PAPER 15

Energy saving and environmentally friendly desalination technology, remix water

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ABSTRACT

EThekwini Water and Sanitation (EWS) has recently engaged on a feasibility study to find out whether it is financially viable to implement desalination as a solution to the water challenges that the city is currently facing. Current studies underway by EWS to assess Inner City Water Demands indicate a demand of approximately 65ML/day. This demand outstrips the supply of 50ML/d and thus the need to augment the supply by 15ML/d by 2020. In response to this, EWS is investigating desalination technologies available to implement in the city, one of them being the Remix Water™ System, an energy-saving and environmentally friendly desalination technology.

A remix water system consists of a combination of seawater desalination and reuse of effluent from a wastewater treatment that is treated with membrane bioreactor technology (MBR) and brackish water reverse osmosis (BWRO). The reject water from the BRWO process unit is used to dilute the seawater before the Sea Water Reverse Osmosis (SWRO) process to decrease the salinity. Furthermore, decreasing the salinity decreases the osmotic pressure. This reduces the energy consumption by 40% compared to conventional SWRO desalination plants. SWRO conventional desalination plants, depending on the intake water quality, consume an average of 3.8 kWh/m^3 and the Remix Water System consumes an average of 2.6 kWh/m^3. This leads to a significant reduction in the operational costs of implementing Remix Water compared to SWRO desalination.

The first Remix Water desalination plant commenced operations in December 2010 at Kita Kyushu, Japan. The current plant capacity is about 1.4ML/d and currently supplies process water to Kyushu Electric Power Company in Japan. EWS, Hitachi and NEDO have collaborated to build and operate a 6 250m^3/d Remix Demonstration Plant at eThekwini's Central Wastewater Treatment Works. The Central Wastewater Treatment Works has been identified as the ideal location of the remix demonstration plant due its close proximity to the sea and the plant will utilize the existing infrastructure such as the sea outfall and the primary settling tanks.

The purpose of the demonstration plant is to test the technology, prove its ability to reliably produce potable water quality and to optimize the design, in order for the technology to be considered for larger commercial-scale implementation. The implementation of the demonstration plant will compromise of a 300 m^3/d containerized unit and a 6 250m^3/d demonstration plant. The demonstration plant will be commissioned in November 2019 and will operate for 12 months thereafter.

1. INTRODUCTION

The eThekwini Metropolitan Municipality is one of the main economic contributors within the KwaZulu-Natal (KZN) province. In order to maintain its significance and realise its future growth potential, this region needs to be supported by a sustainable long-term supply of water. The responsibility for the planning, constructing, operating of the required water resource, and water supply infrastructure rests with the Department of Water and Sanitation, Umgeni Water and the relevant Water Service Authorities.

A study was conducted to review the water demand in the eThekwini region and was found that the water demand will exceed the water supply in 2020. The situation is worsened by current climate change conditions that are being experienced countrywide which is producing lower dam yields and thus putting pressure on the current water supply system. The growing demand of water supply and the climate conditions would require a sustainable solution to address the water supply issues. In response to this, EWS is investigating technologies available to implement in the city, one of them being the Remix Water System, an energy-saving and environmentally friendly desalination technology.

A Remix Water system consists of a combination of seawater desalination and wastewater reuse. The Central Wastewater Treatment Works (WWTW) has been identified as the ideal location of the remix treatment plant because of its close proximity to the sea. A demonstration treatment plant with the capacity of 6.25ML/day has been planned to be constructed at the site to test the technology.

2. WATER DEMAND AND SUPPLY IN THE ETHEKWINI MUNICIPALITY

The average water demand in the eThekwini Municipality is 905ML/day and is supplied from 10 potable water treatment plants. The Municipality purchases majority of its water from Umgeni Water and a small portion the water is supplied from water treatment plants that are owned by the Municipality. However, erratic climate conditions had a negative effect on the eThekwini's current water supply to the extent that water restrictions were imposed across the municipality during the 2015/16 drought season. This reduced the water demand to 875ML/day due to various drought intervention measures.

Current studies underway by EWS to assess Inner City Water Demands indicate a demand of approximately 65 ML/day. This demand outstrips the supply of 50 ML/d and thus the need to augment the supply by 15 ML/d by 2020.

Therefore, the Municipality seeks to secure its water supply from other resources. This dire need is emphasized in two pertinent documents, EWS Security of Water Supply, which had been adopted by Council on the 1st August 2017, and the KZN Reconciliation Strategy. The Reconciliation Strategy is in response to the current economic growth, improved waters supply services, urbanization of the population and associated expansion of residential and other developments being implemented. The trend is expected to continue over the medium term as reflected in planned new urban developments.

The area along the coast between the Tongati and the Thukela Rivers, within the iLembe District Municipality (DM,) is experiencing developments of large residential estates and industries which require additional water resources for the North Coast supply area. In addition, the development of the Dube Trade Port, which includes the King Shaka Airport and the commercial and residential development that the trade port will attract in the vicinity of La Mercy, will also result in increasing water demands.

Therefore, further augmentation of the water supply system is required and there a number of projects to do so. These currently include the Lower Thukela Scheme, Lower Umkhomazi Scheme, uMkhomazi-Mgeni Transfer Scheme (known as the uMkhomazi Water Project Phase 1 - Smithsfield Dam), eThekwini's desalination plant at Central WWTW, potable reuse plants at various WWTWs and Umgeni's north and south coast desalination plants.

Reuse of wastewater is identified in the KZN Reconciliation Strategy as an intervention to mitigate against the deficit in the water supply/demand curve based on the projected future water demands. Therefore, the Municipality is implementing direct reuse projects as a mitigation measure. The proposed construction of two new reuse plants at Northern and KwaMashu WWTWs, 50MLD each, will cater for the increased water demands based on the proposed residential and commercial developments within this catchment.

In addition, Umgeni Water has conducted a feasibility study for the implementation of two 150ML/day desalination plants in the North and South of the eThekwini region. The site of the North plant is adjacent to the southern banks of the Lovu River Estuary and the south plant is located at Lovu. Both sites are ideally located as they are close to Umgeni Water's existing bulk water supply infrastructure. EThekwini Municipality is also investigating the implementation of emergency desalination schemes to supply water to the Municipality during severe drought conditions. The locations of these temporary desalination plants are the Durban Harbour, Southern and Gennazano WWTWs.

3. CHALLENGES OF IMPLEMENTING LARGE-SCALE DESALINATION PLANTS

In the past, desalination of seawater was not considered as an economically viable water source due to the availability of less costly surface and groundwater resources to meet water demands. However, due climate change, population growth, economic growth and increased levels of service, desalination is now being considered a long-term solution to overcome future water shortages in coastal cities (Blersch, 2014). There are obvious limitations in implementing large-scale desalination plants. These include the relatively high costs of operating desalination plants, as the electricity consumption is still relatively high as compared to the treatment of surface water and groundwater. Furthermore, the brine from the desalination process must be disposed in an environmentally friendly manner.

The implementation of emergency desalination schemes during a drought season must be carefully planned. This is to ensure long-term sustainability of these schemes. For instance, Australia suffered a decade long drought between 2000 and 2009, which prompted the implementation of large-scale emergency desalination schemes (Blersch, 2014). However, the drought ended after the desalination plants were commissioned and the country was left with a high financial burden due to the long-term financial implications.

3.1 Energy Consumption of Seawater Reverse Osmosis (SWRO) Desalination Plants

The first commercial seawater reverse osmosis desalination plant was commissioned in the late 1970's (Wang et al, 2011) and due to the lack of energy recovery systems and inefficient membranes, the energy consumption was as high as 10 kWh/m^3. In early 1980s, the Pelton wheel and energy recovery pumps were utilized to improve the efficiency of the reverse osmosis process and the specific energy consumption was reduced to 6 kWh/m^3 (Dashtpour & AL-Zubaidy, 2012).

By the late 1990's, isobaric energy recovery systems were utilized to further reduce the energy consumption. The technology is undergoing continuous development with the emergence of nano-technology and biomimetic RO membranes which are capable of revolutionizing the membrane based desalination processes (Shenvi & Isloor, 2015). The specific energy consumption (SEC) of SWRO trains have decreased over the past few years as indicated in figure 1 below.

Despite the improvements in SWRO desalination processes, the energy consumption of SWRO plants remains relatively high as compared to surface water treatment plants. This is due to the power required to drive the high pressure pump(s) and is typically the largest component of the operating cost of SWRO plants. Table 1 below, illustrates the specific energy consumption of desalination schemes around the world.

TABLE 1: Energy consumption of desalination schemes (Source: Dashtpour & AL-Zubaidy, 2012)

Plant Name	Country	Product Flow Rate (m^3/day)	SEC (kWh/m^3)
Ashkelon	Israel	330 000	4
Taweelah	UAE	227 000	4
Carlsbad	USA	189 000	3.6
Fujairah	UAE	170 000	3.8
Kwinana – Perth	Australia	140 000	3.7
Tuas	Singapore	136 000	4.1
Tugun Queensland	Australia	133 000	3.6

3.2 Brine Disposal

Discharge of the concentrated brine from desalination plants has been a major concern and may result in an adverse effect on the receiving environment's eco-system. All marine species have a tolerance range of salinity. At first consideration, one often tends to ignore the fact that the concentrate (which can be several times more saline than the feed - depending on the application) needs to be disposed of in an appropriate and environmentally friendly manner. However, quite often this unavoidable consequence of the desalination process can contribute to a major portion of the overall project cost.

There's a method to overcome the issue of discharging concentrated brine into the receiving environment. For example, the brine from the Fukuoka desalination plant (located in Japan), is pumped and mixed with the treated effluent from a nearby wastewater treatment plant. Therefore, it reduces the salinity of the discharged brine and has a lower environmental impact. This method requires that the distance between the desalination and wastewater treatment plants must be relatively low for it to be feasible.

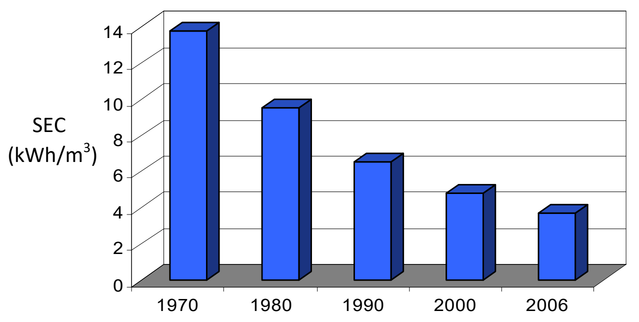

FIGURE 1: SEC of SWRO trains (Source: Aurecon 2016)

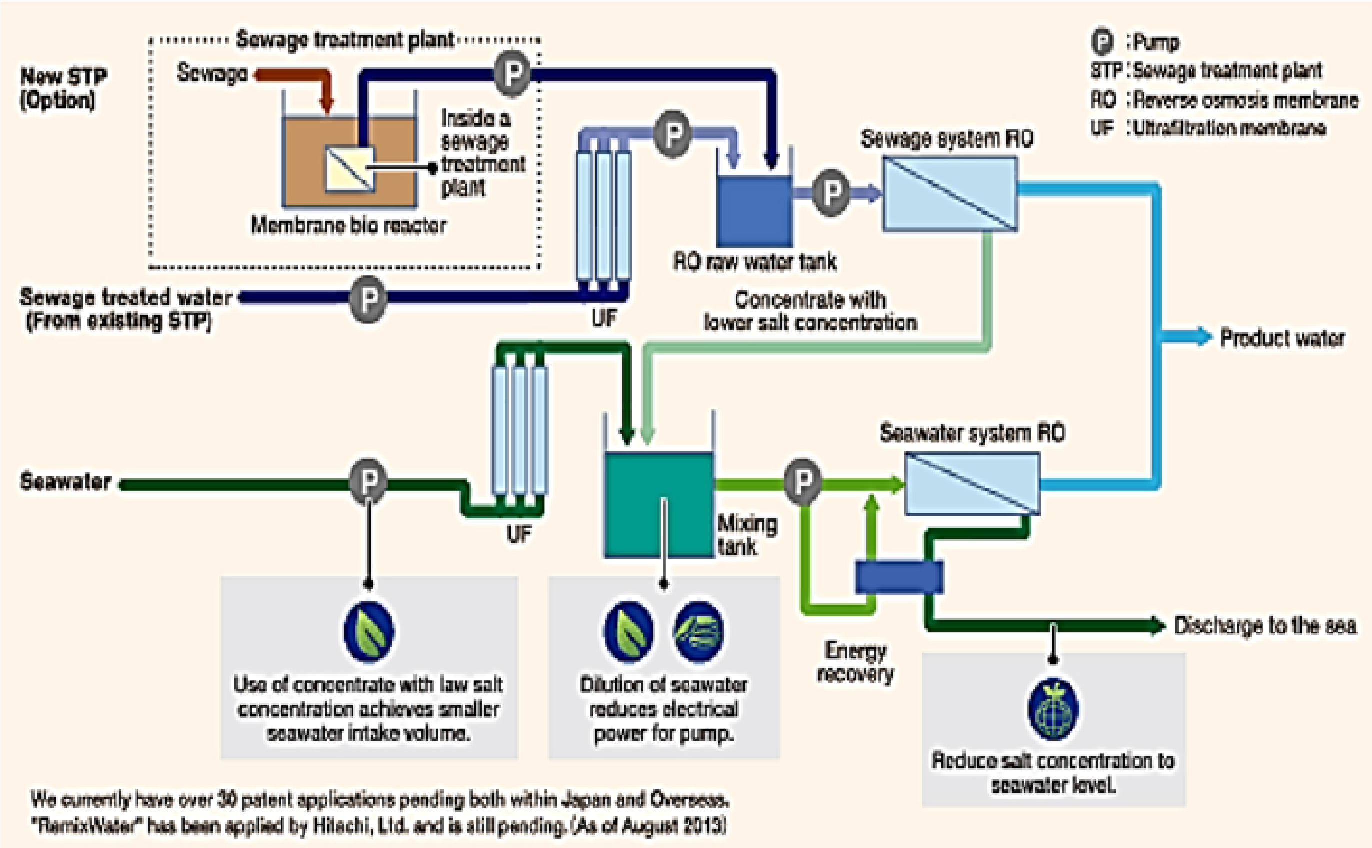

FIGURE 2: Remix Water Process Diagram (Source: Hitachi Ltd)

4. REMIX WATER DESALINATION TECHNOLOGY

4.1 Remix Water Process Design

The Remix Water process was developed by Hitachi Ltd. to address challenges of implementing large-scale desalination plants. The simplified process diagram above, Figure 2: Remix Water Process Diagram, illustrates the process design of the Remix Water system.

The system is a blend of seawater desalination and wastewater effluent reuse. The reject (or brine) from the BRWO process is mixed with the UF seawater permeate in a mixing tank. This dilutes the seawater and reduces the TDS thus reducing the osmotic pressure required to pass through the SWRO. The product water from both the BRWO and SWRO processes are then combined for tertiary treatment (stabilisation and chlorination).

The salinity of the brine is similar to the receiving environment, and thus has a lower environmental impact in comparison to conventional SWRO processes.

The first remix desalination plant commenced operations in December 2010 at Kita Kyushu, Japan. The current plant capacity is about 1.7ML/d and currently supplies process water to Kyushu Electric Power Company in Japan as illustrated in Figures 3 and 4.

Using a membrane process allows for a continuous supply of stable water quality. Although this process has been developed fairly recently, the ability to continuously operate this

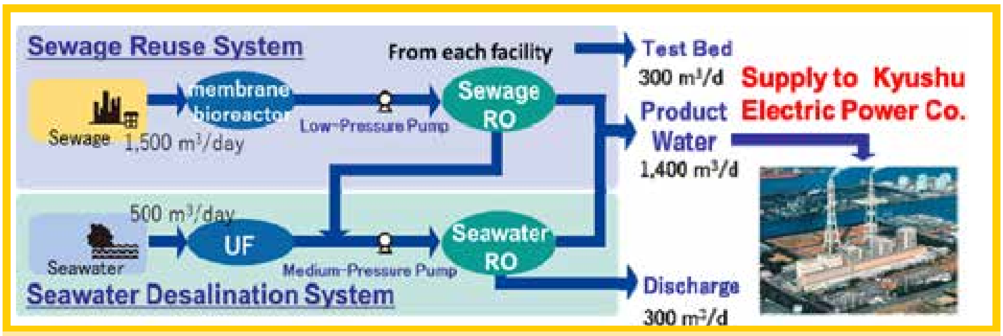

FIGURE 3: Kita Kyushu Remix Water Process Flow (Source: Hitachi Ltd.)

FIGURE 4: Kita Kyushu Remix Water Plant (Source: Hitachi Ltd.)

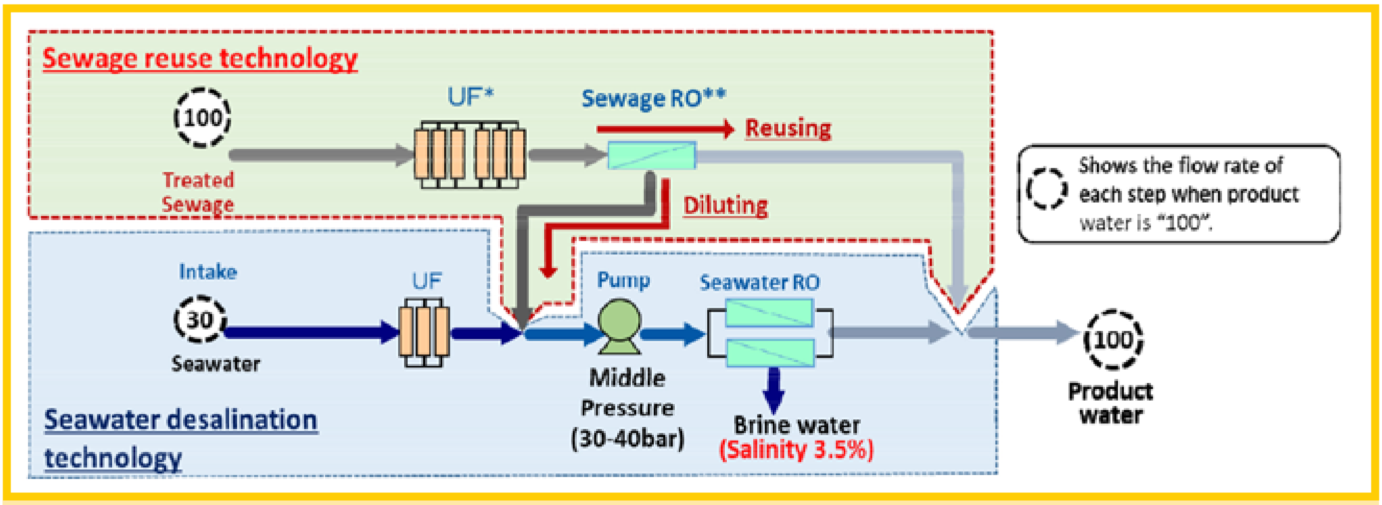

FIGURE 5: Remix Water Process Flow (Source: Hitachi Ltd)

system for over 3 years has been verified at the Kita Kyushu remix plant. Utilizing this system allows pump power energy efficiency to be maximized by reducing the amount of sewage treatment water and salt concentration in the SWRO raw water.

4.2 Energy Consumption of the Remix Water Process

As mentioned, the dilution of the seawater reduces the required feed pressure to pass through the SWRO membrane. Therefore, the power required to drive the high-pressure pump(s) is significantly reduced compared to a conventional SWRO process. This is illustrated in the Figure 4 and Table 2 below.

TABLE 2: TDS Concentration in mg/L (Source: Hitachi Ltd)

	Intake	UF Permeate	Mixing tank	RO Permeate	RO Brine
BWRO	1100	1100	20 670	50	3550
SWRO	39 252	39 252		< 300	41 038

The BRWO process utilises ultra-low pressure spiral wound membranes with a feed pressure of 10 bar. Furthermore, due to the dilution of the seawater UF permeate, the required feed pressure for the SWRO is between 30 – 40 bar which is significantly lower than a conventional SWRO process with a required a feed pressure of over 60 bar. The Remix Water system also utilises a PX Pressure Exchanger energy recovery device to increase the efficiency of the system.

The energy recovery device facilitates pressure transfer from the high-pressure SWRO brine reject stream to the low-pressure SWRO feed stream. Therefore, the estimated maximum SEC of the BRWO and SWRO process is 0.38 kWh/m^3 and 2.26 kWh/m^3 respectively.

5. DEMONSTRATION PLANT IN SOUTH AFRICA

In line with eThekwini Municipality's long-term strategy to investigate the feasibility of implementing a large-scale desalination plant to further supplement the water supply, the Municipality partnered with the New Energy and Industrial Technology Development Organisation (NEDO) for a demonstration project. The purpose of the demonstration project is to test the Remix Water technology to assess whether it can reliably produce potable water and to optimise the design and operation in order for the technology to be considered for a large-scale desalination scheme.

The proposed Remix Water demonstration project requires a combination of seawater desalination and wastewater reuse. As a result, a wastewater treatment plant located within a reasonable distance from the sea is required. Four alternative site locations were identified, namely; Central, Southern, Phoenix, KwaMashu WWTWs. These sites were compared using a matrix approach to select a preferred site.

The exercise was based with the following criteria:

- Existing wastewater treatment processes
- Availability of space on the site
- Inflow Volume
- Source of inflow (domestic or industrial)
- Distance from the sea
- Distance from distribution area

Based on the above-mentioned criteria, the Central WWTW was selected as the preferred site for the implementation of a Remix Water Plant.

Subsequent to the completion of feasibility studies, NEDO is providing grant funding for a Remix Water Demonstration Plant to be implemented by Hitachi Ltd. EThekwini signed a Memorandum of Understanding with NEDO and also a Implementing Document with Hitachi. The implementation of the demonstration plant will compromise of a 300m^3/d containerized unit and a 6 250m^3/d demonstration plant. The project is currently on schedule as all parties are meeting their obligations. The construction of the Demonstration Plant commenced in October 2018 and will finish in November 2019. Thereafter the demonstration plant will run for a period of 12 months.

5.1 Project Site

The project site is located at eThekwini existing Central WWTW positioned along the KwaZulu-Natal coastline in Durban as illustrated in figure 6.

Central WWTW is designed to treat up to 133ML/day of mostly domestic wastewater. The treated wastewater effluent is discharged via an existing 3.2km long outfall pipeline. This is an ideal site as the demonstration plant will utilise some of the existing infrastructure and therefore reducing the project cost.

The feed water contains dissolved gases, dissolved and suspended inorganic solids, dissolved and suspended organic matter and suspended microorganisms. During the desalination process, the concentration of these components can effect various forms of scale formation and other inhibitive contamination of the desalination equipment.

As such, continuous scaling and/or fouling can be one of the most crippling side effects of desalination processes. A well-designed desalination

FIGURE 6: Site Location (Source: Aurecon, 2016)

plant always incorporates a well-designed and appropriate pre-treatment system to minimise fouling.

The feed water for the BWRO process is extracted from one of the existing PSTs and is treated in a MBR unit. An MBR unit is required in this project, as feed wastewater needs to undergo biological treatment. This is to ensure that the feed water quality is ideal for the BRWO process and to reduce the risk of scaling and fouling. The SWRO process requires seawater intake point.

Three options were considered for the demonstration plant including the off-shore intake, harbour intake and a beach well intake point. The selection of the preferred intake point was based on the desired water quality and quantity to be abstracted, costs associated with the construction of the intake works, and the environmental regulations.

The harbour intake point, as illustrated in Figure 7 is preferred for the following reasons;

- Significantly less construction risk
- Ease of maintenance as it is less weather dependent compared to an offshore intake
- Water quantity is guaranteed

The brine from the SWRO process will be discharged via the existing outfall pipeline at Central WWTW. The Department of Environmental Affairs, Oceans and Coasts granted a Coastal Water Discharge Permit (CWDP) to utilise the existing outfall pipeline.

The CWDP requires constant monitoring of the feed water quality and the brine discharge quantity and quality.

The permeate water from the SWRO and BRWO processes is combined in a mixing tank to undergo further treatment. Firstly, the product water is passed through an advanced oxidation process (AOP) were the product water is dosed with hydrogen peroxide and exposed to UV light. The reactive OH- radicals attack the EDC's and thus improving the water quality. The water is then stabilised and chlorinated. However, during the demonstration phase of the project, the product water is tested and discharged to sea via the existing outfall line. The aim of the Remix Water demonstration plant is to produce potable water, which is compliant to SANS 241 standards.

5.2 Capacity Building

As required in the agreements, a Capacity Building Strategy Document was developed and completed in July 2017. The aim of the capacity

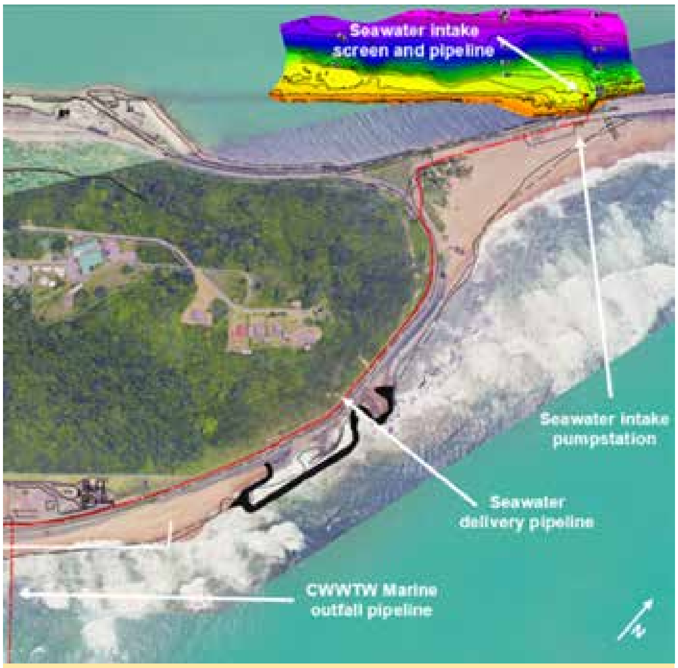

FIGURE 7: Intake Location (Source: Aurecon, 2016)

building strategy document is to facilitate the capacity building process for the next 4 years of the project. This is to ensure that the Municipal staff is properly capacitated during the implementation of the project. This is achieved through various ways such as design workshops and technical tours in Japan.

The first capacity building workshop was held in November 2017 were over 30 EWS engineers, technologists and technicians attended the basic design workshop. Several workshops are in the pipeline, covering every aspect of the project including the commissioning and operation of the demonstration plant.

6. CONCLUSION

The Municipality is facing challenges in securing its future water supply due to climate change, population growth, economic growth and increased water service levels. Therefore, the municipality is currently evaluating the implementation of large-scale reuse and desalination plants as alternative water resources.

The Remix Water demonstration plant and the sub-unit will be operated for 12 months to assess the viability of the desalination plant by testing the water quality of the product water. The success of the Remix Water demonstration project will provide the Municipality with an option to upgrade the demonstration plant and pump the product water into the nearby water reticulation network. The lessons learnt will guide the implementation of the larger-scale project.

7. REFERENCES

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