

WASTEWATER OUTFALLS – INTERNATIONAL PERSPECTIVES RELATIVE TO NEW ZEALAND

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ABSTRACT

New Zealand has many wastewater outfalls, the majority of which discharge to the marine environment either at the shoreline, into harbours and estuaries or as offshore ocean outfalls. While the New Zealand approach to outfall siting investigations, environmental effects assessments, resource consenting, and operation and maintenance is well developed, it is timely to carry out a stock take of current international practice.

The author has been closely involved with many of New Zealand's outfall investigation and consenting projects. As a result of this extensive experience and interest in the topic, he is now a committee member of the International Water Association's (IWA) Specialist Group for Marine Outfall Systems. He attended the IWA International Symposium on Outfall Systems (ISOS) in Ottawa in May 2016 and from that symposium and input into a global outfalls paper, he has prepared this paper as part of an update and up-skilling for those associated outfalls in New Zealand.

KEYWORDS

New Zealand wastewater outfalls, global outfall experience, marine outfalls, outfall receiving environments

1 INTRODUCTION

This paper features some key outputs from the IWA's specialist groups Marine Outfall Symposium (ISOS) held in Ottawa May 2016 and from the global outfall paper the IWA's specialist outfalls committee members recently produced. Topics covered at the Symposium included:

- Current trends and practices in design, operation and regulation of marine outfall systems.
- New paradigms for outfall designs including the consideration of a wide range of operating conditions, maximising water reclamation and energy efficiency and close liaison with governments and regulatory agents.
- Development of improved understanding of mixing phenomena for stratified flow and unstable discharges.
- Future challenges including improvements in design considerations, establishment of regulatory guidelines and better understanding of biological and physical reactions between discharges and receiving environments.
- Physical processes including improved understanding of discharge dynamics under a range of environmental conditions.
- Management of cumulative effects of multiple outfalls in proximity to each other.
- Progress to sustainable outfalls including using natural processes and systems, creating opportunities for nature, added value for developers and stakeholders, potential for cost saving on life cycle basis and the potential for creating new habitats.
- The "state of the art" on research and practice in the field of outfalls

A number of these topics are expanded on below as part of excerpts from the Committee's global paper and from the symposium papers.

In reviewing the global state of knowledge on outfalls and recent projects New Zealand outfall projects, it must be emphasised that New Zealand has a significant number of wastewater outfalls. These are both municipal and industrial outfalls that discharge into the marine environment. They include shore line outfalls, short length outfalls or off shore outfalls. The following figure clearly demonstrates the predominance of marine outfalls discharging treated municipal wastewater from coastal cities and towns into the marine environment.



Figure 1 – New Zealand outfalls

The author estimates that over 70% of New Zealand's treated wastewater discharges directly into the marine environment. In some schemes for example Hastings and Dunedin (Tahuna) the treated wastewater contacts rocks for Maori cultural purposes before discharge into the marine environment.

New Zealand also has numerous outfalls that discharge into freshwater. The two largest municipal outfalls are Hamilton with a full width multiport diffuser into the Waikato River and Palmerston North with a bankside rock wall discharge into the Manawatu River.

In relating this paper and the overseas projects it features to New Zealand circumstances, the reader should keep in mind the matters listed below as they provide a benchmark or comparison on which to gauge the relevance and applicability to the New Zealand context.

- New Zealand has approximately 20 offshore ocean outfalls of between 500m to 3000m in length.
- The Resource Management Act's effects based resource consenting process requires a thorough assessment of alternatives and wide ranging environmental effects studies.

- Almost without exception the degree of wastewater treatment of New Zealand's wastewater discharges are of a high to very high standard, compared to many overseas discharges. The New Zealand approach of matching treatment standard to the receiving environment's assimilative capacity is well developed. In some cases generally for political reasons, discharges have higher levels of treatment than that required from a technical environmental effects assessment viewpoint.
- A number of marine discharge schemes such as those of Timaru District Council and Waimakariri District Council collect wastewater from a number of towns and communities and convey the treated wastewater relatively long distances to be discharged from a single ocean outfall.
- In terms of professional services New Zealand has a number of long established and well recognised outfall modelling organisations and monitoring and research organisations. These include universities, Crown research organisations and specialist consultants. In terms of universities, the Civil Engineering Department of the School of Engineering at the University of Canterbury undertakes specialist research on outfall modelling. This work is led by Professors Davidson and Nokes. Professor Davidson presented a paper titled "Quantifying Boundary Impingement of Inclined Negatively Buoyant Jets" (A Ramakanth, M Davidson, R Nokes) at the Ottawa Symposium.
- With increased pressure on fresh water and a more restrictive regulatory environment as a result of the implementation of the National Policy Statement on Fresh Water Management 2014 (NPSFM), it can be expected that more communities located within an economic conveyance (piping) distance of the coast will adopt the option of a marine discharge for the disposal of their treated wastewater. However it is expected that in the marine environment, especially estuaries and harbours greater emphasis will be placed on water quality and ecological maintenance and improvement.

2 DISCUSSION

2.1 GLOBAL OUTFALL UPDATE PAPER

This paper titled Marine Outfall Systems – Current Trends, Research and Challenges – compiled by the Specialist Group of Marine Outfall Systems – Authored by Botelho and IWA specialist outfall committee members including the author of this paper has been issued by IWA following the International Symposium on Outfall Systems, Ottawa May 2016. This approach is followed throughout this paper.

Extracts from the global paper are shown in italics.

Introduction to the Global Paper

Being a relatively mature field of engineering and science, the ongoing research and changing trends are focused on improving techniques to reduce uncertainties at each of the stages. These trends include: better understanding of acceptable ecological impacts; better field and process measurement techniques; better writing of regulations and legislation; better and more cost effective construction and maintenance; better communication and engagement with community and stakeholders, and better prediction of near and far field dilutions for complex diffusers. However, as regulatory requirements change and new technologies come to light, design of outfalls will necessarily require further thinking to work within a sustainability paradigm.

Table 1 below shows the range of topics covered by the papers presented at this Symposium.

Table 1 – Topics of papers presented at ISOS 2016

Topic	Number of Papers on the Topic (papers can cover one or more topics)
Farfield Modelling	21
Sewage Discharge	15
Nearfield Modelling	13
Nearfield CFD Modelling	11

Topic	Number of Papers on the Topic (papers can cover one or more topics)
Nearfield Laboratory Experiments	11
Desalination Discharge	10
Water Quality Modelling	8
Field Experiments	5
Intake and Outfalls Design	5
Discharges in Rivers	4
Other themes (less than 3 papers on each topic): Oil Spill Modelling, Bubble Plumes, Field Characterization and Monitoring, Hydrothermal Systems Modelling, Industrial Discharges, Near and Farfield Model Integration, Turbulence Measurements, Construction and Installation Methods, Decision Support Systems, Multiple Discharge Analysis, Stormwater Discharges, Data Analysis Techniques, Discharges Under Ice Cover, Internal Diffuser Hydraulics, Nozzle Characteristics, Pollutant Effects on Biota.	

Table 1 highlights a predominance of outfall modelling papers as many of the world's leading modellers attended the Symposium. There was a noticeable interest in and over all request for future Symposiums to include a much wider range of papers on topics relating to ecological and other environmental considerations, community and stakeholder consultation and permitting/licencing experiences.

Terminology and Definitions

The IWA Specialist Group on Marine Outfall Systems identified the need for more consistency in the use of terms internationally and in clearer definitions of the terms such as “near field” and “far field”. In the USA for example, these two terms are often included in outfall discharge licence compliance limit conditions. When confusion exists over definitions, this can result in disputes and even prosecution for non-compliance. The terms the Group has identified and adopted in the global paper are:

Outfall or outfall systems – a piece of engineering structures designed to convey industrial and/or domestic effluent into ambient waters as a means of reducing the impact of (treated or untreated) anthropogenic waste to acceptable impact levels to the receiving environment.

Zone of impact or the regulated mixing zone – a finite and well-established area surrounding an outfall that is agreed with regulators and stakeholders where water quality constituent concentrations can be exceeded over locally accepted and prescribed values for natural waters.

Jet entrainment – incorporation of ambient water into the released effluent stream leading to increased mixing with ambient waters.

Jet shear – the velocity gradient in the interface of the released effluent stream and the ambient water.

Bed scour – erosion of the seabed associated with the location and operation of the outfall system. It may occur from direct impingement of, or increased bottom shear stress caused by the released effluent stream or from interaction between the outfall structure with the local ambient currents and wave action.

Density stratification – vertical density gradient in the ambient waters generally induced by temperature, salinity, suspended, or dissolved solids.

Near field - the region adjacent to the outfall where the initial jet characteristic of momentum flux, buoyancy flux and outfall geometry dominate the dynamics of the released effluent trajectory and mixing with the receiving waters.

Far field - the region of the receiving water where the trajectory and dilution of the released effluent stream that is dominated by a combination of buoyant spreading and ambient diffusion.

Plume – the released effluent stream characterised by its momentum flux and buoyancy fluxes.

Diffuser or manifold – generally the final section of the outfall system that includes one or more ports delivering the effluent stream to the receiving environment.

Nozzle or port – a component of the outfall system of reduced cross section with the intent of maximizing the initial jet momentum flux and associated mixing with the receiving ambient water.

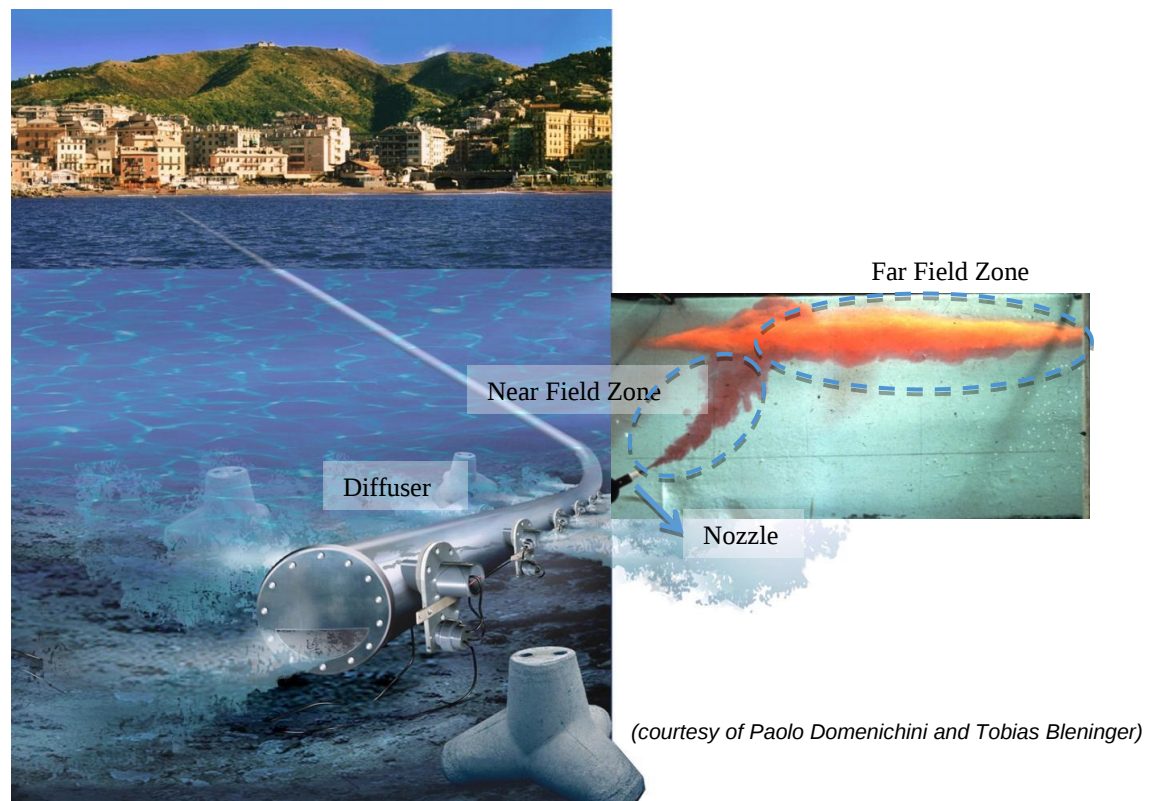


Figure 2 - Some common terms about submarine outfalls adopted in the text

In New Zealand we use the term “Mixing Zone” to mean the zone of reasonable mixing that is permitted in accordance with the provisions of the Resource Management Act 1991 RMA. In terms of the above terminology “mixing zone” or “zone of reasonable mixing” is consistent with the “*zone of impact or the regulated mixing zone*”.

Excerpts of interest for those associated with outfalls in New Zealand include:

Physical Processes

Although the fundamental physical aspects of the dynamics of outfall discharges are reasonably well established, opportunity exists to improve the understanding of the discharge dynamics under a range of environmental conditions. Such an understanding would allow improved outfalls design by optimising their performance with respect to the environments in which they operate and better integration of outfalls on a sustainability basis.

Given its flexibility, compared to laboratory experiments, numerical modelling techniques will also play a crucial role in the advancement of our understanding of physical processes over the next decade. Hydrodynamic and transport models will form the basis for both research and applied studies, particularly considering realistic, local scale, environmental forcing, and the multitude of configurations that can be adopted for multiport diffusers.

Despite advances on both simplified and 3D modelling approaches, there are still some modelling issues that require further research that have not been fully explored. In particular, it is expected that development of more advanced algorithms for dealing with mixing mechanisms will be directly applicable to outfall systems. Of these mechanisms, mixing associated with double diffusion processes (e.g. by both salinity and temperature differences), turbulent mixing in stratified zones, mixing of jets and plumes under crossflows, and mixing under the combined effects of wind, wave and tides are important processes that should receive increased effort in

future research. Recently, large eddy simulation (LES) approaches have become possible for outfall systems and it is expected that this approach will lead to better understanding of mixing phenomena. Nonetheless, further research will be required to create more robust LES software such that mainstream practitioners can use this method for their outfall design.

Future Focus

The IWA Specialist Group on Marine Outfall Systems proposes the following topics for focus in research and development over the coming years:

- *Development of improved understanding of mixing phenomena for stratified conditions and boundary effects for outfall discharges, as well as further understanding of mixing under unsteady environmental conditions. Such understanding should be achieved by means of both laboratory and numerical modelling experiments and will allow better integration of outfalls within a sustainable design concept.*
- *Development of improved understanding of the cumulative effects of several outfalls within a same location to form the basis of science-based guidelines and site-specific, ecologically-relevant environmental criteria with regards to the establishment of industrial estates. This will require the identification of “outfall hot-spots” and medium-to-long term monitoring of their performance and water quality and ecology of surrounding waters. In this case, regional numerical modelling should also form an integral part for the development of guidelines, assisting in exploring different sets of outfall arrangements.*
- *Establishment of a new paradigm for outfall design that is adaptive to future technological changes in treatment technology, maximising water reclamation and energy efficiency, and monitoring and understanding of the impacts of the discharge on the receiving marine environment. Furthermore, instead of only focussing on minimising environmental impacts, to create opportunities with a sustainable outfall design to improve other coastal functions (e.g. improving flushing or coastal protection) or the receiving environment (e.g. creation of local healthy habitats). Creation of this new paradigm should be accompanied of close liaison with governments and regulatory agencies for insertion of this new paradigm within their coastal zone management framework.*
- *Preparation of improved education and communication strategies over outfall systems with governments, regulators, key stakeholders and communities at large in that order to promote further understanding and in some geographies acceptance of such systems.*
- *Improvement of the understanding and rationales for the assessment of the interaction and balance between outfall discharge locations and the associated degree of the treatment of wastewater before discharge.*

The above excerpts from global paper provide a useful stocktake of New Zealand’s situation in terms of outfall investigations, modelling, physical testing, monitoring, design, construction and assessment of the impacts/effects of the discharges into marine and fresh waters.

The following are excerpts from a range of papers presented at the Symposium. They have been selected because the author of this paper considers they have particular relevance to the New Zealand situation in terms of both marine and inland water outfall investigations and outfall schemes.

2.2 MULTIPOINT DIFFUSER DESIGN

Outfall diffuser design is relatively well developed in New Zealand, however, globally as well as in New Zealand ongoing research and development of diffusers continues to take place. There is increased awareness by permitting and compliance authorities regarding the need for regulatory specification of appropriate diffuser requirements.

The following paper by Robert L Doneker et al provides a useful insight into the use of the CORMIX model (which Doneker developed) and also the CorHyd model and how practitioners should be aware of the differences that can exist between “as designed”, “as built” and “as in operation” as they relate to multipoint diffusers.

Multiport Diffuser Design for Regulatory Mixing Zone Compliance - Robert L. Doneker et al

Wastewater disposal systems are generally designed to meet minimum dilution requirements within a regulatory mixing zone, a limited region around the discharge structure where the initial dilution of the effluent occurs. We present a case study to site and design a multiport diffuser for a 0.7 m³/s (16 MGD) pulp mill discharge into a river. The field study includes a site bathymetry and velocity survey to determine optimal diffuser location. CORMIX mixing zone modelling software was used to design the diffuser for near-field mixing and regulatory compliance. In an iterative design process, CORMIX evaluated line source design dilution values within the regulatory mixing zone; the CorHyd model was then used to i) calculate port and pipe velocity, ii) verify uniform discharge distribution from the ports, and, iii) determine the diffuser head requirements.

The recommended design approach is based on modelling analysis with available data, using conservative assumptions. When software is used to design wastewater disposal infrastructure, quality of the analyses largely depends upon reliable input data. Good data and proper schematization of the ambient depth, density stratification, and ambient velocity is essential in addition to discharge geometry, density, and velocity. Dilution modelling by any known technique is not an exact science. CORMIX dilution predictions at the end of the near-field region may be up to +/-50% of the standard deviation of observed values. For hydraulic design calculations in multiport diffusers using CorHyd, a +/- 10% on calculated head values should be assumed.

Practitioners should be aware that differences can exist between “as-designed”, “as-built”, and “as-in operation” for multiport diffusers. Because of the dynamic nature of the natural environment, e.g. storms, floods, landslides, gravel bar migration, etc., the physical infrastructure of wastewater disposal systems must be inspected and maintained to ensure safe and reliable operation.

2.3 USE OF HIGH DENSITY POLYETHYLENE PIPES

Early New Zealand offshore outfalls were almost without exception constructed of pre-stressed concrete or concrete lined steel pipes strings that were shore assembled and towed out and sunk in excavated trenches, e.g. Hastings, Gisborne, Wellington, (Moa Point) Whanganui. More recent outfalls have mostly consisted of High Density Polyethylene Pipes (HDPE), e.g. Dunedin City Council, (Tahuna and Green Island), Christchurch City Council, Waimakariri District Council and others. This trend mirrors overseas trends.

At the Ottawa Symposium a number of papers covered HDPE pipeline projects. These included pipelines for the discharge onto the ocean floor of mining tailings and large offshore cooling water intake systems for power stations.

The following paper was a standout one not only in terms of the 2.5m diameter HDPE line, the largest diameter manufactured in the world to date, but also that the 430m long pipeline strings were towed by a tug from the factory in Norway to the cooling water intake in Algeria. Longer tows have been undertaken from Oslo factory to a number of South American countries.

Discussion at the Symposium also featured on the performance of HDPE pipes in earthquakes. Two examples were discuss - Chile which has 22 HDPE outfalls and only one was damaged in the large earthquakes there, and also the new Christchurch (New Zealand) 3000 m long outfall which the post-earthquake investigations show that it has not been damaged.

Paper: Case Study of Ø2500 mm HDPE Intake Pipelines for Ras Djinet 1200 MW CCPP in Algeria - Ilija Radeljić, Pipelife Norge AS, Norway

This was a paper of international significance.

Ras Djinet combined cycle power plant () in Algeria is a project worth over USD 1.1 billion which is currently under construction (due to commission in 2016), with intake pipelines already installed. Intake pipelines consist of four Polyethylene (HDPE) Ø2500 [mm] pipes, installed in parallel lines, approximately 1 [km] long each. Pipes are produced with solid wall (compact and homogeneous wall, no internal structure) in Norway and towed to the destination for installation.

The technology used to produce and deliver the pipelines is unique, with only one company in the world having the expertise and capability to produce and deliver solid wall Ø2500 [mm] HDPE pipes in long lengths to the site. Such technology has numerous advantages: significant reduction in the number of connections which lowers assembly time and eliminates leakage problems, fast installation of 360-500 [m] per hour, greatly reduced ovality, and no need for on-land storage. These numerous advantages, ensure safe and fast installation of the pipelines whilst maintaining the highest quality of the installed pipeline.

This paper explains all the stages of the project from production of nine pipes in long lengths (430 [m] and 452 [m] sections), transport with ocean going tugs from Norway to Algeria, mounting of weights, other equipment and finally submerging of pipes into ready-made trench. For the project, special fittings Ø2500 [mm], 5-12 [m] long (puddle flange fittings for connection to the pumping station with 15 degree bend and puddle flange fittings for connection with intake head) were produced and delivered on site. Standard specialty electrofusion saddle Ø2500 [mm] with inlet of 1000 [mm] was also produced to ensure watertight connection during projected lifetime of the project.

Manufacturing of the pipes and fittings for this project represents the latest development in plastic pipe technology and clearly shows the numerous advantages over conventional solutions for all projects involving intake or discharge pipelines used in the marine environment.



Photo 1 - The 2.5m diameter pipe section



Photo 2 – Production in progress

Transport by Towing with Ocean Going Tugs

The Ras Djinet Algeria paper referred to above highlights the technique of long tows by tugs. In that project after production of the pipes, backing rings were mounted and stub ends were welded on the pipes and the pipes were further prepared for the sea towage by ocean going tugs. The pipes took four weeks to be towed from our factory in Norway to the destination Port of Arzew in Algeria.



Photo 3 - Departure of the pipes from Norway



Photo 4 - Towing on the ocean

Special and unique towing arrangements have been developed by Pipelife over the years which enables pipe deliveries over long distances to destinations such as Columbia, Brazil, Uruguay and Dominican Republic. The flexibility of the HDPE pipes allows fluid absorption of wave motion as well as all the elements. The pipes have no problem accommodating waves as high as 8 meters (as documented on previous journeys), and the fatigue resistance in PE pipes is extremely good.

Installation of HDPE Pipes by the “S-Bend” Method

The Ras Djinet Algeria project used the “S-Bend” method of installation. The paper states:

Once the ballasting was complete, the pipes were towed one by one to the marine excavation ready to be sunk using the “S-bend” method. This method requires the HDPE pipes to be sufficiently ballasted and positioned on the surface above final installation location prior to the operation commencing.

STEP 4.

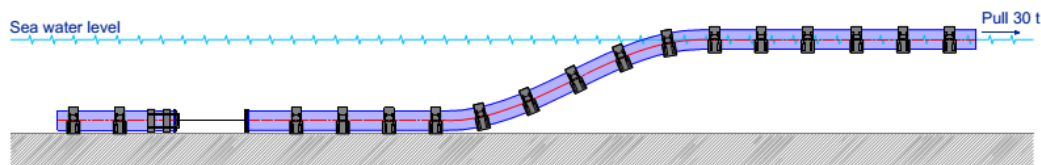


Figure 3 - Sinking schematic sample. Step 4 out of 6

After positioning, valves located on the sinking blind flanges on the end of pipe closer to shore are opened and water is allowed to flow in by either gravity or by the use of pumps. The pipe is then slowly lowered by gravity as the water continues to fill the pipe. At a certain moment during the operation, the pipe, or in this case, the ballast weight, will touch the seabed and form what is called a “J bend”. The process continues as subsequent ballast weights land on the seabed and form an “S bend” similar to a “snake shape”. The process continues until the last weight touches the seabed. During the operation various vessels were assisting the operation pulling the pipe string to keep a calculated tension and direction with assistance from smaller boats pushing the pipe sideways as needed.

The “S bend” installation method is extremely quick (a few hours on average once the process has started), controllable, reliable, reversible and with significantly reduced risks and has been in use for over 50 years to install PE pipes. The short installation time requirement is essential in marine work since weather has a huge impact and installation windows are relatively short and if missed, the whole construction can be postponed until next season (usually next year).



Photo 5 - Pipe is positioned and ready for start of submerging

This reliable and relatively simple installation method is one of main reasons for success of solid wall PE pipes in marine applications, along with inherent flexibility which absorbs wave and current forces, earthquakes and soil settlements.

2.4 DUCKBILL NOZZLER UPDATE

The paper by Michael J Duer of Tideflex Technologies a Division of Red Valve Company of USA highlighted the physical and hydraulic characteristics of Duckbill check valve nozzles (DBNs).

With a number of outfalls in New Zealand having Duckbill valves this paper provides an insight into physical and hydraulic characteristics of DBNs that may not be well known to outfall designers and modellers. The paper focuses on improving design and analysis. The following are extract of the key parts of the paper.

Duckbill Nozzle Knowledge Base for Inland and Marine Outfall Diffuser Designers and Modellers - Michael J. Duer - Tideflex Technologies, Division of Red Valve Company, Inc., USA

The paper's Abstract provides the background explanation and application of DBNs.

Duckbill check valve nozzles (DBNs) are utilized extensively in the design of inland and marine multiport outfall diffusers for both industrial and municipal discharges. When duckbill valves were initially utilized on outfall diffusers circa 1980, the sole intended purpose was to prevent the intrusion of sediment and salt water into the outfall pipe. With continuous hydraulic testing, modelling and research and development, other significant practical, physical, and hydraulic benefits of DBNs, such as enhanced initial dilution, improved salt water purging, and uniform flow distribution among ports have been discovered and presented in Lee (1997), Duer (2000), and Duer (2002).

Presented herein are physical and hydraulic characteristics of DBNs that may not be well known to outfall designers and modellers currently and therefore will improve their design and analysis efforts. A detailed discussion on the construction and fabrication of DBNs is presented to illustrate the large number of hydraulic

variations achievable per nominal size. Guidance on sizing and mixing zone modelling of DBNs is provided. Specification criteria and guidance are presented that can be used by outfall designers to evaluate DBN manufacturers as there is currently no international standard governing the design and construction of DBNs.

In terms of Duckbill valves and their operation, the following photos from this paper provide a useful explanation and communication graphic when consulting on discharge technologies and the details of diffuser valve discharges. The difference in duckbill types and geometry needs to be well understood in order that the appropriate design and operation requirements are achieved.

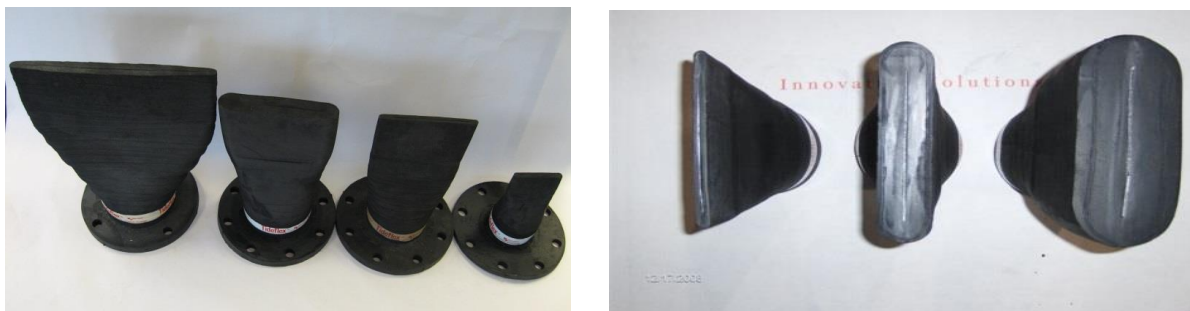


Photo 6 - Some of the geometry (left) and relative stiffness (right) variations of duckbill nozzles

2.5 CHLORINATION OF TREATED WASTEWATER FOR OUTFALL DISCHARGES

A topic that featured both in the key note address of Dr Joseph Lee of the Hong Kong University of Technology and in the following paper highlighted the value of laboratory experiments. In this case a dense chlorine jet discharging into a stationary treated sewage discharge was compared with numerical modelling.

The paper by J K Yang et al referred to below, highlights the considerable economic value that can be achieved by both physical modelling and numerical modelling for infrastructure design/implementation and for lifecycle cost evaluation and the optimisation of ongoing chemical costs for a wide range of treatment applications.

Study of a Vertical Dense Chlorine Jet into Treated Sewage - J. K. Yang et al

Concentrated dense sodium hypochlorite (NaOCl) solution is commonly used in sewage treatment plants for disinfection of treated sewage. In view of the importance of sewage disinfection to the environmental impact, it is essential to understand the mixing and reaction of chlorine with sewage for disinfection dosage optimization. In this study, a laboratory experiment of dense chlorine jet discharging into stationary treated sewage is conducted. To ensure safe operation of the experiment, the set-up is first tested with sugar solution with density similar to that of dense chlorine solution.

Physical results are graphically shown in the following figure showing the dense sugar jet. These results were compared to the computational fluid dynamics (CFD) model.

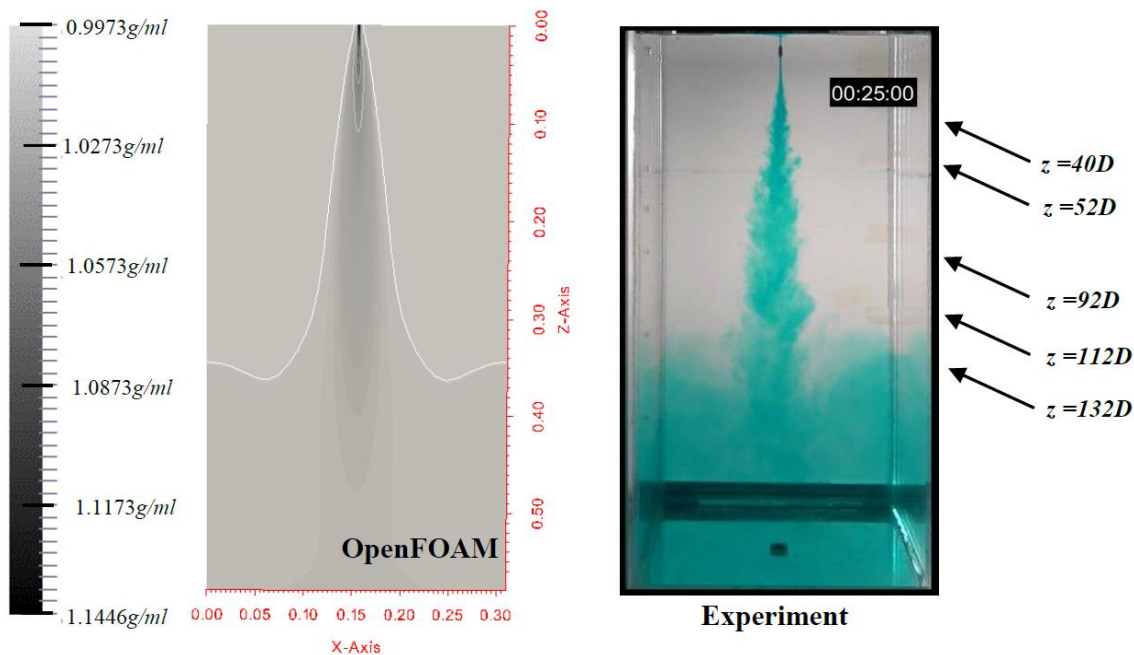


Figure 4 - Experimental observation and CFD prediction of a dense sugar jet ($Q = 4.1$ ml/s) in a confined tank at $t = 25$ s, showing the turbulent jet and the built up of dense fluid at the bottom

SUMMARY

An experiment on studying the mixing of a reacting chlorine dense jet with treated sewage is designed. Dense 5.67% NaOCl solution is discharged to sewage and tap water in a stationary ambient and ambient TRC profiles are obtained. Numerically predicted ambient TRC profiles in tap water agree well with experimental measurement. For chlorine discharging into treated sewage, significant chlorine demand is observed in the first 3-5 minutes of discharge for ambient sewage but the reaction slows down afterwards due to the accumulation of TRC in the tank.

This paper is a notable example of the comparison of physical modelling with computational techniques and of the use of graphical and photographic presentation techniques. The approach relating to chemical mixing efficiencies is not only relevant to chlorination of municipal wastewater before outfall discharge, but should also for many chemical mixing situations in water and wastewater and stormwater treatment plants and for various processing industries that have chemical dosing applications.

2.6 INVESTIGATING ALTERNATIVES – OCEAN OUTFALL DISCHARGE AND LAND APPLICATION

A Marine Outfall as an Alternative Sewerage Disposal Scheme for St. Helena Island (Alternative to Land Application) - F. van Eeden et al

This paper covers investigations relating to the treatment and disposal/discharge of 440 m³/day of municipal wastewater from the island of Saint Helena. The island is located approximately 1,000 nautical miles due west of the Namibia/Angola border in the South Atlantic Ocean. Currently poorly treated sewage is discharged into natural valleys and at the shoreline of St James Bay.

The abstract summarises the investigations process. Overall many aspects are similar to the processes followed in New Zealand including the all-important shellfish microbiological risk assessment approach. The EU Faecal Coliform directives were used in this modelling.

ABSTRACT

This study evaluates a marine outfall as alternative to land based treatment options for the island of Saint Helena in the South Atlantic Ocean. At present, portions of the ageing sewer networks need upgrading while poorly treated sewage discharges directly into natural valleys, as well as into the marine environment. In addition, uncontrolled ingress of storm water into the sewer system causes overflowing of sewers and an

overload of the current treatment facilities (septic tanks). Various treatment options were evaluated: membrane bioreactor, activated sludge, rotating biocontactors, trickling filter, oxidation ponds and disposal via marine outfall pipeline. The feasibility of the various options was initially evaluated in terms of their respective capital cost (CAPEX) and operational cost (OPEX) and it was found that the marine outfall warrants an in-depth investigation due to the potential lower maintenance costs when compared to the land-based treatment options.

The optimal placement of the outfall was investigated in order to satisfy the environmental objectives and determine a cost effective construction solution. The CAPEX and OPEX (to 30% accuracy) of the outfall are compared to the land based treatment options. It was found that a marine outfall is preferred due to its ability to accommodate high variations in flow (added storm water flows), a reasonable construction cost and exhibiting very low maintenance and operational costs when compared to land based treatment options.

The solution selected included outfall lengths of 285 and 500 metres and discharge depths of 15 and 25 metres.

The outfall option was selected discharging into 25 metres of water. The economic evaluation showed that while the capital costs for the treatment and outfall option was approximately 25% lower than land application, the NPV (25 year horizon) was only 50% of that of land application.

This paper highlights that in certain circumstances offshore outfalls can provide the lowest overall lifecycle cost compared to land application even for relatively small community sizes and also for industrial wastewaters. This is contrary to the often held view that offshore outfalls need large flows to provide an economic solution.

2.7 OUTFALL DISCHARGE - LABORATORY AND NUMERICAL MODELLING COMPARED WITH FIELD TRIALS

The following paper reported on work undertaken by the Water Research Laboratory, School of Civil and Environmental Engineering, University of New South Wales – Australia. The paper well highlights how laboratory, numerical and field measurements can be compared to prove how well, or not, the in-situ outfall is performing against predictions.

The approach adopted at this Sydney outfall has application to many outfalls. It highlights that sound and proven approaches that can be used not only to prove the performance of an outfall, but also to assist in the permitting/consenting of outfall projects.

The following excerpts from the paper's abstract and conclusion well illustrates the considerable value of such techniques in outfall investigations, design and operation as well as in the permitting/consenting process.

ABSTRACT

Laboratory and Numerical Modelling Compared with Field Trials of Dilution at the Sydney Desalination Plant Outfall - B.M. Miller et al

Physical and numerical modelling was undertaken as part of the diffuser design of the Sydney Desalination Plant brine multiport outfall. Subsequent to the construction, field investigations to validate the diffuser performance were undertaken with the desalination plant operating at full capacity. This paper presents the laboratory and field methodologies and provides a comparison between the model predictions and field performance.

Laboratory testing of many diffuser configurations were undertaken in a 4.5m x 4.5m x 0.6m tank. Two full days of field dilution testing were undertaken where a known concentration of Rhodamine WT fluorescent dye was injected into the seawater concentrate discharge and the concentrations in the receiving waters were measured using both diver-held and boat-cast fluorimeters. Measurements of the plume depth and geometry were also derived by analysing the backscatter from ADCP current meter transects.

The dilutions in the receiving waters were effected by varying currents. These field observations show how actual conditions can vary from laboratory conditions, but also provide reassurance that the laboratory and numerical predictions are slightly conservative.



Photo 7 - Dye coloured Brine Jet using Rhodamine WT injection

CONCLUSIONS

Physical modelling and field observations can be compared for the same diffuser configuration, flow and densities. The physical modelling was under quiescent conditions whereas the field experiment was undertaken with currents approximately 0.23 m.s⁻¹. The physical modelling predicted the impact zone to be 16m from the diffuser with a dilution of 27 times. The field observations indicated that the impact point was approximately 30m from the diffuser but with dilutions of approximately 30 times. Indeed, all observed field dilutions including those before and after the impact point were greater than the physical model predicted impact dilution.

Clearly the current has a strong influence on the position of the plume, but it is uncertain as to whether it has a significant impact on the dilution. The plume dilutions in the ocean were always slightly greater than the physical modelling indicating that the model was conservative.

2.8 MONITORING MARINE OUTFALLS

With a significant number of marine outfalls in New Zealand discharging municipal and industrial wastewater and also stormwater, appropriate monitoring is of importance not only in the planning for new outfalls, but in the ongoing operation in order to assess both the short term environmental effects and also longer term cumulative effects. Additionally, monitoring programmes required by permitting/consent conditions are often relatively expensive to undertake on an ongoing basis and in some cases not always well founded. A number of papers presented at the Ottawa symposium highlighted these matters in different ways. The following paper well presents the situation in São Paulo state which has the majority of Brazilian sea outfalls. These outfalls have preliminary treatment and chlorination of the municipal wastewater.

ABSTRACT

Monitoring Sea Outfall Discharges in São Paulo Coast – Brazil – C C Lamparelli et al

Most of Brazilian State capitals are located in the coastal zone. In those metropolitan regions where population and tourism have grown significantly in the last years, ocean disposal is an appealing solution for sanitation systems. Although São Paulo State in the south-eastern region represents only 10% of the Atlantic coastline extension, it is the most populated and has the majority of the Brazilian sea outfalls. There are currently eight wastewater sea outfalls in operation. All of them have only preliminary treatment followed by disinfection through chlorination before releasing the effluent into the sea. The first one was constructed in Santos and began to operate in 1979. Since then commissioning protocols have been modified and have improved based on the knowledge acquired with the monitoring programs.

During the first years sampling methodologies were tested in order to establish a monitoring design. The data gathered in these surveys showed that most of marine environment alterations were related to sediments, including accumulation of organic matter and nutrients. In some cases, water quality was also impaired. Alterations such as nutrient enrichment were observed more often in Santos bay. Despite their importance, it is worth mentioning that marine environment monitoring surveys are complex and expensive. One must also consider that in developing countries there is a lack of environmental data records, and in most cases there is practically no previous information about the studied area. Environmental Monitoring conclusions were useful to identify the major alterations in marine environment and to address which improvements and adjustments would be necessary in each outfall to reduce or to prevent future environmental impacts in water and sediment quality.

CONCLUSIONS

In conclusion, monitoring of coastal waters influenced by submarine outfall discharges was useful to understand which impacts would be expected from this kind of disposal. The results showed that alteration in water quality, mainly nutrient enrichment was observed in Santos bay, but the major issue was the observed changes in sediment quality due to the deposition of particulate organic matter that was not removed in the preliminary treatment. As a consequence of these results, additional removal of suspended solids was required for some outfalls, as well as improvements in treatment and diffusers for the existing ones.

The environmental monitoring of the disposal areas was also very important for the licensing process and helped to define necessary treatment levels and other constructive and design aspects in almost all sea outfalls in São Paulo. This experience will certainly be useful to other Brazilian states that can adopt this disposal option. These findings support the idea that environmental monitoring is a very important instrument to ensure the quality of marine environment and very useful to coastal waters management.

2.9 OPTIMIZING OUTFALL CONFIGURATIONS USING DECISION SUPPORT AND NUMERICAL MODELLING TOOLS

In New Zealand we often use decision tools in our decision making process for infrastructure projects be they wastewater scheme options, outfall location assessments, electricity transmission lines, motorway routes etc. A commonly used and accepted tool in terms of Resource Management Act alternatives assessments is the Multi-criteria Assessment (MCA) tool.

Multi-Criteria Analysis is perhaps the most ubiquitous of all formal methods of decision making. The International Infrastructure Management Manual 2011, as adopted by local authorities in New Zealand, describes MCA as “*a decision technique that considers more than one criterion (not just monetary units). It is commonly used where the benefits and costs are more difficult to accurately define and are both quantitative and qualitative in nature*”.

Decisions are guided by rating the options, which is achieved by assigning scores to a set of chosen criteria or attributes of the options considered. Criteria are typically chosen to cover all issues of concern and can cover tangible (e.g. cost) and intangible (e.g. opportunities and benefits) factors. The criteria scores are combined in some way (usually a weighted sum) to rank the options. The contribution that each criterion gives to the sum of scores for an option is weighted to reflect the decision makers’ beliefs about the relative importance of the different criteria.

The following paper traverses the case of the TOPSIS methodology which is a multi-criteria decision making approach. The abstract to that paper summarises how the alternatives were evaluated and how numerical modelling using both a 3D hydrodynamic model and near-field model were validated. The process followed has similarities to a number of outfall investigations in New Zealand over the last decade or more.

ABSTRACT

Optimizing Outfall System Configurations Using Decision Support and Numerical Models. Case study of Santa Catarina Island, Brazil - A.V. Falkenberg et al

This paper presents the methodology used to define the optimal design for the outfall system to be implemented in the northern part of Santa Catarina Island, south of Brazil. Among several relevant

factors there were considered the current sanitation infra-structure, population growth estimation, social aspects, cost analysis and potential environmental impacts. In order to evaluate the different feasible alternatives, the TOPSIS methodology was used, which represents a multi-criteria decision making approach based on similarity to an ideal solution. There were evaluated 42 possible alternatives varying several criteria, such as geographic location, effluent discharge, treatment levels, construction and operating costs and environmental and social aspects. Subsequently, a numerical modeling phase was started implementing a 3D hydrodynamic model (Delft3D-FLOW) which was calibrated and validated for a one year period using measured oceanographic data. Afterwards, a near-field model (CORMIX) was used to evaluate the dilution performance for each location and to set up the input concentration data for the far field water quality model (Delft3D-WAQ) to analyze the dispersion of nutrients, BOD and bacteria in order to ascertain the performance of each alternative with the environmental legal requirements.

The results show that even though initially there were dozens of potential alternatives, decision support methodologies and models exist to provide guidance to decision makers, as well as sanitation and environmental agencies, and stakeholders to find optimal solutions.

2.10 RIVER OUTFALLS AND WATER QUALITY MODELLING

The symposium also included a number of river outfall investigations and projects and how numerical and physical modeling had been applied in river situations. Those papers also have much relevance to a number of New Zealand situations involving both single and multiple outfalls along a section of river. With increasing focus on stormwater discharges where there is normally multiple outfalls, often in relatively close proximity, such modelling can be most useful not only in understanding the effects of discharges, but also in providing information for planning for the improvement needs and associated infrastructure. The same also holds true for urban areas on rivers and also in coastal locations which have combined sewer overflows (CSO's).

The following paper on the Ottawa River well illustrates the above points. It reviews the approach and outputs of modelling undertaken over a 28km length of that River into which there are over 70 point source discharges. The Abstract highlights the overall need for improvement in river water quality and the associated objectives of achieving a healthy environment and longer term sustainable community. In the New Zealand fresh water environment there is increasing pressure being applied through the implementation of the current National Policy Statement on Freshwater Management 2014 (NPSFM) and the expected updated NPSFM. This will lead to greater need for better information and an increased understanding of our freshwater bodies that receive outfall discharges. In this respect greater application of techniques like those outlined in this Ottawa River paper can be expected to be used.

Using graphics like the ones illustrated in below also provide a useful visual output that can be effectively used in consultation with stakeholders and in dialogue with the consent authorities in the RMA resource consenting phase of a project.

ABSTRACT

Ottawa River Water Quality Model Improvement Study – D M Fullarton et al

The Ottawa River has long been the lifeblood of the communities of Ottawa and Gatineau. From early days of voyageur travel, exploration and inland routes of commerce, to a present day recreational resource and source of drinking water. The Ottawa River has played an extremely important role to both communities. A healthy environment is vital to quality of life and the longer-term sustainability of communities. The City's Growth Management Plan (Ottawa 20/20) recognizes and endorses this idea. The improvement of water quality in the Ottawa River is a complex but necessary challenge. The City has taken important steps in beginning to address the river's water environment issues. One such step is the development of a water quality river modelling tool to support the evolution of an action plan to protect river water quality. This two-dimensional hydrodynamic and transport model extends from the Chaudiere Dam downstream to Masson-Cumberland, a distance of approximately 28 km. Over seventy point sources were defined in the model; including storm and combined sewer outfalls, creeks/streams and wastewater treatment facilities. Hydrological models were developed for fifty catchments to improve wet weather loading estimates to the river. The numerical model was developed to support an assessment of the effluent inputs and bacteriological water quality in the Ottawa River and assist with the prioritization of water quality initiatives by assessing the predicted improvements on river

water quality. Through incremental development, the Water Quality Model has become a "living" tool to assist in decision-making for complex problems associated with the water quality on the Ottawa River.

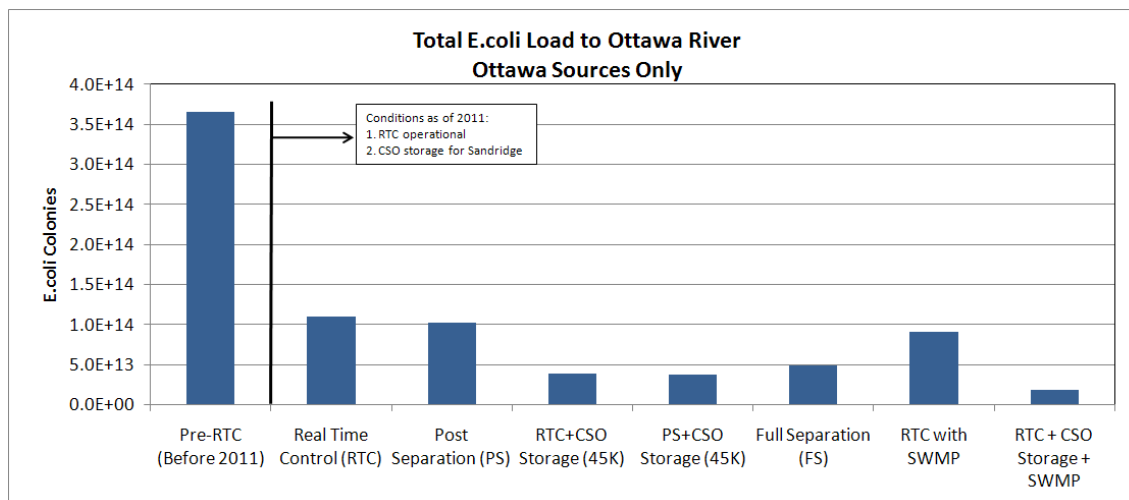


Figure 5 - Estimated E.coli load to the Ottawa River

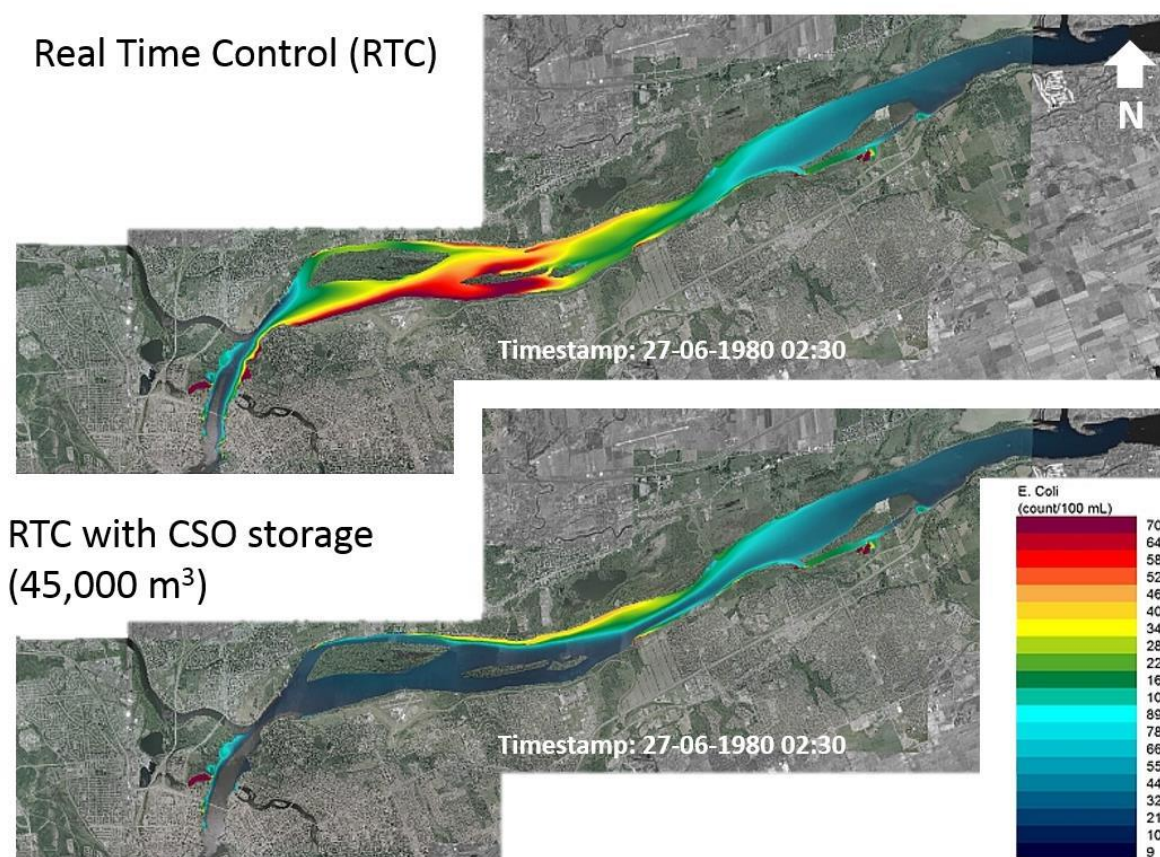


Figure 6 - Example of water quality model output

3 CONCLUSIONS

New Zealand is well served by outfalls, especially outfalls discharging treated wastewater into the marine environment through both shoreline, short and offshore ocean outfalls. A number of features relating to the New Zealand situation are traversed in Section 1 - Introduction to this paper. Notwithstanding the well-developed approach to investigations, design, construction and ongoing monitoring, New Zealand can always learn more from international developments and project experiences. This paper takes up this challenge by outlining a number of such international developments and project practices that were presented at the International Water Association's specialist group's Marine Outfall Symposium in Ottawa 2016.

The papers featured have been selected on the basis that they have some similarities to the New Zealand outfall scene and thereby allow comparisons and possible advances that can be adopted and/or adapted for future New Zealand outfall projects be they associated with investigations, consenting, design, construction and/or ongoing monitoring.

ACKNOWLEDGEMENTS

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