SUSTAINABLE MANAGEMENT OF DESALINATION PLANT CONCENTRATE - DESALINATION INDUSTRY POSITION PAPER – ENERGY AND ENVIRONMENT COMMITTEE OF THE INTERNATIONAL DESALINATION ASSOCIATION (IDA)

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ABSTRACT

At present, 16,000 desalination plants provide drought-proof water supply for nearly 5% of the world's population located in the most arid urban coastal municipalities of Europe, Africa, Australia, the Americas, and the Middle and Far East. Similar to conventional water treatment plants and water reclamation facilities, desalination plants generate source water treatment byproducts. The main desalination plant byproduct is concentrated source water typically referred to as concentrate or brine. This paper discusses the most common practices for concentrate management and the potential environmental challenges and solutions associated with these practices.

The environmentally safe and sustainable management of treatment byproducts is of prime importance to the desalination industry. Desalination plants maintain comprehensive systems to predict, monitor and prevent potential impacts on the ecosystems in the vicinity of desalination plant discharges during all phases of project development and implementation – from planning to design, construction and operation. Compliance with monitoring and mitigation requirements detailed in every plant's Environmental Impact Assessment (EIA) is a condition for issuance of certificates of completion of project construction and for ongoing maintenance of operating licenses.

Case studies from large seawater desalination projects operating around the world for up to 20 years catalogue the range of concentrate discharge systems used, how they are monitored, what impacts have been detected, the strategies used to minimize impacts, and how regulators and local populations have responded to these projects.

Long-term experience worldwide indicates that discharges from seawater desalination plants are environmentally safe and do not result in negative impacts on the marine habitat in the area of plant discharge. While desalination plants use small amounts of chemicals to enhance the treatment processes these chemicals are not different from chemicals used in conventional water treatment plants and are specifically selected not to cause toxicity and harm of the aquatic environment.

Keywords: brine, concentrate management, zero liquid discharge, disposal, discharge

I. INTRODUCTION

1.1 General Background

Desalination of seawater is becoming increasingly popular for production of drinking water worldwide, as many coastal municipalities and utilities are looking for reliable and drought-proof sources of new local water supply. According to the International Desalination Association, in June 2018, there were over 16,000 desalination plants in operation worldwide, producing 87.5 million cubic meters per day, and providing water for 300 million people.

Similar to conventional water treatment plants and water reclamation facilities, desalination plants generate water treatment byproducts. The environmentally safe and sustainable management of these treatment byproducts is of prime importance to the desalination industry.

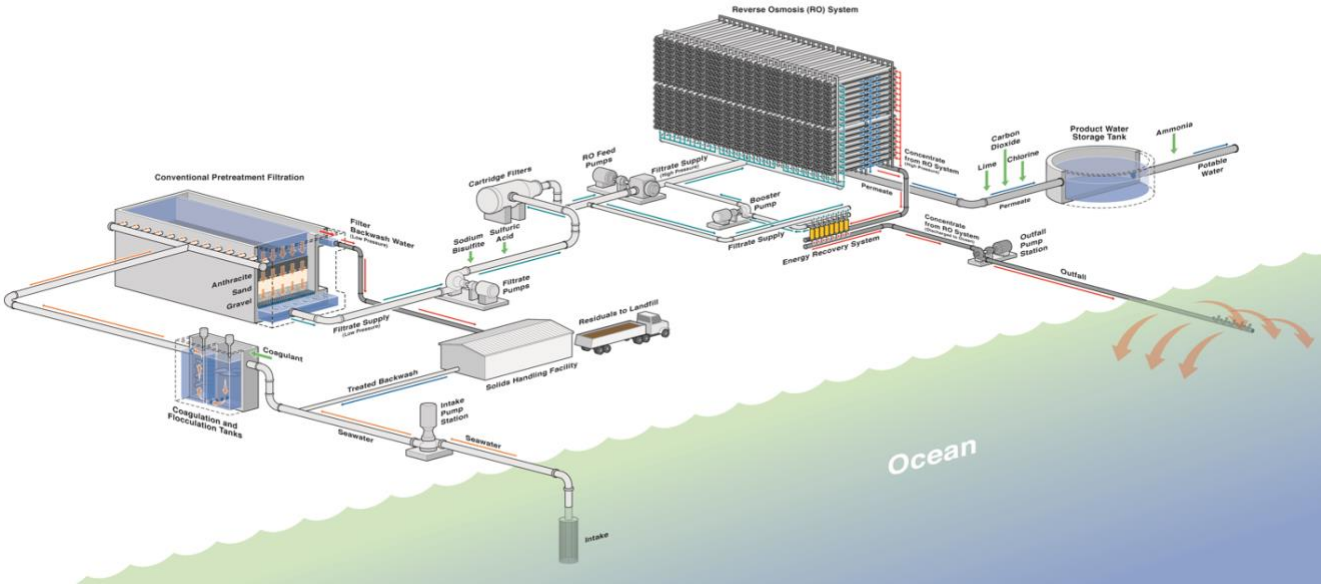
The purpose of this Position Paper is to present comprehensive information about the composition of seawater desalination byproducts; provide an overview of contemporary concentrate management practices; highlight case studies of concentrate disposal; and provide a glimpse of future trends in concentrate management.

Desalination technologies for production of fresh water are divided into two categories – membrane-based and thermal evaporation-based. Over the last decade, seawater reverse osmosis (SWRO), the most prevalent membrane-based technology, has become the method of choice for desalination worldwide because of its relatively lower energy use and cost of water production. After 2015, even most Middle Eastern countries stopped or drastically reduced the construction of new thermal desalination plants. Therefore, this paper will focus on SWRO desalination plants.

Most SWRO plants have the following key components: intake to collect source seawater; pretreatment system to remove solid particulates from the source water; reverse osmosis system to separate the salts from the source water, thereby producing fresh water (permeate); a post-treatment system to condition permeate for conveyance and final use; and an outfall – see Figure 1.

The percentage of the total volume of seawater converted into fresh water is referred to as desalination plant recovery. SWRO desalination plants are typically designed to recover 40% to 50% of the source water as fresh product water. In simple terms, a desalination system operating at 50% recovery collects two cubic meters of source seawater to generate one cubic meter of fresh water and one cubic meter of concentrate. In brackish water desalination plants, the recovery is usually higher (65 to 90%) – however the concentration of the saline source water is lower (typically between 800 and 4,000 mg/L of TDS), and therefore the concentrate generated by these plants do not exceed the salinity of ambient seawater.

The fresh water produced during the desalination process has a very low mineral content – typically 100 mg/l to 500 mg/L of salinity in the form of total dissolved solids (TDS). Containing over 99% of all source seawater salts and dissolved constituents, concentrate mineral content is approximately 1.5 to 2 times higher than that of the source seawater.



Source: Water Globe Consultants

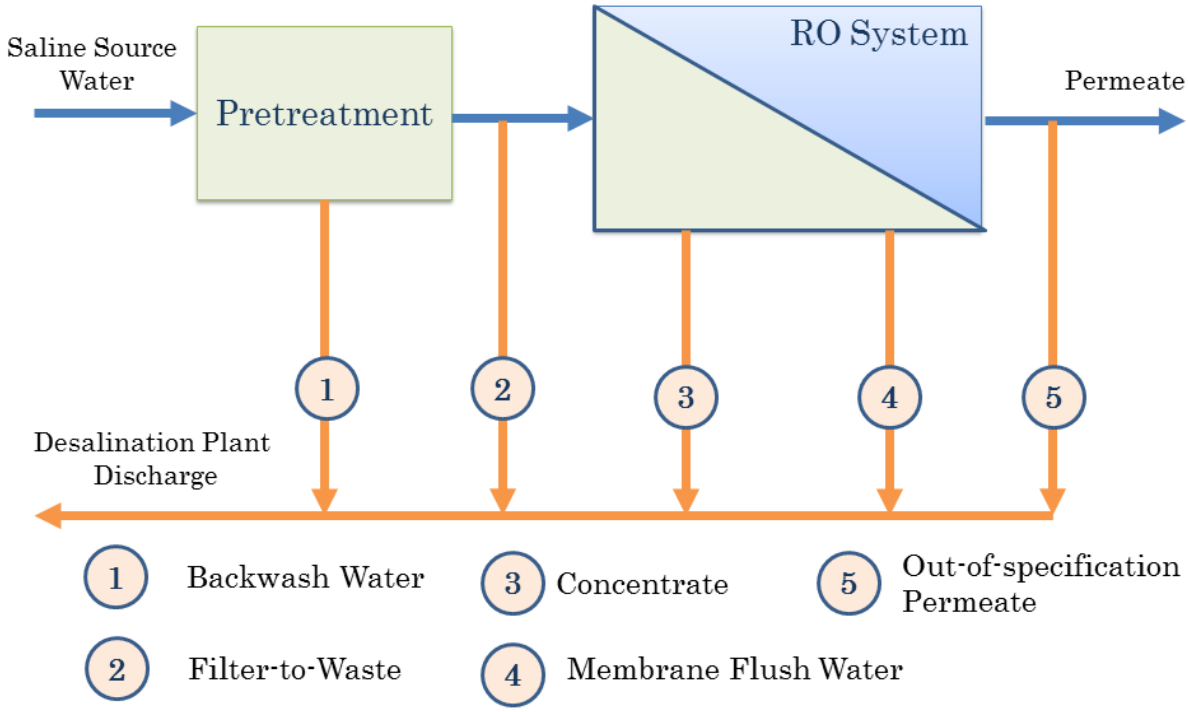
Figure 1 – Schematic of Typical Desalination Plant

II. SEAWATER DESALINATION BYPRODUCTS

The main by-product generated by the desalination plant's salt separation process is commonly referred to as concentrate or brine. In addition to concentrate, desalination plant discharges may include other treatment process side-streams, such as spent pretreatment filter backwash water, membrane rinsing water, and treated membrane cleaning water (Figure 2).

Desalination concentrate is concentrated seawater. It consists of dissolved compounds found in the ocean (minerals, organics, metals, etc.) that are rejected by the reverse osmosis membranes. Concentrate typically constitutes 90% to 95% of the total desalination plant discharge volume. Backwash water is generated during the periodic cleaning of the pretreatment filters, containing particulates and other compounds removed from source water prior to desalination. Membrane cleaning water, containing low levels of spent detergent and produced in very small quantities (0.1% or less) compared to concentrate flows, is produced when the membranes are cleaned. Chemicals used for membrane cleaning are typically the same as these used in toothpaste, soaps and commercial detergents. Both backwash water and membrane cleaning water are typically treated to remove solids or other contaminants prior to being added to the desalination concentrate for discharge.

Concentrate from seawater desalination plants using open ocean intakes typically has the same color, odor, oxygen content and transparency as the source seawater from which the concentrate was produced. Therefore, concentrate discharge to surface water bodies (ocean, river, etc.) does not typically change its physical characteristics or have aesthetic impact on the aquatic environment, except for its density.



Source: Water Globe Consultants

Figure 2 – Typical Discharge Components of Seawater Desalination Plant

When a coagulant, such as ferric chloride or ferric sulfate, is used for pretreatment the spent pretreatment filter backwash has a red color due to the high content of ferric hydroxide in the backwash water. If this backwash water is blended with the SWRO system concentrate, the entire desalination plant discharge will typically be visibly discolored.

In order to address this challenge, desalination projects built over the last 20 years worldwide are equipped to remove the ferric hydroxide from the backwash water, dewater it and dispose of it to a landfill in a solid form. As a result, the visual appearance of the desalination plant discharge is the same as that of the ambient seawater – i.e., the concentrate is transparent and clear and does not have aesthetic impact on the environment.

Desalination treatment processes do not cause depletion of the natural oxygen content of the source seawater used to produce fresh water. In fact, the backwashing with a mix of air and water of the filters used for pretreatment of the seawater enriches the oxygen of the plant discharge and prevent occurrence of hypoxia (low content of oxygen) in the discharge area.

Some desalination plants use sodium hypochlorite to prevent excessive bio-growth of shellfish in the source water intake pipelines and subsequently add sodium bisulfite to remove the residual chlorine after the chlorinated water passes through the pretreatment facilities of the desalination plant. While theoretically, if grossly overdosed the added sodium bisulfite could impact oxygen content in the discharge, such possibility is eliminated by closely monitoring the content of the added chemical and practically has never occurred in desalination facilities.

There is no relationship between the level of salinity and biological or chemical oxygen demand of the desalination plant concentrate. Over 80% of the minerals that comprise concentrate salinity are sodium and chloride, and they are not food sources or nutrients for aquatic organisms. The dissolved solids in the concentrate discharged from seawater desalination plants are not of anthropogenic origin as compared to pollutants contained in discharges from industrial or municipal wastewater treatment plants.

The concentration of particles, total suspended solids and biochemical oxygen demand in the concentrate is typically very low (≤ 5 mg/l). The filter backwash water is processed at the desalination plant site by settling. Therefore, the treated backwash water which is combined and discharged with the SWRO system concentrate is also very low in terms of total suspended solids and biochemical oxygen demand.

The organics and solids removed from the source seawater are disposed to a landfill as solid residuals. As a result, the total suspended solids content of the desalination plant discharge is lower than the solids content of the ambient source seawater collected for desalination.

III. DESALINATION PLANT DISCHARGE MANAGEMENT ISSUES AND SOLUTIONS

3.1. Environmental Impact of Elevated Discharge Temperature

Membrane desalination processes do not change the temperature of the desalination plant discharge because the process of desalination does not involve heating of the source seawater to produce fresh water. While in its early years thermal desalination plants in the Middle East had environmental impacts associated with elevated temperature of the discharge, most of such plants have been phased out over the past 10 years or their discharges modified to dissipate the thermal load of the discharge within 50 meters from the point of entrance into the sea and to reduce to temperature in the zone of initial dilution down to 2 to 4°C above ambient very quickly.

3.2. Environmental Impact of Elevated Salinity

3.2.1. Salinity Concentration.

Seawater desalination plants usually produce concentrate salinity which is approximately 1.5 to 2 times higher than the salinity of the ambient seawater. Since ocean water salinity worldwide typically varies between 35 to 46 parts per thousand (ppt), the concentrate salinity is usually in a range of 55 ppt to 70 ppt.

While many marine organisms can adapt to this salinity range, some aquatic species are less tolerant to elevated salinity concentrations. For example, gobies, which are one of the most common species inhabiting coastal waters, tolerate very high salinity concentrations. Gobies are well-known to inhabit the Salton Sea of California which currently has an ambient salinity of 45 ppt. However, other common organisms, such as abalone and sea urchins, have lower salinity tolerances of 44 to 50 ppt. Benthic marine organisms are least sensitive to salinity variations and they usually can withstand salinities upwards of 60 ppt without negative impacts.

The nature, magnitude and significance of elevated concentrate salinity impacts mainly depend upon the type of marine organisms inhabiting the discharge area and the length of time of their exposure. A salinity

tolerance study implemented in 2005 as part of the environmental impact review of the 50 million gallon per day (MGD) - 200,000 m^3/day - Carlsbad seawater desalination project, completed based on testing of over two dozen marine species frequently encountered along the California coast, indicates that these marine species can safely tolerate a salinity of 40 ppt (19.4 % above ambient salinity) based on whole effluent toxicity (WET) tests. This study also indicated that highly salinity sensitive marine species could be exposed to salinity as high as 60 ppt for a period of more than 2 hours without any negative impacts.

Site investigations of a number of existing full-scale seawater desalination plants operating in the Caribbean was completed by scientists from the University of South Florida and the South Florida Water Management District in 1998[1]. It concluded that salinity levels of 45 ppt to 57 ppt have not caused statistically significant changes in the aquatic environment in the area of the desalination plant discharges.

3.2.2. Discharge Salinity Related Regulatory Requirements.

At present, the regulations of most countries with desalination plants worldwide do not have general limits for discharge salinity as they do for suspended solids, biological oxygen demand, turbidity, temperature and pH. Instead, the pertinent environmental laws regulate concentrate discharges by establishing project-specific acute and chronic whole effluent toxicity (WET) objectives from which salinity limits and mandatory dilution ratios are derived. WET is a more comprehensive regulatory measure than a salinity limit because toxicity also accounts for potential synergistic environmental impacts of concentrate constituents with other constituents in the receiving body of water.

According to current regulations associated with desalination plant discharges of most countries worldwide, if a desalination plant discharge meets all water quality objectives defined in the applicable environmental regulations as well as acute and chronic WET objectives, then the proposed discharge does not present a threat to aquatic life. This is the case regardless of what the actual salinity level of this discharge is or what increase above ambient salinity this discharge may cause because WET accounts for the salinity related environmental impacts of concentrate.

Salinity tolerance of aquatic life is site specific and depends on the organisms inhabiting the area of the discharge as well as the nature of the discharge. Therefore, a single, non-site specific “blanket” narrative or numeric water quality objective (discharge limit) for salinity does not provide additional protection to the site-specific marine environment in the area of a given discharge, beyond that which is already provided by the acute and chronic toxicity objectives.

Despite the fact that environmental impacts associated with concentrate salinity are indirectly regulated through site-specific acute and chronic WET objectives, the discharge permits for some of the existing seawater desalination plants in the US for example, also contain specific numeric salinity limits (see Table 1).

The discharge permit of the 200,000 m^3/day (50 MGD) Carlsbad seawater desalination plant in California for example, contains an effluent limitation for chronic toxicity at the edge of the zone of initial dilution in combination with numeric limitations for average daily and average hourly total dissolved solids (salinity) concentrations of 40 parts per thousand (ppt) and 44 ppt, respectively. These salinity limits were established based on a site-specific Salinity Tolerance Study and chronic and acute toxicity testing

completed for this project. The referenced limits are applicable to the point of discharge and reflective/protective of the acute toxicity effect of the proposed discharge.

Table 1 – Examples of Desalination Plant Discharge Limits

Desalination Plant	Total Flow (MGD)	TDS (Avg.) (ppt)	TDS (Max.) (ppt)	Acute Toxicity TUa	Chronic Toxicity TUc	Flow Ratio
Carlsbad - 50 MGD; • 33.5 ppt - TDS(source); • 67.0 ppt (conc.)	54/60.3 (Conv. Pretreat) 57/64.5 (Mem. Pretreat)	40 (daily) (19.4 % Above Ambient)	44 (Maximum Hourly) (31.3 % Above Ambient)	0.765	16.5	Mixing Zone 15.1:1
Huntington Beach – 50MGD • 33.5 ppt – TDS (source); • 67.0 ppt (conc).	56.59 (Conv. Pretreat)	None	None	None	8.5	Mixing Zone 7.5:1 Min. Dilution =2.24:1
Tampa – 25 MGD • 26 ppt – TDS (source); • 43 ppt (conc.)	22.8 (Conv. Pretreat)	35.8 (38% Above Ambient)	35.8 (38% Above Ambient)	None	None	Dilution =28:1 (20:1– minimum)

Notes: 1 part per thousand (ppt) = 1,000 mg/L, TDS = total dissolved solids, MGD = million gallons per day; Conv – conventional; Pretreat. – Pretreatment; conc. – concentration.

3.2.3. Discharge Salinity Dispersion Modeling.

The long-term impacts of medium and large-size desalination plants on the receiving aquatic environment are thoroughly studied before project implementation by computer-assisted modeling of the dispersion of the concentrate in the discharge area. The main purpose of the evaluation of the concentrate dispersion is to establish the size of the zone of initial dilution (ZID) required to dissipate the discharge salinity plume to near-ambient seawater TDS levels and to determine the TDS concentrations at the surface, mid-level of the water column, and at the ocean bottom in the ZID for which the discharge salinity will be environmentally safe. The TDS concentration fields at these three levels are compared to the salinity tolerance of the marine organisms inhabiting the surface (mostly plankton), the water column (predominantly invertebrates) and the bottom dwellers (such as crabs, and worms) in order to determine the impact of the concentrate salinity discharge on these organisms.

The discharge salinity field in the ZID and the ZID boundaries are established using hydrodynamic modeling. This modeling allows for determination of the most suitable location, design configuration and size of the ocean outfall and diffusers if a new outfall is needed, or assessment of the feasibility of using existing wastewater or power plant outfall facilities.

The models most widely used for salinity plume analysis are CORMIX and Visual Plumes. Both models allow depicting the concentrate plume dissipation under a variety of outfall and diffuser configurations and operational conditions. These models are approved by the US Environmental Protection Agency for this and other water quality management applications, such as mixing zone analysis and establishment of total maximum discharge limits (TMDLs). However, CORMIX and Visual Plumes are near-field models that do not account for the far field mixing and advective processes associated with shoaling waves and coastal current systems. Therefore, discharge modeling is extended beyond the near-field ZID using various computational fluid dynamics (CFD) software packages which are tailored to a given application.

3.3. Effect of Source Water Conditioning Additives

Desalination plants use many of the same additives (treatment chemicals) applied for source water conditioning in conventional drinking water treatment plants and therefore, have very similar side-stream discharge water quality. The long-term track record of environmentally safe operation of surface water treatment plants worldwide using many of the same water conditioning additives is a testament to the fact that, if properly handled and utilized, such additives do not pose environmental challenges.

The state-of-the-art desalination processes employed in contemporary desalination plants use a very limited amount of chemicals. All chemicals added to enhance the quality of the produced water are of food grade quality, biodegradable, and specifically selected not to cause any aquatic marine life toxicity. If the desalination plant pretreatment side-streams were discharged along with the concentrate, the blend could contain elevated turbidity, suspended solids and biochemical oxygen demand. As indicated previously, for conventional granular media pretreatment systems, iron-based additives (coagulants) such as ferric salts are often used for source water conditioning (particle coagulation for enhanced removal). Depending on their dosage, iron additives could discolour the pretreatment side-stream, which, if blended with concentrate, could also change the colour of the desalination plant discharge. For these reasons, the desalination plant pre-treatment side-streams are either processed in a separate solids handling system (common practice for large plants), or discharged to a sanitary sewer for further treatment at a wastewater plant (typical for small plants). Most membrane-based pretreatment systems do not use coagulant and therefore are not challenged with the discharge discoloration issue.

Acids and scale inhibitors are often added to the desalination plant source water to facilitate the salt separation process. Typically, these additives are rejected by the reverse osmosis membranes and are collected in the concentrate. However, such source water conditioning compounds are applied at very low concentrations and their content does not alter significantly the water quality and quantity of the concentrate. The environmental implications of the use of such additives are tested before their use, and only additives that are proven harmless for the environment and approved by pertinent regulatory agencies are applied for seawater treatment. All chemical additives used at both desalination and conventional water treatment plants are of food grade purity and are approved for human consumption.

IV. DESALINATION INDUSTRY STEWARDSHIP OF THE AQUATIC ENVIRONMENT

The desalination industry is often challenged about the potential impact of brine discharges into the marine environment. Early in 2019, articles were published by Bloomberg News and few other news outlets that vilified desalination discharges as “toxic brine” and challenged the ability of the desalination industry to minimize the impact of such discharges on the environment.

However, the reality is that today, the desalination industry and its regulators have comprehensive systems to predict, monitor and prevent potential environmental impacts during all phases of project development and implementation – from planning to design, construction and operation. Safeguarding the aquatic

environment and ecosystems in the vicinity of desalination plant discharges is an essential component of good operation practices by the desalination industry. Desalination plants in operation worldwide continuously monitor and comply with strict environment regulations and discharge water quality standards set by governmental bodies in charge of protecting the aquatic environment.

During desalination project inception and planning phases, all desalination projects worldwide undergo thorough Environmental Impact Assessments (EIA). Compliance with the environmental impact mitigation measures delineated in each project's EIA is monitored and enforced by specially designated construction management and regulatory compliance oversight teams throughout the project construction and commissioning process. Compliance is usually a condition for issuance of certificates of completion of project construction to the contractors responsible for project delivery and for approval of plant operations licenses and discharge permits.

The discharge permits of most desalination plants worldwide contain requirements for comprehensive end-of-pipe water quality monitoring and frequent offshore marine environment studies to ascertain permit compliance and identify and mitigate any potential environmental impacts.

In contemporary desalination plants, onsite environmental compliance monitoring professionals located at each desalination plant are responsible for on-going water quality-monitoring. In addition, most medium and large size desalination plants have teams of marine biologists, which complete frequent offshore source water quality monitoring and evaluation of the environmental health and diversity of marine habitats.

Local and regional regulatory agencies in charge of the monitoring and compliance of desalination plant discharges provide another layer of oversight of the compliance of desalination plant discharges with their environmental permit requirements. These agencies have expert staffs of aquatic biologists and water quality specialists as well as water quality laboratories which independently verify discharge compliance and environmental health of the aquatic habitat in the vicinity of the discharge.

V. CONCENTRATE MANAGEMENT ALTERNATIVES

The most commonly used methods of seawater desalination concentrate management include: discharge to the ocean via onshore or offshore outfalls; concentrate conveyance to a nearby sanitary sewer; and subsurface discharge through exfiltration wells and galleries. Discharge to a sanitary sewer and exfiltration wells are typically only practiced by small size desalination plants, where desalination plant flows are much smaller than the overall discharge flows.

5.1. Discharge via New Outfalls

New plant outfalls are designed to dissipate plant concentrate within a short time (20 to 30 min) and distance (100 to 300 m) from the point of its entrance into the ocean in order to minimize environmental impacts. The two options available to accelerate and enhance the concentrate mixing process are to either rely on the naturally occurring mixing capacity of the near-shore zone (e.g., tidal movement, near-shore currents, wind), or to discharge concentrate beyond the near-shore zone through diffusers which release concentrate at high velocity towards the ocean surface, thereby enhancing mixing.

The near-shore tidal zone is usually a suitable location for concentrate discharge when it has adequate capacity to receive, mix and transport desalination plant discharge into the open ocean. The mixing/transport capacity of the tidal zone can be determined using hydrodynamic modelling.

If the salinity discharge load is lower than the tidal zone threshold mixing/transport capacity, then concentrate discharge to this near-shore zone is environmentally benign. In these cases, discharge to the near-short zone is environmentally preferable to the use of long, open outfalls equipped with diffuser systems. For example, the sites of the 200,000 m^3/day (50 MGD) Carlsbad Desalination Plant (Figure 3), and the 350,000 m^3/day (92 MGD) Hadera Desalination Plant (Figure 4) in Israel were specifically selected for their vicinity to coastal locations with very intensive natural near-shore tidal mixing, which eliminated the need for construction of lengthy outfalls and costly outfall diffuser structures.

Source: Poseidon Water

Figure 3 – Carlsbad Desalination Plant Near-shore Discharge

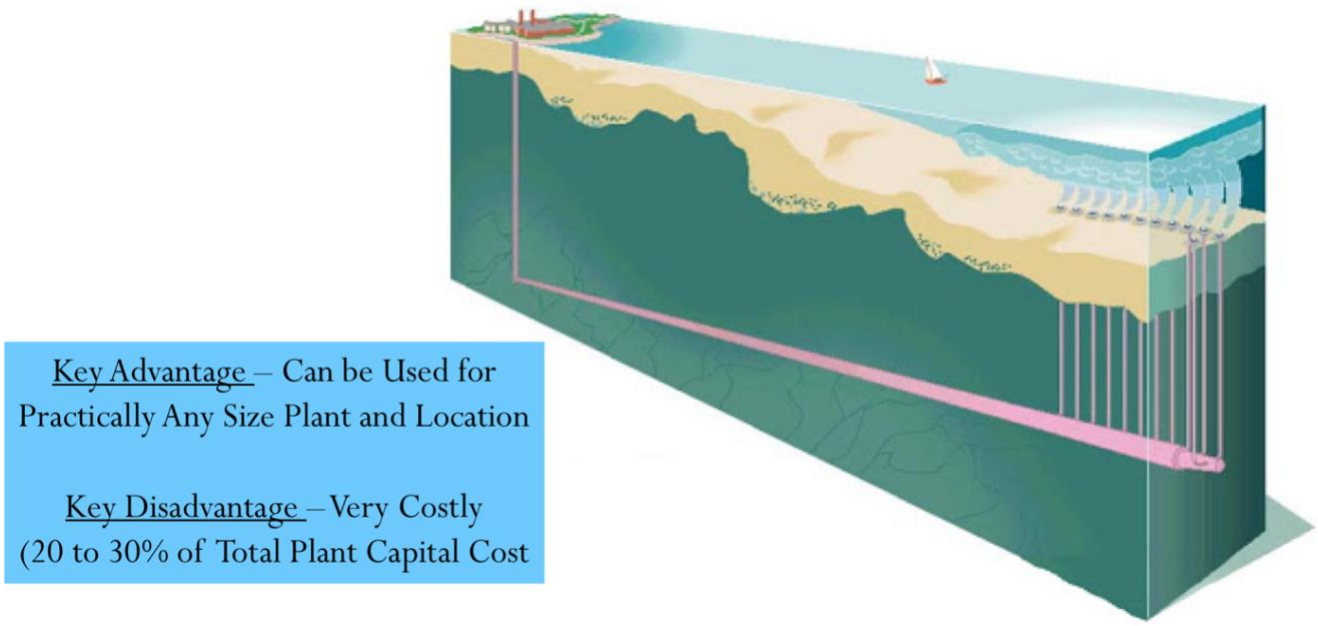
Source: IDE

Figure 4 – Near Shore Discharge of Hadera Desalination Plant

Although the tidal (surf) zone may have significant amount of turbulent energy and often may provide better mixing than an end-of-pipe type diffuser outfall systems, this zone has limited capacity to transport and dissipate the saline discharge load into the open ocean. If the mass of the saline discharge exceeds the threshold of the tidal zone's salinity load mixing and transport capacity, the excess salinity could begin to accumulate in the tidal zone and could ultimately result in a sustained salinity increase in this zone.

For such conditions, the construction of a new outfall structure with diffusers is often the concentrate discharge system of choice. The diffuser system provides the mixing necessary to prevent the heavy saline discharge plume from accumulating at the bottom in the immediate vicinity of the discharge (see Figure 5). The length, size and configuration of the outfall and diffuser structure are typically determined based on hydrodynamic modelling for the site-specific conditions of the discharge location. Figure 6 depicts the diffuser outfall of the Gold Coast desalination plant in Australia.

Key advantages of constructing new discharge outfalls include accommodating discharge from practically any size desalination plant and providing for more freedom in selecting plant location, as compared to the other discharge alternatives which rely on the use of existing wastewater treatment plant or power plant outfalls at specific locations. The key disadvantage is that a new outfall is usually the most expensive alternative for disposal of concentrate from medium and large size desalination plants. Nevertheless, new ocean outfalls with diffuser structures are commonly used worldwide and are the concentrate discharge alternative of choice for the seawater desalination plants in Australia constructed to date.



Source: Water Globe Consultants

Figure 5 – New Ocean Outfall – Typical Configuration

Source: The Water Corporation

Figure 6 – Outfall with Diffusers - Gold Coast Desalination Plant, Australia

5.2. Discharge through Existing Wastewater Treatment Plant Outfalls

The key feature of this combined discharge method is the benefit of accelerated mixing that stems from blending high-salinity concentrate with low-salinity wastewater discharge. Depending on the volume of

the concentrate and how well the two waste streams are mixed prior to discharge, the blending may reduce the size of the wastewater discharge plume and dilute some of its constituents.

A number of large desalination plants worldwide co-discharge their concentrate through existing wastewater treatment plant (WWTP) outfalls. For example, the concentrate from the 150,000 m^3/day (40 MGD) Beckton desalination plant in London, England is blended with secondary effluent from the Beckton Wastewater Treatment Works at a dilution ratio of 1:50 and safely discharged to the Thames River.

The largest plant in operation at present which practices co-discharge of desalination plant concentrate and wastewater effluent is the 200,000 m^3/day (50 MGD) SWRO facility in Barcelona, Spain (see Figure 7). Co-disposal with wastewater effluent is also used at the 80,000 m^3/day (21 MGD) Fukuoka SWRO plant, which is the largest SWRO plant in Japan.

Source: Suez

Figure 7 – Barcelona Seawater Desalination Plant, Spain

The key advantage of co-discharge with wastewater treatment plants is that it avoids substantial costs and environmental impacts associated with construction of a new outfall for the desalination plant. Mixing of the negatively buoyant wastewater discharge with the heavier than ocean water concentrate, promotes the accelerated dissipation of both the wastewater plume, which otherwise tends to float to the ocean surface, and the concentrate, which otherwise tends to sink towards the ocean bottom. In addition, metals, organics and pathogens in seawater concentrate are typically at significantly lower levels than those in the wastewater discharge, which helps with reducing their discharge concentrations in the combined effluent.

5.3. Collocation with Existing Power Plants

Collocation with existing power plants involves using the cooling water discharge of an existing plant as both the source of saline water for desalination and as dilution water for discharge of desalination

plant concentrate. For collocation to be viable, the power plant cooling water discharge flow must be greater than the proposed desalination plant intake flow, and the power plant outfall configuration must be adequate to avoid entrainment and recirculation of concentrate into the desalination plant intake. Special consideration must be given to the effect of power plant operations on the cooling water quality, since this discharge is used as source water for the desalination plant.

Power plant thermal discharge is less dense than ambient ocean water because of its elevated temperature. Consequently, the discharge tends to float on the ocean surface. The denser saline discharge from the desalination plant, when mingled with the warmer, less dense water, diverts the flow downward and thereby engages the entire depth of the ocean water column into the heat and salinity dissipation process. This accelerates its mixing and blending into the ambient seawater. The beneficial impact of such blending compared to desalination concentrate discharge without blending is illustrated in Figure 8.

Opponents of collocated seawater desalination plants often argue that if a coastal power generation plant discontinues its once-through cooling practices, the associated seawater desalination project would no longer be viable. On the contrary, the desalination facility typically retains the significant and primary cost-benefit of collocation: avoidance of the need to construct a new intake and outfall and only having to modify the existing outfall infrastructure to accommodate a diffuser system. The capital cost savings from the use of the existing power plant intake and outfall facilities are typically 10 to 50% of the total construction costs of a desalination plant that is not collocated.

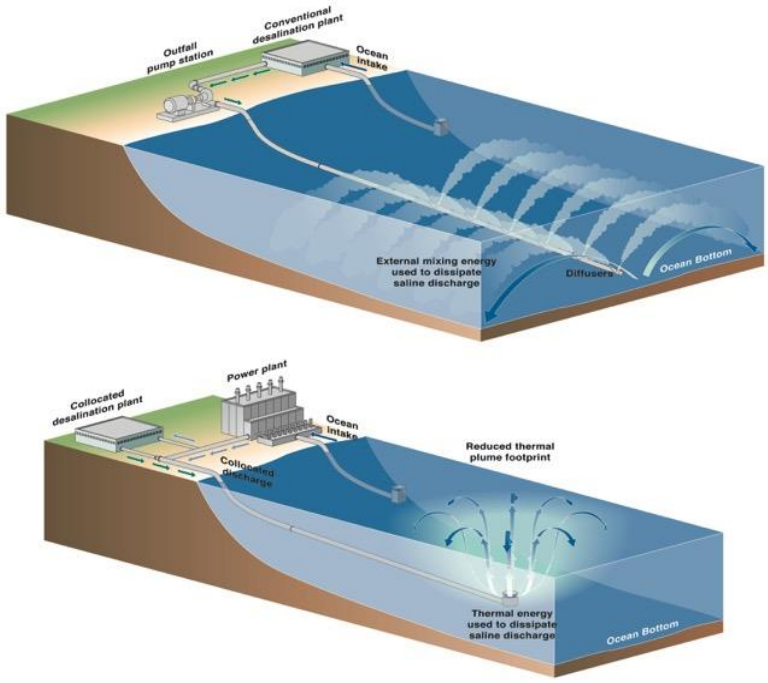
VI. CONCENTRATE DISCHARGE CASE STUDIES

Around the world, seawater desalination has a comprehensive track record of successful operation and environmentally safe performance. The concentrate disposal project case studies presented below illustrate worldwide experience with concentrate management for large seawater desalination projects.

6.1. Tampa Bay Seawater Desalination Plant

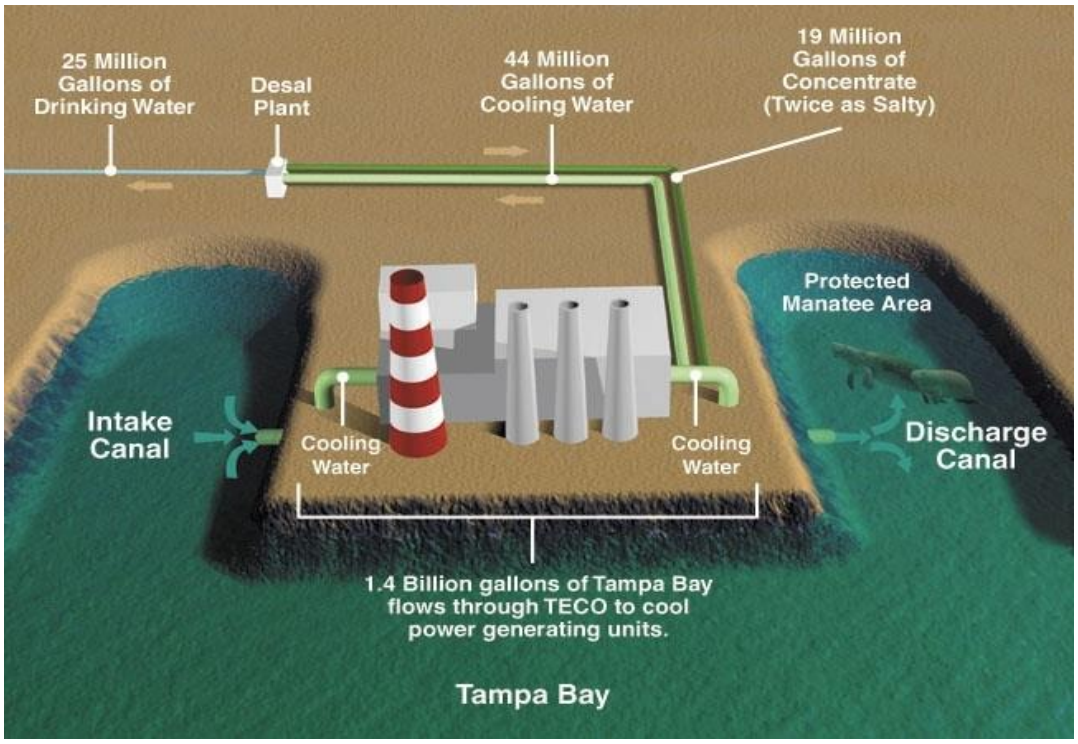
Collocation with a power station in a large-scale application was first proposed for the Tampa Bay Seawater Desalination Project in 1999. The intake and discharge of the completed Tampa Bay Seawater Desalination Plant are connected directly to the cooling water discharge outfalls of the Tampa Electric Company (TECO)'s Big Bend Power Station (Figure 9)**.** Since then, collocation has been considered for numerous plants in the US and worldwide.

The TECO power generation station discharges an average of 5.2 million cubic meters of cooling water per day (1,350 MGD), of which the desalination plant takes an average of 166,000 m^3/day (44 MGD) to produce 95,000 m^3/day (25 MGD) of fresh drinking water. 71,000 m^3/day (19 MGD) of desalination plant concentrate is discharged into the TECO cooling water outfall downstream from the desalination plant intake connection.



Source: Water Globe Consultants

Figure 8 – Comparison of Concentrate Mixing Patterns of Collocated and New Outfalls



Source: Water Globe Consultants

Figure 9 – Tampa Bay SWRO Plant Collocation Schematic

In this case, the source seawater is treated through fine screens, coagulation and flocculation chambers, a single stage of sand media followed by diatomaceous filters for polishing, and cartridge filters prior to desalination. Spent prefilter backwash water from the desalination plant is processed through lamella settlers and dewatered using belt filter presses. Treated backwash water and desalination concentrate are blended and disposed through the power plant outfalls in compliance with a discharge permit administered by the Florida Department of Environmental Protection.

Environmental monitoring of the desalination plant discharge has been ongoing since the plant first began operating in 2002[2] The desalination plant discharges concentrate of salinity from 54 ppt to 62 ppt, which is blended with the remainder of the power plant cooling water prior to its discharge to Tampa Bay. Because of the large dilution volume of the power plant discharge, the blend of concentrate and cooling water has a salinity level which is well within 2 ppt of the ambient bay water salinity.

The environmental monitoring program in the area of the desalination plant discharge is implemented by Tampa Bay Water independently from the desalination plant operator, American Water-Acciona Agua, in fulfillment of the plant's discharge permit requirements. Overall objectives for the monitoring program are to detect and evaluate effects of discharge through comparison to a control area at time intervals defined by facility operation (pre-operational, operational, and off-line periods).

The plant discharge permit requires additional supplemental sampling to be performed as part of Tampa Bay Water's hydrobiological monitoring program. Water quality and benthic invertebrate monitoring is conducted at fixed and random sites, and is focused on areas most likely to be affected by the discharge including the power plant discharge canal, and areas of Hillsborough Bay and the middle of Tampa Bay. A control area considered representative of ambient background bay water quality conditions is used for comparison. For fish and seagrass, data collected by other government agencies monitoring in the vicinity of the desalination facility have been used to assess potential changes. In addition, the discharge permit also requires monitoring of chemical constituents to ensure that water quality in Tampa Bay is protected.

The Tampa Bay desalination facility first began operating in 2003. Since then, it has operated at varying production levels until being taken off-line for system upgrades in May 2005. The facility came back on-line in March 2007. Evaluation of monitoring data from the period of 2002 to 2008 shows that even during periods of maximum water production (110,000 m^3/day, 29 MGD), changes in salinity in the vicinity of the discharge were within or below the maximum thresholds (less than 2 ppt increase over background) predicted by the hydrodynamic model developed during the design and permitting phases of the facility. Review of monitoring data to date indicates that the plant operation does not have any adverse impacts on Tampa Bay's water quality and abundance, or diversity of the biological resources near the facility discharge.

While benthic assemblages varied spatially in terms of dominant taxa, diversity, and community structure, the salinity did not vary among monitoring strata. Also, the observed spatial heterogeneity of marine life distribution has been found to be caused by variables not related to the discharge from the desalination facility (e.g., temperature and substrate). Patterns in fish community diversity in the vicinity of the facility were similar to those occurring elsewhere in Tampa Bay, and no differences between operational and non-operational periods were observed.

6.2. Antigua Desalination Plant Discharge Study

In 1998, the Southwest Florida Water Management District and the University of South Florida completed a study entitled "Effects of the Disposal of Seawater Desalination Discharges on Near Shore Benthic Communities"[1]. The purpose of this study was to identify the environmental impact of discharge from an existing desalination plant on the benthic, plant and animal communities that inhabit the discharge area. The selected test site was located near a 6,800 m^3/d (1.8 MGD) seawater desalination plant in Antigua, the Caribbean. The discharge salinity of this plant is 57 ppt.

The desalination plant outfall extends approximately 300 feet (100 m) from the shore and does not have diffusers – the concentrate exits the open pipe directly into the ocean and is mixed by the kinetic energy of the discharge and ocean tidal movement. The salinity within 3.0 feet (1.0 meter) from the point of discharge was measured to be in a range 45 to 50 ppt.

The research team developed six transects extending radially from the point of discharge and completed two monitoring studies of the condition of the marine organisms encountered along the six transects within a 6-month period including: seagrass; macro algae; benthic microalgae; benthic foraminifera; and macro-fauna. The results of these studies indicate that the desalination plant discharge did not have a detectable effect on the density, biomass and production of seagrass. In addition, the discharge did not have a statistically significant impact on the biomass and the numerical abundance of the benthic micro-algal community, benthic foraminifera and macro-fauna (polychaetas, oligochaetes, bivalves, gastropods, pelagic fish, anemones, worms, sea stars and other species inhabiting the discharge).

6.3. Gold Coast Desalination Plant, Australia

This 170,000 m^3/day (45 MGD) desalination plant is located in South East Queensland, Australia in an area which is a renowned tourist destination (see Figure 10). The desalination plant has been in operation since November 2008 and employs an open intake, granular media pretreatment filters, and a reverse osmosis desalination system.

The Gold Coast plant is a stand-alone facility, which discharges concentrate with salinity of 67 ppt into the ocean through a multiple diffuser system. The zone of initial dilution of this plant is 360 feet x 960 feet (120 meters x 320 meters). The Gold Coast plant discharge diffusers are located at the ocean bottom and direct concentrate upwards into the water column to a height of approximately 30 feet (see Figure 6). As presented at the 2009 World Congress meeting of the International Desalination Association[3], the aquatic habitat in the area of Gold Coast Desalination Plant discharge is sandy bottom, inhabited primarily by widely scattered tube anemones, sipunculid worms, sea stars, and burrowing sponges. For 18 months prior to the beginning of desalination plant operations, the project team completed baseline monitoring to document the original existing environmental conditions, as well as flora and fauna in the area of the discharge.

Once the plant began operations in November of 2008, the project team conducted studies to assess potential environmental impacts and verify salinity projections. Specifically, they completed marine monitoring at four sites around the discharge diffuser area at the edge of the mixing zone, as well as at two reference locations 1,500 feet away from the edge of the mixing zone.

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The water quality and benthic infauna abundance and diversity results after commissioning of the Gold Coast plant were compared with the baseline monitoring results, as well as with the results of the monitoring sites.

The results of pre-and-post plant commissioning clearly indicate that the desalination plant operations did not have a measurable impact on the marine habitat in the area of the discharge – the aquatic fauna has practically remained the same in terms of both abundance and diversity. After the Gold Coast plant had been in operation for over one year, continued monitoring confirmed that the plant's discharge was environmentally safe. Further monitoring of the discharge zone over the last 10 years confirm that plant performance does not have negative impact on the aquatic environment in terms of biodiversity and population number.

Source: WaterSecure

Figure 10 – Gold Coast Seawater Desalination Plant

6.4. Perth Seawater Desalination Plant, Australia

As of the November 2009 World Congress meeting of the International Desalination Association[4], the 38 MGD Perth Seawater Desalination Plant had been in continuous operation since November 2006. This plant supplies over 17% of the drinking water for the City of Perth, Australia which has over 1.6 million inhabitants (Figure 11).

The treatment facilities of the Perth seawater desalination plant are very typical for state-of-the-art desalination plants worldwide. This plant has an open intake structure extending 200 meters from the

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shore. Source seawater is pretreated using a single-stage of granular media filters, 5-micron cartridge filters, and a two-pass reverse osmosis membrane system with pressure exchangers for energy recovery. Spent filter backwash water from the plant's pretreatment system is treated on site in lamella settlers, and the supernatant from this treatment process is discharged with the desalination plant concentrate. The solids generated as a result of the backwash treatment process are dewatered using a belt filter press and disposed to a landfill.

Source: The Water Corporation

Figure 11 – Perth Seawater Desalination Plant

The Perth SWRO plant discharges to Cockburn Sound, which is a shallow and enclosed water body with a very limited water circulation. Cockburn Sound frequently experiences naturally occurring low oxygen levels. Since the area has very limited natural mixing, the desalination plant project team constructed a diffuser-based outfall which is located approximately 500 meters offshore and has 40 ports along the final 200 meters at approximately 0.5 meters from the seabed surface at a 60-degree angle.

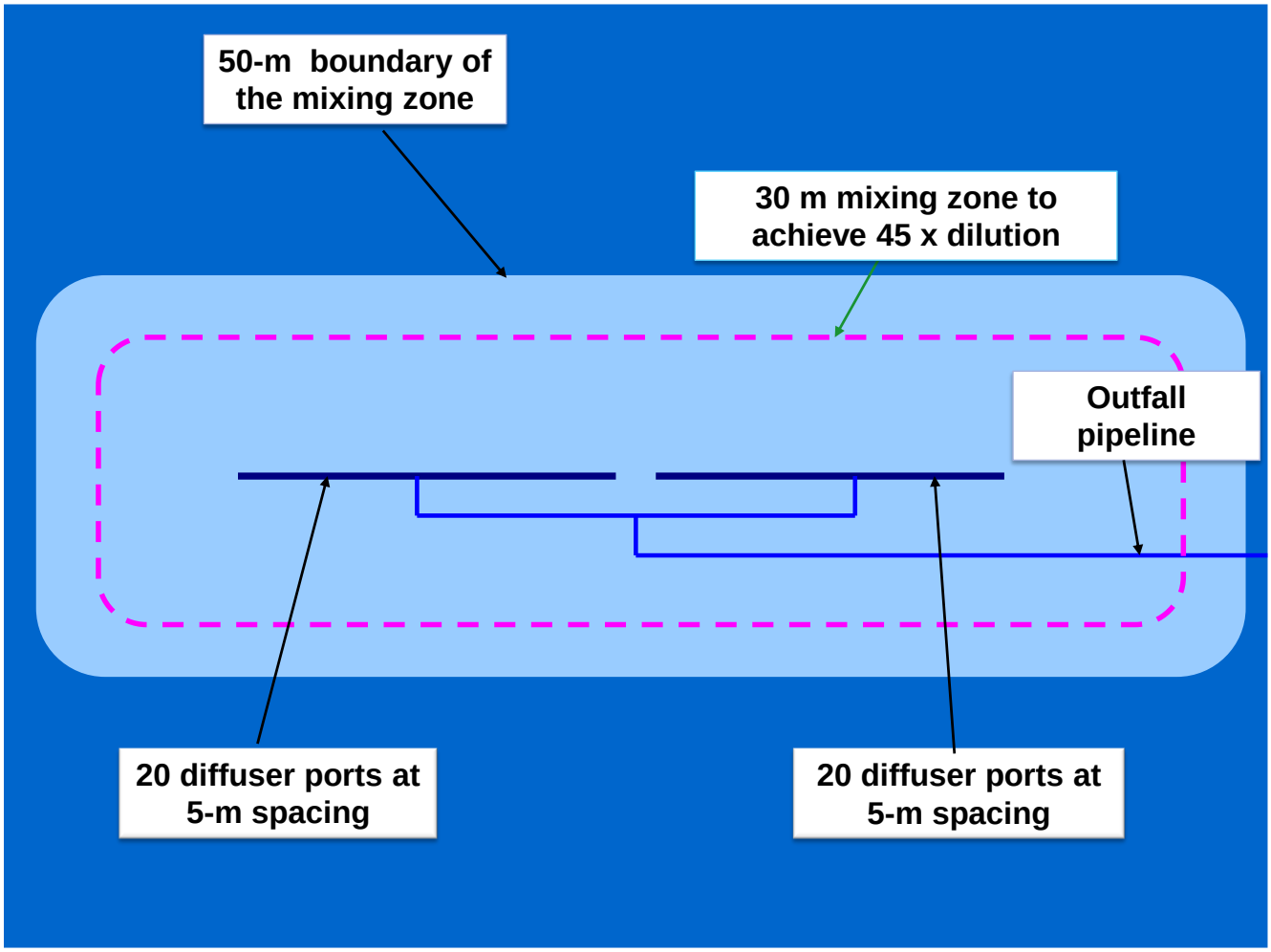
The diffuser ports are spaced at 5 meter intervals with 0.22 m nominal port diameters at a depth of 10 meters (see Figure 12). The diffuser ports extend 0.5 meters from the floor of the Sound. Diffuser length is 160 meters. The outfall is a single glass reinforced polymer pipeline with a diameter of 1600 mm.

This diffuser design was adopted with the expectation that the concentrate plume would rise to a height of 8.5 meters before beginning to sink due to its elevated density. The outfall structure was designed to achieve a plume thickness at the edge of the mixing zone of 2.5 meters and, in the absence of ambient

cross-flow, to extend to approximately 50 meters laterally from the diffuser to the edge of the mixing zone (see Figures 12 and 13).

Extensive real-time monitoring was undertaken in Cockburn Sound since the plant began operating in November 2006 to ensure that the marine habitat and fauna were protected. This monitoring included continuous measurement of dissolved oxygen levels via sensors located on the sandy bed of the Sound. Visual confirmation of the plume dispersion was achieved by the use of 52 liters of Rhodamine dye added to the plant discharge.

The dye was reported to have billowed to within approximately 3 meters of the water surface before falling to the seabed and spilling along a shallow sill of the Sound towards the ocean.
The experiment showed that the dye had dispersed beyond what could be visually detected within a distance of approximately 1.5 kilometers – well within the protected deeper region of Cockburn Sound which is located approximately 5 kilometers from the diffusers.

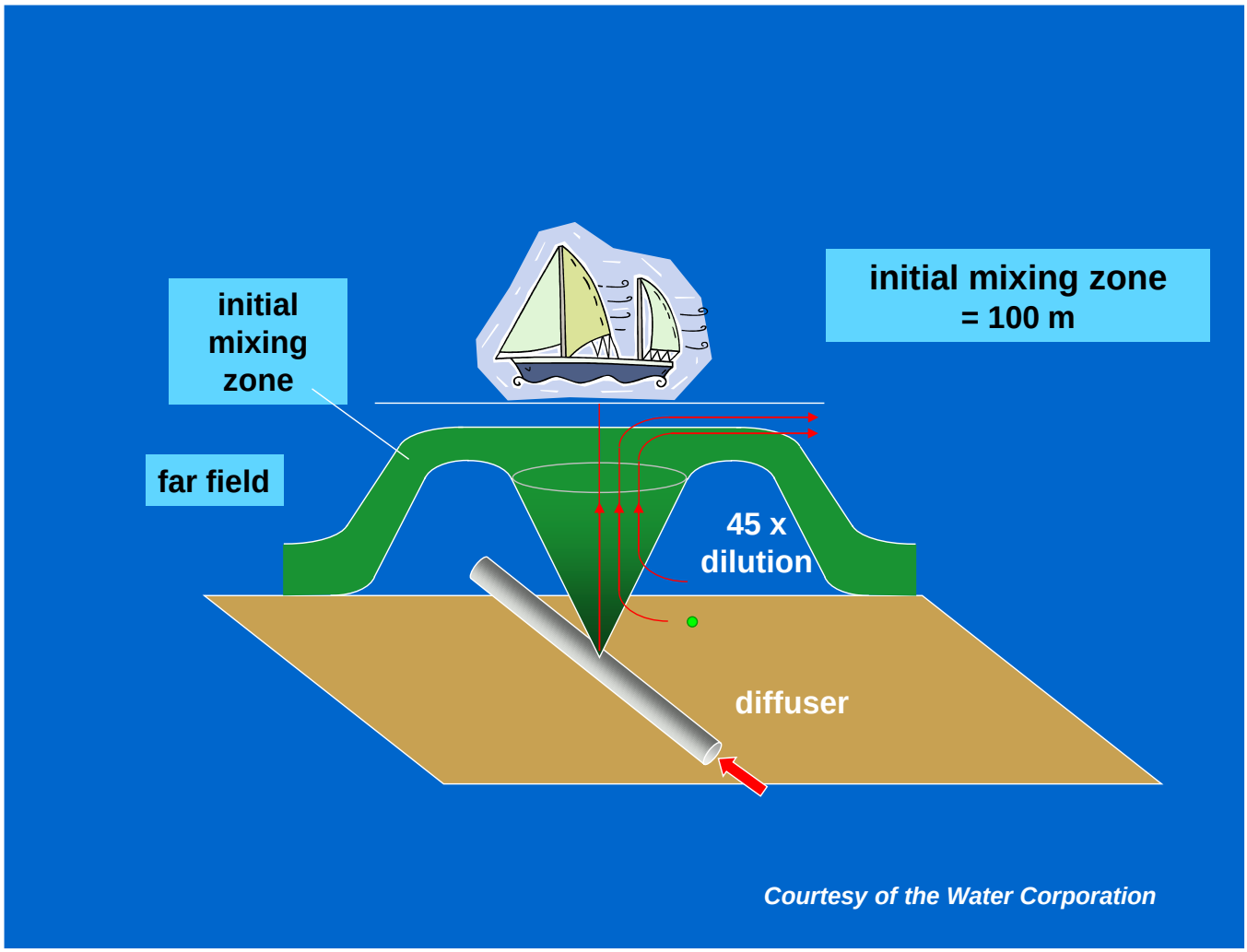


Source: The Water Corporation

Figure 12 – Perth SWRO Plant Discharge Configuration

In addition to the dye study, the project team completed a series of toxicity tests with a number of species in larval phases to determine the minimum dilution ratio needed to be achieved at the edge of the zone of initial dilution:

- 72-hour macro-algal germination assay using the brown kelp *Ecklonia radiate*;
- 48-hour mussel larval development using *Mytilis edulis*;
- 72-hour algal growth test using the unicellular algae *Isochrysis galbana*;
- 28-day copepod reproduction test using the copepod *Gladioferens imparipes*; and
- 7-day larval fish growth test using the marine fish pink snapper *Pagrus auratus*.



Source: The Water Corporation

Figure 13 - Perth Desalination Plant Mixing Zone

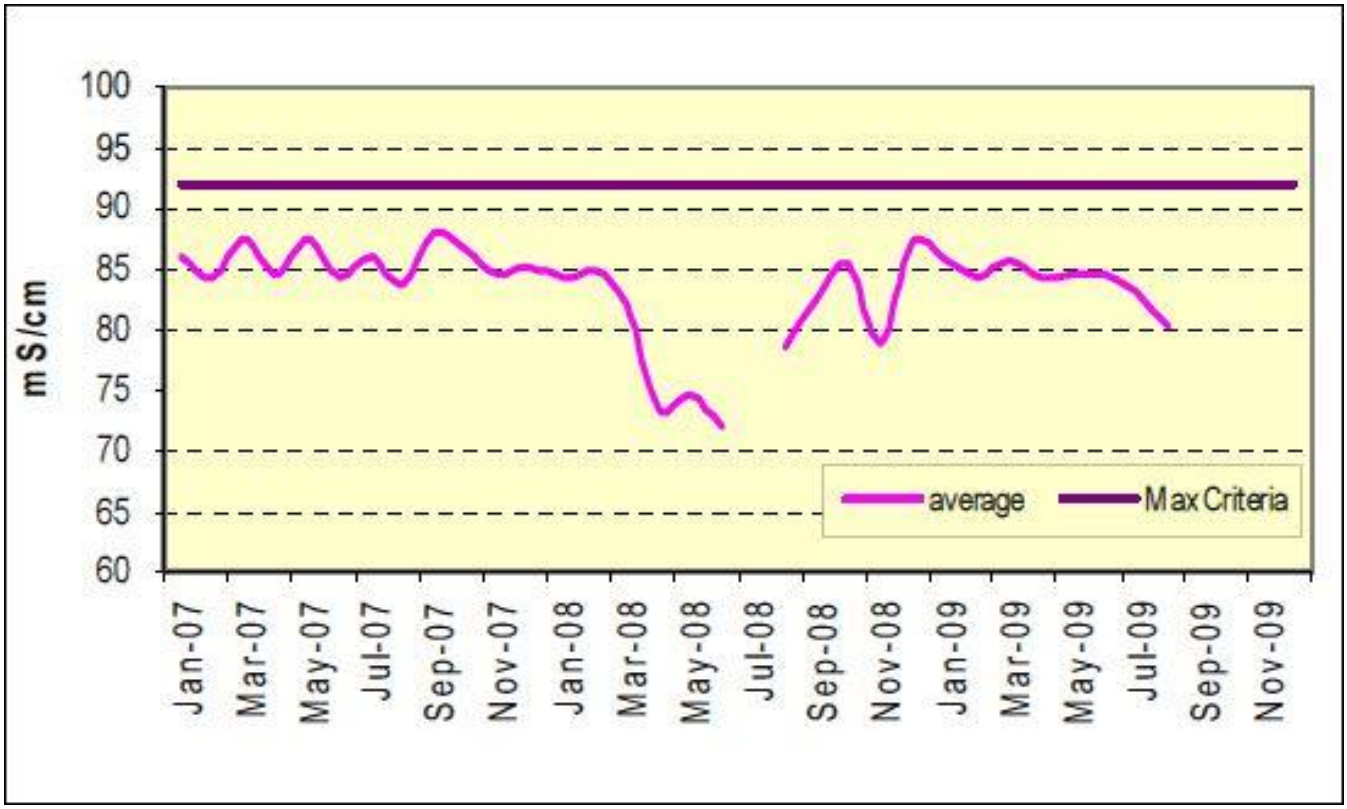
The results of the toxicity tests indicated that the plant concentrate dilution at the edge of the zone of initial dilution needed to be greater than 9.2:1 to 15.1:1 in order to protect the sensitive species listed above. The design mixing ratio of the diffuser system was 45:1 - well above the required minimums.

In addition to toxicity testing, the Perth desalination project team also completed two environmental surveys of the desalination plant discharge area in terms of macro-faunal community and sediment

(benthic) habitat[5,6]. The March 2006 baseline survey covered 77 sites to determine the spatial pattern of the benthic macro-faunal communities, while the repeat survey in 2008 covered 41 sites originally sampled in 2006, as well as five new reference sites. Some of the benthic community survey locations were in the immediate vicinity of the discharge diffusers, while others were in various locations throughout the bay. The two surveys have shown no changes in benthic communities that can be attributed to the desalination plant discharge.

Water quality sampling completed in the discharge area has shown no observable effect on ocean water quality, except that the salinity at the ocean bottom increased up to 1 ppt, which is well within the naturally occurring salinity variation[7].

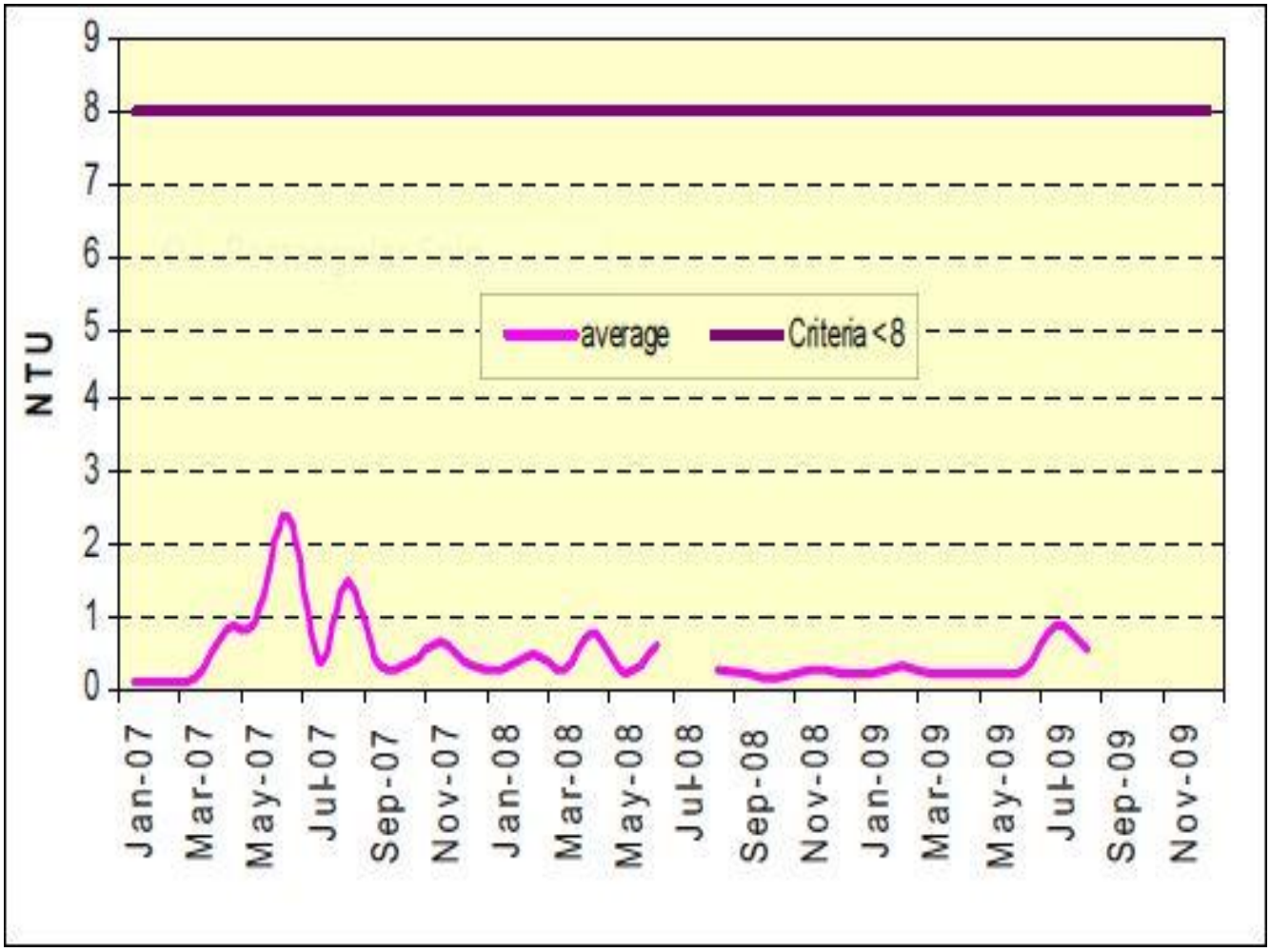
Figure 14 depicts the conductivity of the Perth SWRO plant discharge over the period of January 2007 to September 2009. Taking into consideration that the ratio between conductivity (shown on Figure 14) and salinity is 0.78, the plant discharge salinity varied between 64.5 ppt (88 mS/cm) and 56.2 ppt (72 mS/cm). Dissolved oxygen concentration of the discharge for the same period was between 7.6 and 11.0 mg/L, and was always higher than the minimum regulatory level of 5.0 mg/L. Similarly, concentrate pH was between 7.2 and 7.6, which was well within 10% of the ambient ocean water pH.



Source: The Water Corporation

Figure 14 – Perth Desalination Plant – Discharge Conductivity

Discharge turbidity for the same period (January 2007 to September 2009) was always less than 3 NTU (see Figure 15).



Source: The Water Corporation

Figure 15 – Perth Desalination Plant – Discharge Turbidity

Pictures of the discharge diffusers taken approximately one year after the plant operation (see Figures 16 and 17) show that despite the high salinity of the concentrate (56.2 ppt to 64.5 ppt), the area around the discharge diffusers is abundant with marine life. Figure 17 is especially significant since it shows that seahorses (which are known to be sensitive to varying marine water quality conditions) inhabit the zone of initial dilution at the plant's discharge.

In summary, all studies and continuous environmental monitoring completed at the Perth Seawater Desalination Plant to date indicate that the desalination plant operations do not have a significant environmental impact on the surrounding marine environment.

Source: The Water Corporation

Figure 16 – Perth Desalination Plant Diffuser with Swimming Fish

Source: The Water Corporation

Figure 17 – Seahorse Inhabiting Perth Desalination Plant Diffuser

6.5. Examples of Discharge Configurations of Spanish Desalination Plants

An independent overview of the discharges of three desalination plants in Spain [22,000 m3/day (22 MLD, 5.8 MGD) Javea SWRO Plant; 68,000 m3/day (68 MLD, 18 MGD) Alicante 1 SWRO Plant; and 68,000 m3/day (68 MLD, 18 MGD) San Pedro Del Pinatar] was completed in 2008 by the University of Alicante, Spain[8]. The three plants are located within 50 miles (80 kilometers) of each other (see Figure 18), and the salinity of their discharges ranges from 68 ppt to 70 ppt.

Source: F. Y. Torquemada

Figure 18 – Location of Three Large Desalination Plants in Spain

The Alicante 1 plant is located in a turbulent, tidally-influenced area exposed to intense naturally occurring mixing. This feature of the desalination plant discharge allows the Alicante plant to operate without a measurable environmental impact even at relatively low mixing ratio of 1.5 to 5 between concentrate and ambient seawater at the edge of the zone of initial dilution.

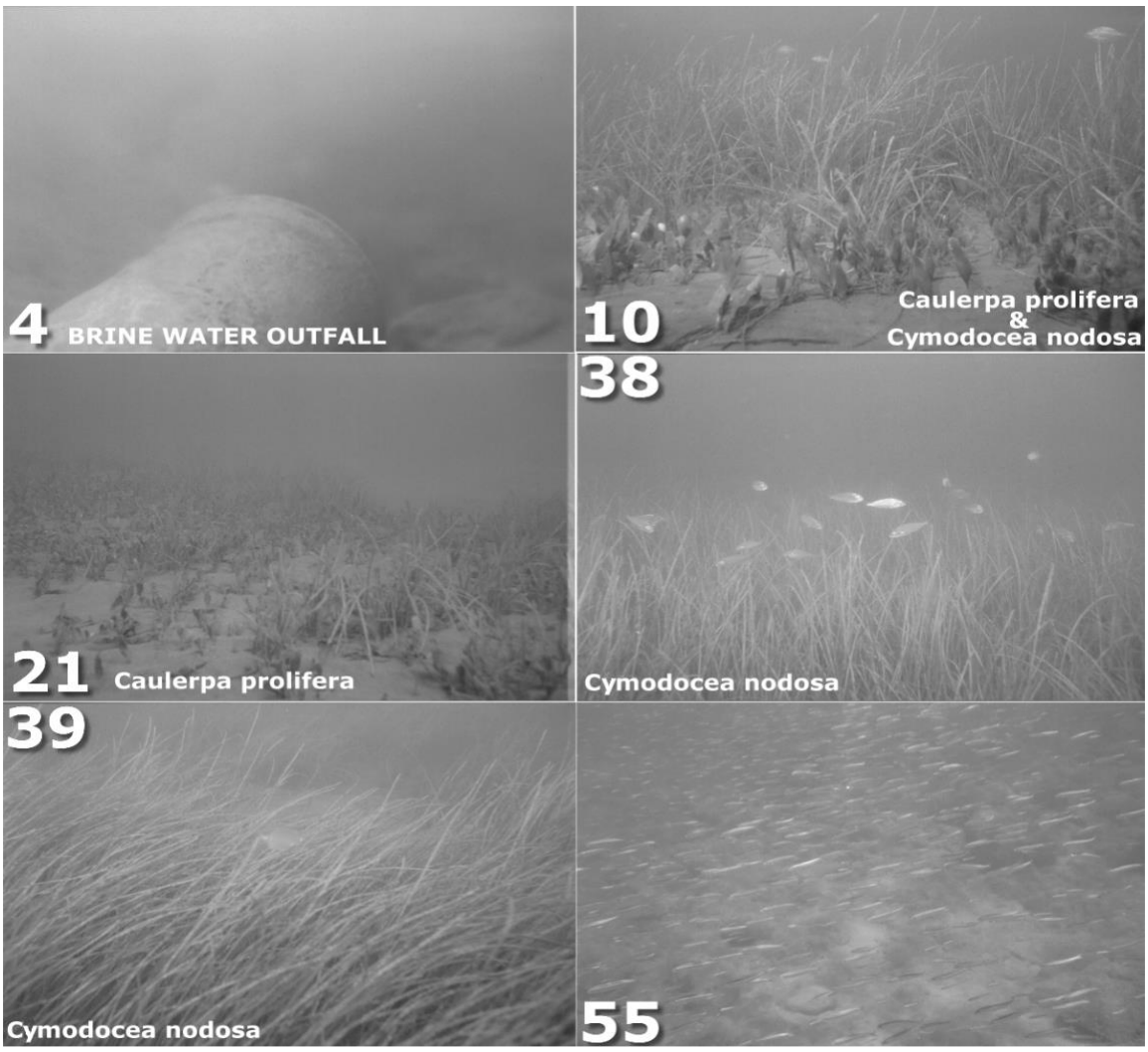
The Javea SWRO plant discharge is in an open canal which carries the concentrate into the ocean. The concentrate from this plant is diluted in the channel from 69 ppt down to 44 ppt in a 4:1 mixing ratio. This salinity level was found to have no negative impact on the marine habitat in the discharge area.

The discharge of the San Pedro del Pinatar Plant is through a diffuser located approximately 5 kilometers away from the shore at 38-meter depth.

All three desalination plants have been in operation for over 10 years. The water quality and environmental monitoring of the three discharges indicates that the size and time for dispersion of the salinity plume varied seasonally. These variations however, did not affect the benthic organisms inhabiting the seafloor. The desalination discharge of the Javea plant has high oxygen levels that diminish the naturally occurring apoxia in the area of the discharge. The independent overview emphasizes the fact that well designed desalination discharge can result in minimal environmental impacts, and, in some cases, can be beneficial to the environment due to its high oxygen content.

6.5.1. Maspalomas II Desalination Plant, Canary Islands, Spain.

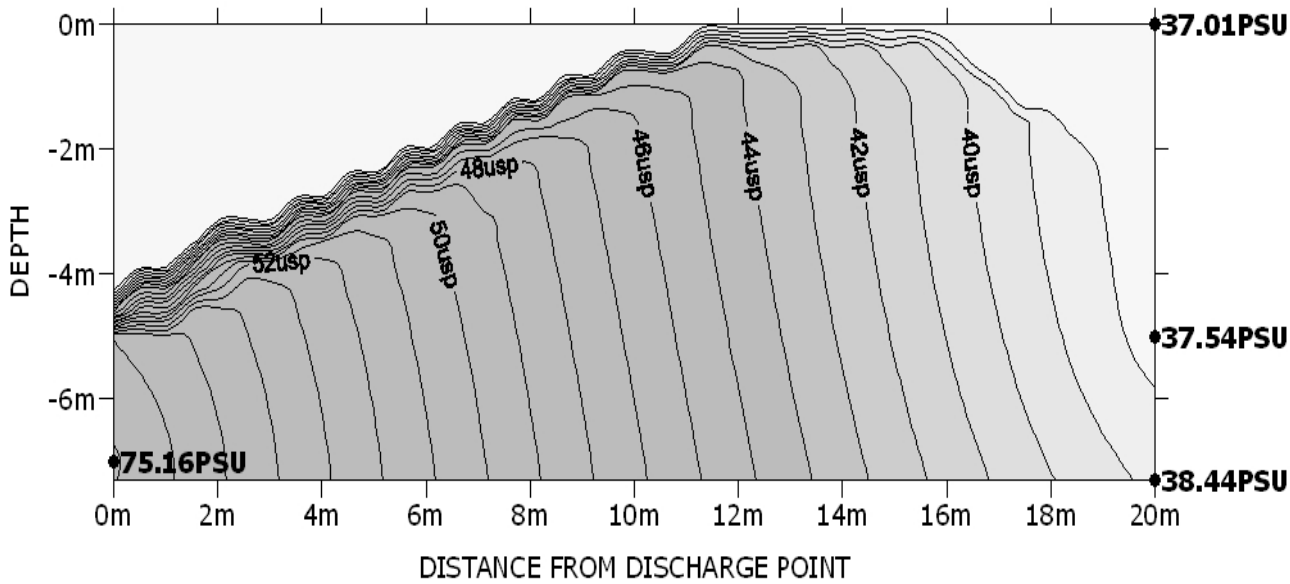
This desalination plant is located in Gran Canarias and has two concentrate outfalls which extend 300 m away from the shore[9]. The outlet of the discharge outfalls does not have diffusers (see Figure 19), and the mixing between the concentrate and ambient seawater is mainly driven by the velocity of the discharge and the fact that the discharge is located in an area with naturally occurring underwater currents of high intensity. The depth of the discharge is 7.5 to 8.0 meters.



Source: J. L. Talavera

Figure 19 – Discharge of Maspalomas SWRO Plant

The Maspalomas discharge conditions are challenging for two reasons: (1) very high salinity of the concentrate (90 ppt); and (2) seagrass habitat for fish and other marine organisms. Due to the naturally occurring near-shore mixing, the salinity of the discharge is dissipated down to 38 ppt (38 PSU) within 20 m from the discharge point as shown on Figure 19. The salinity on this figure is presented in PSU (practical salinity units), which have the same value as ppt (parts per thousand) of salinity concentration.



Source: J. L. Talavera

Figure 19 – Maspalomas SWRO Plant – Outfall Salinity Field

The zone of initial dilution of the Maspalomas II desalination plant is a sandy bed with practically no flora. However, this zone is surrounded by seagrass beds. Based on environmental studies of the discharge area, the beds are not significantly affected by the desalination plant discharge.

6.6. Case Studies – Summary and Conclusions

The case studies presented above from large seawater desalination projects operating around the world for up to 20 years provide a representative overview of the range of concentrate discharge systems used, how they are monitored, what impacts have been detected, the strategies used to minimize impacts, and how regulators and local populations have responded to these projects. Long-term experience worldwide indicates that discharges from seawater desalination plants are environmentally safe and do not result in change of aquatic flora and founa in the vicinity of the discharge or other negative impacts on the marine habitat in the area of plant discharges. If the discharge diffuser system is designed appropriately no apoxia is expected to occur even in very shallow areas such as the case of the discharge of the Perth desalination plant into the Cockburn Sound.

VII. THE FUTURE OF CONCENTRATE MANAGEMENT

7.1. Chemical Free Desalination

Over the past 5 years, many countries with large desalination plants such as the Kingdom of Saudi Arabia, Australia, Israel and Spain have initiated the implementation of comprehensive programs for green desalination, which aim to reduce both the amount and the types of chemicals used in the production of desalinated water. These programs will ultimately convert all existing facilities into chemical-free seawater desalination plants by implementing the latest advancements of desalination technology and science.

What has been done in particular to reduce chemical use? Desalination plants used to continuously chlorinate their intake seawater using sodium hypochlorite to suppress the growth of marine life in the intake piping and on the reverse osmosis membranes. Such practice has been abandoned by most desalination plant operators close to a decade ago, and currently chlorination is used only one to two times per month for a period of 6 to 8 hours. In addition, some desalination plant operators do not apply any disinfectants to the intake seawater because they prefer to use the pretreatment system of the plant for control of biofouling instead of chemicals.

Ferric chloride and ferric sulfate are the most commonly used coagulants for pretreatment of seawater at present. These chemicals used to be dosed at a constant rate and a relatively high dosage. At present, the desalination industry has adopted an automated monitoring of the content of solids in the seawater and automated adjustment of the coagulant dosage proportionally to the actual content of suspended solids in the water. This operational strategy, introduced over the last 10 years at most plants worldwide, has reduced the use of coagulant to less than one half of what it once was.

Acids and flocculants were used for optimization of the chemistry of water treatment in many desalination plants until a decade ago. Most advanced desalination plants and skilled plant operators today no longer use acids and flocculants for pretreatment – instead they rely on optimized pretreatment system design and operation to manage water chemistry.

Until 2010, antiscalants and sodium hydroxide were commonly applied in many desalination plants worldwide, mainly to prevent scaling associated with removal of boron from the desalinated water. Since 2011, when the World Health Organization increased the drinking water guideline limit for boron from 0.5 mg/L to 2.4 mg/L, most desalination plants discontinued the addition of sodium hydroxide and antiscalants.

The desalination industry as a whole is proud of its environmental stewardship achievements and is constantly developing and adopting new chemical-free, renewable energy-based technologies. The next step in this development process is to use calcium extracted from the brine for post-treatment of the desalinated water instead of using commercially supplied calcium compounds such as lime of limestone.

7.2. Beneficial Use of Brine – Zero Liquid Discharge and Mineral Extraction

Nature teaches us that the sustainable existence of closed systems such as our planet has to rely on an efficient circular path when using resources like energy and water. A circular economy is the *only* path forward towards worldwide sustainable economic growth. For example, applying the circular economy model, brine generated from desalination plants can be used as a source of valuable minerals, such as

calcium, magnesium and sodium chloride. Rare-earth elements can also be extracted from brine including lithium, strontium, thorium and rubidium.

Recent stresses in the global market of rare-earth elements have brought the availability and supply of rare metals to the forefront of the sustainability debate and research agenda. These metals are used to fabricate critical components of numerous products, including airplanes, automobiles, smart phones, and biomedical devices. There is a growing realization that the development and deployment of clean energy technologies and sustainable products, processes and manufacturing industries of the 21st century will also require large amounts of rare metals and valuable elements including platinum group metals such as, lithium, copper, cobalt, silver, and gold.

The latest technology trends show that magnesium is replacing aluminum in the car, computer and cell phone industries because it is over 30% lighter. While the world's mining sources of magnesium are fairly limited, seawater brine contains very large quantities of magnesium which could be recovered by concentration of desalination brine followed by selective extraction by adsorption.

The Desalination Technology Research Institute of the Saline Water Conversion Corporation (SWCC) of Saudi Arabia has recently developed and patented a dual brine concentration technology (Dual Concentrator) that allows generation of two high mineral content streams from seawater. The brine from nanofiltration (NF) membrane separation systems is rich in calcium and magnesium and has low sodium chloride content. This brine can be applied for the remineralization of desalinated water, adding both calcium and magnesium hardness, and can be applied as liquid fertilizer of high-magnesium demanding crops such as mangos. Using calcium and magnesium extracted from desalination brine is a step forward towards elimination of the use of commercial chemicals in the production of desalinated water. Further concentrated, the magnesium rich NF brine can also be processed for extraction of solid magnesium via ion-selective resins, which then can be used as raw material for the automotive and other high-tech industries.

The brine from a reverse osmosis system which is downstream from an NF system is of very high sodium chloride content and can be used as source material by the chloralkaline industry. This industry cannot use brine with high calcium and magnesium content, but after NF desalination, the SWRO brine contains low-enough content of these minerals to be suitable for the chloralkaline industry.

Over the last several years, the desalination industry has developed a number of other brine concentration and mineral extraction technologies which enable the manufacture of commercially valuable products from the brine. Extracting minerals from seawater is a more environmentally friendly enterprise than terrestrial mining. Moreover, seawater extraction will not require fresh water for processing nor create volumes of contaminated water or tailings for disposal. In addition, these new brine concentration technologies enable dramatic reduction or complete elimination of brine discharge to the sea.

This example shows that transitioning to a circular economy can achieve far more than reducing the negative impacts of the linear economy. Rather, it represents a systemic shift that builds long-term resilience, generates business and economic opportunities, and provides environmental and societal benefits.

Beneficial reuse of brine could also be the key to solving the energy sustainability challenges of desalination. A type of next-generation nuclear power plant will use thorium and rubidium as a power source instead of uranium. A plant with capacity of between 10 and 50 Megawatts, which size can fit in a trash can, could power a medium or large size desalination plant. The key advantage of this new energy source is that the building blocks can be directly extracted in adequate quantities from seawater desalination plant brine. Besides being readily extractible from the brine, a further advantage of these rare elements is that they cannot be used in building atomic weapons, thus providing desalination brine as the new fuel for peaceful use of atomic energy for the greater benefit of humanity.

VIII. SHIFT OF PARADIGM IN THE UNDERSTANDING OF THE IMPACT OF DESALINATION PLANT CONCENTRATE ON THE ENVIRONMENT

8.1.Concentrate Generated from Desalination Plants is Toxic

Most desalination plants worldwide have to continuously monitor the toxicity of their discharges. Multi-year water quality and environmental habitat monitoring information from dozens of desalination plants worldwide shows that desalination plant discharges do not exhibit any toxicity – neither acute nor chronic.

8.2.Desalination Plants Use Toxic Chemicals and Discharge Them to the Environment

Desalination plants use exactly the same chemicals as conventional water treatment plants use for production of drinking water in most countries worldwide. However, desalination plants use an order of magnitude lower quantities of these chemicals because conventional drinking water sources in the industrialized world (rivers, lakes, dams) are much more heavily polluted than the oceans or saline aquifers.

At present, desalination plants use very limited quantities and types of chemicals. Environmental regulations and water quality requirements specifically prohibit the use of harmful chemicals. Indeed all chemicals added to enhance the treatment processes are of food grade quality, are biodegradable, and are specifically selected not to cause any aquatic marine life toxicity.

9.3.Intakes from Desalination Plants Cause Significant Damage to the Environment by Impingement and Entrainment

Impingement and entrainment refer to the potential injury of marine species when they enter the desalination plant through intake screening facilities. However desalination plants use the same intakes as conventional water treatment plants and usually rivers, estuaries or lakes from which source water is collected for drinking water production contain an order of magnitude larger number of aquatic species than seawater.

How much environmental impact do desalination plants intakes actually cause? A comprehensive multi-year impingement and entrainment assessment study of the open ocean intakes of 19 power generation plants using seawater for once-through cooling, completed by the California State Water Resources Control Board in 2010, provides important insight. Based on this study, the estimated total average annual impingement of fish caused by the seawater intakes varied between 0.31 pounds (lbs.) per million gallons a day (MGD) of collected seawater (Diablo Canyon Power Plant) and 52.29 lbs./MGD (Harbor Generating Station); and for all 19 plants it averaged 6.63 lbs./MGD. Taking into consideration that this amount is the total annual impact, the average daily impingement rate is estimated to be 0.018 lbs./MGD of intake flow

(6.63 lbs./365 days = 0.018 lbs./MGD).

Using the California State Water Resources Control Board impingement and entrainment study results as a baseline, for a large desalination plant of 50 MGD production capacity collecting 110 MGD of intake flow, the daily impingement impact is projected to be 2 lbs. per day (0.018 lbs./MGD x 110 MGD = 2 lbs./day). This impingement impact is less than the daily food intake of one pelican – 3 to 4 lbs./day. The comparison illustrates the fact that the impingement impact of seawater desalination plants with open ocean intakes is not significant and would not have measurable impact on natural aquatic resources.

Figure 20 - Average Daily Desalination Intake Impingement Impact Is Less than the Daily Fish Intake of One Pelican

VIII. CLOSING REMARKS

Long-term experience worldwide indicates that discharges from seawater desalination plants are environmentally safe and do not result in speciation change or other negative impacts on the marine habitat in the area of plant discharges. Results from recent worldwide studies also indicate that marine organisms can tolerate long-term exposure to desalination plant discharge of salinity in a range of 40 ppt to over 70 ppt. However, salinity tolerance of marine organisms is very site specific and dependent on the type of organisms inhabiting the discharge area, their mobility, and the time of their exposure to elevated salinity. Recent desalination industry shifts toward chemical-free desalination and recovery of valuable minerals

and rare metals from brine are expected to transform desalination into one of the most environmentally sound and sustainable water supply alternatives of the 21-st century.

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