Design And Construction Challenges Of The Kindasa SWRO Desalination Plant Expansion

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Abstract

In the year 2000 Kindasa Water Services (KWS) constructed the first private 14,000 m3/d (Phase A) seawater reverse osmosis (SWRO) desalination plant within the existing desalination plant site of Jeddah Islamic Port (JIP). Kindasa's customers are JIP and various industries in Jeddah Industrial City (JIC). The Phase–A plant was built inside JIP, because of the non-availability of suitable free land close to the sea and close vicinity of the Industrial City. On successful operation of the Phase –A plant, KWS decided to augment the capacity of the plant to the maximum possible limits in the present plant location. Dar Al Taqniya, the Consultant to KWS, carried out the feasibility study and recommended the maximum possible capacity increase to be 34,000 m^3/d. Hence, it was decided to build Phase –B SWRO plant with 4 units of 8500 m^3/d capacity. The deteriorating seawater quality in the seaport with the frequent ship movements had made the operation of the conventional pre-treatment system of the existing Phase-A plant particularly difficult. A state of the art hybrid pre-treatment system utilising both media and ultra filtration was envisaged for the expansion to overcome this problem.

The following issues were identified to be the challenges to be resolved with building a plant of 34,000 m^3/d additional capacity:

- Utilising the existing intake facility consisting of 242 meters long intake pipe of l meter internal diameter with 25 years of marine deposits creating a flow restriction.
- Upgrading the existing 25 year old intake structure and modifying it to suit the positioning of the Phase B equipment along with Phase A seawater pumps in the restricted space
- Continuing the Phase-A plant operation while refurbishment of the intake structure and other Phase-B integration works are being carried out.
- Utilising the existing outfall facilities with the available gravity flow head and redesigning it to handle large transient flows associated with the operation of the Phase B plant.
- System integration of Ultra Filtration (UF) with a conventional Filtration System, to improve the feed water quality and optimizing their sizes to minimize the pre-treatment system cost.
- Site space limitation posing problem to design efficient plant layout and material storage during constuction.

Dar Al Taqniya (DAT), Kindasa Water Services and Weir Westgarth Limited (EPC Contactor) worked together to solve the above challenges. The paper describes in detail the above problems encountered during the design and execution stages and how these problems were resolved.

I. INTRODUCTION

Availability of land with an access to the Red Sea, suitable for building a desalination plant, is very scarce in Jeddah City. Kindasa Water Services (KWS), built it's 14,000 m^3/d (Phase A) Sea Water Reverse Osmosis (SWRO) desalination plant in Jeddah Islamic Port (JIP) by replacing an ageing and uneconomical 4500 m^3/d MSF plant. On successful operation of the Phase-A plant, KWS decided to expand the desalination capacity to the maximum possible limit using the available space and the existing intake and outfall facilities, as construction of a new intake and outfall facilities inside the busy JIP was not possible. Dar Al Taqniya (DAT) was awarded the Consultancy Contract for the Phase-B expansion. DAT's preliminary study identified that the existing 1000 mm internal diameter intake pipe and two 600 mm and one 350 mm diameter outfall pipes limited the maximum capacity of expansion to 34,000 m^3/d. The Phase B Engineering Procurement and Construction (EPC) contract for construction of 3 X 8500 m^3/d (Phase-B1) with an infrastructure suitable to add a 8500 m^3/d (Phase-B2), at a later date, was awarded to Weir Westgarth Ltd. (WWL). The design and construction challenges encountered in Phase-B expansion and approach followed to resolve the challenges are described in detail in this paper.

II. DESIGN AND CONSTRUCTION CHALLENGES TO BE RESOLVED

The following significant engineering challenges were identified in the design and construction of Phase-B plant:

- Up grading the existing 25 years old intake structure and modifying it to suit the positioning of the Phase B plant equipment along with Phase-A plant seawater intake pumps, within the restricted space.
- Cleaning of the 25 years of marine growth inside the intake pipes with out damaging the internal cement lining of the intake pipe.
- Designing an outfall to integrate the existing two 600 mm and one 350 mm diameter outfall pipes and discharging the Phase-A and Phase-B brine / rejects, surface and storm drains to berth #57.
- Designing a pre-treatment system to produce consistent improved quality RO feed water, as the existing seawater quality deteriorates with the frequent ship movements & seasonal changes.
- Minimizing the Phase-A plant outage while cleaning the intake pipe, refurbishing the intake structure, integrating the outfall, etc.
- Severe plant layout limitations within the site for the plant and construction materials requiring careful sequencing of the equipment erection and operating the existing Phase-A plant with limited space for mobility.

III. UPGRADATION OF THE EXISTING INTAKE STRUCTURE

3.1. Original Intake Arragement

The desalination plant site is located 250 metres (approximately) from the coast and the seawater flows by gravity from JIP berth #39 through an underground pipe to the seawater intake structure. The intake facility was developed twenty five years ago for a multi-stage flash (MSF) desalination plant of 4500 m^3/d capacity. Figure 1 illustrates the layout of the intake structure. The seawater at the intake structure was divided into two chambers. Each chamber consisted of a bar screen and a drum screen. The screened water then flows into a common pump sump where the seawater pumps were located.

3.2. Modified Intake Arrangement for Phase-A

KWS took over the MSF plant from JIP and replaced it with a 14,000 m3/d (Phase A) SWRO desalination plant, to augment the capacity and reduce the water cost. Phase-A plant, came into operation, on a fast track basis, in the year 2000. Operation of 14,000 m^3/d SWRO plant requires 1,750 m^3/hr of seawater, which was well within the capacity of the existing seawater intake system. The existing seawater pumps and one of the drum screens were removed from the intake structure, and four new seawater intake pumps of Phase A were installed in the removed drum screen chamber and new fine screens were installed behind the existing bar screen, leaving the existing pump sump for Phase-B intake pumps. Figure 2 shows the layout of the seawater intake structure for the Phase-A desalination plant.

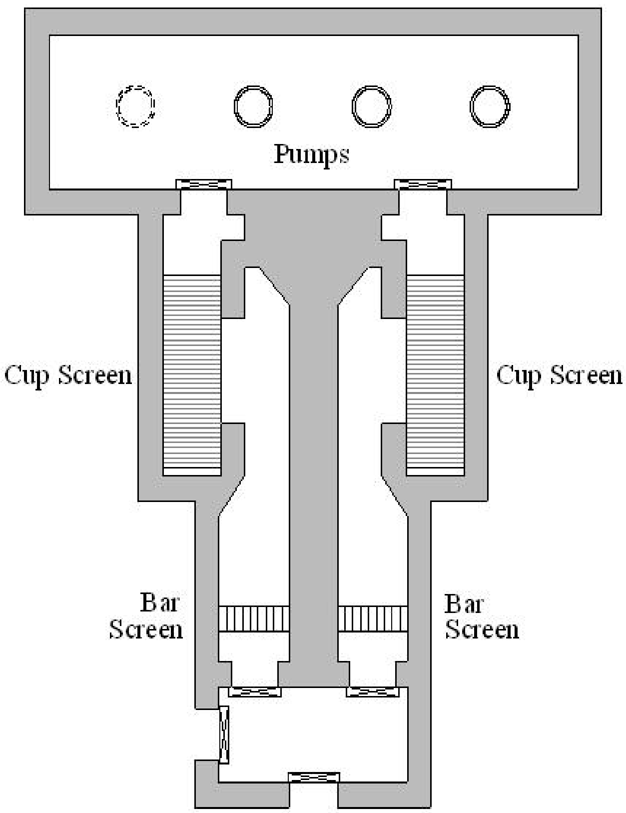

Figure1: Original Seawater Intake Structure

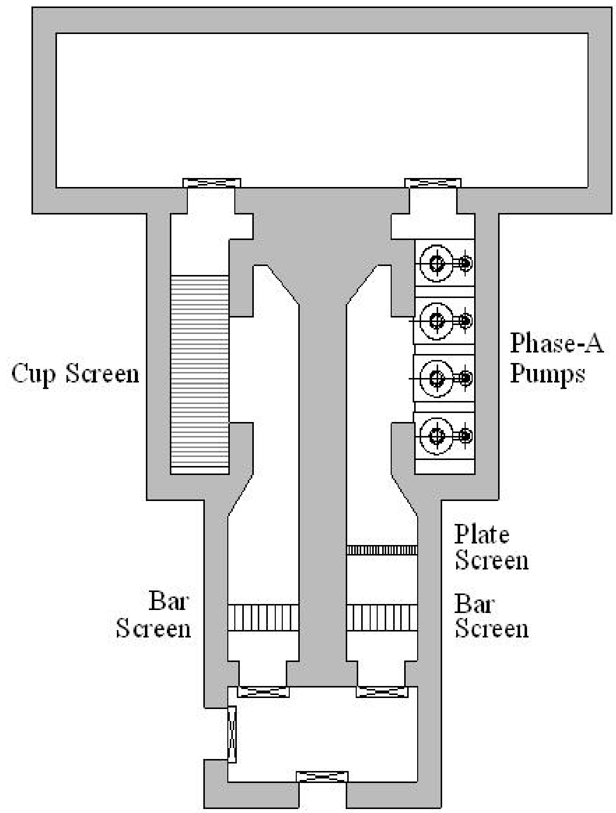

Figure 2: Seawater Intake Layout for Phase-A

3.3. Modification of Intake Structure for Phase-B

To meet the seawater requirements of Phase-A and Phase-B (Phase-B1 and Phase B2 future extension), the existing seawater intake system has to be suitable to supply 5600 m^3/h of seawater. The above requirement exceeds the original capacity of the seawater intake structure. Due to physical constraints, the intake structure cannot be increased in size and has to be redesigned internally.

The existing seawater intake structure was to house four seawater pumps of Phase-A plant and five submerged bowl type pumps of Phase B1 and Phase B2 plants. In addition to above, the existing bar screens and drum screens were replaced by new two bar screens and two band screens. The existing structure was redesigned to accommodate all the nine pumps, two bar screens and two band screens while still maintaining the facility to isolate 50% of the screening chamber for maintenance when the remaining intake structure remained in operation. The new layout conflicted with many design guidelines and hence model testing was undertaken at BHR Solutions' laboratories as an essential part to assess the viability of the system proposed.

3.4. Modeling Approach and Solution

To ensure that satisfactory flow conditions for all the pumps, under varying operation conditions can be achieved, the following modeling approach was undertaken.
The objectives of the physical model tests were:

- To assess the hydraulic conditions generated by the different combination of pumps operating conditions
- To determine the degree of swirl at the pump inlets
- To look out for vortex activity in the structure
- To make recommendations for benching, baffling and anti-vortex devices as required to achieve satisfactory performance
- To indicate likely areas of sediment deposition

A 1:6 scale model of the intake structure was constructed extending from the seawater inlet pipe to the pump discharge pipe work. The length of the seawater inlet pipe was sufficient to ensure representative inlet flow conditions to the model. Flow rates were calculated to give Froude scale similarity, which is appropriate for modelling pumping stations. At the selected model scale, Reynolds numbers were sufficiently high to ensure fully turbulent flow in all critical areas. In addition, selected tests were carried out at 1.5 times Froude scale flows to check both for Reynolds number dependence and to assess the 'factor of safety' for surface vortex formation. Vortometers were placed at the pump impeller locations to measure swirl. Figures 3 and 4 shows a general view of the model and a view of the model pumps respectively.

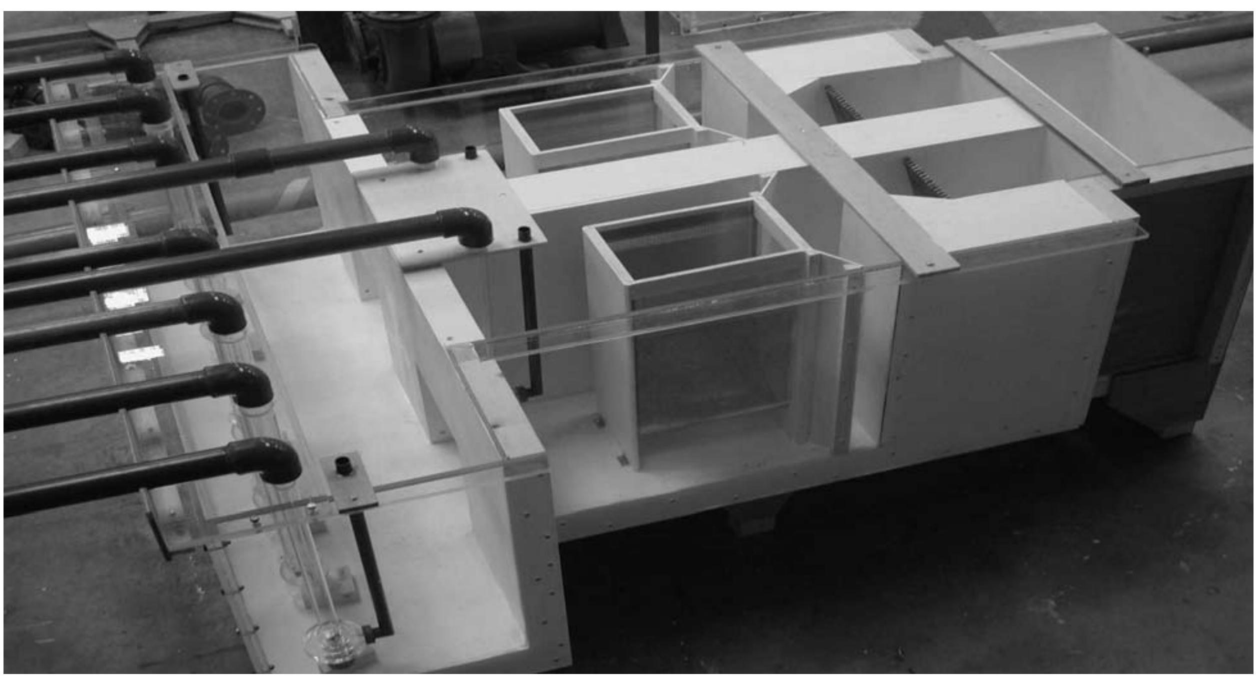

Figure 3: General view of scale model

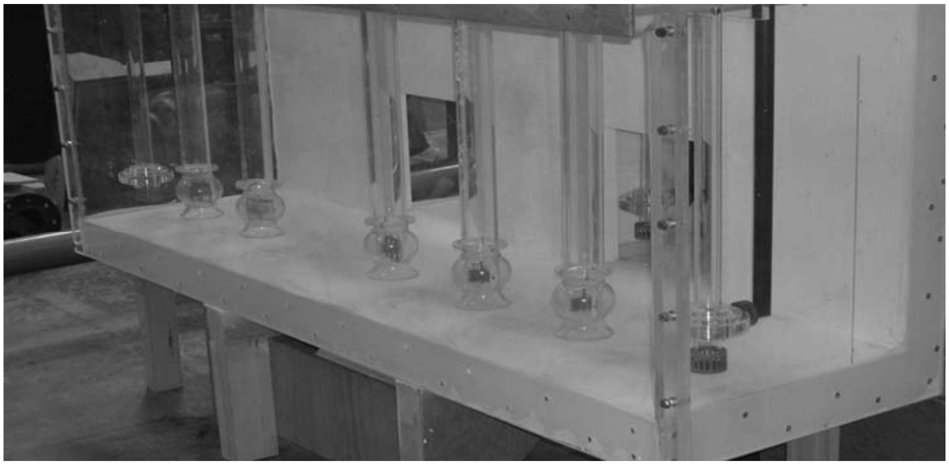

Figure 4: View of model pumps and pump chamber

A matrix of more than 40 tests covered the range of operation of the pump station at both high and low water levels and with various pump combinations for Phases-A and B plants operation. Some of these tests were carried out with one screen chamber in closed condition. The model study, after several revisions, produced a satisfactory solution that enabled the seawater intake structure to be upgraded for an increased capacity while maintaining the physical size of the structure. The results from the model testing confirmed the feasibility of incorporating the additional pumps and screens for the Phase-B expansion, while maintaining satisfactory flow conditions throughout the intake structure. The final proposed arrangement of Phase A and B Plant equipments are illustrated in Figure 5.

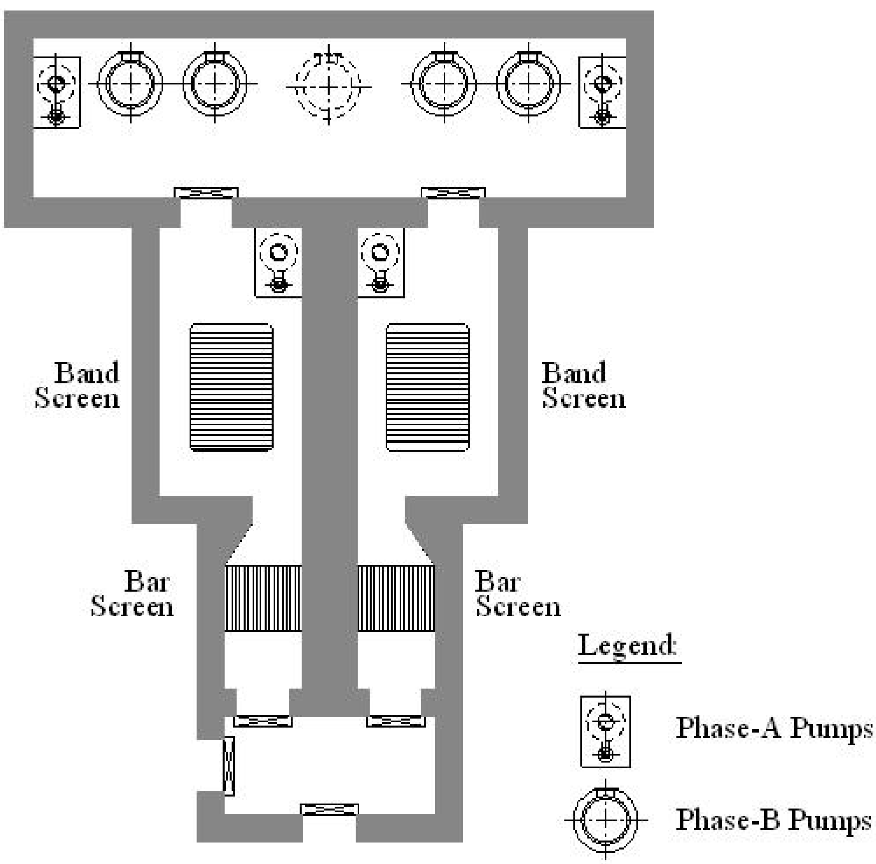

Figure 5: Final Seawater Intake Layout for Phase A and B Plants

The refurbishment required some civil restructuring, but this was limited only to internal walls and did not affect the integrity of the structure of the intake. The remainder of the changes in design required the installation of steel plates as a curtain wall in the pump sump to control surface vortices and circulation, splitters under all pumps to control swirl, and horizontal flat plate between the two penstocks opposite the inlet pipe to reduce the surface disturbance and consequent air entrapment, which could be incorporated during the period when the intake structure is shut down for the installation of the screens and pumps.

IV. INTAKE PIPE CLEANING

The existing intake seawater supply piping arrangement consists of 48 Numbers of 200mm diameter PVC pipes supplying seawater from JIP berth # 39 quay wall to the seawater sump adjacent to quay wall. A 1 m diameter pipe from this seawater sump transfers seawater to the intake sump located in the plant site. Figure 6 illustrates the intake piping arrangement. The flow test carried out, initially by DAT/KWS as well as by WWL at a later date, indicated considerable marine fouling inside the intake pipe and cleaning of pipe was essential to achieve the desired feed water flow for the Phase-A & B plants.

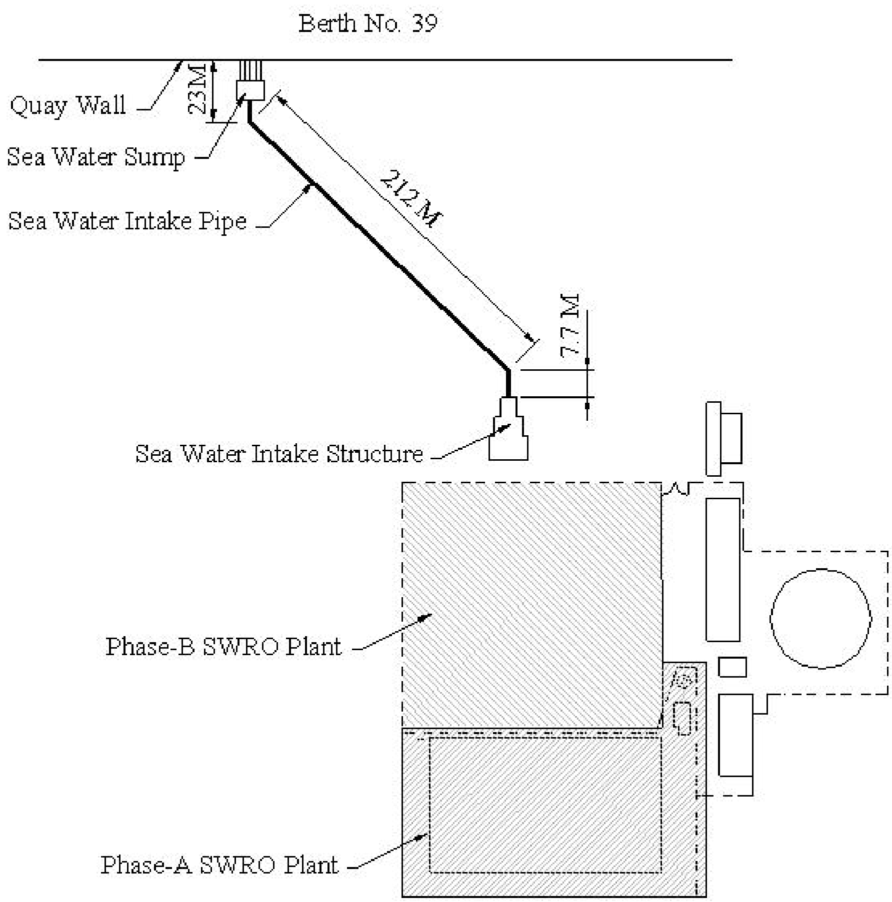

Figure 6: Existing Intake piping arrangement

Initially WWL planned to dewater the pipe, seawater sump and intake sump and then clean the empty pipe by automatic jet cleaning machine. But, due to the construction arrangement of quay wall, it was not possible to completely evacuate the seawater sump due to the continuous seawater leak from the quay block joints. An experienced diving company was engaged by WWL to execute the Intake Pipe cleaning. Divers checked the type of marine growth inside the pipe and found it to be loose and easily cleanable manually. In addition, as the structural integrity of the 25 year old cement lined pipe could not be ascertained and the risk involved in damaging the lining due to high pressure jet cleaning was high, it was decided to clean the pipe manually.

As a first step under water video inspection of the pipe was carried out to identify the fouling pattern and locations. A CCTV camera with a light mounted on a sledge, was pulled from seaside to the plant end and a co-axial cable connected to the camera enabled recording and live viewing of the pipe internal condition when the camera was pulled through the pipe. From the video inspection it was observed that the pipe had marine growth throughout it's entire length with deposit thickness varying from 5 mm to 30mm and loose deposits at the pipe bottom to a depth varying between 50 to 250mm in the 225 meters of plant end pipe. To clean the pipe completely, cleaning team had to cover around 130 meters of pipe from both ends. Oxygen support was required for the cleaning team to reach deep inside the pipe. A detailed study on the options of cleaning the pipe with and without water inside the pipe was carried out and finally it was decided to clean the pipe in flooded condition using divers. The reason for selecting flooded pipe cleaning was to relieve the cleaning team (divers) of carrying loads of air bottles as well as to facilitate easy working in floating condition instead of working on hands and knees in the empty pipe.

4.1. Cleaning Arrangement and Execution

As the cleaning and intake refurbishment operation was expected to take more than 6 months, a temporary intake, explained later in this paper, was designed by DAT and was constructed by KWS, to enable uninterrupted operation of Phase-A plant during the intake pipe cleaning and intake structure refurbishment. Air for the divers was arranged to be supplied through an external hose of about 200 m long. In addition a small bottle of oxygen with regulator was made available, in front of the diver, for emergency use. Only one diver was allowed to clean at a time from one end. If required two divers were proposed to be used to clean from both ends simultaneously. A trash pump, capable to pump solid particle of up to 30 mm size was installed to continuously pump out the cleaned material from the pipe. The pump was installed on the surface of intake sump and a long suction hose of about 200 M length was sent inside the intake pipe to evacuate the cleaned material.

The divers entered the pipe in reverse (i.e. with the legs towards inner side of the pipe) and carried out the cleaning & moved backwards, to enable them to swim out faster in case of any emergency. The pump suction hose was in front of the diver. The diver used curved scrapers to remove the barnacles and other marine growth. As the deposits were removed, they were sucked out through the suction hose by the trash pump. The pump delivered all the debris with water into a selected portion of the intake chamber in the plant end and garbage skip in the berth #39 end. The chamber/skip was dewatered and the debris was periodically trucked out.

The cleaning operation was completed over two months. The cleaned pipe was surveyed using video equipment for a further review of the condition of cleaned pipe. A special blank was fabricated to isolate water entry into the pipe from the sea side end and after blanking, the intake pipe and the intake sump was dewatered to keep the pipe under dry conditions to avoid further marine growth. An inspection trolley with air bottle was arranged for visual inspection of the cleaned pipe. Visual inspection was limited to 30 m length of pipe, from the plant end, due to the hazard involved. The cleaning of the pipe and the condition of the internal cement lining was found to be satisfactory.

V. HYBRID PRE-TREATMENT SYSTEM

The deterioration of seawater quality in the JIP, with the frequent ship movements, results in poor quality of raw seawater and increased the loading on the pre-treatment system. The Phase-A plant designed with a single stage conventional dual media filtration (DMF) system faced the problems of frequent back washing (up to once in 6 hours) of DMFs, higher RO feed water SDI (above 4.5) and operation of SWRO plant at reduced recovery (30% instead of 41%) during the poor seawater condition.

Realizing the need for an improved pre-treatment system, DAT/KWS in co-operation with Kalsep carried out the pilot testing of Ultra Filtration (UF) System for a period of one year prior to the contract award of the Phase B plant. Based on the encouraging results WWL was contracted to provide a hybrid pre-treatment system consisting of the UF and a conventional DMF system, to ensure consistent and improved seawater quality specifically to meet the challenge of 50% SWRO recovery in Phase-B SWRO plant.

5.1. Pilot Plant Test

As per the contract WWL along with Hydranautics carried out pilot field testing of the Integrated Membrane System (IMS) with conventional DMFs located on the upstream side of UF system. The objectives of the pilot test were as given below:

- Verify the proposed design of hybrid pre-treatment system under different operating conditions and seawater quality.
- Select the DMF media
- Optimize DMF filtration velocities
- Optimize process chemical dosing rate.
- Integrate the UF system and demonstrate a steady trans membrane pressure (TMP) at the specified steady flux.
- Demonstrate the steady SWRO performance at specified flux with a steady membrane differential pressure.

The pilot plant set up, schematics shown in Figure 7, consisted of two conventional DMFs of 500mm internal diameter (each loaded with Grade 10/12 and 16/40 pumice granules and silica sand 0.4 -0.8 mm) with the raw water tank, feed pump, backwash pump, backwash tank, air scour compressor, sulphuric acid and ferric chloride dosing sets and an IMS test rig consisting of Hydracap 40” UF module, UF back flush pump, back flush tank, calcium hypo chlorite dosing set, UF filtrate booster pump, RO High Pressure Pump, One SWC 2540 Hydranautics membrane with appropriate instrumentation, inter connecting pipes, valves and fittings. The raw water for the pilot plant was taken from the Phase-A seawater pumps discharge header.

The pilot test was started with the operation of dual media filters, selection of media and optimization of it’s performance. On stabilizing the performance of the dual media filters, the UF system was started and the integrated pre-treatment system performance was stabilized before the operation of the SWRO pilot skid. DMF pilot test was performed for nearly 4½ months whereas the IMS test was performed for nearly 3 months.

The following parameters were monitored:

- DMF Feed flow, backwash flow, air scour flow , feed pressure, outlet pressure, differential pressure, backwash water inlet pressure and dosing pumps stroke and motor frequency.

- Raw water conductivity, turbidity, total suspended solids, pH, temperature, particle counts, total iron concentration and SDI
- DMF inlet pH and DMF effluent turbidity, particle counts, total iron concentration and SDI. DMF backwash temperature and backwash waste water effluent turbidity.
- UF feed, brine reject and permeate pressures, feed flow, feed particle counts, permeate SDI, back flush flow, dosing pumps stroke and motor frequency.
- SWRO feed, brine and differential pressures, permeate and brine flow, permeate temperature and conductivity.

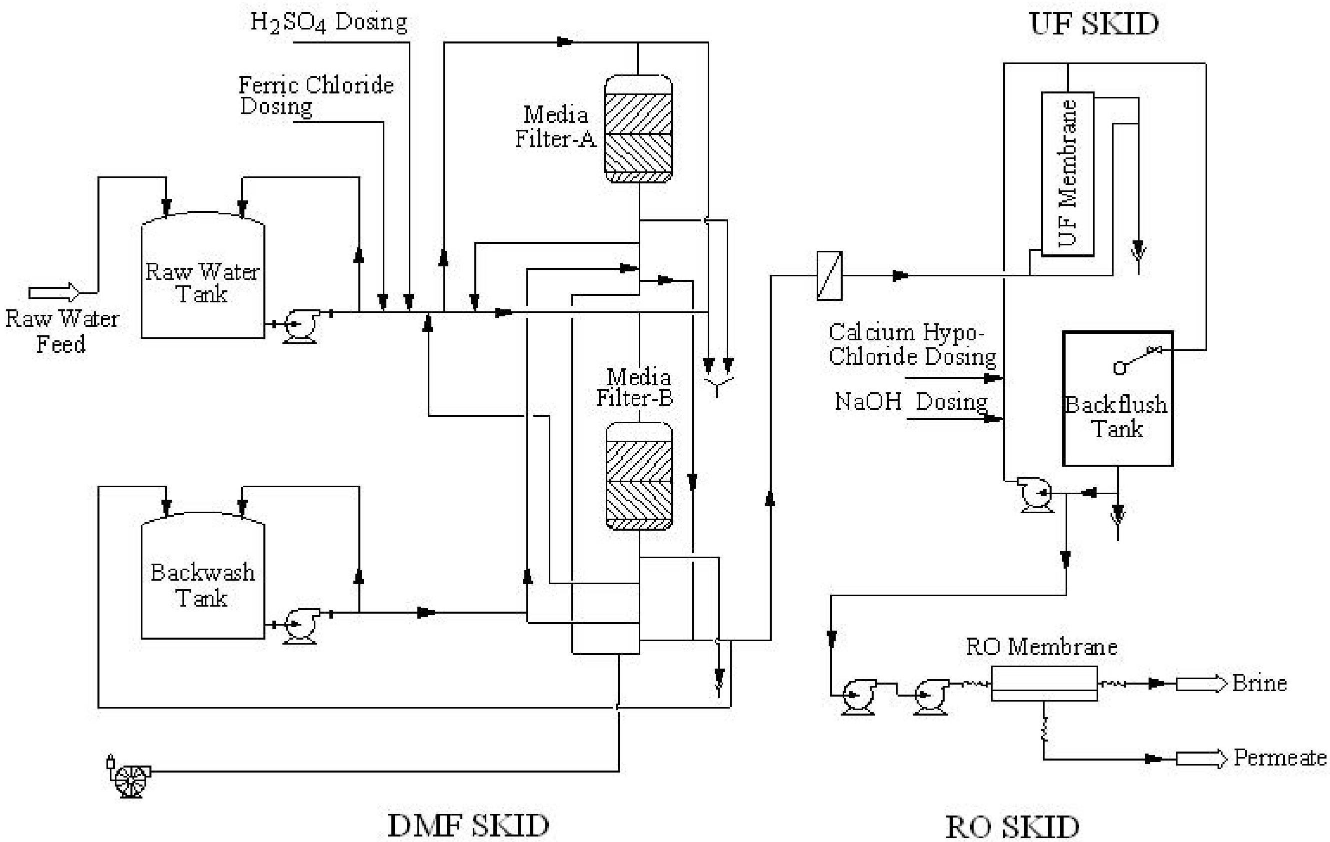

Figure 7: Pilot Plant Schematic Arrangement

5.2. Pilot Plant Test Results

The test results are summarized as follows:

- Pumice 10/12 showed better performance over Pumice 16/40 in terms of filtration cycle and differential pressure increase.
- The DMF with design filtration velocity of 15.3 m/h (Maximum 20 m/h corresponding to one filter under backwash condition in Phase B) performed satisfactorily. Best DMF filtrate quality was obtained with ferric chloride dosing rate between 0.4 to 0.6 mg/l as Fe. Backwashing was required not more than once per day during the entire test period.
- The performance of UF and RO (IMS) was observed to be better without coagulant dosing in terms of steady TMP and membrane differential pressure respectively at the water quality experienced during the trials.

- UF membranes did not require any chemical cleaning apart from disinfection by calcium hypo chlorite (Chemically enhanced back flushing – CEB1) at a frequency of once per every 6 hours for period of one minute. Maximum TMP reached during operation was 0.3 bars.
- Air enhanced back flush was essential once in 6 hours after every CEB1 instead of once in a day proposed during initial starting of pilot test. This was also essential to purge the chlorinated water retained in the fibers after the CEB1 and reduce the back flush requirements.
- After the initial stabilization period the particle count in the UF filtrate was consistently at low level of 5 particles per ml.
- UF membranes gave a stable performance at a flux of 95 l/m²hr. UF membranes were also tested to operate satisfactorily during last week of trial period at 107 l/m²hr flux corresponding to operation of Kindasa Phase B with one out of 8 UF skids under chemical cleaning and one UF skid under maintenance.
- Differential pressure across SWRO increased gradually during ferric chloride dosing and became considerably stable on stopping ferric chloride dosing. This could be probably due the short retention time of the ferric chloride in the DMF system resulting in incomplete coagulation with some iron being carried through to the UF/RO system
- Hydranautics recommended that ferric chloride dosing may not be required if the feed water condition is similar to the one encountered during testing period. (However, the requirement of ferric chloride dosing will be decided based on the actual plant operational requirements)

VI. Outfall System Design

6.1. Existing Phase A Outfall Arrangement

The Phase A desalination plant brine reject from RO units 1,2 and 3, feed seawater dump and surface drains discharges into the brine pit located adjacent to control room close to the north wall of the underground storage tank .

The brine pit is connected to a 600mm diameter buried asbestos cement pipeline. Phase-A DMF backwash water is also connected to the above 600 mm pipeline further down and the combined flow discharges into berth #57.

In addition to the above 600mm pipeline, two 350mm and 600mm diameter buried pipelines, run parallel from the plant site up to berth #57.

The 350 mm pipe is presently used to carry storm water and brine reject from Phase-A RO units 4, 5, 6 and 7 to berth #57.

6.2. Modified Outfall Arrangement

The Phase-B plant has the following major discharges to be disposed-off to sea through the spare capacity available in the presently used 600mm and 350mm pipelines and the unused 600mm pipeline:

- Brine reject (Continuous).
- Backwash water from DMF (Intermittent) / DMF rinse dump (Intermittent).
- Back flush water from UF (Intermittent).
- Permeate dump from one SWRO Plant (Intermittent).
- Intake sludge pump discharge (Intermittent).
- Backwash flow from self cleaning strainer (Intermittent).
- Neutralized water dump (Intermittent).
- Surface drains (Intermittent).

The outfall design calculations indicated that the existing hydraulic gradient available under the high tide level condition is not sufficient to dispose-off the brine and waste water from Phase-A and Phase-B plants, by gravity, with all intermittent discharges occurring simultaneously, through the existing three outfall pipes. However, the calculations indicated that if Phase-B DMF backwash and UF back flush do not occur simultaneously the existing outfall pipes could suitably integrated to handle the brine and waste water from Phase-A and Phase-B plants.

Of the intermittent discharges, the DMF backwash flow of 1112 m^3/h and UF back flush flow of 1000 m^3/h were identified to be the major ones. DMF backwash discharge with DMFs being backwashed once in 24 hours was expected to occur approximately once in 4½ hours for a period of 15 minutes, whereas the UF back flush will occur once in 30minutes for a period of one minute. Since the UF back flush flow is considerably large for a very small duration, it was decided to build a back flush water collection tank and regulate the discharge from this tank uniformly at slow rate to reduce the outfall system design load. An outfall surge tank was also introduced to take care of the surge due to all the other intermittent flows.

AFT Impulse model software was used to study all the transient operating conditions and the following optimized design provided the satisfactory results:

- Phase-B energy recovery turbine (ERT) pit wherein all Phase-B reject brine and equipment cooling water is discharged, is to be connected to 600 mm unused pipe through a 800mm diameter pipe to discharge into berth #57.
- The Phase-B DMF pit in which DMF backwash, regulated UF back flush, neutralization sump outlet, intake sludge pump discharge, back flush flow from self cleaning strainer is collected, to be connected to outfall surge tank by a 800mm diameter pipe.
- Phase-A RO trains 1, 2 and 3 brine discharge, feed water dump, chemical cleaning waste water and surface drains to be routed directly to the outfall surge tank of 300 m^3 capacity to accommodate surges from the transient operating conditions.
- Phase-A RO trains 4, 5, 6 and 7 brine discharge and storm drain are to be connected to the 350mm pipe which in turn to be connected to outfall surge tank.
- The surge tank to integrate the presently used 600mm and 350mm diameter pipes to collect all discharges other than those connected to ERT pit and discharge them to berth #57.

The modified outfall schematic arrangement is illustrated in Figure 8.

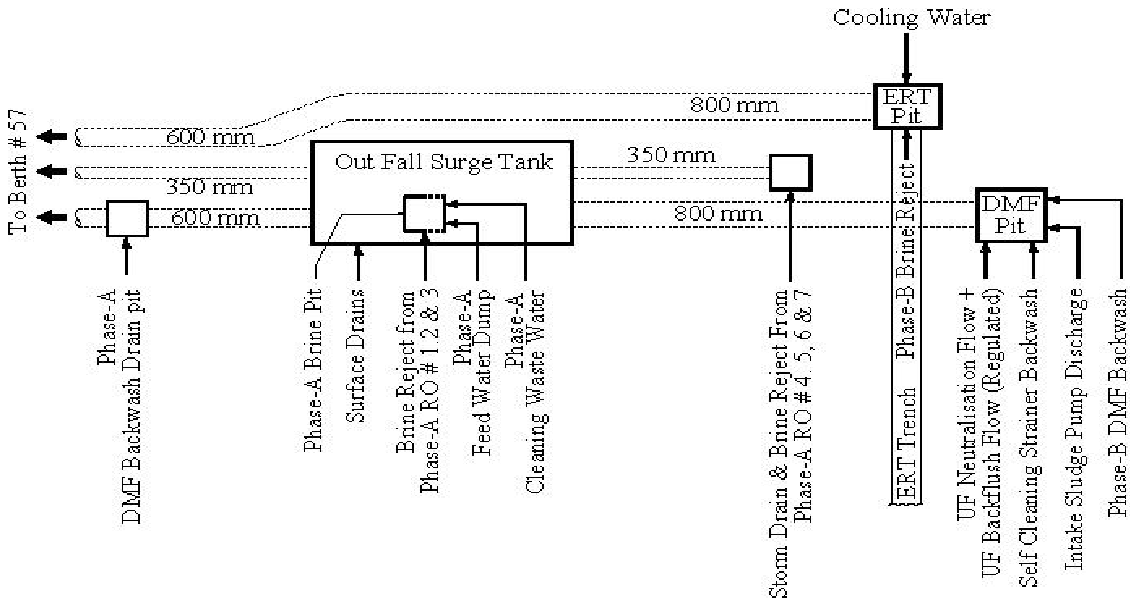

Figure 8: Modified outfall schematic arrangement

VII. MINIMIZING PHASE-A PLANT SHUTDOWN

KWS permitted a Phase-A shut down for only 3 to 4 days, at a time, due to the limited potable water storage capacity facilities and their commitments to supply water to various Industries in the Jeddah Industrial City.
Phase-A plant shutdown is required to carry out the following activities for Phase-B expansion:

- Cleaning of existing intake pipe
- Refurbishment /modification of intake structure to accommodate the Phase-B screens and Phase-A and B intake pumps.
- Integration of Phase-B plant's brine, and waste water to existing outfall system.
- Phase-B plant product water connection to existing Phase-A plant potable water tank.
- Connect power supply to Phase-A & B plants from Saudi Electricity Company (SEC) by disconnecting the JIP network power supply to Phase-A.

Power supply connection to Phase-A & B plants from SEC was planned to be combined with any other plant shutdown activity as the cables have been already laid and only termination has to be done.
Details of the modifications implemented and proposals envisaged to minimize the Phase-A shutdowns for the above works are described below.

7.1. Construction of Temporary Intake

Cleaning of the intake pipe with modification and repair of the intake structure warranted an extended Phase-A plant shutdown for more than 6 months. Hence, it was decided to construct a temporary intake to supply raw seawater to Phase A during the intake pipe cleaning and intake structure refurbishment period. Though, JIP principally approved the request for installing temporary intake, KWS was advised to position the intake pump platform in berth #39 with minimum disruption to the ship docking and route the piping in such a way that there will be a minimum disruption to the JIP trailers traffic movements. DAT and KWS engineers evaluated the different pipe routing and Phase-A intake pumps installation options to access the sea with shortest possible pipe length, minimum disruption to JIP trailers traffic movements,& ship docking and the ease of construction at minimum cost. A value engineering analysis was carried out and finally it was decided to draw seawater from berth #39 and connect to existing Phase-A intake pumps discharge header with the route illustrated in Figure 9.

The following criteria were considered to minimize the construction cost of the temporary intake.

- Use the existing Phase-A intake pumps and install them on a new intake pump platform erected at berth #39.
- Install the available basket strainers housings with new 3mm pores basket, at the intake pump discharge (purchased for installation on the Phase-A booster pumps suction) to remove the suspended particles as the temporary intake did not have any screens to remove bigger suspended particles.
- Connect the temporary intake pipe to existing intake pump discharge header so that the existing ferric chloride and sulphuric acid injection points and static mixture need not be relocated.
- Use the local control panel of the existing intake pumps in their present location to supply power and control the temporary intake pumps, thereby requirement of diesel generators near berth # 39 and relocation of control panel, etc was eliminated.
- Obtain JIP approval to install above ground piping close to berth # 39, to avoid excavation of thick concrete layers in berth # 39.

The temporary intake was designed by DAT, the construction work was sub-contracted and the installation and commissioning was supervised by KWS engineers. Phase-A shutdown was minimized to 3 days instead of 6 months. The temporary intake is successfully in service for the last 6 months, meeting the feed water requirement of Phase-A plant.

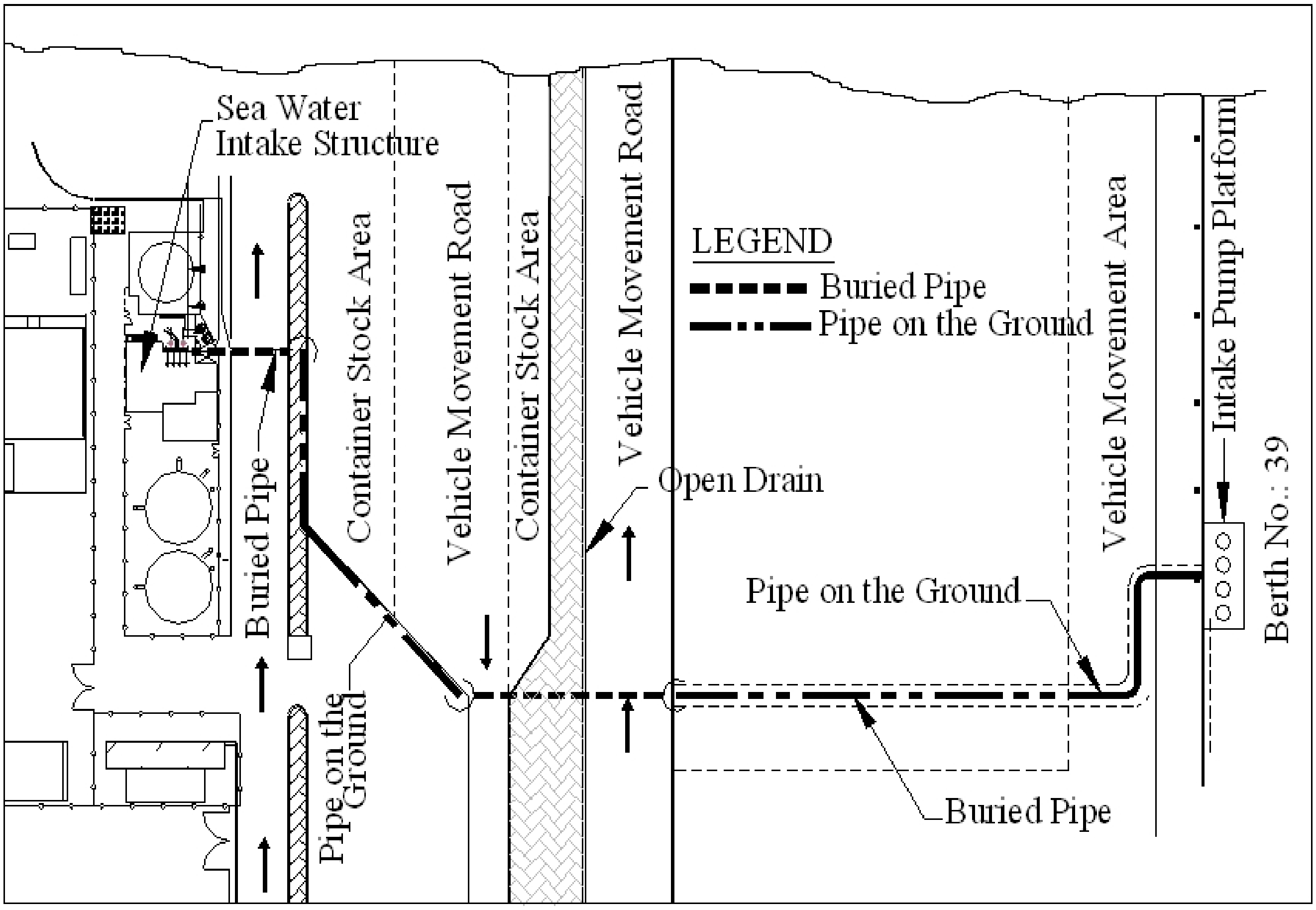

Figure 9: Temporary Intake pipe routing

7.2. Integration of Phase-A & Phase-B Brine and Waste Water Disposal System

The major challenge in integrating the Phase-A & Phase-B brine and waste water disposal system was the construction of the outfall surge tank that integrates the presently used 600mm and 350 mm diameter buried pipeline and the Phase-A brine pit with a short Phase-A shutdown.

Following sequential integration of the outfall surge tank could limit the complete Phase-A shutdowns to less than 3 days:

- Construct a sump over 350mm diameter pipeline close to the east wall of the outfall surge tank. Shutdown the Phase-A RO plants 4, 5, 6 and 7 and connect the brine channel and surface drain to this sump. Remove the piece of 350 mm diameter pipe within the sump. Put RO plants 4,5,6 and 7 into operation.
- Construct a bulk head of the outfall tank with temporary wall on the east side over the 600mm and 350 mm diameter pipeline.
- Shutdown Phase-A RO plants 1, 2 and 3 and divert the pipeline discharging to Phase-A brine pit to bulk head tank. Remove the portion of 600mm pipe within the bulk head tank. Put RO plants 1, 2 and 3 into operations after completing the diversion of pipeline.
- Demolish the Phase-A brine pit

- Complete the construction of outfall surge tank by removing the east side temporary wall of bulk head.
- Shutdown the Phase-A plants completely and remove the portion of 600mm and 300mm pipelines inside the outfall surge tank and put back the phase A plant into operation.

7.3. Phase-B Potable Water Supply Connection to Phase-A Potable Water Tank

Due to the space limitation within the plant area KWS decided to use the Phase-A potable water tank to store the water from Phase-B also and transfer it to KWS storage tanks located in the tanker filling station, approximately two kilometers from the plant site and outside JIP. The potable water transfer pumps located adjacent to the tank draw water from the potable water tank and transfer it to the storage tanks located in the tanker filling station.
To connect Phase-B potable water piping to the storage tank, the tank is to be emptied and taken out of service. An outage of one week was envisaged by WWL to connect the Phase-B potable water piping to the tank.
To minimize the Phase-A outage to less than 3 days, KWS and DAT decided to make temporary spool arrangement with valves to connect the Phase-A potable water discharge piping to the Potable transfer water pumps inlet header to enable transfer of Phase-A potable water directly to the filling station storage tanks bypassing Phase-A storage tank. On completion of Phase-B connections, the valve position in the spool will be changed to discharge the potable water from Phase-A directly to the potable water tank instead of suction header of transfer pumps.

VIII. SPACE RESTRICTION

The space restriction for the Phase-B expansion posed a major challenge to the development of plant layout. Layout of the plant had to be revised several times to ensure adequate space for safe and easy operation and maintenance. The temporary facilities like chemicals store, equipment spares store and workshop had to be accommodated in the available free area, as the existing phase-A facilities were demolished for constructing new facilities. Hence, KWS had to manage and operate the Phase A plant with the smaller area allotted for the temporary facilities.

WWL had limited storage space close to the Phase-B plant area for materials storage. Hence, the delivery of the materials had to be sequenced to match the erection schedule and to avoid unnecessary blockage of useful space. Free movement of cranes, heavy equipments, concrete trucks etc. during construction was also greatly affected due to the limited space. The plant layout that was finalized after several reviews is shown in Figure -10

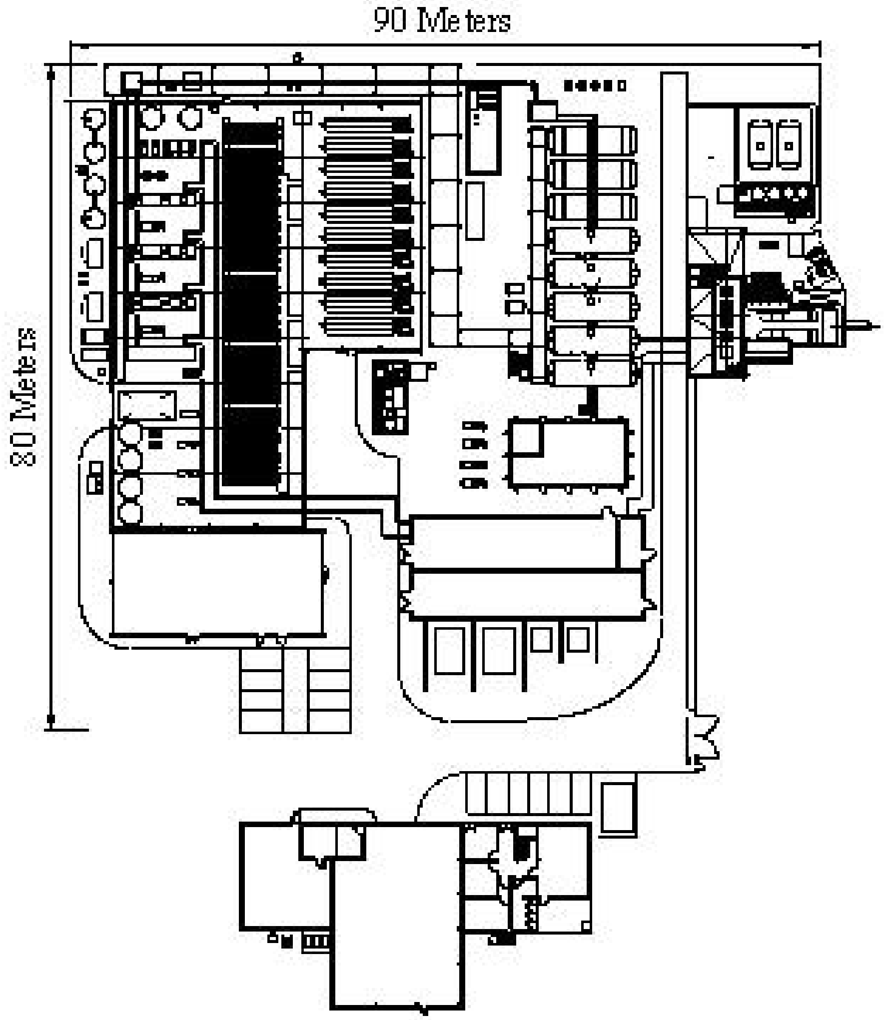

Figure 10: Phase B Plant layout

IX. CONCLUSION

The engineering and construction challenges encountered were very tough; all of them were successfully resolved through a close working relationship of all the contracted parties. The model study produced an optimized design that enabled the seawater intake structure to be upgraded for an increased capacity while maintaining the physical size of the structure. The intake manual pipe cleaning though laborious, achieved the desired results without any damage to the internal cement lining. The hybrid pre-treatment pilot trials have been useful in optimizing the system design and giving confidence that the pre-treatment problems encountered in Phase-A will not be repeated in Phase-B. The complex outfall system design analysis gave a suitable, cost effective and practical solution to dispose of the brine and waste water produced in the Phase-A & B plants. Though the provision of temporary intake and temporary bypassing of potable water tank are expensive, they made it possible for KWS to maintain it's reputation with the clients for being a reliable supplier. By effective and efficient planning the space restriction problem was also over come.

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XI. AUTHORS REFERENCES

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