for addressing overflows which occur during wet weather events. Internationally these technologies are generally referred to as "wet weather treatment systems", but can consist of a range of processes which provide various degrees of treatment for overflows. A common element to all of these technologies is the ability to provide intermittent treatment during wet weather events, usually done with a form of physical/chemical treatment that can be turned on and off when needed. This is in contrast to a conventional biological treatment system which must run continuously and generally is not appropriate or capable of treating intermittent high peak flows associated with wet weather overflows and bypasses. It is also important to note that some forms of wet weather treatment technology can also be configured to include a disinfection process, including the use of UV disinfection. This paper explores various technologies and options for treating intermittent wet weather overflows and provides an assessment of the cost effectiveness relative to other more conventional options.

KEYWORDS

Wet Weather Treatment, combined sewer overflows, ballasted flocculation, vortex separation, UV disinfection

1 INTRODUCTION

Watercare Services Limited (Watercare) are in the process of developing a consent application and concept level design for the Central Interceptor – a proposed tunnel that addresses the key drivers of asset duplication for risk, capacity for growth and mitigation of targeted combined sewer overflows. Figure 1 below provides an illustration of one potential alignment option being considered for the Central Interceptor.

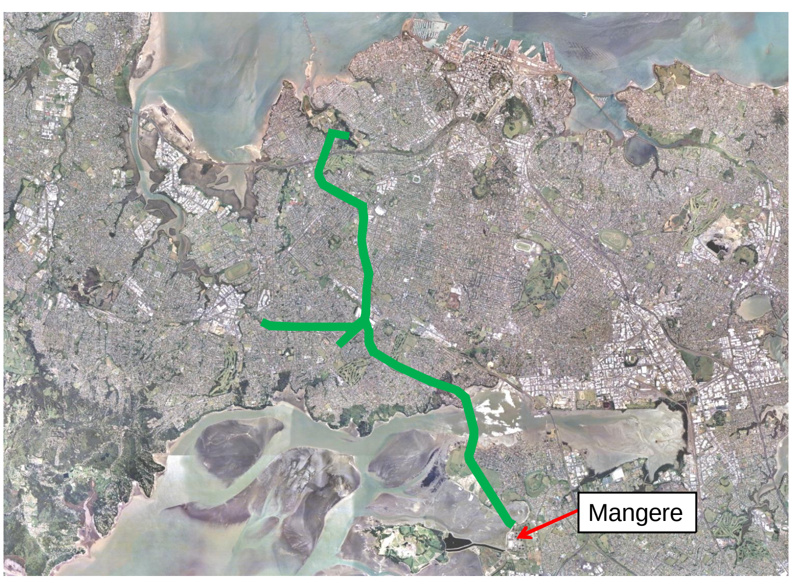


Figure 1 – One Option for Central Interceptor Alignment

This tunnel will connect to Watercare's existing Mangere Waste Water Treatment Plant (WWTP) and extend approximately 15kms into the existing network to address these key drivers. The tunnel will likely provide both a conveyance and storage function, with peak flows to the Mangere WWTP limited by available plant consented capacity at any given time. In parallel to the assessment of the Central Interceptor, Watercare are evaluating the technology of the Mangere WWTP to ensure optimised treatment capacity exists now and into the future.

A crucial aspect of the Central Interceptor Programme is optimising the balance of conveyance, storage and treatment capacities to ensure the least whole-of-life cost. Identifying the optimal balance of treatment, storage and conveyance requires a careful understanding of the inter-relationship between these three technologies in providing a regionally acceptable level of Combined Sewer Overflow (CSO) control. The Central Interceptor tunnel could provide both conveyance and storage to address control of CSOs, but any captured overflow volume, which in a combined system is significant, must receive an appropriate form of treatment. As the Central Interceptor will be connected to the Mangere WWTP the available capacity to treat flows will have a substantial impact on how big the tunnel must be, which in turn has a direct impact on the cost of the tunnel. Consideration of wet weather treatment technologies as a means to provide an enhanced capacity to treat wet weather flows is an important part of developing the least whole-of-life cost solution.

As stated above, Watercare are currently focused on options to reduce targeted (larger) CSOs, but are in the process of assuming control of the entire combined sewer system and as such will need to possibly address many other CSOs which are currently operated by Auckland City Council. The required timing, extents and degree of CSO control are uncertain. Watercare will be carefully evaluating this as they refine the concept of the Central Interceptor. Options to address CSO control include use of the Central Interceptor either for conveyance, storage or both, as well as other options such a strategic partial separation and/or local storage tanks. An additional option of utilising wet weather treatment technologies has been identified as a potentially cost-effective alternative which could be applied as a local/satellite scheme or as a regional scheme in the form of a parallel treatment train at the existing plant.

The purpose of this study was to evaluate process technologies for treatment of wet weather flows at either Mangere treatment plant or at a satellite location. To assess a satellite option Watercare chose their two largest overflows which are located within the Meola Catchment as shown in Figure 2. These two CSOs are located within approximately 500 meters of each other and options were assessed for treating both in combination.

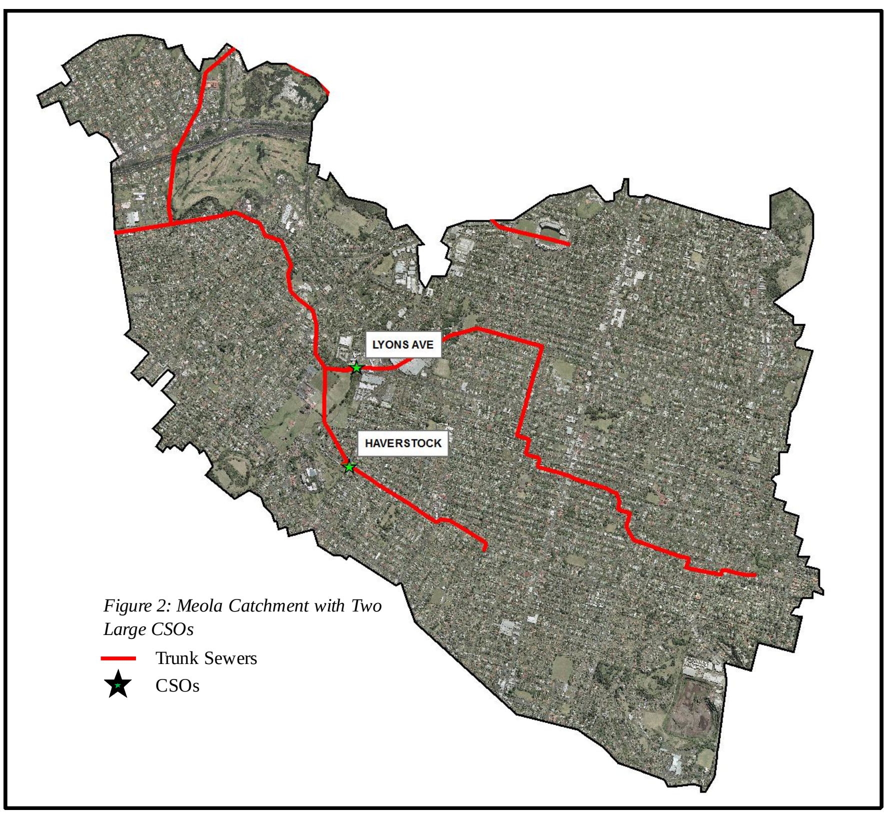


Figure 2: Meola Catchment with Two Large CSOs

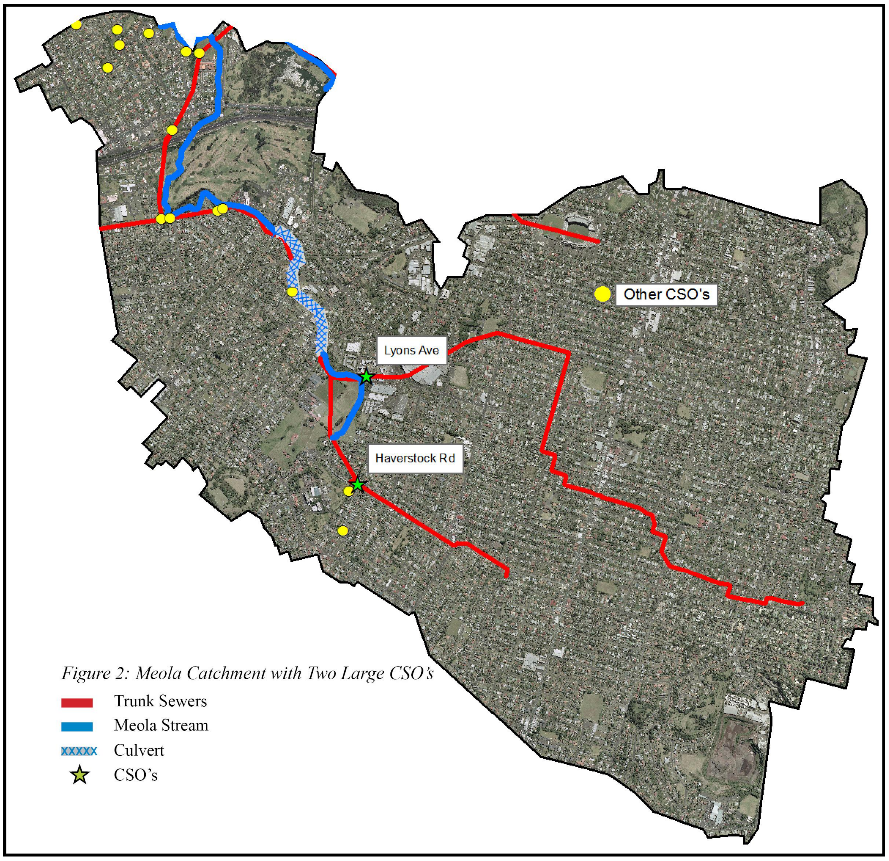


Figure 2: Meola Catchment with Two Large CSO's

This paper will guide the reader through CSO treatment by undertaking an assessment of applied and proven technologies for CSO treatment, and will show how options of satellite and regional wet weather treatment compared.

High rate treatment technologies would allow for currently untreated CSO flows to be treated to varying levels for such constituents as gross solids/visible floatables, TSS, biological oxygen demand (BOD), total phosphorus (TP), metals, and disinfection targets prior to discharging into public waterways. Depending on the treatment and disinfection types, a range of treatment options are available to lower capital and operational cost to the Mangere WWTP upgrade pathways with regards to processing peak flow and loads.

The wet weather technologies evaluated for this report are as follows:

- Ballasted flocculation (BF) – Using either microsand or recycled sludge
- Compressed media filtration (e.g. "Fuzzy Filter") (CMF) – varying particle size removal depending on filter interstitial void spacing in the media based on level of compression
- Chemically enhanced primary treatment (CEPT) – primary treatment using a metal salt (ex: Alum) and polymer (ex: anionic)
- Primary treatment (PT) – similar to the Mangere WWTP's current primary sedimentation process
- Detention treatment (DT)– This technology is considered as it provides good treatment over a range of performance conditions and is simple to operate, reliable, and rugged in its construction. Settling chemical application is uncommon and rare; however, it is being discussed in the USA as of late. The technology can also be readily blended into the community. This technology has a 'footprint' smaller than most conventional primary sedimentation tanks as the disinfection can be achieved in 10 to 12 minutes with rapid dispersion of sodium hypochlorite. UV disinfection with this technology would not be appropriate

- Vortex swirl separator (Vortex) – with no disinfection – uses flow velocity into unit and results in a centrifugal force pushing solids to the bottom of unit and discharging to sewer while treated water discharges
- Continual deflection separation (CDS)– using flow velocity to create centrifugal force and removal of gross particle constituents with a screen

2 PROJECT BACKGROUND AND OPTIONS EVALUATION CRITERIA

For purposes of the Central Interceptor Programme, Watercare are focusing options for controlling targeted large CSOs which are part of the current Watercare trunk sewer system. As part of the ongoing regionalisation of water and wastewater services in the Auckland region, Watercare will soon take ownership of the complete combined sewer system and as such will be considering how to address other CSOs that are presently owned by Auckland City. Watercare will be going through a process of understanding the location, size, magnitude and effects of these CSOs, and subsequently developing targeted levels of service which provide an adequate level of control. Through this process Watercare will analyse various options, and associated cost, including utilisation of the proposed Central Interceptor and locally based solutions such as storage tanks and strategic partial separation.

Watercare are considering utilisation of various wet weather treatment technologies which can be applied either locally or regionally, such as an additional treatment train at Mangere to handle high peak wet weather flows. This paper presents the results of an assessment of currently used wet weather treatment technologies including existing applications, ongoing performance and cost. Also presented are hypothetical examples of how this technology might be applied within the Auckland combined sewer system, using examples of a satellite application in the Meola Catchment targeting Watercare's two largest CSOs and a regional application as a parallel treatment train at Mangere. These examples have not been explored for purposes of developing recommended detailed solutions, but rather to assess the general viability of wet weather treatment and a high level understanding of cost and probable treatment performance. Further work is required to assess detailed specific options of utilising of wet weather treatment either in a satellite/local or regional form. This assessment will be largely dependent on key drivers for controlling CSOs, and the timing for achieving targeted levels of service. In evaluating these options it is important to consider the following issues with regards to satellite or regional applications:

Issues of satellite wet weather treatment applications:

- Operational complexity and control
- Distinction from conventional treatment plants in terms of not introducing a new discharge load to the environment (rather would be reducing an existing load) and only operating during wet weather conditions
- Proximity to residential areas
- Robustness of technology
- Reliability of technology including disinfection
- Treatment performance track record
- Required levels of treatment based on targeted levels of service
- Simplicity of operations and maintenance requirements
- Limitation of addressing multiple overflows and providing effects based benefits given the presence of other untreated overflows
- Management of solids and screenings
- Odour management
- Ability to consent
- Cost relative to other options
- Potential use as an interim measure

Issues of regional wet weather treatment application as parallel train at Mangere:

- Operational complexity and control
- Ability to enhance operational robustness including protection of secondary biological processes during peak wet weather flows
- Robustness of technology
- Treatment performance track record
- Ability to reduce required amount of tunnel storage and associated cost
- Enhancement of effluent quality and UV disinfection during high peak flow events

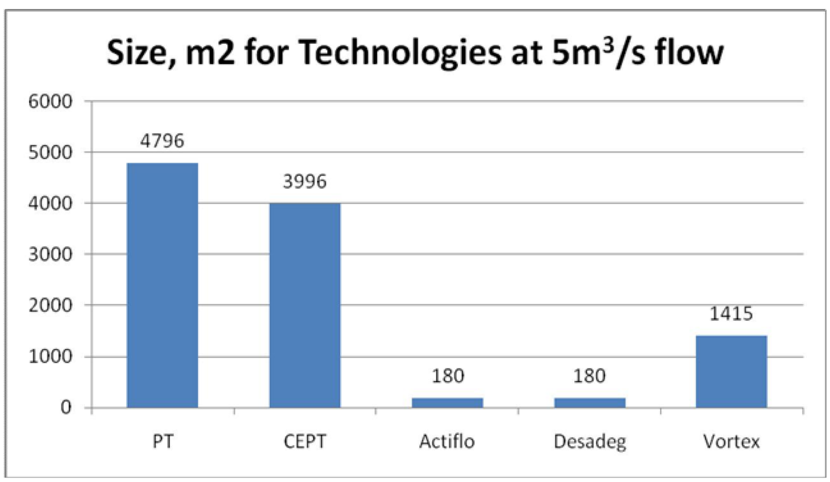
- Potential use as a redundancy and protection for primary and secondary clarifiers
- Required levels of treatment to meet overall effluent quality requirements
- Cost relative to other options for regional control of CSOs

For purposes of evaluating CSO treatment requirements a primary focused was placed on the ability to remove undesirable solids and floatables and utilisation of UV to disinfect to an appropriate level. Due to the short-term intermittent nature of wet weather CSO events and information about known impacts from CSOs, less emphasis was placed on the need to remove soluble constituents such as ammonia which are more important for treatment of normal base flow condition sewage. This is consistent with known applications of wet weather treatment in the United States and Europe.

3 OVERVIEW OF WET WEATHER TECHNOLOGIES ASSESSED

As described above, several technologies were assessed to provide wet weather treatment in either a regional form at the Mangere WWTP, or as a satellite facility in the Meola Catchment. To conduct an initial evaluation of wet weather treatment options an assumption of a required peak flow treatment rate of 5 m^3/s was established based on a cursory assessment of peak flows observed at the Lyons and Haverstock CSOs, and an evaluation of additional peak flows likely to occur at Mangere In some cases certain technologies were dismissed from detailed evaluation as a specific option due the current state of the technology (i.e. limited full scale applications and/or relatively unproven), or constraints regarding space requirements and treatment limitations. Regarding site space constraints Figure 3 is presented below, taken from Metcalf & Eddy 4th Edition, which shows required facility footprint sizes for various technologies evaluated based on an assumed design flow of 5 m^3/s. Based on this initial review, and an assumption that UV disinfection would be required, a decision was made to place emphasis on a detailed assessment of the ballasted flocculation technologies which is presented below. Other technologies such as vortex separation and detention tanks were assessed at a high level, but are not presented in this paper.

Figure 3 – Estimated Facility Footprint Sizes Based on 5 m3/s Design Flow



Ballasted flocculation is a general class of high rate wet weather treatment technologies which involves rapid mixing of chemicals to enhance settling, rapid flocullation, addition of a ballast material to add weight to the flocculants, and rapid settling using such technologies as a lamella plate system. This approach allows for very high loading rates, small facility footprints and utilisation as a temporary treatment system which can be brought on and off line during interim wet weather periods. The following provides an overview of the two most common ballasted flocculation technologies, Actiflo and DensaDeg, as they are typically applied to address wet weather treatment requirements.

Ballasted Flocculation (BF)

Objective

Treatment of excess wet weather flow via a physical and chemical process in either a regional or satellite location. The effluent from this process is also be disinfected utilising a UV system. The effluent from a satellite facility would be discharged directly to the environment at an appropriate location. A regional process located at Mangere could have a separate outfall or be blended with the plant liquids stream in a variety of pathways prior to UV disinfection.

Product Description

Ballasted flocculation, also known as high rate clarification, is a physical-chemical treatment process that uses continuously recycled media (microsand or recycled sludge) and a variety of additives (metal salt and polymer) to improve settling properties of suspended solids through improved floc bridging. Ballasted flocculation can also achieve pollutant removal through chemical precipitation of certain dissolved constituents.

The objective of this process is to form microfloc particles with a higher specific gravity. Faster floc formation and increased particle settling time allow clarification to occur up to ten times faster than with conventional clarification. Both Actiflo and DensaDeg use lamella settling components in the clarification area to further assist settlement. The result is a very small “footprint” in regards to land area.

Actiflo and DensaDeg are two industry standard processes and are considered suitable for either a stand alone, satellite wet weather system or as a parallel wet weather treatment train at a WWTP.

Disinfection would most likely be with UV. While chlorination and de-chlorination is widely used in North America, UV is the preferred disinfection method for wastewater in NZ. UV in series with ballasted flocculation is being used at installations in the USA and the UK. One constraint that must be imposed in order to use UV disinfection is the use of aluminium-based coagulants as iron-based coagulants interfere with the UV disinfection. While both Actiflo and DensaDeg both perform better in wet weather applications with iron-based coagulants, aluminium-based coagulants have been successfully used.

Comparisons between Actiflo and DensaDeg give the Actiflo system a slight edge in overall comparisons between the two based on the literature and information gathered for the report.

Actiflo can process flows between 10 and 100 percent of its nominal design capacity which allows the system to handle a wide range of wet weather events. Screening is required upstream of both processes. Actiflo requires 6mm screens while DensaDeg requires 12mm screens (Actiflo requires finer screens to avoid blocking the hydrocyclone for sand removal from sludge). The requirement for grit removal is typically a function of annual activations. For higher activation frequency (say >10 to 12 per year) grit removal would be required.

This technology provides the highest level of TSS and BOD removal of those considered in this paper and it also requires the highest level of operator involvement in terms of monitoring and control, however, this is minimal if located at an existing wastewater treatment plant.

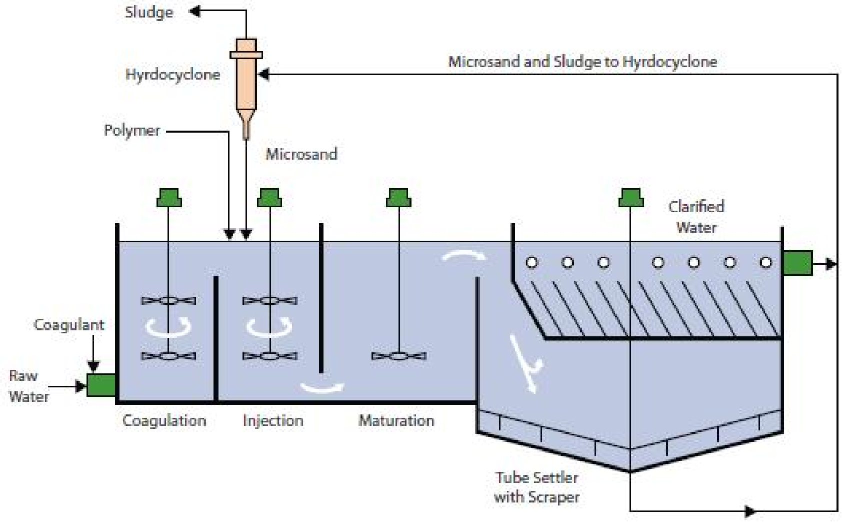
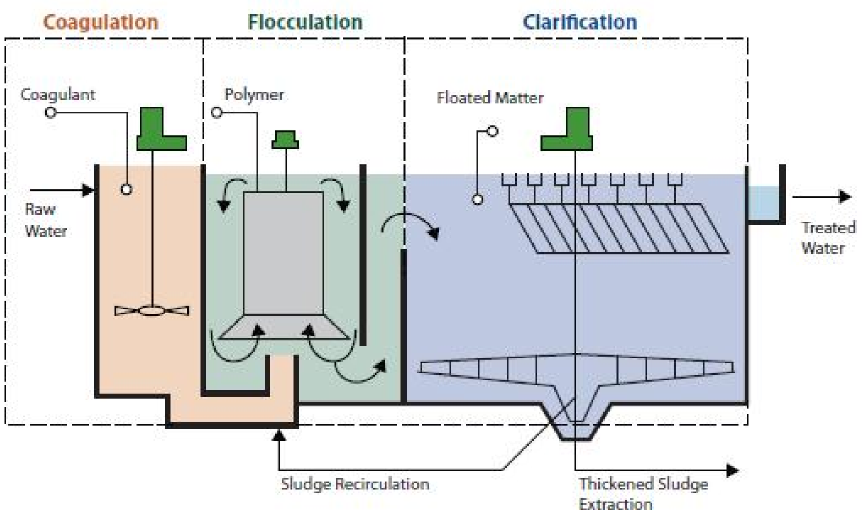
Operation and Maintenance

- BF with microsand (Actiflo) has a quick start up time compared to a dense sludge type BF (DensaDeg)
- Requires more optimization and control as compared to other CSO technologies
- Simple technology if compared to some WWTP unit processes
- Manned 4-8 hours per event on average

Key Product Points

- High treatment efficiency
- Good technology coupled with UV disinfection

- Small footprint compared with conventional clarifiers
- High loading rates 2400 $m^3/m^2/d$ or 100 m/h rise rate
- Short start-up time (10 to 20mins Actiflo, <30-45 min DensaDeg)
- Can be entirely automated and with local and remote monitoring and operational capability depending on degree desired

Actiflo

About the Manufacturer Veolia Environmental Services is one of the world's leading providers of waste management and cleaning services and is represented locally in NZ. Examples of Actiflo facilities in New Zealand can be found in Gore and Warkworth.
DensaDeg


4 EXAMPLE APPLICATIONS AND PERFORMANCE OF BALLASTED FLOCCULATION

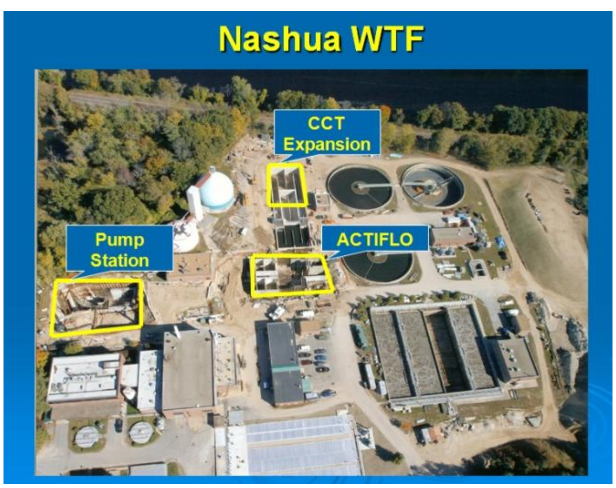
This section focuses on the Actiflo ballasted flocculation process due to the lack of presence with DensaDeg in New Zealand and concerns over required facility start-up times.

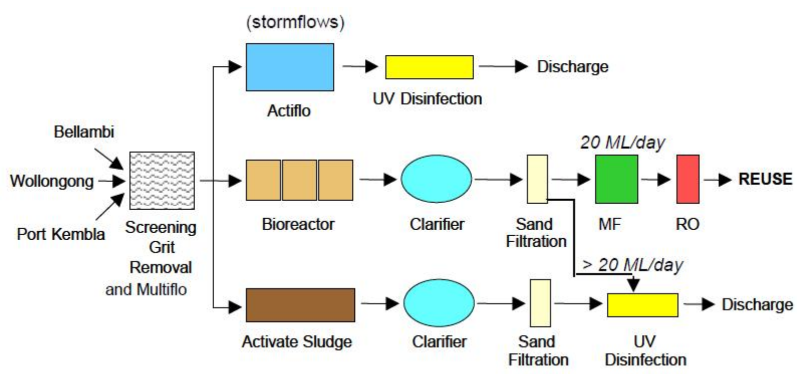
4.1 EXAMPLE FACILITY OVERVIEWS

The following presents summary fact sheets for example applications of ballasted flocculation facilities applied for treatment of wet weather flows. This includes examples of satellite (remote locations at specific overflows sites) and regional (located in parallel with existing wastewater treatment plants) facilities.

Treatment Technology	**Ballasted Flocculation – Regional Facility at Existing WWTP**
Project Name	**Nashua, New Hampshire**
Treatable flow rate	2.6m^3/s
Cost	$US27.5m (includes new pumping station and expanded disinfection facility)
Description	AECOM conducted a re-evaluation of Nashua's long-term CSO control plan, which will save the city nearly $US200 million compared to a previous plan. As part of this revised plan, AECOM designed the high-rate CSO treatment facility with a capacity of 2.6m^3/s that will discharge treated wet weather flow blended with existing plant effluent. The facility includes screening and grit removal, a 2.6 m^3/s pump station, ballasted flocculation treatment and chlorine disinfection. It is activated very little during the year with total activations to date of less than 10 times. The wet weather treatment facility controls have been incorporated into the wastewater treatment plant's existing SCADA system. The plant uses sodium hypochlorite disinfection. Construction of the wet-weather facility was completed in January 2009, and preliminary performance and acceptance testing has been satisfactorily completed. The facility has a construction cost of $US27.5m. Testing results (shown in the following section) indicate consistently high TSS removals up to 90%+.

Photo



Treatment Technology	Ballasted Flocculation – Regional Facility at Existing WWTP
Project Name	**Illawarra, Wollongong -NSW, Australia**
Treatable flow rate	1.7m^3/s
Cost	Cost unavailable
Description	Sydney Water supplies more than 1.7 billion litres of water to more than 1.6 million homes and businesses each day. It provides drinking water, wastewater services, and some stormwater services to customers in the communities of Sydney, the Blue Mountains and the Illawarra. Veolia Water Systems was contracted by Sydney Water Corporation to design, build and provide operational advice for upgrading three wastewater treatment plants south of Sydney (Bellambi, Port Kembla, Wollongong) to serve 300,000 residents. As part of the upgrade was the conversion of existing Bellambi and Port Kembla STPs to storm sewage treatment plants to store and treat wastewater. As a result of this upgrade, the city of Wollongong now has one of the most advanced coastal treatment plants in the world. The system is currently providing benefits such as: Improving water quality at Illawarra beaches, particularly those near sewage treatment plants. Protecting coastal water sand reducing impact on sensitive marine ecosystems. Minimising the effluents negative impacts when effluent from BF is released to the environment. Supply high-quality recycled water for industrial reuse. The upgraded facility at Wollongong will provide biological treatment to flows of up to 2.1 m^3/s (three times ADWF). Flows in excess of this, up to maximum of 3.7 m^3/s, will be treated using the high rate ballasted flocculation process, Actiflo®, followed by UV disinfection.
Schematic	

Treatment Technology	Ballasted Flocculation – Satellite Facility at CSO Location
Project Name	**East Bremerton Satellite CSO Treatment Facility, Bremerton, Washington USA**
Treatable flow rate	1 m^3/s
Cost	US $4.1m (includes cost of UV disinfection system)
Description	Bounded by the Puget Sound and divided by the Port Washington Narrows, the city of Bremerton, Washington, is also home to the Puget Sound Naval Shipyard. In its early development, the city combined its sewer and stormwater into one system that conveyed the water directly into the Puget Sound, untreated. As the city continued to develop during the 1940s, primary sewage treatment plants were built, into which combined sewer flows were redirected for treatment. By design, CSOs occurred during storm events. The city decided to build a satellite CSO treatment facility in East Bremerton adjacent to the Port Washington Narrows. The facility needed to have rapid start-up capability and be equipped to quickly meet peak removal efficiencies. As a result, chemical feed and ultra-violet (UV) disinfection equipment, coupled with a high-rate clarification system, were recommended. The Actiflo process has consistently exceeded state performance requirements for CSO treatment plants at the 20-mgd (1 m^3/s) East Bremerton CSO treatment facility in the US state of Washington, according to John Poppe, wastewater manager at Bremerton's Public Works and Utilities. The process is at the heart of the 10-mgd East Bremerton CSO treatment facility, which has complied with state and federal CSO rules since coming online in December 2001. Consequently, the improved water quality has increased the potential for shellfish harvesting in Puget Sound. The Bremerton facility can start up and achieve excellent performance in only 15 minutes. The process is removing between 90 percent to 95 percent of TSS, 80 percent of BOD, and 85 percent of total phosphorous. Effluent turbidity levels are less than 3 NTU. Post-clarification, the treated effluent passes through medium-pressure, high-output UV disinfection before it is discharged into the Puget Sound.
Photo	

4.2 SUMMARY OF EXAMPLE BALLASTED FLOCCULATION PERFORMANCE RESULTS

Table 1 presents performance data summaries for various supplemental treatment technologies including ballasted flocculation.

Table 1 – Performance Data for Selected Wet Weather Treatment Technologies

Technology	Sources	Hydraulic Capacities and Removals			
		Hydraulic Capacity ($m^3/m^2/d$)	Hydraulic Capacity ($m^3/m^2/d$)	BOD Removal (Percent)	TSS Removal (Percent)
		Lower	Upper		
Primary Clarification / Detention Treatment	Metcalf and Eddy 1991: NEIWPCC 1998 WEF 1996	28	141	25-40	50-70
Chemically Enhanced Primary Treatment	US EPA: In Plant Flow WW Management 2007	140	165	40-50	75-85
Screening	Metcalf and Eddy 1991:				
Coarse (5mm-25mm)		987	4042	NA	15-30
Fine (0.1mm-5mm)		7.05	65.8	NA	40-50
Micro(<0.1mm)		7.05	65.8	NA	40-70
Vortex Separation/CDS	EPA 1996 Boner et al 1995 WERF 2002	NA	4700	Up to 55	5 to 60
Ballasted Flocculation	Raddick et al. 2001 Scruggs et al. 2001 Vick 2000 Poppe et al 2001	NA	4230	65-80	70-95
Chemical Flocculation	Metcalf and Eddy 1991; Moffa 1997	NA	940	40-80	60-90

The following present performance results of Actiflo wet weather treatment facilities including pilot studies and full scale plants. In all cases reviewed the Actiflo system consistently met removal performance targets, and using the appropriate chemicals produced an effluent quality acceptable for UV disinfection to meet typical standards.

United Utilities Millom Works Pilot Test

In the UK, a 200m3/h Actiflo pilot plant was operated for 12 months at United Utilities' Millom works on the Cumbrian coast in the Lake District National Park. Some 90 trials were carried out on the pilot plant over the 12-month period; 50 under storm conditions and the remainder taking stored storm water from the works' storm-water tank. In every case, the effluent UV transmissivity was consistently high

enough (greater than 50 per cent) for an ultraviolet disinfection unit downstream of the clarifier to meet the microbiological consent for discharge to a bathing beach or shellfish water. Both ferric and aluminium coagulants were trialled, and both gave suspended solids reduction in excess of 90 percent, producing effluent suspended solids below 25mg/l; a figure that was reached within 10 minutes of start-up. COD reduction was generally 60-70 percent and total phosphorus removal was in excess of 80 percent.

Berlin CSO Pilot Facility Test

A shorter-term trial was carried out, this time over 52 days, in Germany starting in mid-January 2008. A mobile pilot plant was located in the car park of the Berliner WasserBetriebe office building in Bellermannstrasse, Berlin. It was situated approximately 5m away from, and running parallel to the CSO chamber installed at this location. A temporary submersible pump was installed to take water from the chamber and deliver it to the inlet of the Actiflo unit. Clarified water from the Actiflo unit was discharged under gravity to the adjacent sewer, together with the sludge from the hydrocyclone. During the trial period, 10 runs were carried out: the first with simulated raw water produced by diluting raw sewage with mains water in the CSO chamber, the rest of the runs were conducted during actual storm-overflow conditions. The pilot plant results from the Berlin trial confirmed the results from the Millom trial, namely a better than 60 percent removal of COD, more than 80 percent reduction in total suspended solids and more than 80 percent reduction in total phosphorous. They also confirmed that this performance can be achieved within 10 minutes of start-up.

Lawrence Wastewater Treatment Plant Full Scale (2m³/s) Wet Weather Facility Performance

The Lawrence Wastewater Treatment Plant (WWTP) was expanded and improved to accommodate the City of Lawrence, Kansas, future growth, maintain compliance with new regulatory requirements, and meet facility needs up through the design year 2020. To accommodate future projected storm flows or sanitary sewer overflows (SSO), a wet weather facility consisting of 40 million gallons per day (mgd) ballasted flocculation system was constructed to direct discharge with the main WWTP effluent to the Kansas River. The Actiflo® system, which has been in service for over a year and half, has been operated during ten peak flow storm events that lasted anywhere from four hours to 47 hours. The disinfection and dechlorination system selected for the Lawrence WWTP wet weather treatment facilities was sodium hypochlorite and sodium bisulfite, respectively. A separate contact basin was provided for the wet weather facilities flow. The wet weather facility effluent is blended with the main plant effluent to meet the combined chlorine residual as indicated in the plant's NPDES permit. During the first year of operation, the Actiflo® unit encountered a variety of influent flow characteristics and operating conditions. Real-time operating experience has been obtained. For each storm event, the polymer and ferric chloride dosages were optimized to enable the effluent to meet the plant's permit. Over the operating period the Actiflo system has consistently removed 80 percent of the turbidity. The TSS percent removal is around 88 percent. As a result of the removed solids, the City of Lawrence is able to meet the plant's NPDES for BOD, TSS, and chlorine residual.

East Bremerton Full Scale Satellite CSO Treatment Facility, Bremerton, Washington USA

The Actiflo process has consistently exceeded state performance requirements for CSO treatment plants at the 20-mgd (1 m3/s) East Bremerton CSO treatment facility in the US state of Washington, according to John Poppe, wastewater manager at Bremerton's Public Works and Utilities. The process is at the heart of the 20-mgd East Bremerton CSO treatment facility, which has complied with state and federal CSO rules since coming online in December 2001. Consequently, the improved water quality has increased the potential for shellfish harvesting in Puget Sound. The Bremerton facility can start up and achieving excellent performance in only 15 minutes. The process is removing between 90 percent to 95 percent of TSS, 80 percent of BOD, and 85 percent of total phosphorous. Effluent turbidity levels are less than 3 NTU. Post-clarification, the treated effluent passes through medium-pressure, high-output UV disinfection before it is discharged into the Puget Sound.

5 OVERVIEW OF OPTIONS AND COST DEVELOPED FOR SATELLITE AND REGIONAL WET WEATHER TREATMENT

The following presents a summary of options and cost estimates developed for applications of a satellite ballasted flocculation treatment system, using the Actiflo technology, in the Meola Catchment and a regional ballasted flocculation treatment system at Mangere. In both cases it was assumed that UV disinfection treatment would need to be included and a peak design flow rate of 5 m³/s would be used.

5.1 MEOLA SATELLITE WET WEATHER TREATMENT CONCEPT OPTION AND COST

Figure 4 below provides a concept process flow diagram schematic for a satellite ballasted flocculation in the Meola Catchment which would treat two of the largest CSOs in Auckland up to a maximum peak flow of 5 m³/s.

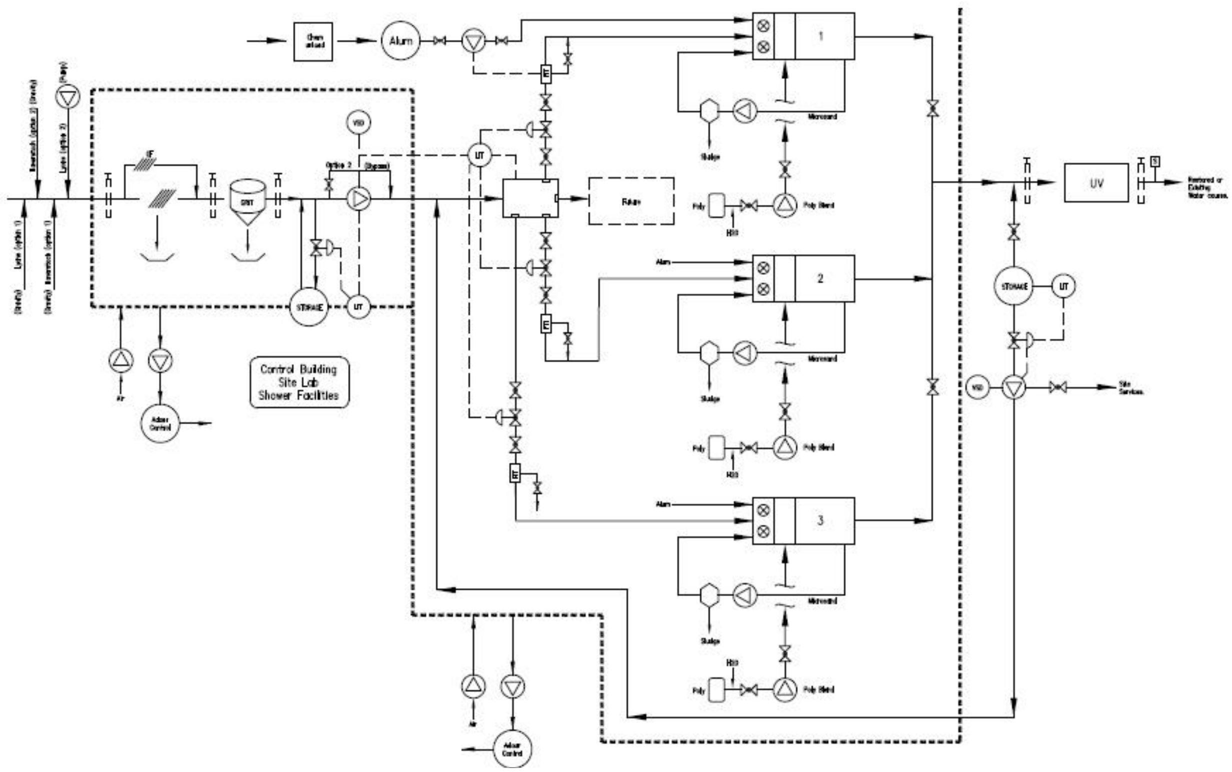


Figure 4 – Concept Process Flow Diagram for Meola Satellite Ballasted Flocculation System

Overflow from Haverstock and Lyons would be conveyed to a centralised location for initial screening and grit removal. Smaller overflow events would be stored within a small, storage tank prior to being pumped back into the trunk sewer. Larger events would use the stored overflow to prime the ballasted flocculation facility before activating to treat flows to a peak of approximately 5 m³/s. Overflows in excess of this would bypass the treatment device. Treated effluent would then pass through UV disinfection prior to discharge into the Meola Creek. Two concepts were developed for the configuration of Actiflo at this location as shown in Figure 5 on the next page.

Sludge from the Actiflo would discharge into the trunk sewer downstream of the overflows for treatment at Mangere.

Key points about this option are:

- A high capacity pump station would be required for the design to work hydraulically

- The facility would be located within a residential area and would therefore require potential extensive public consultation. Considerable effort may be required with regard to the aesthetics and odour control of the facility. There are numerous examples of satellite wet weather facilities which have been placed in residential areas, but typically require additional cost to address aesthetic, odour and noise issues

- Start-up and operation of this facility would need careful consideration. Key issues to address would include operational complexity, use of telemetry, chemical handling and storage, and regular maintenance requirements. Facility operations would require on site personnel prior to and during wet weather events. This would include required procedures to prep the facility for start-up in anticipation of a CSO activation, perhaps facilitated through the use of remote monitoring telemetry

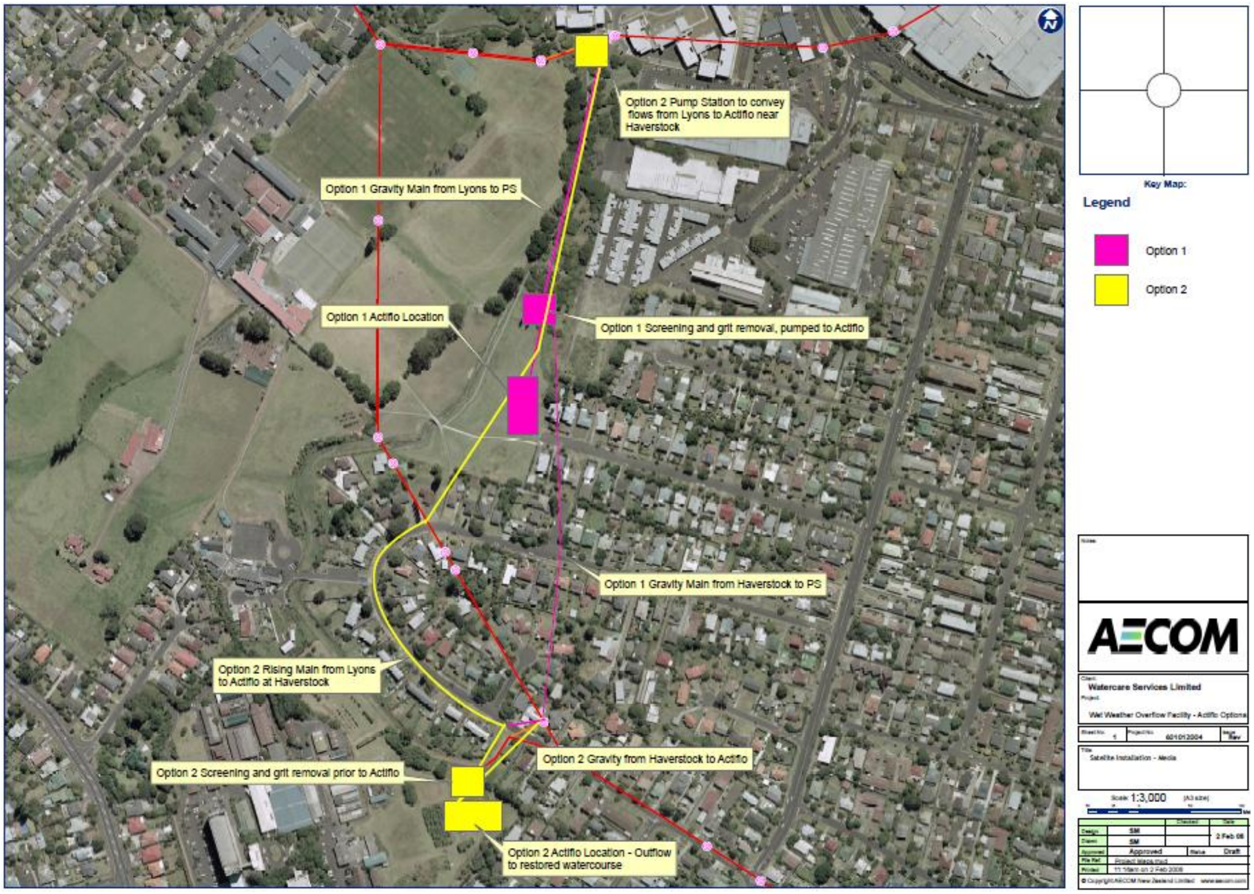


Figure 5 – Concept Options for Satellite Wet Weather Treatment in the Meola Catchment

Capital cost for this option have been estimated at approximately $38m which includes the wet weather treatment system, pumping station, buffer storage tank, UV system, enclosure buildings to address visual/noise/odour issues and a 30 percent contingency to address unknowns and risk. Annual operating cost, based on monitoring data from the CSOs, are estimated at $0.8m/year – resulting in a 20 whole-of-life cost $43m.

5.2 MANGERE REGIONAL WET WEATHER TREATMENT CONCEPT OPTION AND COST

Figure 6 below provides a concept process flow diagram schematic for a regional ballasted flocculation system at Mangere which would treat intermittent wet weather peak flows up to 5 m^3/s that exceed the biological treatment system.

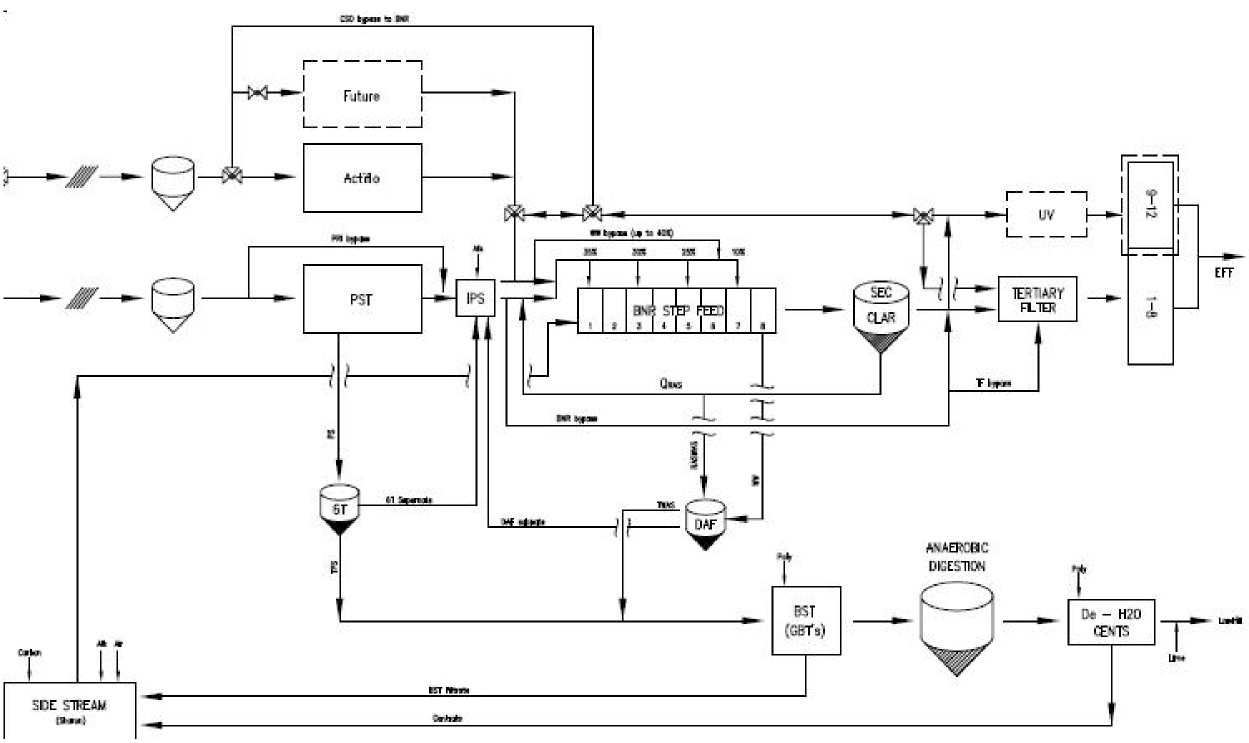


Figure 6 – Concept Process Flow Diagram for Regional Wet Weather Treatment at Mangere

An Actiflo ballasted flocculation system could be placed at Mangere as a parallel treatment train to the existing biological nutrient removal (BNR) system. In concept, this wet weather treatment system would accommodate flows in excess of the BNR system for up to 5 m³/s, including wet weather flows delivered by the Central Interceptor tunnel system. The effluent from the ballasted flocculation system would be treated either with a new independent UV disinfection system or more likely would be blended with the BNR effluent and treated with the existing UV disinfection system which has sufficient capacity.

Sludge from the Actiflo facility would be processed in the plant and the effluent could be blended at multiple points depending on the degree of treatment and process consent condition at time of year.

Key points about this option are:

- Issues of operational complexity and start-up requirements are somewhat alleviated by placing the wet weather treatment facility at an existing plant which is manned 24 hours a day.
- Ballasted flocculation could possibly be used to enhance the overall performance of Mangere during interim peak wet weather flow conditions by de-stressing the existing BNR system. Detailed monitoring and process modelling may show that the effluent quality will be enhanced by utilising wet weather treatment at Mangere during high flow events.

Capital cost for this option have been estimated at approximately $30m which includes the wet weather treatment system, new parallel wet weather UV system, and a 30% contingency to address unknowns and risk. Annual operating cost, based on network hydraulic models, are estimated at $0.8m/year – resulting in a 20 whole of life cost $35m.

6 CONCLUSIONS

Wet weather treatment technologies have developed dramatically over the past 20 years. There are many different technologies to consider which provide varying degrees of treatment. Site specific conditions and local treatment

requirements for wet weather overflows and intermittent high peak flows must be carefully considered in assessing options and cost. Many full scale examples of satellite and regional wet weather treatment facilities exist, and detailed performance shows that these technologies can achieve targeted wet weather treatment requirements when applied appropriately.

As part of the Central Interceptor Programme options for wet weather treatment have been assessed for both a satellite application in the Meola Catchment to address two of the largest CSOs, and as a regional treatment facility operating at Mangere in parallel with the existing BNR system. Concepts for these options have been developed, including estimates of cost and performance ability.

Results of the analysis completed for the Central Interceptor Programme indicate that a regional wet weather treatment facility at Mangere would be the preferred option over satellite treatment facilities in the targeted combined sewer area. This conclusion only applies to the targeted service area for the Central Interceptor as there are other overflows which will not be directly addressed by this tunnel. For overflows outside of the Central Interceptor service area local solutions such as storage, targeted separation and satellite wet weather treatment will likely prove to be highly cost effective depending on targeted levels of service and performance criteria.

Regional wet weather treatment at Mangere appears to provide a highly cost effective solution to addressing targeted CSOs for the Central Interceptor Programme. The following provides key reasons which indicate that regional wet weather treatment should be assessed in more detail as viable solution for the Central Interceptor Programme:

- The cost of a regional wet weather facility at Mangere is less than a satellite facility due to issues of local site requirements and the ability to utilise existing systems at Mangere. Both facility cost, ranging in total from $35m to $48m on a 20-year NPV basis, provide a highly cost effective means to address intermittent wet weather flows.

- Issues of operational complexity, visual impacts, odours, noise, etc are far more easily addressed by placing a facility at Mangere than within a highly developed residential area which is remote from existing Watercare operational facilities.

- Wet weather treatment technologies are proven to provide a highly cost effective means for addressing intermittent peak wet weather flows that cannot be addressed through conventional biological treatment systems. Many full scale facilities exist which have been proven to work and to meet targeted performance criteria.

- Wet weather treatment in the form of ballasted flocculation will likely address required treatment needs at Mangere during intermittent peak flow conditions. This technology has been shown to produce a high quality effluent in terms of low turbidity which is amenable to UV disinfection – arguably the primary focus during short term wet weather periods. It has also been shown to be quite effective in removing BOD, TSS, metals, phosphorus and other constituents of concern. This includes additional flow which will be conveyed by the Central Interceptor system, providing a facility that can address multiple CSOs from one location.

- Initial assessments of wet weather treatment at Mangere show a cost effective means of optimising conveyance, storage and treatment cost for the Central Interceptor Programme. Utilisation of wet weather treatment allows the size of the Central Interceptor tunnel to be reduced to an optimal point which still addresses all targeted drivers including control and treatment of CSOs. One comparison shows that wet weather treatment could potentially reduce the cost of the Central Interceptor system by as much as $100m in whole-of-life cost – and perhaps deliver better total annual pollution load reductions to the environment.

- Additional work required to assess the concept of wet weather treatment for the Central Interceptor Programme includes detailed wet weather sampling at Mangere, process modelling and trunk sewer modelling including representation of the Central Interceptor tunnel. This work is moving forward as part

of the development of the Mangere Wastewater Treatment Master Plan and the Central Interceptor concept design.

- Consideration of wet weather treatment technologies to address overflows and intermittent high peak flows at other locations needs to carefully assess site specific conditions and treatment needs. In many cases this technology has proven to be highly cost effective in lieu or more traditional solutions such as local storage, conventional treatment, separation and inflow/infiltration reduction programmes. Quite often the technology has been shown to produce better overall results for reducing pollution loads associated with wet weather impacts.

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