TECHNICAL
MEMORANDUM

Report: Cape Town Desalination
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PROJECT: World Bank advisory support - City of Cape Town Water Resilience Program (WRP) (Funded by the Swiss State Secretariat for Economic Affairs (SECO)

SUBJECT: Critical Review of the Desalination Component of the WRP
DATE: December 12, 2017

EXECUTIVE SUMMARY

In May 2017, the City of Cape Town (the City) has adopted a Water Resilience Program (WRP), which aims to supplement the existing surface water reservoir-based water supply system with 500 mega-liters per day (500 MLD) of new water sources. The City of Cape Town's Water Resilience Program is fundamentally sound, and is based on well-balanced mix of ground water extraction, water reuse, and seawater desalination, which are combined with the continuous use of the existing surface water storage reservoirs and aggressive water conservation measures. Based on the detailed review of the desalination component of the Water Resiliency Program the following adjustments are recommended to this program:

1. **Develop Groundwater Extraction Projects in Parallel with Water Reuse and Desalination Projects Capable of Recharging the Aquifers Used for Potable Water Supply** – Groundwater extraction is the least costly and fastest to implement option for production of new drinking water but it will not be sustainable in the long run unless groundwater recharge, water reuse and desalination projects are designed to recharge the exploited aquifers at the rate of water extraction.

2. **Accelerate the Implementation of Near-term Potable Water Reuse Projects** – Indirect (through groundwater recharge) or direct potable water reuse projects have the potential to deliver drinking water faster than desalination plants and therefore they should be implemented in parallel with the permanent desalination projects.

3. **Discontinue the Procurement of New Containerized Desalination Plants** – Such plants will provide minimal to no relief in terms of public water supply challenges and will produce water at unreasonably high costs.

4. **Do Not Use Ship or Barge-based Marine Desalination Plants** – Current experience shows that such plants are very costly and have poor track record of producing target fresh

water quantity due to the source seawater challenges when the plant is docked in port located in an urbanized or industrial area.

5. **Build One Permanent 125 MLD SWRO Desalination Plant at the Harbor Site Instead of Containerized Desalination Plant of 50 to 100 MLD at This Site** - The time for construction of permanent and containerized plants of this size will be comparable (18 to 24 months) and the cost of water produced by the permanent plant will be significantly lower.

6. **Build One or Two Additional Permanent Desalination Plants of Capacity of 100 to 150 MLD within the Next Three Years** – One plant located in False Bay and one located on the Atlantic Ocean coast. Select the location of the False Bay plant such that the intake could capture lower salinity source water produced by the concentrated discharge of the fresh water aquifers into the False Bay.

7. **Do Not Build Desalination Plants of Capacity Larger than 200 MLD** – Practical experience over the past 10 years shows that the optimum size of permanent desalination plants is between 100 and 150 MLD, as discussed in the main document. Typically, plants with capacity larger than 200 MLD have measureable diseconomy of scale due to technological constraints, which results in elevated costs of water production.

8. **Deliver Permanent Desalination Projects Under DBO or BOOT Approach** – The standard design-bid-build approach used by the City for procurement of capital projects, goods, services and consumables is not suitable for delivery of cost-effective large-size seawater reverse osmosis (SWRO) desalination projects. For the site-specific conditions of the City of Cape Town, the two most cost-effective project delivery methods are design-build-operate (DBO) and build-own-operate-transfer (BOOT). Under DBO method of project delivery the project will be funded and owned by the City. If BOOT method of delivery is selected, the project will be funded and owned by a private contractor. If the City could obtain lower cost project funding than the private turnkey contractor, than DBO method of delivery is preferable. If the selected private contractor can provide project funding that results in lower cost of water production, than BOOT method of delivery is more desirable.

9. **Accelerate/Immediately Initiate the Preparation of Technical Support Studies for Development of Permanent SWRO Desalination Plants at Three Locations - Harbor Site, Atlantic Coast Site and False Bay Sites -** The development of such procurement

documentation will require the expedited completion of permanent desalination plant site selection along the Atlantic ocean coast and the False Bay, including immediate implementation of water quality monitoring and dispersion modeling.

10. **Prepare Procurement Documentation for Permanent Desalination Projects Commensurate with the Requirements of the International Markets for Such Projects** – the standard methodology and documentation used by the City for procurement of capital projects and consumables, is not suitable for procurement of large-size SWRO desalination plants. Project delivery under DBO or BOOT scheme requires the use of different procurement documentation in order to yield lowest possible cost of desalinated water.

The recommendations listed above are discussed in a greater detail in the next sections of this report. Please note that these recommendations are firmly founded on relevant experience at other locations worldwide where municipalities or utilities have attempted to implement practically all alternative solutions considered by the City. These recommendations aim to assist the City in making decisions based on lessons learned and actual experience from other similar projects implemented worldwide rather than on vendor-driven commercial information and tender offers from companies that have no prior practical experience in delivering the projects for which they have submitted bid offers.

1. INTRODUCTION

In May 2017, in response of unprecedented drought, the City of Cape Town has embarked on the implementation of a Water Resilience Program (WRP) which aims to supplement the existing surface water reservoir-based water supply system with 500 MLD of new water sources including fresh water produced from groundwater extraction, seawater desalination, and water reuse. The ultimate goal of the Water Resilience Program is to secure sustainable drought-proof water supply for the city based on diversified portfolio of water resources. The WRP is planned to be implemented in two phases: Phase 1 – Emergency and Tactical Planning Program;[1] and Phase 2 – Strategic Planning Program. At present, the City has committed to implementing:

- Transfer of water from agriculture (10 million kl over this summer)
- Ground water projects (100 Ml/day or more)
- Water reuse (initial yield of 10 Ml/day with expansion possibilities)
- Three small scale desalination plants (7, 7 and 2 MLD respectively)

The city has developed further plans for desalination, including issuing tenders for a 50 MLD Land Based Containerized desalination plant and 50 MLD of Barge desalination plant at a City Industrial Harbor Site.

Both phases include implementation of various desalination projects. Phase 1 focuses on the installation of small and medium-size containerized desalination plants, which are planned to be operational by mid-2018, and potentially barge- or ship-based plants; while Phase 2 encompasses the planning and construction of permanent land-based seawater desalination plant/s within the next 2 to 3 years.

This technical memorandum provides a critical review of the desalination projects incorporated in the Water Resilience Program and includes recommendations for streamlining of the process of desalination project planning, procurement and implementation. The recommendations included in the memorandum are based on discussions with key City staff involved in the development and implementation of the WRP, visits of potential desalination plant sites, and review of pertinent WRP documentation, including desalination plant siting and feasibility studies completed by the City over the past 10 years.

[1] The original program comprised three phases: emergency, tactical and strategic. The first two phases have been merged.

2. IMPLEMENT GROUNDWATER EXTRACTION IN PARALLEL WITH DESALINATION AND WATER REUSE PROJECTS

Groundwater extraction is projected to yield 100 to 200 MLD of new fresh water supply and is the least costly and fastest to implement – therefore it should be given a first priority. It should be pointed out however, that the feasibility of groundwater extraction is dependent on the ability of the City to recharge the exploited aquifers during years of high rainfall ("wet years") at a rate equal to or faster than the rate of extraction during dry years. For this reason, groundwater recharge by reclaimed and desalinated water is essential for the long-term sustainability of the groundwater extraction alternative.

Figure 1 shows the cost of water of alternative water supply options included in the City Water Resilience Program. Besides the three sources of new water supplies – seawater desalination, water reclamation for reuse, and groundwater extraction, the City is also pursuing core transfers of water from the agricultural sector and implementing a robust water conservation program.

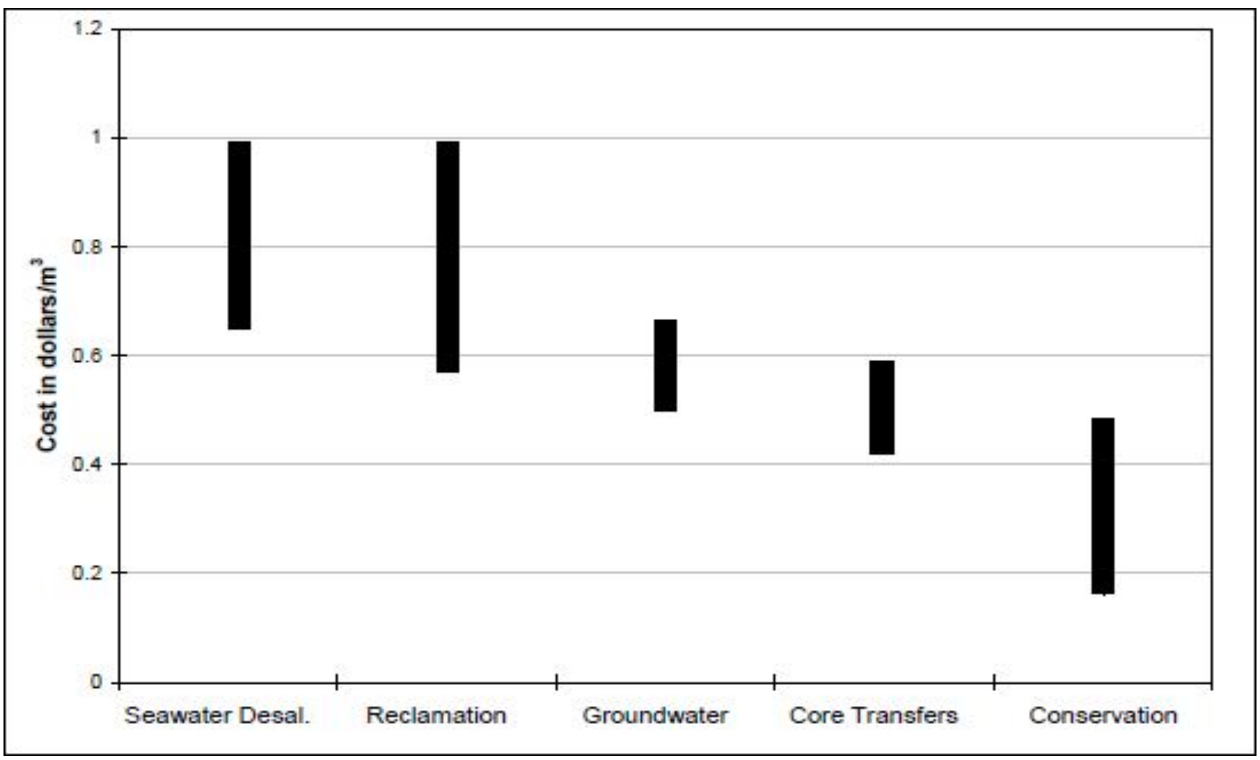

Figure 1 – Cost of Water of Alternative Water Supply Sources

Review of Figure 1 reveals that introduction and enforcement of water conservation measures is the lowest cost alternative for achieving drought resilience. Core transfers of water from agricultural users and industry to domestic water use is also very cost competitive and exploring such transfers is highly encouraged. Groundwater extraction is significantly less costly than desalination and potable water reuse. However, the principal limitation of this this new source of water is its limited availability and sustainability. Similar to surface water reservoirs, groundwater aquifers are naturally replenished by rain water and are equally vulnerable to depletion over time. Therefore, groundwater extraction can only be sustained over long periods of time if the aquifers tapped for drinking water supply are artificially recharged using fresh water produced by indirect potable reuse and desalination.

Based on the review of existing pertinent information, the City groundwater aquifers are expected to have water storage capacity that could provide sustainable water supply of 100 to 200 MLD for a period of 3 to 5 years. During years of low rainfall ("dry years"), the rate of aquifer drawdown could be increased to the maximum, while during wet years and the winter season when drinking water demand subsides, the aquifers would need to be recharged with reclaimed wastewater and desalinated water. Which water would be used for aquifer recharge will depend of what type of plant (water reuse or desalination) is closest to the recharge field of a given aquifer and what are the water quality requirements of the aquifer.

Global international experience suggests that the recharge facilities located within 5 to 10 km of the seacoast should be designed such that they create fresh water barrier to prevent seawater intrusion and the associated deterioration of aquifer water quality. Such seawater intrusion barriers have been successfully used in the US, Spain, Australia and other parts of the world.

Since the safe yield of the groundwater aquifers targeted for immediate use is unknown at this time, the first priority of the water extraction projects is to establish their safe yield by standard pumping tests. Once the safe rate of groundwater extraction is known, the groundwater recharge fields and water reuse and desalination plants should be designed with adequate capacity to be capable of recharging the exploited aquifers at a rate equal to the safe groundwater extraction yield or the respective aquifers.

3. ACCELERATE IMPLEMENTATION OF POTABLE WATER REUSE PROJECTS

Indirect or direct potable water reuse projects may have a potential to deliver drinking water of substantive quantity (20 to 50 MLD) faster than desalination plants, if the wastewater treatment plant effluent quality is adequate such that it allows simplified treatment (e.g., membrane ultrafiltration and disinfection only).

If membrane treatment by ultrafiltration only would allow to match the water quality of the drinking water or the raw water delivered to the surface drinking water plants, the potable water production from secondary effluent could be initiated within 10 to 12 month from initiation of construction. If reverse osmosis and advanced oxidation treatment of the secondary effluent is necessary after ultrafiltration in order to produce water of potable quality, then the time needed for construction of 50 MLD water reclamation plant for potable reuse will be comparable to that of the construction of SWRO plant. Overall costs and energy use for production of potable water through re-use will be approximately two times lower than that of desalinated water.

4. DISCONTINUE PROCUREMENT OF NEW CONTAINERIZED DESALINATION PLANTS

Such plants will provide minimal to no relief in terms of public water supply challenges and will produce water at unreasonably high costs. Containerized desalination plants have many disadvantages in terms of costs, energy use and operational flexibility and only one advantage – if they are of capacity smaller than 5 MLD, they can be installed and commissioned within a period of 3 to 4 months only – which is shorter than the installation of permanent desalination plants of the same capacity. Since the City needs very large volume of new water supplies (300 MLD or more) and 5 MLD plants, even if deployed in multiple locations, provide only 1% of the needed supply, at a cost that is typically 5 to 8 times higher than the current cost of water, installation of such plants is not a solution for immediate drought relief nor it is cost effective.

Experience elsewhere in the world indicates that containerized desalination plants are attractive alternatives for supplying very small volumes of water for disaster relief (rather than emergency water supply) or for creating of water supply in remote areas where the only other alternative is trucking drinking water over long distances.

In the Middle East, trucking of drinking water from large-size permanent desalination plants to areas which lack local water resources have been found to be more cost effective for trucking distances of 50 km or less. Therefore, it is more cost effective to build permanent cost-effective large-scale desalination plants and truck water to locations where there are water shortages than to build local package plants, especially if the volumes of the water needed in the shortage stricken area are larger than 5 MLD – as it is the case for the City of Cape Town.

5. DO NOT USE SHIP OR BARGE-BASED MARINE DESALINATION PLANTS

At present, worldwide there are only two barge-based 50 MLD SWRO desalination plants in operation – they are located in Saudi Arabia and operate on the Red Sea (see Figure 2 for one of the barges, located in the port of Yanbu). The barges have been in operation since 2010 and have been built and operated by the largest Saudi Arabian company specialized in desalination (Aqua Power).

Actual operational experience with the barge-based desalination plants shows that such plants are very costly and have poor track record of producing target fresh water quantity due to the source seawater challenges when the plant is docked in port located in an urbanized or industrial area – high content of silt, hydrocarbons, and biofouling substances). Since their installation and after multiple enhancements, the plants were able to produce only 25 to 30 MLD each and the cost of water produced by such plants has increased from their initial tender bid value of US$4.5/$m^3$ (63 ZAR/m^3) to an actual cost of US$8.6/$m^3$ (120 ZAR/m^3). After the extremely disappointing experience with the two referenced barge-based SWRO plants, no other plants of such kind have been build and installed worldwide and most contractors that offer such plants do not have neither the experience to build or operate such facilities.

Figure 2 – 50 MLD Barge-based SWRO Desalination Plant in Yanbu, Saudi Arabia

At present, worldwide ship- or barge based desalination plants are only considered for disaster relief, rather than for emergency water supply. However, even in disaster struck zones of the world, the preferred methods of water supply are either trucking water from adjacent areas not impacted by the disaster or by mobile containerized desalination plants installed on trucks, such as these used by the military forces of most countries. The main reasons why barge- and ship based floating desalination plants have not found application for either disaster or emergency relief is because of their low reliability, inconsistent performance and extremely high water production costs. Therefore, the use of such plants is not recommended either as emergency or as disaster relief water supply option for the City of Cape Town.

6. BUILD ONE PERMANENT 125 MLD SWRO DESALINATION PLANT AT THE HARBOR SITE INSTEAD OF CONTAINERIZED DESALINATION PLANT OF 50 TO 100 MLD AT THIS SITE

At present, the implementation of containerized seawater desalination projects and barge and boat plants is prioritized by the City over the implementation of one or more permanent land-based desalination plants because of the expectation that such projects at the Harbor Site will yield 50 to 125 MLD of desalinated water within the next 6 months at a reasonable price. In our opinion, such expectation is unrealistic, even if the City receives favorable tenders from potential containerized system contractors, because of the following four reasons:

- Practical experience to date shows that containerized desalination plants are suitable for fast-track (3 to 4 month) delivery of desalinated water of up to 5 MLD only.

- There is a significant diseconomy of scale, as well as cost and time penalties, for installing containerized desalination plants to produce fresh water of the volumes targeted by the City – 50 to 125 MLD.

- To date, there has been no experience worldwide with building containerized seawater reverse osmosis (SWRO) desalination plants of fresh water production capacity higher than 24 MLD. The two largest containerized SWRO plants built to date required significantly more time than expected by the City – the 20 MLD plant is Cyprus (see Figure 3) took 12 months to complete and the time needed for the 24 MLD SWRO plant in Ghubra, Oman (see Figure 4) to reach design capacity was 14 months. Therefore, the probability of 50 MLD containerized plant to be built for less than 14 months is extremely low and there are no contractors with track record of being able to build 50 MLD plant for such period of time. The most likely time of completion of 50 MLD containerized plant is 16 to 20 months

– which is comparable to the time needed to build a permanent desalination plant with production capacity of 100 to 125 MLD.

- Because of the complexity of flow distribution and completion of multiple interconnections and auxiliary facilities (intake, discharge and electrical supply systems) as well as the short amortization time of the assets (2-year contract for water supply) as well as the high mobilization and demobilization costs, the actual cost of water production of 50 to 100 MLD containerized SWRO plant will likely be two to three times higher than that of permanent 100 to 125 MLD desalination plant, despite the fact that the offers for installation of 50 MLD containerized plant at the Harbor site may show lower cost of water production.

Figure 3 – 20 MLD Containerized SWRO Desalination Plant in Cyprus

Figure 4 – 24 MLD Containerized SWRO Desalination Plant in Ghubra, Oman

In summary, the construction of a short or long-term 50 MLD containerized plant at the Harbor site is not recommended. Global experience shows that the actual time for construction of permanent and containerized plants of 50 to 125 MLD will be comparable (18 to 24 months) and the actual cost of water produced by the permanent plant will be significantly lower.

Phasing is crucial if the City decides to proceed with the construction of a permanent 100 to 125 MLD desalination plant at the Harbor site. The procurement documents for such plant should specify a requirement for the permanent desalination plant to be constructed in 10 MLD modules and design and construction to be staged such that the plant can begin production of the first 10 MLD of fresh water within 10 months of contract award.

The mission has completed inspection of the Harbor site on November 28, 2017, and on this basis we conclude that the plant site is adequate for construction of a permanent 125 MLD desalination plant. In addition, the existing power plant intake channel and the storm drain channel located at the referenced site will be of adequate size and capacity to build intake and outfall facilities for 125 MLD plant. The use of these existing facilities will simplify and expedite the construction of plant with possible early completion within 18 months from the time of contract award.

BUILD ONE OR TWO ADDITIONAL PERMANENT DESALINATION PLANTS OF CAPACITY OF 100 TO 150 MLD WITHIN THE NEXT THREE YEARS

It would be realistic to assume that the City can deliver 100 MLD of new water form groundwater extraction in the next 6 to 8 months. Given that, the remaining 400 MLD gap of new water supplies have to be closed by the construction of 50 MLD of water reclamation plant/s and 350 MLD of desalinated water production capacity (if 500 MLD is assumed to be an appropriate target – this is subject to review). Under the assumption that the City proceeds immediately with the construction of one 100 to 125 MLD SWRO desalination plant at the Harbor Site, achieving the 500 MLD goal of new water resources will require the construction of two additional 100 to 150 MLD desalination plants within the next two years. Similar to the 125 MLD Harbor Site desalination plant, the other two plants can be constructed such that each of these plants can produce 10 MLD of desalinated water within the next 12 to 14 months if the data collection and procurement for such plants are triggered in January 2018.

In as far as desalination is adopted, it is recommended that one of the other two new desalination plants is located on the False Bay Coast, and one along the Atlantic Ocean coast. It will be prudent to select the location of the False Bay desalination plant such that the intake could capture lower salinity source water produced by the concentrated discharge of the fresh water aquifers into the False Bay. Review of the location of the Cape Flats fresh groundwater aquifer draining into False Bay depicted on Figure 5, along with inspection of the condition of the coastline completed on December 1, 2017 indicates that there are a number of potential sites where such plant can be located.

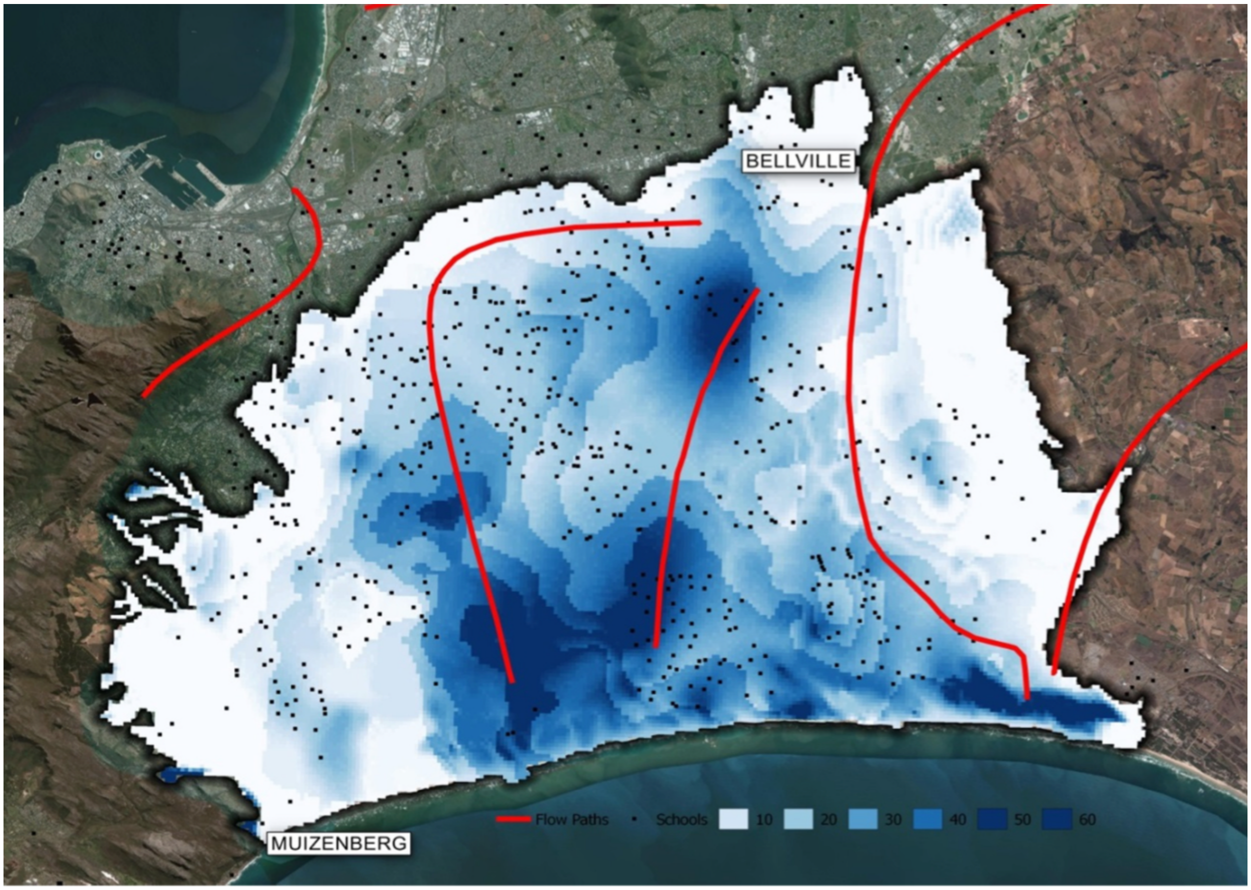

Figure 5 – Cape Flats Aquifer Drainage Area into False Bay

The best potential sites with lowest seawater salinity would be located in the areas along the shore with the highest intensity blue color (see Figure 5) indicating large volumes of fresh water exiting into the False Bay in concentrated locations.

The Review of Desalination Plant Feasibility Study completed by the City in 2012 allows to conclude that a 100 to 200 MLD plant on the Atlantic coast could be sited at or near the Koeberg Nuclear Power Plant to benefit from the use of existing infrastructure, or at another location in the vicinity of existing large fresh water delivery pipeline in order to avoid construction of water supply infrastructure in highly urbanized environment.

It is recommended to construct three separate seawater desalination plants of capacity between 100 and 150 MLD rather than one large 350 to 450 MLD plant for the following reasons: (1) environmental impacts – the concentrated discharge of large volume of brine in one location may pause a significant threat to the surrounding aquatic environment in case of desalination plant failure; (2) the total capital cost for construction of three 150 MLD plants will be lower than that of the construction of one 450 MLD plant due to diseconomy of scale associated with construction of plants larger than 200 MLD (see Figure 6). The cost information presented on Figure 6 is based on actual expenditures for construction of 40 SWRO desalination projects built between years 2007 and 2017.

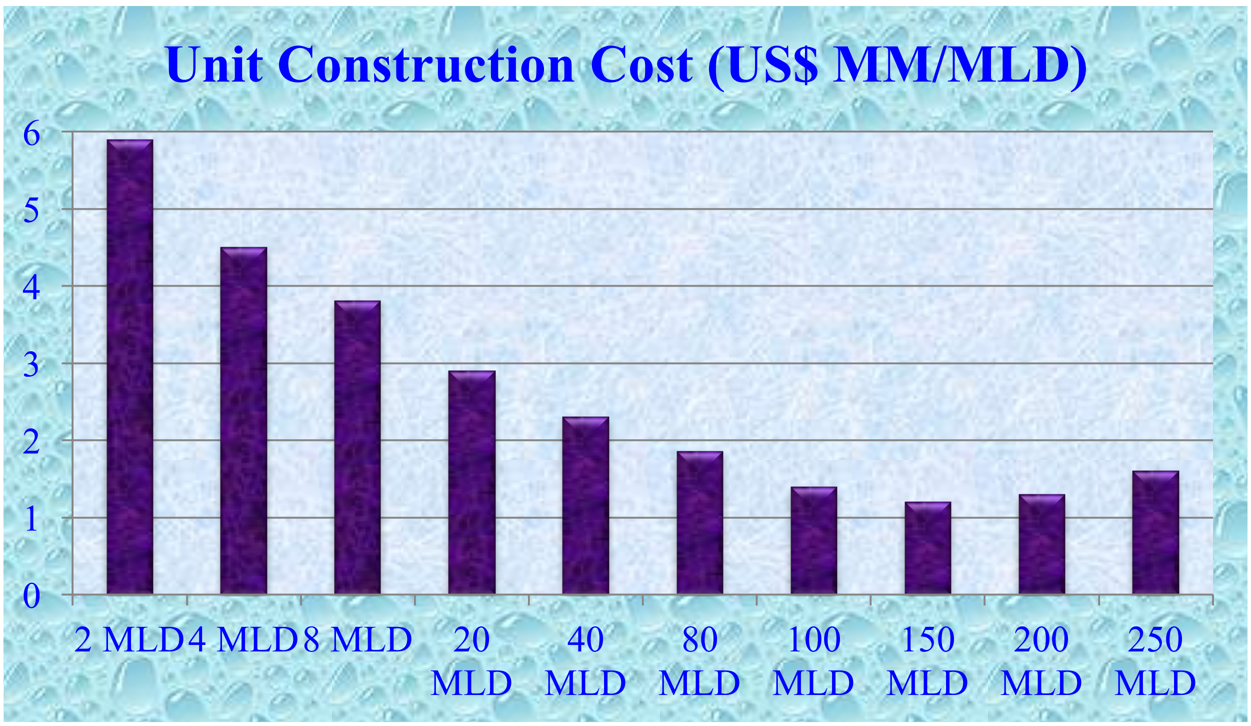

Figure 6 – Unit Construction Cost of SWRO Desalination Plants
(Million US$ per MLD of Installed Fresh Water Production Capacity)

7. **DO NOT BUILD DESALINATION PLANTS OF CAPACITY LARGER THAN 200 MLD.**

Practical experience from desalination plants built over the past 10 years shows that the optimum size of permanent desalination plants is between 100 and 150 MLD. Construction of larger size plants usually results in increased construction and operation and maintenance (O&M) costs because of the diseconomy of scale associated with the practical constraints of size of the equipment and piping used for construction of plant intakes and outfalls, low-cost pretreatment systems, and SWRO membrane racks.

As shown in Figure 6, the optimum size of the individual desalination plants that will yield the lowest cost of desalinated water is between 100 and 150 MLD. In this range, the projected capital cost of the SWRO desalination project will be between US1.2 and 1.4 million per MLD of installed desalination plant capacity. Figure 7 summarizes the projected capital costs for construction of SWRO desalination plants of production capacity of 50, 120, 150 and 450 MLD.

- ✓ **Optimum Desalination Plant Capacity – 100 to 150 MLD**
- ✓ **Projected Capital Cost of:**

One 50 MLD Plant – US$100 million

One 120 MLD Plant – US$156 million

One 150 MLD Plant – US$180 million

Three 150 MLD Plants – US$540 million

One 450 MLD Plant – US$810 million

- ✓ **It is Less Costly to Build Three 150 MLD Plants than One 450 MLD Plant!**

Figure 7 – Projected Capital Costs for SWRO Desalination Plants of Different Sizes

8. DELIVER PERMANENT DESALINATION PROJECTS UNDER DBO OR BOOT APPROACH

The standard design-bid-build approach used by the City for procurement of capital projects, goods, services and consumables is not typical and suitable for delivery of cost-effective large-size SWRO desalination projects because desalination projects are much higher-risk projects than conventional water and wastewater plants and how key project related risks are apportioned between the City and the contractor, and managed in the procurement documentation has a very significant impact on the actual project costs.

For the site-specific conditions of the City of Cape Town, the two most suitable project delivery methods are DBO and BOOT. Under both methods of project delivery a private contractor is responsible for the turnkey design, construction and operation of the plant. When DBO method of project delivery is applied the project is funded by the City, while under BOOT method of project delivery, the funding for the project is secured by a private contractor and the City purchases drinking water from this contractor at a firm guaranteed price, quantity and quality. Which of the two methods of funding would be preferable would mainly depend on whether the City could obtain lower cost project funding than the selected turnkey contractor.

The key desalination project related risks are associated with:

- Source Seawater Quality
- Selection of Treatment Technology
- Construction
- Power Supply
- Plant Operation and Maintenance (O&M)
- Project Financing
- Desalinated Water Demand

Practical experience with the implementation of SWRO desalination projects built over the past 15 years indicates that the BOOT or DBO approach of project delivery yields the lowest cost of water production, because it allows to cost effectively apportion the project risks to the party best suited to take and manage them. At present, the City does not have experience in the procurement, design, construction, commissioning and operation and maintenance of seawater desalination plants. The BOOT and DBO approach of project delivery allows the City to transfer all risks associated with their lack of experience in the implementation and operation of the desalination projects to experienced international contractor/s with proven track record to build and operate desalination plants.

The DBO approach is preferable if the City can tap into low-cost public funding and government grants or other forms or local or state subsidies. The key advantage of this method of project delivery is that the City will own all of the project assets. Under the BOOT approach of project delivery, the City would only have the responsibility of purchasing drinking water – it does not own the desalination plant and is not responsible for project funding. All risks and costs associated with the implementation and operation of the desalination plant are born by a private turnkey contractor selected by the City under competitive procurement process.

The DBO/BOOT contractor is responsible for all aspects of project implementation, including: environmental and construction permitting; design; equipment procurement; construction, startup, and commissioning; long-term operations and permit compliance; and project finance. The BOOT contractor usually finances the project with a combination of equity and debt. The debt bond/commercial construction loan repayment obligations for this type of projects are typically revenue-based and are "non-recourse" to the private project company that delivers the project and to the City, because the net worth of the owners of the project company and the City does not have to be used to provide security for debt repayment. In this arrangement, the City can also choose to be the provider of a portion of the project financing if it is able to secure finance at a lower cost. This will further reduce the cost.

Under this method of project delivery, the City will procure a turnkey (DBO or BOOT) contractor based on a performance specification developed by the owner's engineer. The turnkey contractor will sell the City product water at a guaranteed price, quality and quantity and point of delivery under a water purchase agreement (WPA).

If BOOT method of project delivery is applied to the three permanent SWRO desalination projects and the water supply contract under which the City purchases desalinated water from the turnkey contractor is of duration of at least 15 years (preferable 20 to 25 years), the projected cost of water for 100 to 150 MLD desalination projects is projected to be in a range of 12 to 18 ZAR/m^3. Lower costs of water (8 to 10 ZAR/m^3) are expected if the desalination plant intake is built in a location capable of capturing lower salinity water at the point of exit of fresh water aquifers into the False Bay or the West Atlantic Ocean coastline.

9. ACCELERATE/IMMEDIATELY INITIATE TECHNICAL SUPPORT STUDIES FOR DEVELOPMENT OF PERMANENT SWRO DESALINATION PLANTS AT THREE LOCATIONS - HARBOR SITE, ATLANTIC COAST SITE AND FALSE BAY SITE

The development of such procurement documentation will require the immediate initiation and expedited completion of site selection along the Atlantic Ocean coast and the False Bay, as well as the expedited completion of a number of Technical Support Studies for the site-specific conditions of each desalination project. Such Technical Support Studies should as a minimum include:

1. Source Water Quality Study
2. Bathymetric Survey of the Plant Intake and Discharge Areas
3. Brine Dispersion Study
4. Site Geotechnical Survey
5. Site Hazardous Materials Survey
6. Site Subsurface Investigation of Existing Utilities and Structures
7. Legal Description of the Site and Topographic Study
8. Environmental Impact Statement Defining Project Mitigation Measures, if Any
9. Product Water Integration Study
10. Site Power Supply Study

11. PREPARE PROCUREMENT DOCUMENTATION FOR PERMANENT DESALINATION PROJECTS COMMENSURATE WITH THE REQUIREMENTS OF THE INTERNATIONAL MARKETS FOR SUCH PROJECTS

The standard methodology and documentation used by the City for procurement of capital projects and consumables, is not suitable for retaining qualified and experienced turnkey (DBO or BOOT) contractors capable of delivering the permanent SWRO desalination projects and will not yield competitive cost of water in the target range of 12 to 18 ZAR/m^3. Such procurement should be completed using two-step, prequalification/firm turnkey bid tender process and performance-based specifications and documentation, which are of structure and content corresponding to international standards for procurement of permanent large turnkey (DBO or BOOT) desalination projects.

The typical internationally recognized procedure for procurement of DBO and BOOT desalination contractors which is proven to yield competitive market prices for desalinated water consists of the following four key steps:

1. Issue Request for Qualifications (RFQ).
2. Review Qualification Packages and Shortlist 5 to 8 Contractors with Proven Experience and Track Record to Deliver Similar Size Desalination Projects.
3. Issue Request for Proposal (RFP) to the Shortlisted Contractors Only – Contractor proposals should contain firm and binding offers for cost of water, project delivery schedule; and guaranteed fresh water production capacity; plant availability; maximum energy use; maximum chemical use; and maximum membrane replacement rate.
4. Select turnkey contractor based on lowest cost of water offer.

In order for the contractors to be able to offer low, international market-based cost of water the Request for Proposal should contain as a minimum the following key components:

1. Performance Based Technical Specifications for Scope of Work, which Contain all Technical Support Studies Described in the Previous Section of this Report as well as:
    a. Source Water Quality Specification
    b. Product Water Quality Specification
    c. Plant Discharge Water Quality Specification
2. Water Purchase Agreement (WPA)
3. Contract for Engineering, Procurement and Construction Services
4. Contract for Operation and Maintenance Services
5. Bid Bond Requirements
6. Performance and Payment Bond Requirements
7. Parent Company Guarantee Requirements

8. Water Tariff Model in Excel Spreadsheet Format
9. Power Supply Documentation Indicating the Conditions Under Which Power Will be Supplied to the Project (e.g., Power Purchase Agreement)
10. Land Use Documentation Indicating the Conditions Under Which the Contractor Should Use the Land on which the Desalination Plant will be Located and Specifying How Subsurface Risk will be Managed (e.g., Land Use Agreement)

The WPA, EPC and O&M contracts in combination with other entitlements, such as environmental and construction permits; land purchase or lease agreement; power purchase agreement; agreement for access to source water; and agreement for concentrate and waste disposal services, are used as a proof of control of the turnkey contractor over the project cash flow, which is necessary to secure private financing for the BOOT project.

The financing costs associated with the project are a direct function of the strength of the BOOT project's contracts and the financial and operating strength of the entity purchasing the water and the EPC and O&M contractors. Well-structured BOOT project with good WPA, EPC and O&M contracts and willing participants typically can be financed with 80 % debt and 20 % equity. If the project structure is strong and the project risk profile is favorable, a lower percentage of equity may be required.

The WPA guarantees water delivery to the City at pre-determined quantity, quality and availability over the entire term of the agreement. On the other hand, this agreement guarantees a pre-determined payment for the delivered water to the BOOT contractor and thereby, secures a revenue stream that the BOOT contractor can pledge to obtain private project financing. The key provisions recommended to be incorporated in the Water Purchase Agreement in order to minimize the project financing cost and therefore, the overall cost of water production are:

- "Take or Pay" Clause – by which the City agrees to purchase a minimum amount of water at any given time and/or to pay for the fixed costs of water incurred by the BOOT contractor, if the desalination facility is put on "standby".

- Firm Water Purchase Obligations – the contract should not contain provisions that allow the City to unilaterally terminate or substantially revise the contract in the future.

- Provisions to Assign Water Contract to Lenders – the financial institutions that will provide equity and debt funds for project implementation should have the right and ample opportunity to cure project default if the BOOT contractor fails to perform its obligations under the WPA.

- Firm and Clear Water Tariff Structure – the WPA should have a water tariff structure that provides adequate coverage of the fixed water production costs and includes water cost escalation factors tied to third-party commodity (power, chemicals, labor, etc.) price adjustment indexes and foreign exchange fluctuations.

- Change in Law Clause – which allows the BOOT contractor to adjust the water tariff in order to reflect the additional costs which the BOOT contractor will incur in order to comply with future environmental and/or other regulations than have material impact on the water production costs.

- Unambiguous Water Quality Standards – the WPA should contain clear specifications of the product water quality and quality; the plant capacity availability factor; the location/s of water delivery; and the procedures for measurement of the delivered water flow and monitoring of the quality of the desalinated water.

- Liability for Third-Party Claims – the WPA should have provisions protecting equally both the BOOT contractor and the City from claims from the ultimate water consumers. The BOOT contractor can only be required to be liable for the product water quality at the point/s of delivery to the City and cannot take the responsibility for changes in water quality caused by malfunction of the City's distribution system and conveyance facilities. On the other hand, the BOOT contractor should carry liability for impacts on the City's water distribution system if the BOOT contractor supplies inferior out-of-spec product water quality which is the cause such impacts.

The Water Purchase Agreement should also have a number of other provisions, which aim to define contractual division of responsibilities and risks between the turnkey contractor and the City. These provisions in general have to be such that the project risks are apportioned between the turnkey contractor and the water City commensurate with their ability to control and mitigate the risks and to deliver water to the ultimate consumer at lowest overall cost and competitive market price.

11. CONCLUSION

This brief report is based on international experience; review of existing desalination project planning and procurement documentation; as well as brief visits and exploratory inspection of the Cape Town's Atlantic ocean and False Bay coastlines. It draws strongly on relevant experience at other locations worldwide where municipalities or utilities have attempted to implement practically all alternative solutions considered by the City.

In our opinion, the City of Cape Town's Water Resilience Program is fundamentally sound, and the core challenge is to develop fast-track desalination plants in balanced mix with ground water extraction, water reuse and seawater desalination, aggressive potable water demand management and conservation. While creating new drinking water by desalination of seawater is of critical importance for the long-term sustainability of City water supply, it is strongly recommended that Cape Town discontinues the procurement of new containerized desalination plants, which will provide limited - if any – relief of the current water challenges, and will do so at very high costs. Desalination is only a component of the City's multi-pronged Water Resilience Management strategy, and needs to be judiciously applied and prioritized so it compliments other lower cost sources of water supply available to the city – groundwater extraction and reuse.

The City is strongly encouraged to accelerate its activities in developing key technical support studies needed for the preparation of competitive procurement documentation for turnkey contractors and to retain an owner's engineer with extensive experience in the preparation of procurement documentation for the permanent desalination projects commensurate with international standards for such projects.