CHENNAI METROPOLITAN WATER SUPPLY & SEWERAGE BOARD

REPORT ON BRINE DISPERSION MODEL

Construction of 400 MLD Chennai Seawater Desalination Plant at Perur, Chennai with 20 years of Operation & Maintenance (DBO Basis)

January 2021

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1. INTRODUCTION

1.1 Background

Chennai is currently experiencing a chronic water shortage due to the impacts of climate changes and uncertain monsoons to deliver enough and even rainfall and associated stream flow to refill the existing water supply system's surface water sources.

To augment and improve the current water supply system, the Chennai Metropolitan Water Supply and Sewerage Board ("CMWSSB" or "the Client") has obtained a loan from the Japan International Cooperation Agency ("JICA") through the Tamil Nadu Government, to build a 400 MLD Sea Water Reverse Osmosis Desalination plant at Perur in Chennai.

CMWSSB has selected a Project Management Consultant ("PMC") through a competitive bidding process to support the CMWSSB Project Implementation Unit ("PIU") for implementation of the 400 MLD Seawater Desalination Plant and its components. A Consultancy Contract agreement was signed on January 09, 2020, for Consulting Services.

The Reverse Osmosis (RO) desalination plant takes seawater from open intake and separates it into two streams, i.e., potable water stream and a concentrated waste stream (brine). The concentrated waste stream from the RO desalination plant will be within 54-58% of the total seawater intake to the plant (for plant recovery within 42-46%) depending on the salinity and fouling nature of the seawater, which will then be discharged into the offshore sea through the pipeline at a specified distance from the shoreline. As the brine release in the sea adversely affects the seawater quality at the intake and the marine ecosystem in surrounding areas, a thorough investigation is required in the selection of the brine discharge location so that the recirculation of brine to the seawater intake and the effect of brine on the marine ecosystem can be minimised. A brine diffusion mathematical modelling is required to simulate the effects of the brine discharge in the coastal environment and understand the salinity diffusion over the distance from the brine discharge point and increase in total suspended solids (TDS) in seawater near the intake point.

PMC started working on the project in Chennai from February 20, 2020. As part of the Term of Reference (TOR), PMC reviewed the design of Intake system carried out for Detailed Design Report (DPR) by M/s AECOM and Initial Feasibility Report prepared by M/s JICA (Japan International Cooperation Agency). The locations for intake and brine discharge (Outfall) heads proposed by DPR and JICA differ. Contrary to the DPR, the dispersion modelling carried out by JICA recommends the brine discharge position to be kept far off the seashore to avoid recirculation of the brine to the seawater intake. Nevertheless, the proposal of keeping the brine discharge location far off the seashore (at 1800m) envisages an increase in the capital cost for the construction of the brine outfall.

Considering the above, PMC found it prudent to carry out the brine dispersion modelling again by an external agency to confirm the results proposed by JICA. This was discussed with Project Implementation Unit (PIU), CMWSSB in the meeting held on 11 June 2020 and subsequently, PMC engaged M/s. Indomer Coastal Hydraulics Ltd., Chennai by the end of June 2020 to carry out brine dispersion modelling. The selection of M/s Indomer was done mainly due to its extensive experiences in such modelling works. The brine dispersion modellings for the Minjur and Nemmeli desalination plants have been done by M/s Indomer.

M/s. Indomer Coastal Hydraulics (P) Ltd., Chennai, did the seawater sample collection and Bathymetric study in August 2020. PMC was fully involved in conducting the sample collection and Bathymetric study along with the proposed locations. Indomer carried out the task of brine dispersion modelling for three brine outfall locations and submitted the final modelling report on 30th November 2020. The Indomer Modelling Report is attached along with this report as Annexure-1.

It is imperative to mention here that the Coastal Regulation Zone (CRZ) clearance for the intake and outfall positions for the 400 MLD desalination plant has been already achieved by the CMWSSB, based on DPR proposal. It is to be noted that getting CRZ clearance for the brine discharge location is a very intricate task to complete involving a lot of resources and time duration. Any change in the position of intake and outfall and subsequent CRZ approval for the revised locations will be strenuous, which may take even more than 6 months. Therefore, it is suggested to approach CRZ at the earliest to get the clearance for the amended location of the outfall as suggested in the report.

This report presents the results of the brine dispersion model conducted by JICA and PMC (through M/s Indomer) and comparison of the results with discussion and inferences.

1.2 Objectives of this Report

The objectives of this report are as follows:

- to discuss the results of the brine dispersion modelling carried out by JICA and PMC through M/s Indomer.
- to compare the dispersion model results conducted by JICA and PMC
- to recommend the intake and outfall locations to be adopted in the Concept Design Report for Perur DSP and ultimate inclusion in RFP bid specifications as the indicative design criteria.

2. PREVIOUS WORK DONE FOR INTAKE AND OUTFALL DESIGN

The design of Intake and Outfall heads was done by M/s AECOM during DPR preparation and by M/s JICA during Feasibility Report preparation. The work was done to complete the DPR and to achieve the ODA loan from JICA. There are no details provided in the DPR about any brine dispersion simulation work conducted by M/s AECOM for the selection of the locations for intake and outfall heads, but the simulation work conducted by the JICA study team has been presented in the JICA Feasibility Report.

JICA conducted brine dispersion simulation for three seasonal conditions, i.e. a) Static condition, b) Northeast Monsoon, and c) Southwest Monsoon. The TDS of the ambient seawater was considered as 38000 mg/l based on the Nemmeli seawater quality test report.

2.1 Design Proposed in DPR

DPR presents the open intake and offshore brine discharge (outfall) positions. Two intake HDPE conduits and a single outfall HDPE conduit, each of 2400 mm ID is proposed for the 400 MLD Perur desalination plant. Twin intakes extending 1,200 m offshore at a depth of 11 m below chart datum and an outfall extending 700 m offshore at a depth of 7.5 m below chart datum were adopted in the design. However, the study conducted by the JICA study team reveals that the brine plumes at the three desalination plants (DSPs) have a significant adverse effect on the intake water quality of the plants.

The DPR for 400 MLD plant does not provide any information about the brine dispersion modelling and the effect of brine discharge and increase in salinity on the marine ecosystem in the vicinity and on the plant intake seawater desalination process.

2.2 Design Proposed in JICA Feasibility Report

2.2.1 Simulation using DPR Design Conditions

The brine dispersion simulation was carried out by the JICA team considering all the three desalination plants operating in the vicinity and discharging brine in the offshore sea. The DPR locations for intake and outfall heads of the Perur DSP were used in the simulation program as input data. The results of the simulation are shown below in Figure 1.

Due to the huge volume of the brine discharge from the Perur DSP, the impact on the seawater TDS at the plant intake is found significantly high. The results indicate that the salinity as high as 600 to 800 mg/l above the ambient seawater salinity (TDS =

38000mg/l), diffuses to the intake heads of all the DSPs. Therefore, with the DPR proposal of Intake and outfall locations, the simulation results reveal that the brine recirculation causing a significant increase in salinity at the seawater intakes of DSPs is inevitable. The obvious effect of this brine recirculation was the additional power consumption at RO system by about 19680 kWh per day with the increase in operational cost per day by up to 1.5 lakhs due to high-pressure requirement for the required 400 MLD permeate production.

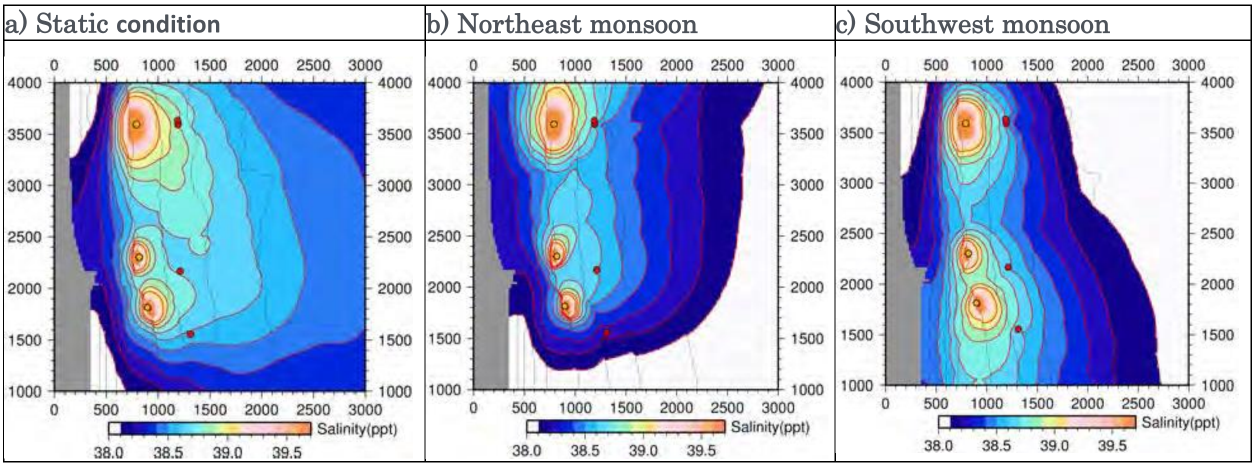


Figure 1: Brine Diffusion at the Discharging Location proposed in the DPR

2.2.2 Simulation using JICA Proposed Design Conditions

As the brine dispersion simulation results for the intake and discharge heads proposed by DPR revealed significant recirculation of brine and increase in energy cost for desalting high TDS feed seawater, JICA suggested change in the intake and discharge heads as a mitigation measure to avoid a hike in the operation cost.

The JICA Study Team proposed to set the location of the discharge head at 12 m of water depth located at 600 m away from the intake head inside the sea, i.e., the intake head at 1200m and discharge head at 1800m. The results of the simulation are shown in Figure 2 below. As shown in the figure, the impact of the brine diffusion gets drastically mitigated compared to the location proposed in the DPR. There is no effect of Perur plant discharge on the two Nemmeli plants during Northeast and Southwest Monsoon seasons while there is little to insignificant effect during Static condition.

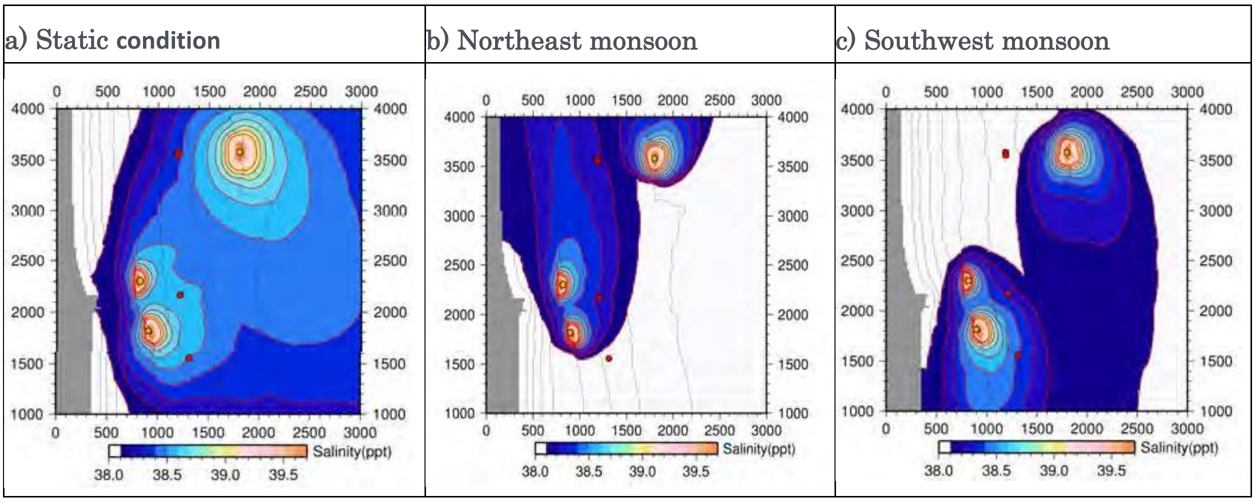
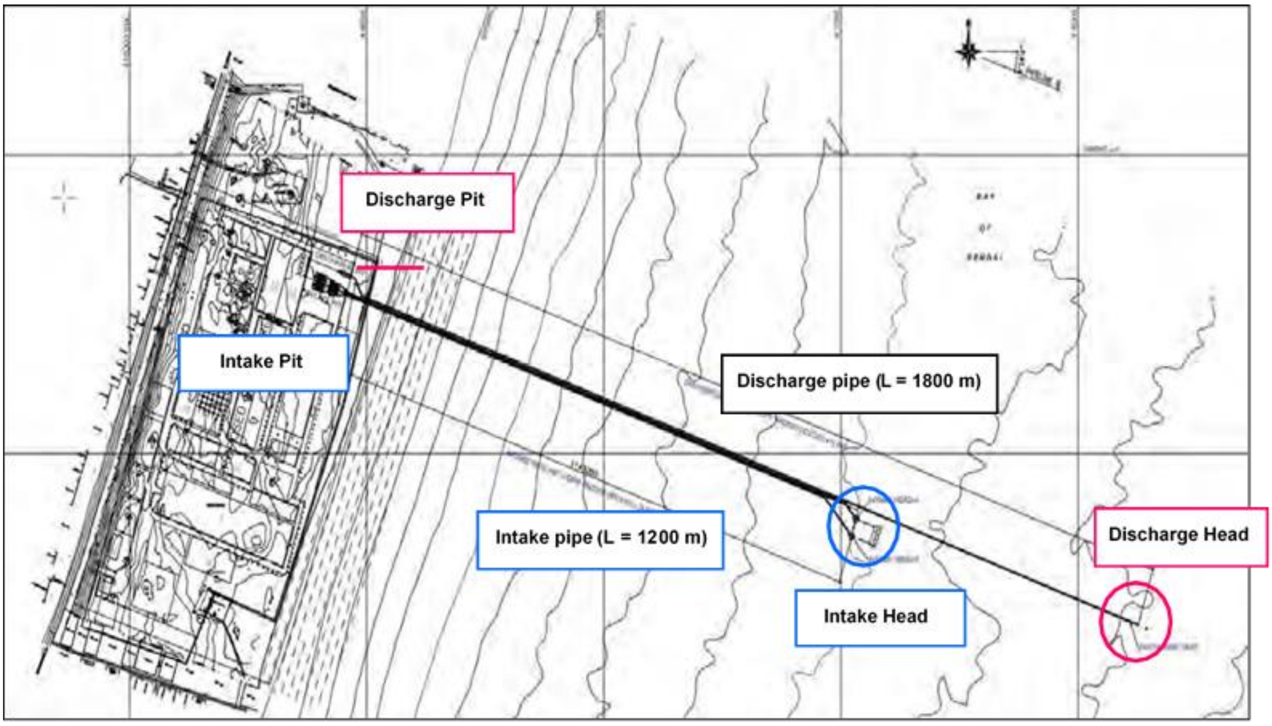


Figure 2: Brine Diffusion at the Discharging Location proposed by JICA Study Team

The general layout of seawater intake and brine discharge locations, as proposed by JICA, is shown in Figure 3.



Source: JICA Study Team

Figure 3: Layout of the Seawater Intake and Discharge locations as proposed by JICA

3. BRINE DISPERSION MODELS BY PMC (VIA INDOMER)

Due to difference in the locations of intake and outfall proposed by DPR and JICA, PMC initiated to carry out the brine dispersion study and verify the results to decide on the optimum locations for intake and outfall. After discussion with PIU, PMC assigned the task of brine dispersion model to M/s Indomer. A mathematical dispersion model was configurated for the brine diffusion study taking into consideration of the brine discharges from all the three desalination plants, i.e. 100 MLD existing Nemmeli plant, under-construction 150 MLD Nemmeli plant and the proposed 400 MLD Perur plant. Features of the sea (bathymetry, currents, waves, tides, temperature, salinity, oceanic recirculation), as well as characteristics of the brine outfall (concentration, discharge rate, pressure, temperature), were used as the input to the dispersion model. Three case studies were conducted as given below in Table-1. It was intended to evaluate and confirm the intake and brine discharge design locations proposed by M/s AECOM for DPR and JICA study team.

Table 1: Three (3) Case Studies Performed for Brine Dispersion Study by PMC

Sl. No.	Description	Outfall Head Offshore	Intake Head Offshore	Work Undertaken
CASE 1	DPR design proposal	700 m	1200 m	Dec 2014
CASE 2	JICA design proposal	1800 m	1200 m	Feb 2017
CASE 3	Indomer's design proposal	850 m	1300 m	Nov 2020

3.1 Mathematical Model for Brine Dispersion Study

The dispersion pattern of brine discharge in the sea was simulated using MIKE 21 mathematical models developed by the Danish Hydraulic Institute (DHI), Denmark. The modelling program is composed of two separate mathematical models, and the first is the MIKE 21 Hydrodynamic (HD) model which provides the flow pattern in coastal water which in turn is used as input to the main model, i.e., MIKE 21 Advection-Dispersion (AD) model for brine dispersion study.

The MIKE 21 AD model determines the concentration of the dispersing brine by solving the equation of conservation of mass for both dissolved and suspended substances. The concentration of the substance is calculated at each point of a rectangular grid covering the area of interest using a two-dimensional finite difference scheme. Information on currents and water depths at each point of the grid is provided by the MIKE 21 HD model.

The Mike 21 HD model computes two-dimensional non-steady free-surface flow fields in response to various environmental fluctuating processes in seawater bodies. The environmental processes include bottom shear stress, wind shear stress, barometric pressure gradients, currents, Coriolis force, momentum dispersion, sources and sinks, evaporation, flooding and drying and wave radiation stresses. This model is applicable for the simulation of flow fields in natural water bodies, such as lakes, estuaries, bays, coastal areas and seas, wherever stratification can be neglected. The model can be used to simulate tide, wind and wave-driven currents. The details of the models are given in the Annexure-1

3.2 Input to the HD Model

To set and run the hydrodynamic model, the input parameters considered are the bathymetry, tides, winds, waves, bottom friction, location of discharge, the quantity of discharge, ambient TDS, return brine TDS etc. The details of the important parameters are given below.

3.2.1 The Volume of Brine Discharge

The volume of the brine from three desalination plants in the vicinity is given in Table-2 below.

Table 2: Volume of Brine Discharge from 3 Desalination Plants

Details	Existing Nemmeli 100MLD Plant	Under-Construction Nemmeli 150 MLD Plant	Proposed Perur 400 MLD Plant
Flow - MLD	138	207	400
Flow – m3/hr	5750	8625	22750
Flow – m3/s	1.60	2.40	6.32

The ambient TDS of the seawater is considered as 39000 mg/l, and the return brine TDS is considered as 67000 ppm. The ambient TDS taken by PMC is 1000 ppm higher than the value taken by DPR and JICA. This is based on the discussion with PIU during finalisation of the Concept Design Report.

3.2.2 Location Co-ordinates

The co-ordinates of the various locations of intake and outfall in 3 study cases are shown in Figures 1 to 3. The detailed location coordinates and other details are given below in Annexure-1- Simulation Report from M.s Indomer.

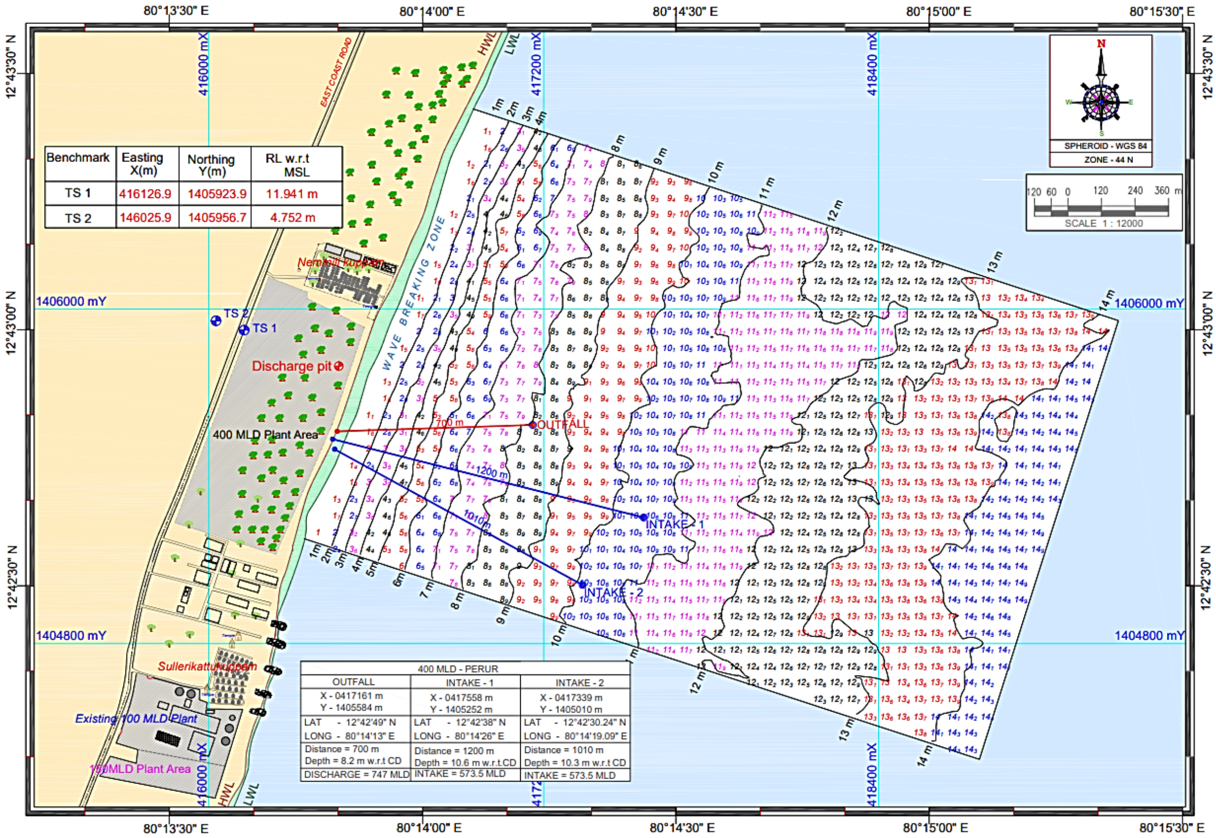


Figure 4: Case-1 Co-ordinates of Intake and Outfall Locations as per DPR

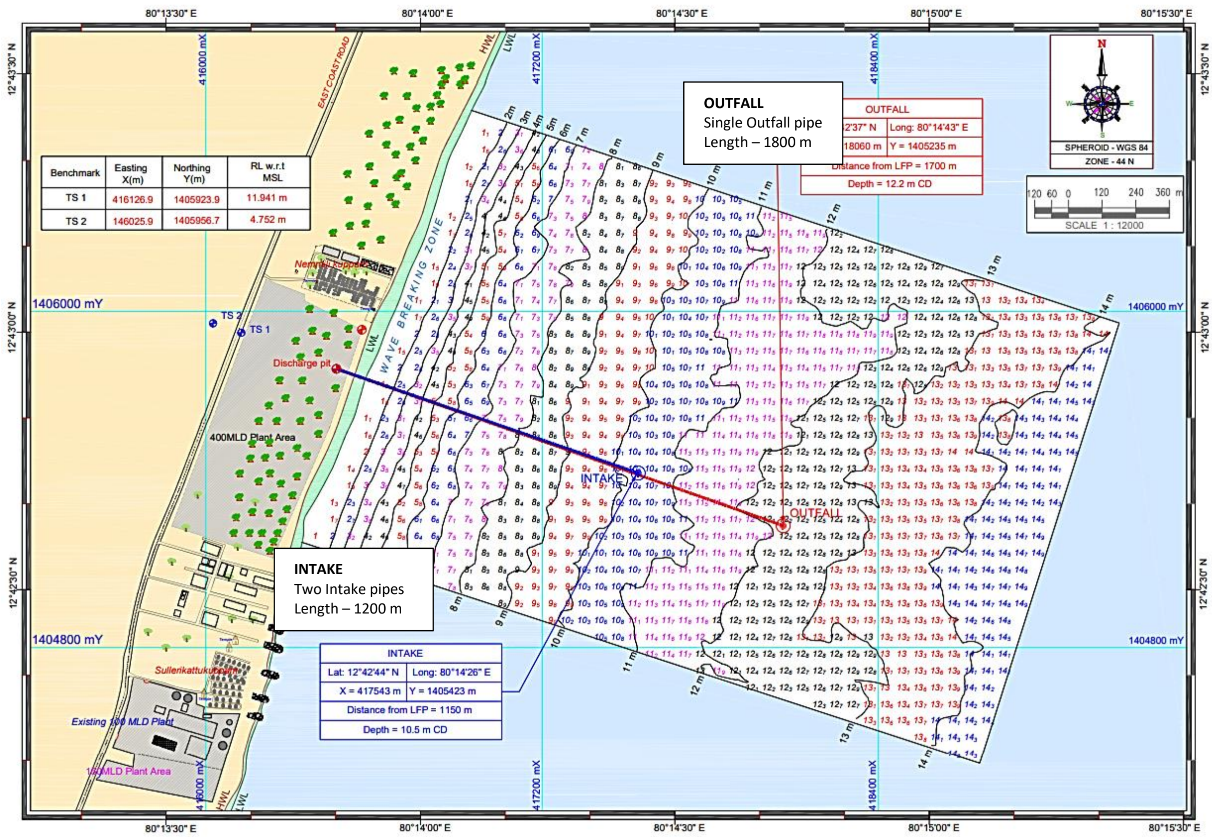


Figure 5: Case-2 Co-ordinates of Intake and Outfall Locations as per JICA

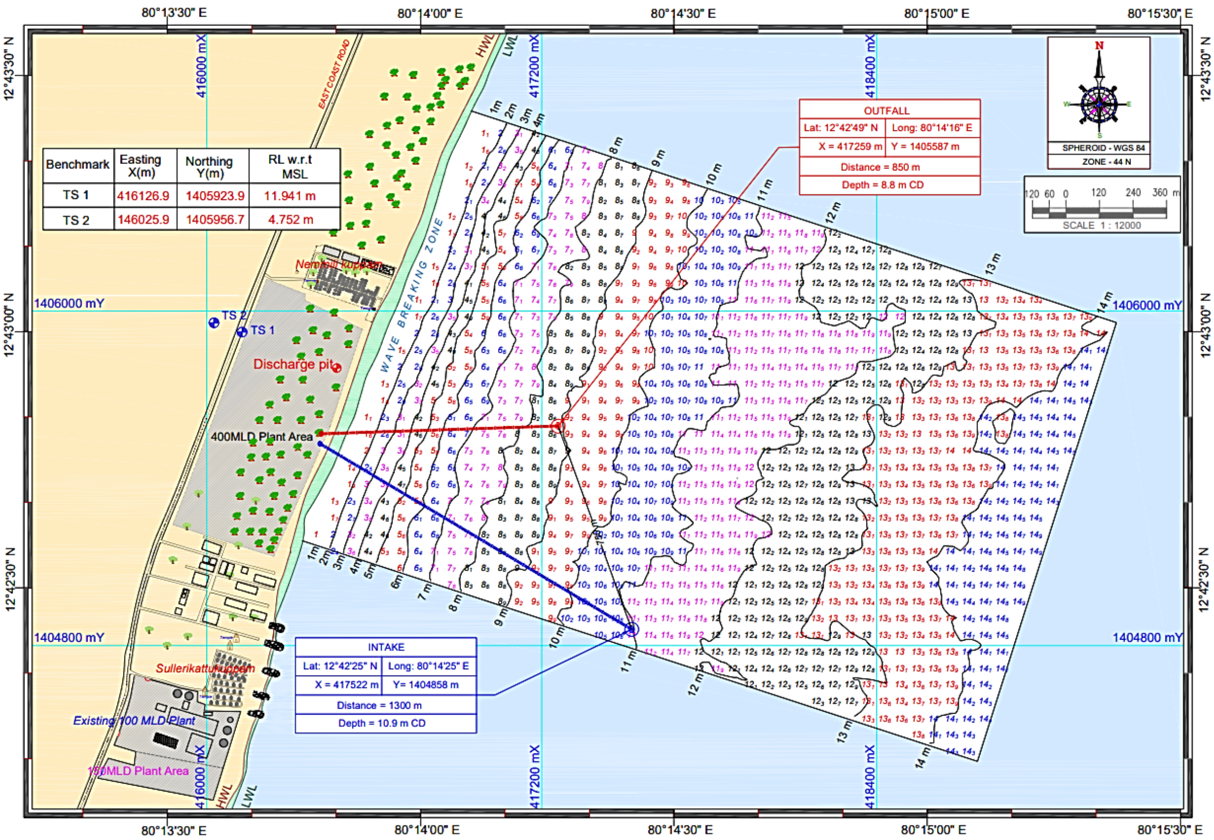


Figure 6: Case-3 Co-ordinates of Intake and Outfall Locations as per M/s Indomer

3.2.3 Seasons

The flow fields induced by tides and wind velocity over the sea surface and the associated mixing of brine reject have been simulated to cover the following three different seasonal conditions presented below in Table 3. The flow conditions vary over the lunar tidal cycle, i.e. for every tidal cycle covering two consecutive spring to neap tidal cycles for 29 days.

Table 3: Seasons and Wind Velocities

Sl. No.	Seasonal Conditions	Months	Details
1	Fair (Static) Condition	February to May	Wind speed assumed 1 m/s - low mixing of brine reject
2	Southwest Monsoon	June to September	Wind speed assumed 10 m/s - high mixing of brine reject
3	Northeast Monsoon	October to January	Wind speed assumed 7 m/s - relatively high mixing of brine reject

4. CORRESPONDENCE WITH LABORATORIES

PMC prepared the ToR and raised work order for brine dispersion study. The results provided by the work executing agency - M/s Indomer were reviewed, commented, and virtual meetings were conducted for finalisation of the study results. A chronology of the activities with respect to the task of the study is given below in Table 4.

Table 4: Details of the Activities and Interaction of PMC with M/s Indomer

Sl. No.	Details of Activities	Date of Activities
1.	Release of Work order for sampling collection and analysis of Seawater, Bathymetric survey and Brine Dispersion Modelling study	19 August 2020
2.	Submission of Draft Modelling report by M/s Indomer	19 September 2020
3.	PMC reviewed the report and commented on the report. The location of outfall points for all the three desalination plants was earmarked to reduce the effect of brine discharge on the seawater intake.	21 September 2020
4.	Virtual meeting of the PMC team was held with M/s Indomer to discuss the progress of the study work.	22 September 2020
5.	A meeting with M/s. Indomer and PMC team was again held to review the Bathymetry survey and Modelling results. It was suggested to find out the distance from the brine discharge point where brine diffusion reaches 41 g/l and 39 g/l.	29 September 2020
6.	M/s Indomer had undergone internal QCI Assessment, and so there was no reporting for a month. Then after, Indomer provided the revised Modelling report.	30 October 2020
7.	Virtual meeting with M/s. Indomer and PMC team for review of revised Modelling report.	5 November 2020
8.	Submission of the Final report on Modelling by M/s. Indomer	30 November 2020
9.	PMC raised queries for clarification on the inputs used for modelling	02 December 2020
10.	Receipt of response from M/s. Indomer regarding Inputs used for modelling.	03 December 2020

5. RESULTS AND DISCUSSION

As discussed above, the brine dispersion study has been conducted by JICA and PMC. DPR has not included any brine dispersion study results. The results of the brine dispersion studies from JICA and PMC are given below.

5.1 JICA Brine Dispersion Results

The JICA modelling results for DPR proposed locations show that static sea condition during the month of February to May is the worst period for brine dispersion when the brine diffusion is the least, and so high salinity remains around the outfall points with its concentration plume touching the intakes of all the three desalination plants. The profiles of brine concentration during Static and Northeast/Southwest Monsoon seasons have been presented above in Figures 1 & 2. The figures show that the saline plume surrounds complete area within 4 km covering all the three intakes of the desalination plants during Static sea condition.

The change in intake seawater TDS of 400 MLD plant due to brine discharge for the case of DPR and JICA design proposals in all the three sea conditions is given below in Table 5.

Table 5: Results of TDS Increase at Intake during Study Conducted by JICA

Sea Conditions	Increase in TDS (mg/l) at Intake of 400 MLD Plant		Effect on Two Nemmeli DSPs
	DPR Locations	JICA Locations	
Static Condition (Feb – May)	900 mg/l	400 mg/l	Some effect
Northeast Monsoon (Oct – Jan)	700 mg/l	200 mg/l	Little effect
Southwest Monsoon (Jun-Sept)	600 mg/l	000 mg/l	Little effect

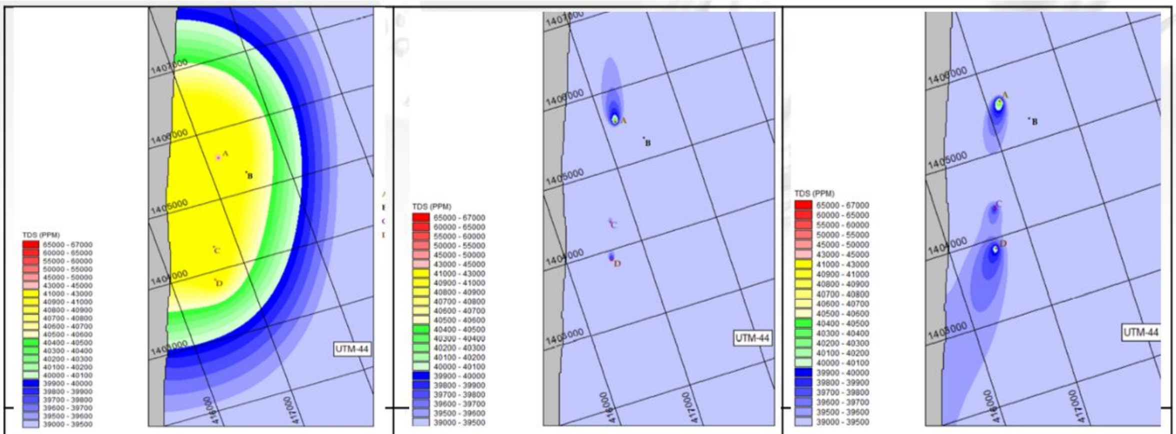
DPR Proposal : With the DPR proposal when intake location is at 1200 m, and outfall location is at 700m from the seashore, the increase in TDS of intake seawater is expected up to 900 mg/l in Static sea condition while it is 700 mg/l during Northeast Monsoon season and 600 mg/l during Southwest Monsoon season. The effect of brine outfall of the proposed 400 MLD desalination plant on the two Nemmeli DSPs has some effect during Static condition but not significant during Monsoon conditions.

<u>JICA Proposal</u> : With the JICA study proposal when intake location remains the same at 1200m, but outfall location is kept further away from the seashore at 1800m, the increase in TDS of intake seawater is expected up to 400 mg/l in Static sea condition while it is only 200 mg/l during Northeast Monsoon season and there is no significant effect of brine discharge from the 400 MLD plant on seawater intake TDS of the two Nemmeli DSPs during any sea conditions over the year.

5.2 PMC Brine Dispersion Results

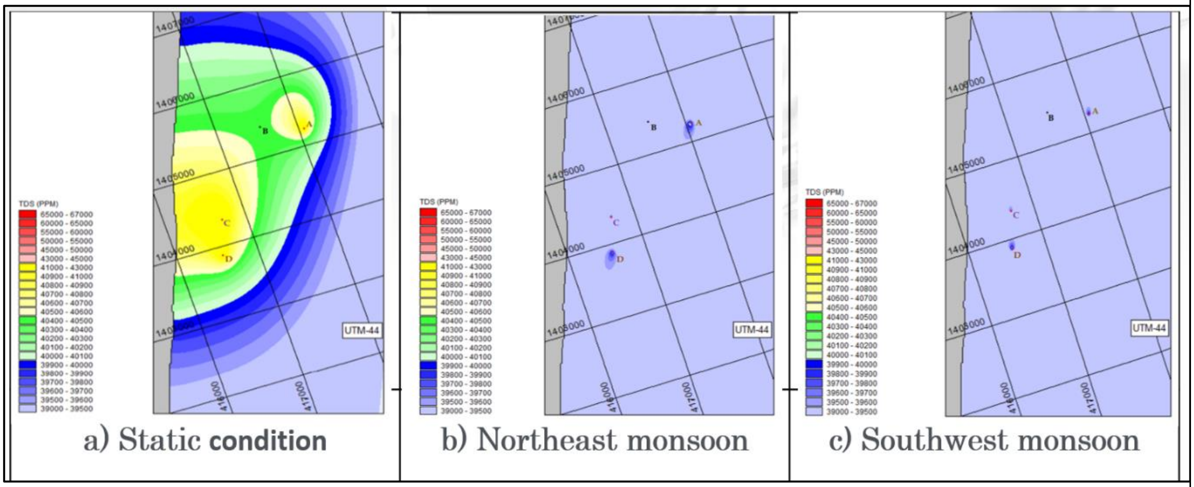
PMC employed M/s Indomer to conduct the brine dispersion modelling for 3 case studies as mentioned above in Table-1. The brine diffusion profiles and graphical results for the three case studies are presented below in Figure 7 for all the sea conditions.

Brine Diffusion Profile for DPR Proposal (Case-1)



a) Static condition b) Northeast monsoon c) Southwest monsoon

Brine Diffusion Profile for JICA Proposal (Case-2)



Brine Diffusion Profile for M/s Indomer Proposal (Case-3)

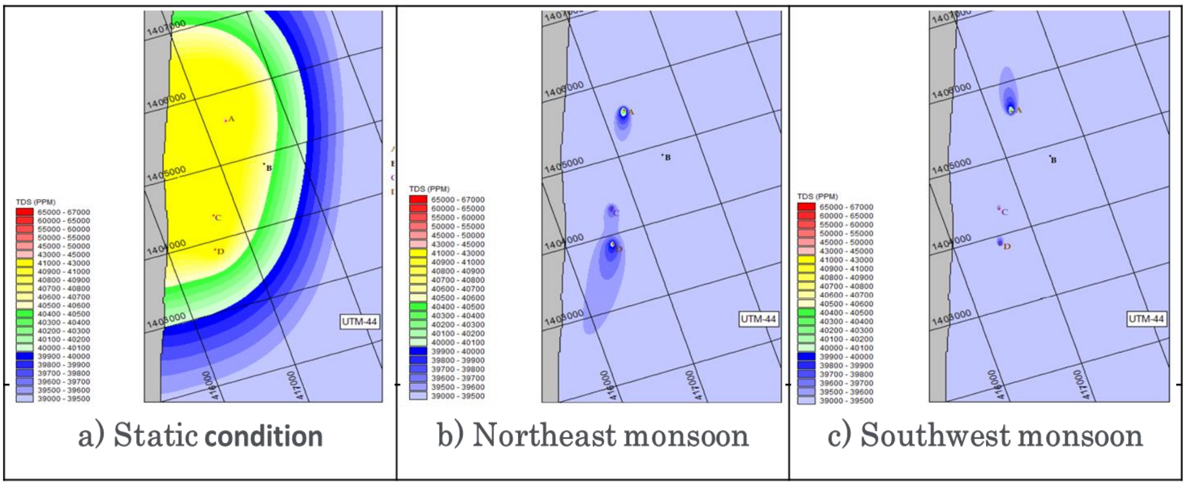


Figure 7: Brine Diffusion Profile during 3 Case Studies Conducted by PMC

The effect of salinity increase at intake is more pronounced in the static sea condition. During the static sea condition, the wind speed over the sea remains low. The sea is considered relatively calm with low wave activity and very moderate currents. This leads to relatively low mixing of the brine reject discharged into the sea.

The shape and extent of the concentration profiles in case of DPR and Indomer proposals are about the same with an increase in TDS during static condition at the intake of 400 MLD DSP up to 2000 mg/l. Also, there is a high effect on the intake TDS of other two Nemmeli DSPs where the salinity increase is in the same range. The brine diffusion process is better in case of JICA proposed outfall location when an increase in TDS at the intake of 400 MLD plant is limited to 1200 mg/l during the static condition. However, the study indicates that there is no significant effect on the intake seawater during other two Monsoon seasons in all the three case studies when the brine dispersion is recorded sufficient to complete the diffusion within a short distance.

The effect of brine discharge and change in seawater TDS at the intake of 400 MLD plant for the design proposals of DPR, JICA and Indomer during all the three sea conditions is provided below in Table 6.

Table 6: Results of TDS Increase at the Intake during Study conducted by PMC

Sea Conditions	Increase in TDS (mg/l) at Intake of 400 MLD Plant			Effect on Intakes of Two Nemmeli DSPs
	DPR	JICA	Indomer	
Static Condition (Feb – May)	2000 mg/l	1200 mg/l	1500 mg/l	High effect
Northeast Monsoon (Oct – Jan)	000	000	000	No effect
Southwest Monsoon (Jun-Sept)	000	000	000	No effect

DPR Proposal:

The results show that for the DPR proposal when intake location at 1200 m and outfall location at 700m, the effect of brine discharge is up to 2000 mg/l at intake of 400 MLD plant during the Static sea condition. The salinity effect on intakes of other two Nemmeli DSPs is also high during Static condition. There is no salinity increase at intake of all the three DSPs during the two-Monsoon conditions. The brine diffusion is achieved within 200m during the Monsoon conditions.

JICA Proposal:

The JICA proposal with outfall at 1800 m from seashore provides an increase in salinity up to 1200 mg/l at the intake of 400 MLD plant during the Static sea condition which is the minimum salinity increase during Static condition. As the diffusion completes in the short distance during two Monsoon conditions, there is no effect of brine discharge on the intake seawater of all the DSPs, which is similar to the results for DPR proposal.

Indomer's Proposal:

Indomer has also recommended the intake and outfall locations which are 1300 m and 850m from the seashore, respectively. The modelling result for this proposal shows the salinity increase of up to 1500 mg/l at the intake of 400 MLD plant and up to 2000 mg/l at the intakes of two Nemmeli plants during the Static sea condition. The effect of brine discharge and the salinity increase at intakes of two Nemmeli plants during two monsoon conditions remains the same as in DPR proposal.

6. CONCLUSIONS AND RECOMMENDATIONS

The brine dispersion simulation results obtained from the JICA and PMC studies have been evaluated to select the most optimum locations for the intake and brine outfall to achieve the least adverse impact on the marine ecosystem and also on the plant process design and operating cost.

In all the above studies, it is evident that major increase in salinity at intake is during Static sea condition and there is little to no impact of brine discharge from 400 MLD DSP on the intake seawater of any of the two Nemmeli DSPs in its vicinity. Although JICA study indicates an increase of TDS up to 400 mg/l at the intake of Perur DSP during monsoon period.

PMC Dispersion Studies

PMC dispersion studies for the DPR and JICA proposed intake and outfall positions demonstrate the following influence on the intake seawater salinity:

i) For the DPR proposed intake and outfall positions, the increase in salinity at 400 MLD plant intake is as high as 2000 mg/l during the Static sea condition while there is no salinity increase during other two Monsoon conditions.

ii) For the JICA proposed intake and outfall positions, the PMC studies reveals that the increase in salinity is up to 1200 mg/l during Static sea condition. Like DPR, the effect of brine discharge has no effect on intake seawater during the other two Monsoon seasons.

The above investigation indicates that in the case of JICA intake and outfall position with outfall location at 1800 m offshore, about 800 mg/l less salinity is expected at 400 MLD plant intake.

JICA Dispersion Studies

JICA dispersion studies indicate the following salinity increase at intake of 400 MLD plant during Statis sea condition:

i) For DPR proposed intake and outfall positions, the increase in salinity at the intake of 400 MLD desalination plant will be about 900 mg/l.

ii) For JICA proposed intake and outfall positions, the increase in salinity at the intake of 400 MLD desalination plant will be about 400 mg/l.

Similar to the PMC study outcome, the JICA study also suggests up to 500 mg/l more salinity at the intake of 400 MLD desalination plant for the DPR proposed outfall position compared to the JICA proposed outfall position.

As per the PMC studies, the effect of 800 mg/l increase in salinity at an intake of 400 MLD DSP for the case of DPR proposed locations, will have a significant effect on energy consumption. The energy consumption is expected to increase up to 20000 kWh per day, which will cost about INR 1.5 lakh per day during Static sea condition through February to May each year. This increase in operational cost may be relieved when JICA proposed outfall location is selected for 400 MLD desalination plant.

<u>Considering the above, PMC recommends adopting the JICA proposed intake and outfall locations, i.e. intake at 1200 m and outfall at 1800 m from the seashore.</u>

PMC understands the difficulties in getting CRZ approval for the changed intake and outfall locations. In this connection, PMC has a discussion with CRZ officials in Chennai, and they informed that any change in the intake and outfall positions will be investigated again and that the approval will not be delayed if the changed outfall positions do not have any adverse effect on the marine environment.

After discussion with the CRZ Chennai, we are expecting to get the CRZ approval for the JICA proposed locations within the six-month time duration, and with the ministerial mediation, it may be possible with 3 months. The bidding process and selection of the contractor for the project work is expected to take minimum six-month time from the time of the release of FRP to the bidders. If we start the application soon for the CRZ approval for the changed intake and outfall positions, the CRZ approval will select a contractor and award the works. It is expected to achieve early CRZ clearance of the revised proposal due to the following reasons.

- There is a change in only Outfall location while Intake location is not changed.
- Outfall pipe length increases from 750m as in DPR to 1800m inside the sea where sea depth is more than 13m.
- More water depth and more distance inside the sea will result in the better brine diffusion and reduced recirculation of the brine to the shore.
- Better brine diffusion and reduced brine recirculation will have the least effect on the marine environment and its ecosystem.
- Reduced salinity impact on intake seawater of all the three DSPs will reduce the operational cost.
- The increase in CAPEX cost due to increase in outfall pipe will be offset by the whole life cycle cost saving.

7. ANNEXURES

Annexure 1: M/s. Indomer Brine Dispersion Report

Annexure 1

MATHEMATICAL MODELLING STUDY FOR SETTING UP 400 MLD DESALINATION PLANT AT PERUR, CHENNAI

PROJECT CODE: 696082021

For

SMEC

Member of the Surbana Jurong Group

SMEC INDIA PVT. LTD.

GURUGRAM

NOVEMBER 2020

INDOMER COASTAL HYDRAULICS (P) LTD.

(ISO 9001: 2015 CERTIFIED, NABET- QCI AND NABL ACCREDITED)

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Client	SMEC India Pvt Ltd., Gurugram.
Project Title	Mathematical modelling study for setting up 400 MLD Desalination Plant at Perur, Chennai.
Project Code	696082021
Abstract	CMWSSB has planned to set up a 400 MLD desalination plant at Perur. CMWSSB has nominated SMEC India Pvt Ltd., Gurugram as Project Consultant. SMEC has asked Indomer Coastal Hydraulics (P) Ltd., Chennai to carryout mathematical modelling study on dispersion of brine reject over the proposed nearshore region planned for fixing seawater intake and brine reject outfall. Accordingly, Indomer had carried out the modelling studies using DHI MIKE 21 suites to meet the required scope.
Foreword	
Document	Controlled
References	SMEC India Pvt Ltd.- SCA4 Rev00 10051/dt.19th August, 2020

Date	Report Type	Originator	Checked by	Approved by	Approvers sign
12.11.2020	Final	R. C. Bragath	Dr. Susant Kumar Misra	Mr. J. Guru Prasath	
Project Code	696082021			Text pages	22
File Location	F:/2020 Projects/October 2020/ SMEC			Figures	41

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Mr. S. Akhil Babu	M. E. (Environmental Engineering) Senior Project Officer
Mr. S. R. Koushikk	B.E (Civil Engineering) Project Officer

CONTENTS

LIST OF FIGURES

1. INTRODUCTION

CMWSSB has planned to set up a 400 MLD desalination plant at Perur. CMWSSB has nominated SMEC India Pvt Ltd., Gurugram as Project Consultant. SMEC has asked Indomer Coastal Hydraulics (P) Ltd., Chennai to carryout mathematical modelling study on dispersion of brine reject over the proposed nearshore region planned for fixing seawater intake and brine reject outfall. Accordingly, Indomer had carried out the modelling studies using DHI MIKE 21 suites to meet the required scope.

Indomer Coastal Hydraulics (P) Ltd., Chennai is an ISO 9001:2015 certified organization promoted under CSIR – NIO Entrepreneurship scheme, Government of India. It also carries accreditation for preparation of Feasibility Report/ DPR – Marine sector by Consultancy Development Centre, DSIR, Ministry of Science and Technology; and NABET - QCI accreditation for carrying out EIA studies for *Sector 27: Oil & Gas Transportation pipeline (crude and refinery/petrochemical products), passing through national parks/ sanctuaries/ coral reefs/ ecologically sensitive areas including LNG terminal and Sector 33: Ports, harbours, jetties, marine terminals, breakwaters and dredging.*

The location map and satellite imagery of the project region is shown in **Fig. 1.1**.

All calendar dates are referred in Indian style as dd.mm.yy. (eg. 25.10.20 for 25th October 2020) and the time is referred to Indian Standard Time in 24 hour clock, eg. 3 P.M. is written as 1500 hrs. The WGS84 spheroid in Zone 44 is used for the presentation in this report. SI units are followed for fundamental and derived units. The depths are referred with respect to Chart Datum.

2. SCOPE OF STUDY

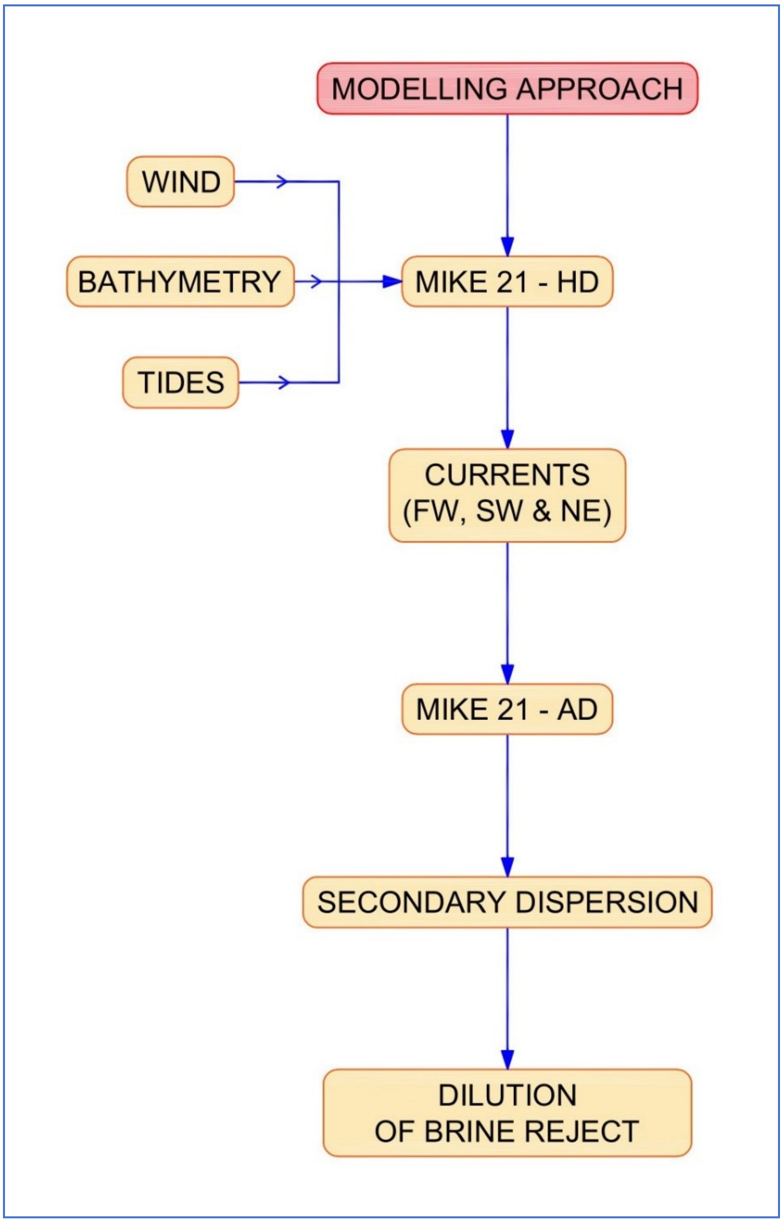
To conduct DHI-MIKE 21 -AD modelling to understand the dispersion pattern for the three outfall cases

a) *CASE I – Given in DPR – 700 m offshore*
b) *CASE II – Adopted in JICA study – 1700 m offshore*
c) *CASE III – Suggested by Indomer – 850 m offshore*

3. MODELLING APPROACH

To identify the feasible location for the discharge of brine reject at open sea, it is essential to understand the tide and flow characteristics in and around the vicinity of outfall during different tidal condition over a Spring - Neap tidal cycle. It is convenient to use mathematical modelling studies to simulate the variation of tides and currents under different tidal condition.

DHI - MIKE 21 model is comprised of the modules on *Hydrodynamic – HD and Advection Dispersion – AD.* These models have been developed by Danish Hydraulic Institute (DHI), Denmark, and are being used worldwide for many coastal engineering applications. The flow chart of the model describing the approach followed in the present study is given below.



4. SECONDARY DISPERSION – MIKE 21 MODEL

The dispersion pattern of the return water discharged into the coastal waters are simulated using the DHI - MIKE 21 Advection-Dispersion (AD) model. The flow pattern in coastal water required as input to this model is derived from the MIKE 21 Hydrodynamic (HD) model. These MIKE 21 models have been developed by Danish Hydraulic Institute (DHI), Denmark, and are being used worldwide in many coastal engineering applications.

4.1. Methodology

Units and Conventions used

Units: Units of all parameters and variables in the model study are according to international SI Units. Coordinate system: The coordinate system used for model grid generation and other horizontal positioning was based on UTM on WGS 84 spheroid. Vertical reference level: The depth information used in the tidal flow models is relative to Mean Sea Level (MSL); depths below MSL are defined negative.

Directions

Current – Ocean current directions refer to the direction towards which the flow is taking place. Directions of the flow are always given clockwise with respect to North; the Unit is degrees, where 360 degrees cover the circle. Wind - Wind directions refer to the direction from which the wind is approaching. Directions of the wind are always given clockwise with respect to North; the Unit is degrees, where 360 degrees cover the circle.

4.2. MIKE 21 Hydrodynamic (HD) model

This model is a two-dimensional hydrodynamic flow simulation model, which solves shallow-water equations for given boundary conditions to compute non-steady free-surface flow fields in response to a variety of environmental forcing and processes in natural water bodies. The environmental forcing and processes include: bottom shear stress, wind shear stress, barometric pressure gradients, Coriolis force, momentum dispersion, sources and sinks, evaporation, flooding and drying and wave radiation stresses. This model is applicable for the simulation of flow fields in natural water bodies, such as lakes, estuaries, bays, coastal areas and seas, wherever stratification can be neglected. The MIKE 21-Flow model can be used to simulate Tide, wind and Wave-driven currents.

This model uses an Alternate Direction Implicit (ADI) Finite Difference Method on staggered orthogonal grids; this model also has the option to use Finite Element Method.

The basic shallow-water equations in the Cartesian co-ordinate system solved in the MIKE 21 HD flow model are:

Continuity equation:

$$\frac{\partial \zeta}{\partial t}+\frac{\partial p}{\partial X}+\frac{\partial q}{\partial Y}=S-e$$

Momentum equations in x- and y- directions:

$$\frac{\partial p}{\partial t}+\frac{\partial}{\partial X}\left[\frac{p^2}{h}\right]+\frac{\partial}{\partial Y}\left[\frac{p\,q}{h}\right]+gh\frac{\partial \zeta}{\partial X}+F_{bx}-K_aWW_X-\frac{h}{\rho_W}\frac{\partial p_a}{\partial X}-\Omega\,q-F_{EX}=S_{iX}$$

$$\frac{\partial q}{\partial t}+\frac{\partial}{\partial X}\left[\frac{p\,q}{h}\right]+\frac{\partial}{\partial Y}\left[\frac{q^2}{h}\right]+gh\frac{\partial \zeta}{\partial Y}+F_{by}-K_aWW_Y-\frac{h}{\rho_W}\frac{\partial p_a}{\partial Y}+\Omega\,p-F_{EY}=S_{iY}$$

$$F_{EX}=\left[\frac{\partial}{\partial X}\left[\varepsilon_X\,h\frac{\partial u}{\partial X}\right]+\frac{\partial}{\partial Y}\left[\varepsilon_Y\,h\frac{\partial u}{\partial Y}\right]\right]$$

$$F_{EY}=\left[\frac{\partial}{\partial X}\left[\varepsilon_X\,h\frac{\partial u}{\partial X}\right]+\frac{\partial}{\partial Y}\left[\varepsilon_Y\,h\frac{\partial u}{\partial Y}\right]\right]$$

$$F_{bx}=\frac{g}{C^2}\sqrt{\frac{p^2}{h^2}+\frac{q^2}{h^2}}\,\frac{p}{h}$$

$$F_{by}=\frac{g}{C^2}\sqrt{\frac{p^2}{h^2}+\frac{q^2}{h^2}}\,\frac{q}{h}$$

Symbol List:

ζ (x, y, t)	-	Water surface level above datum (m)
p(x, y, t)	-	flux density in the x-direction (m3/s/m)
q(x, y, t)	-	flux density in the y-direction (m3/s/m)
h(x, y, t)	-	water depth (m)
S	-	source magnitude per unit horizontal area (m3/s/m2)
S_{iX}, S_{iY}	-	source impulse in x and y-directions (m3/s/m2.m/s)
e	-	evaporation rate (m/s)
g	-	gravitational acceleration (m/s2)
C	-	Chezy resistance No. (m1/2/s)
Ka	-	$c_w \frac{\rho_{air}}{\rho_{Water}}$
Cw	-	wind friction factor
W, WX, WY(x, y, t)	-	wind speed and its components in x- and y-directions (m/s)
pa (x, y, t)	-	barometric pressure (Kg/m/s2)
ρw	-	density of water (kg/m3)

Ω	-	Coriolis coefficient (latitude dependent) (s-1)
ε(x, y)	-	eddy or momentum dispersion coefficient (m2/s)
x, y	-	space coordinates (m)
t	-	time (s)

4.3. Boundary conditions

The HD model is forced by the tidal water level variations along the open sea boundaries. For the generation of these boundary conditions, the MIKE 21 C-Map tide data base is used. These boundary conditions are prescribed as time series of tidal water level variations along the open boundaries of the model. If the tidal constituents along the boundaries of the model are available, then the boundary conditions are represented by:

$$h_t = A_0 + \sum_{i=1}^{n} f_i A_i \cos\left(\omega_i t + (v_0 + u)_i \quad g_i\right)$$

With:

ht	=	water level at time = t
Ao	=	mean value of the signal
Ai	=	amplitude of component i
fi	=	nodal amplitude factor of component i
ωi	=	angular frequency of component i
(v0+u)I	=	astronomic argument of component i
gi	=	phase lag of component i

4.4. MIKE 21 Advection and dispersion (AD) model

The advection-dispersion (AD) model of the MIKE 21 model suite simulates dispersion of return water in natural water bodies under the influence of the fluid transport and associated natural dispersion process. The dispersing substance may be conservative or non-conservative, inorganic or organic: e.g. salt, heat, dissolved oxygen, inorganic phosphorus, nitrogen and other such water quality parameters. Applications of the MIKE 21 AD model are in principle essential for two types of investigations, viz., i) cooling water recirculation studies for power plants and salt recirculation studies for desalination plants, and ii) water quality studies connected with sewage outfalls and non-point pollution sources.

This model determines the concentration of the dispersing substance by solving the equation of conservation of mass for both dissolved and suspended substances. The concentration of the substance is calculated at each point of a rectangular grid covering the area of interest using a two-dimensional finite difference scheme. Information on currents and water depths at each point of the grid, are provided by the MIKE 21 HD model.

Other data required in the model include effluent volume discharged, the concentration of the pollutant, and the initial & boundary conditions.

The MIKE 21 AD model solves the advection-dispersion equation for dissolved or suspended substances in two dimensions. This is the mass-conservation equation of substances discharged at source and sink points considering their decay rates,

$$\frac{\partial}{\partial t}(hc)+\frac{\partial}{\partial x}(uhc)+\frac{\partial}{\partial y}(vhc) = \frac{\partial}{\partial x}\left[hD_x\frac{\partial C}{\partial x}\right]+\frac{\partial}{\partial y}\left[hD_y\frac{\partial C}{\partial y}\right]-Fhc+S$$

Symbol list

C	-	compound concentration (arbitrary units)
u, v	-	horizontal velocity components in the x, y directions (m/s)
h	-	water depth (m)
Dx, Dy	-	dispersion coefficients in the x, y directions (m2/s)
F	-	linear decay coefficient (1/s)
S	-	Qs . (Cs – C)
Qs	-	Source / sink discharge per unit horizontal area (m3/s/ m2)
Cs	-	concentration of compound in the source / sink discharge.

Information on u, v and h at each time step is provided by the MIKE 21 HD model.

4.5. Model domain

The model domain was setup for the study region to include the finer details of the local geometry, bathymetry and other site specific conditions in the model. The coarse resolution grid covers an area of approximately 100 km x 150 km with the grid spacing of 405 m in both x and y directions. The grid comprised of approximately 91,390 computational points. The finer resolution grid covers an area of approximately 3.6 km x 10.5 km with the grid spacing of 15 m in both x and y directions. The grid comprised of approximately 1,68,941 computational points. The finer bathymetry is shown in **Fig. 5.1**.

Data requirements: The data for the MIKE 21 HD module is described below:

i) Bathymetry
ii) Initial Conditions:
iii) Water surface levels and
iv) Flux densities in x and y directions
v) Boundary Conditions:
vi) Water levels or flow magnitude and low direction
vii) Other Driving Forces:
viii) Wind speed and direction
ix) Source/sink discharge magnitude and speed.

Depth Schematization: Depth schematization has been made from MIKE-CMAP, a worldwide electronic chart database. This database on bathymetric data over the ocean has been developed jointly by DHI, Denmark and C-MAP, Norway. The extracted bathymetry data from CMAP have been corrected with the depths presented in Indian Naval Hydrographic Charts (NHC:313) and the bathymetry data collected by Indomer specific to the study area.

Model Input: To set and run the hydrodynamic model, the input parameters considered are the bathymetry, tides, winds, waves, bottom friction, location of discharge, quantity of discharge, ambient TDS, return brine TDS etc.

Input on wind: For the flow simulation, to represent the fair weather, it is assumed as low wind with a value of 1 m/s coming from southwest direction. In case of southwest monsoon season, higher wind speed of 10 m/s from southwest direction was introduced. For northeast monsoon period, moderate with speed of 7 m/s from northeast direction was introduced.

Volume of discharge: The volume of the brine reject released into the sea is given below.

Volume of discharge		
Nemmeli- Existing 100 MLD Plant	Perur proposed 400 MLD Plant	Nemmeli – proposed 150 MLD Plant
138 MLD	546 MLD	207 MLD
5750 m^3/hour	22750 m^3/hour	8625 m^3/hour
1.60 m^3/s	6.32 m^3/s	2.40 m^3/s

The tide induced flow field over the study area for one lunar month (29 days) were simulated using MIKE 21-HD model. Dispersion of return water in natural water bodies under the influence of the fluid transport and associated natural dispersion process was simulated using MIKE 21.

TDS: *As per client email vide dt. 01.10.2020, the ambient TDS of the seawater is considered as 39000 ppm and the return brine TDS is considered as 67000 ppm.*

4.6. Model calibration

The HD model is calibrated using the measured tides at the project location. A good agreement was observed between the simulated and measured tides. Similarly, a reasonable agreement was observed between the simulated and measured currents.

5. SIMULATIONS

i) Locations: The simulation was carried out for three different cases of location of outfall tentatively considered for Perur plant. The details are given below.

Simulation	Detail	Distance of outfall at offshore
Case I	Given in DPR	700 m
Case II	Adopted in JICA study	1700 m
Case III	Suggested by Indomer	850 m

The various locations of intake and outfall are shown in **Figs. 5.2 to 5.4**. The location coordinates and other details are given below.

Scenarios	Geographical Coordinates (WGS 84)		UTM Coordinates (Zone 44)	
	Latitude, N	Longitude, E	X (m)	Y (m)
CASE I – DPR				
Intake Distance = 1200 m from LFP	12°42'38"	80°14'26"	0417558	1405252
Outfall diffuser Length= 700 m from LFP	12°42'49"	80°14'13"	0417161	1405584
CASE II - JICA				
Intake Distance = 1150 m from DP	12°42'44"	80°14'26"	0417543	1405423
Outfall diffuser Length= 1700 m from DP	12°42'37"	80°14'43"	0418060	1405235
CASE III – SUGGESTED BY INDOMER				
Intake Distance = 1300 m from LFP	12°42'25"	80°14'25"	0417522	1404858
Outfall diffuser Length= 850 m from LFP	12°42'49"	80°14'16"	0417259	1405587

ii) Seasons: The flow field induced by tides and wind and the associated mixing of brine reject has been simulated to cover following three different seasons.

Season	Representative months
Fair Weather	February to May
Southwest monsoon	June to September
Northeast monsoon	October to January

iii) Simulation period: In each simulation, the flow field and the secondary advection – diffusion has been done for a period of one lunar month, i.e. March representing fair weather, July representing southwest monsoon and November representing northeast monsoon.

Scenarios	Fair weather	SW Monsoon	NE Monsoon
Case I	√	√	√
Case II	√	√	√
Case III	√	√	√

6. MODELLING RESULTS FOR COMBINED SCENARIOS

The secondary dispersion of the brine reject from the existing and proposed outfall locations covering spring and neap tidal phases for three different cases are given below.

Simulation	Detail	Distance of outfall at offshore
Case I	Given in DPR	700 m
Case II	Adopted in JICA study	1700 m
Case III	Suggested by Indomer	850 m

CASE I – Given in DPR – 700 m offshore

Fair weather

During the fair weather, the wind speed over the sea remains low. The sea would be relatively calm with low wave activity and very moderate currents. This will lead to relatively low mixing of the brine reject released into the sea. The flow conditions will vary over the lunar tidal cycle, i.e. for every tidal cycle covering two consecutive spring to neap tidal cycles for 29 days. The brine reject released into the sea also will have variable mixing pattern according to the instantaneous turbulence caused by the current speed and direction. Accordingly, the typical scenario of the dispersion on the spring tidal day and neap tidal day are extracted and summarized below.

Spring tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.5(A) to 5.5(B).** The brine of resultant TDS of 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 3200 m and 41, 000 ppm at 250 m distance from the outfall.

Neap tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.6(A) to 5.6(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 3300 m and 41, 000 ppm at 260 m distance from the outfall.

SW monsoon

During the SW Monsoon, the wind speed over the sea remains high. The sea would remain with relatively higher wave activity and currents. This will lead to relatively high mixing of the brine reject released into the sea. The flow conditions will vary over the lunar tidal cycle, i.e. for every tidal cycle covering two consecutive spring to neap tidal cycles for 29 days. The brine reject released into the sea also will have variable mixing pattern according to the instantaneous turbulence caused by the current speed and direction. Accordingly, the typical scenario of the dispersion on the spring tidal day and neap tidal day are extracted and summarized below.

Spring tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.7(A) to 5.7(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 1200 m and 41, 000 ppm at 80 m distance from the outfall.

Neap tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.8(A) to 5.8(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 1300 m and 41, 000 ppm at 90 m distance from the outfall.

NE monsoon

During the NE Monsoon, the wind speed over the sea remains high. The sea would remain with relatively higher wave activity and currents. This will lead to relatively high mixing of the brine reject released into the sea. The flow conditions will vary over the lunar tidal cycle, i.e. for every tidal cycle covering two consecutive spring to neap tidal cycles for 29 days. The brine reject released into the sea also will have variable mixing pattern according to the instantaneous turbulence caused by the current speed and direction. Accordingly, the typical scenario of the dispersion on the spring tidal day and neap tidal day are extracted and summarized below.

Spring tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.9(A) to 5.9(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 2300 m and 41, 000 ppm at 90 m distance from the outfall.

Neap tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.10(A) to 5.10(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 2350 m and 41, 000 ppm at 100 m distance from the outfall.

CASE II – Adopted in JICA study – 1700 m offshore

Fair weather

During the fair weather, the wind speed over the sea remains low. The sea would be relatively calm with low wave activity and very moderate currents. This will lead to relatively low mixing of the brine reject released into the sea. The flow conditions will vary over the lunar tidal cycle, i.e. for every tidal cycle covering two consecutive spring to neap tidal cycles for 29 days. The brine reject released into the sea also will have variable mixing pattern according to the instantaneous turbulence caused by the current speed and direction. Accordingly, the typical scenario of the dispersion on the spring tidal day and neap tidal day are extracted and summarized below.

Spring tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.11(A) to 5.11(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 2200 m and 41, 000 ppm at 90 m distance from the outfall.

Neap tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.12(A) to 5.12(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 2300 m and 41, 000 ppm at 100 m distance from the outfall.

SW monsoon

During the SW Monsoon, the wind speed over the sea remains high. The sea would remain with relatively higher wave activity and currents. This will lead to relatively high mixing of the brine reject released into the sea. The flow conditions will vary over the lunar tidal cycle, i.e. for every tidal cycle covering two consecutive spring to neap tidal cycles for 29 days. The brine reject released into the sea also will have variable mixing pattern according to the instantaneous turbulence caused by the current speed and direction. Accordingly, the typical scenario of the dispersion on the spring tidal day and neap tidal day are extracted and summarized below.

Spring tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.13(A) to 5.13(B)**The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 1100 m and 41, 000 ppm at 30 m distance from the outfall.

Neap tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.14(A) to 5.14(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 1120 m and 41, 000 ppm at 50 m distance from the outfall.

NE monsoon

During the NE Monsoon, the wind speed over the sea remains high. The sea would remain with relatively higher wave activity and currents. This will lead to relatively high mixing of the brine reject released into the sea. The flow conditions will vary over the lunar tidal cycle, i.e. for every tidal cycle covering two consecutive spring to neap tidal cycles for 29 days. The brine reject released into the sea also will have variable mixing pattern according to the instantaneous turbulence caused by the current speed and direction. Accordingly, the typical scenario of the dispersion on the spring tidal day and neap tidal day are extracted and summarized below.

Spring tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.15(A) to 5.15(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 1500 m and 41, 000 ppm at 50 m distance from the outfall.

Neap tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.16(A) to 5.16(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 1650 m and 41, 000 ppm at 50 m distance from the outfall.

CASE III – Suggested by Indomer – 850 m offshore

Fair weather

During the fair weather, the wind speed over the sea remains low. The sea would be relatively calm with low wave activity and very moderate currents. This will lead to relatively low mixing of the brine reject released into the sea. The flow conditions will vary over the lunar tidal cycle, i.e. for every tidal cycle covering two consecutive spring to neap tidal cycles for 29 days. The brine reject released into the sea also will have variable mixing pattern according to the instantaneous turbulence caused by the current speed and direction. Accordingly, the typical scenario of the dispersion on the spring tidal day and neap tidal day are extracted and summarized below.

Spring tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.17(A) to 5.17(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 3000 m and 41, 000 ppm at 190 m distance from the outfall.

Neap tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.18(A) to 5.18(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 3250 m and 41, 000 ppm at 210 m distance from the outfall.

SW monsoon

During the SW Monsoon, the wind speed over the sea remains high. The sea would remain with relatively higher wave activity and currents. This will lead to relatively high mixing of the brine reject released into the sea. The flow conditions will vary over the lunar tidal cycle, i.e. for every tidal cycle covering two consecutive spring to neap tidal cycles for 29 days. The brine reject released into the sea also will have variable mixing pattern according to the instantaneous turbulence caused by the current speed and direction. Accordingly, the typical scenario of the dispersion on the spring tidal day and neap tidal day are extracted and summarized below.

Spring tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.19(A) to 5.19(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 1150 m and 41, 000 ppm at 50 m distance from the outfall.

Neap tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.20(A) to 5.20(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 1200 m and 41, 000 ppm at 60 m distance from the outfall.

NE monsoon

Spring tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.21(A) to 5.21(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 1800 m and 41, 000 ppm at 60 m distance from the outfall.

Neap tide: The mixing pattern of the brine reject in the nearshore region are shown in **Figs. 5.22(A) to 5.22(B).** The brine of resultant TDS = 67,000 ppm, discharged in the sea undergoes dispersion and reaches the TDS of 39,000 ppm at 1900 m and 41, 000 ppm at 70 m distance from the outfall.

7. CONCLUSION

The secondary dispersion takes place due to convection currents and undergoes further dilution. Mixing zones of TDS of 39,000 ppm and 41,000 ppm for the proposed and existing outfalls resulting from the secondary dispersion study using MIKE 21 AD are given below:

Scenarios	Season	TDS (ppm)	Spring tide (m)	Neap tide (m)
CASE I	Fair weather	39000	3200	3300
	SW monsoon	39000	1200	1300
	NE monsoon	39000	2300	2350
CASE II	Fair weather	39000	2200	2300
	SW monsoon	39000	1100	1120
	NE monsoon	39000	1500	1650
CASE III	Fair weather	39000	3000	3250
	SW monsoon	39000	1150	1200
	NE monsoon	39000	1800	1900

Scenarios	Season	TDS (ppm)	Spring tide (m)	Neap tide (m)
CASE I	Fair weather	41000	250	260
	SW monsoon	41000	80	90
	NE monsoon	41000	90	100
CASE II	Fair weather	41000	90	100
	SW monsoon	41000	30	50
	NE monsoon	41000	50	50
CASE III	Fair weather	41000	190	210
	SW monsoon	41000	50	60
	NE monsoon	41000	60	70

FIGURES

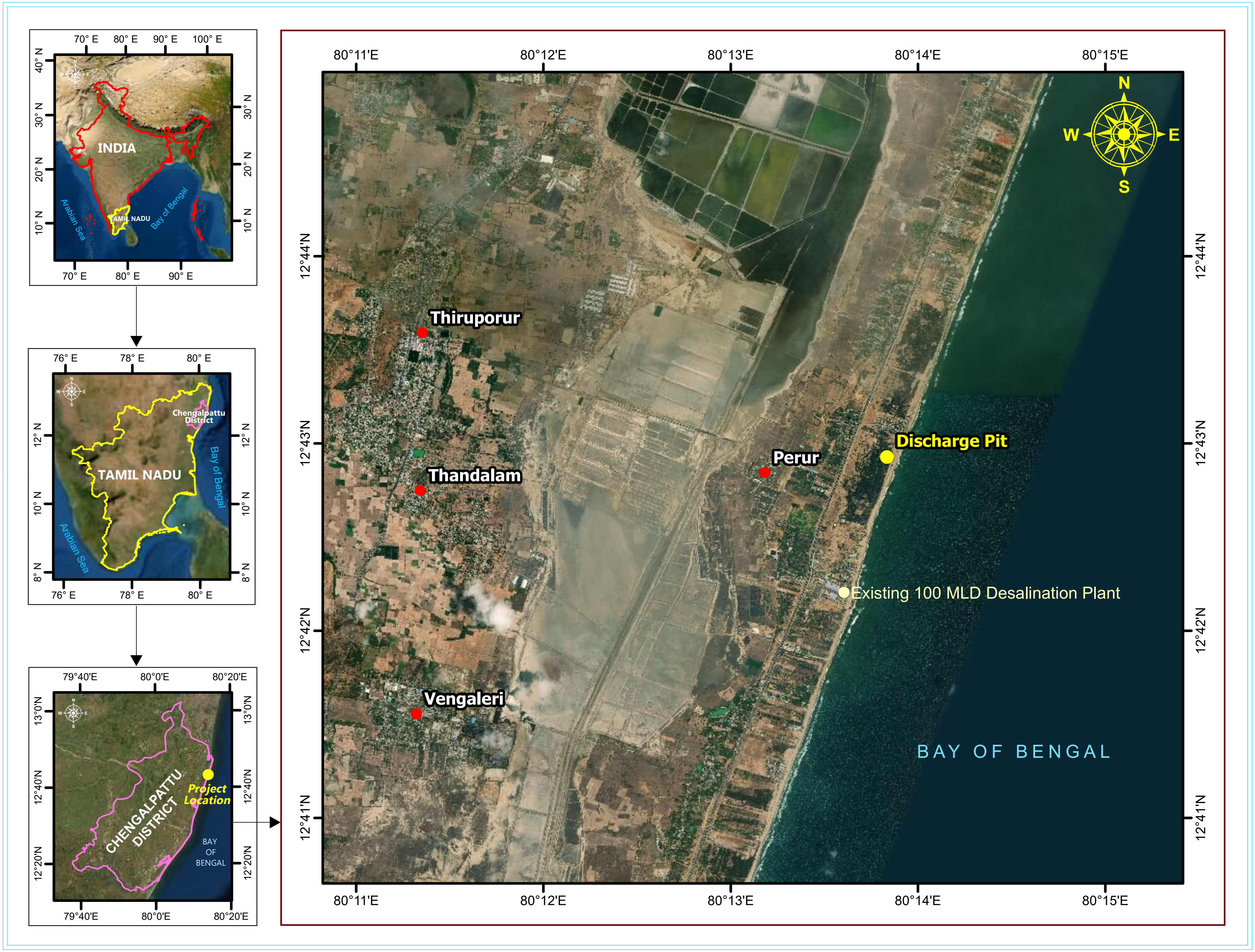


FIG. 1.1. LOCATION MAP

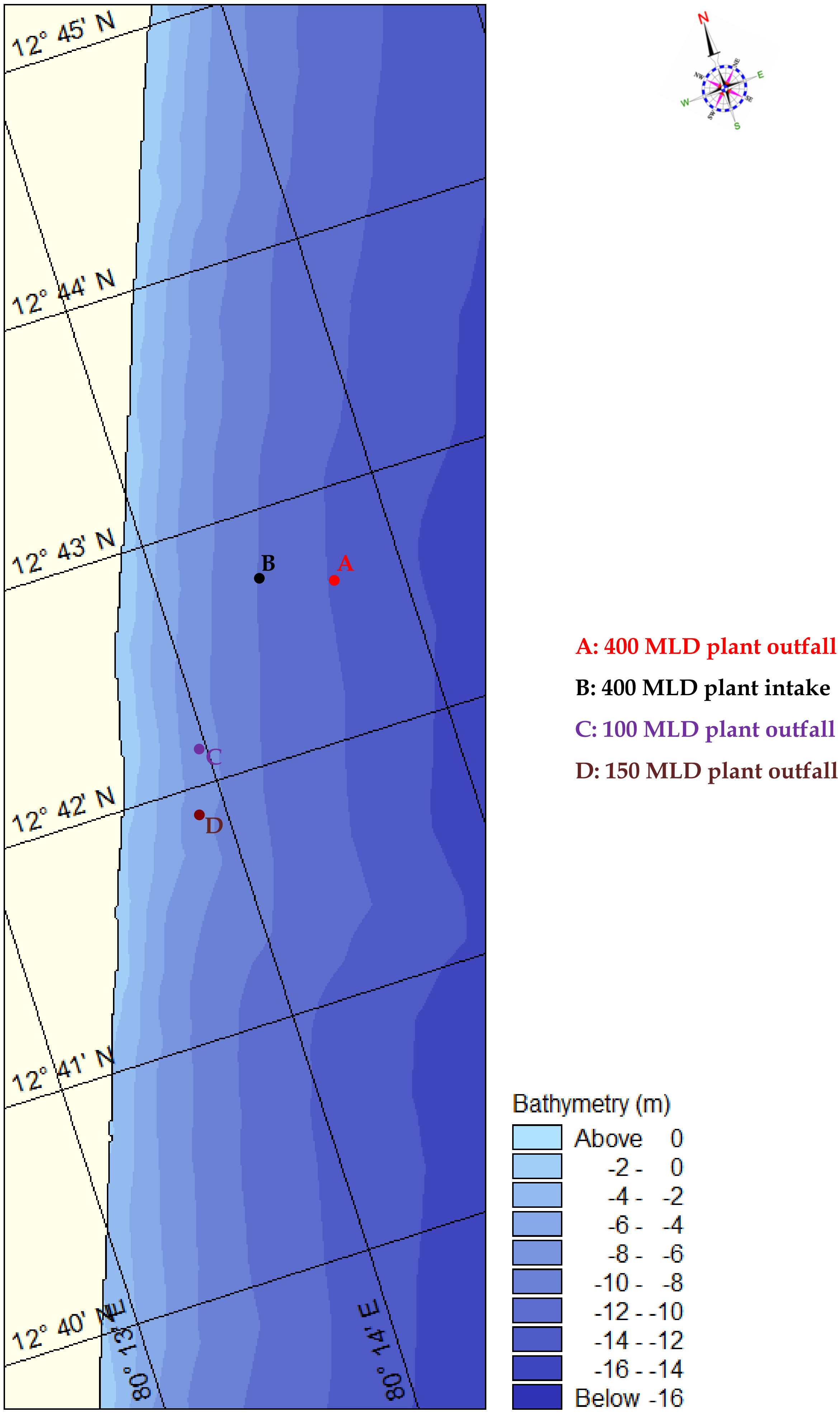
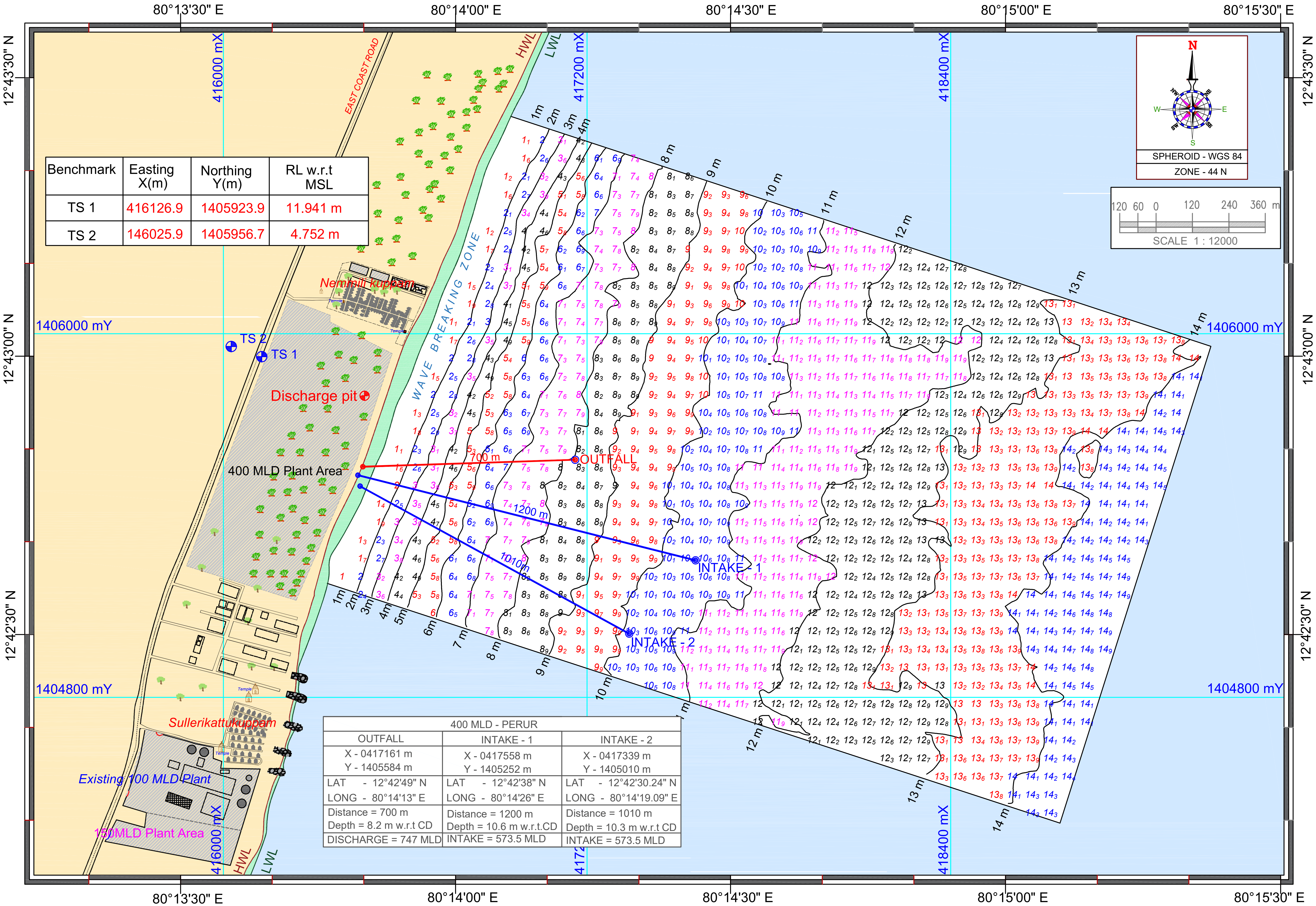


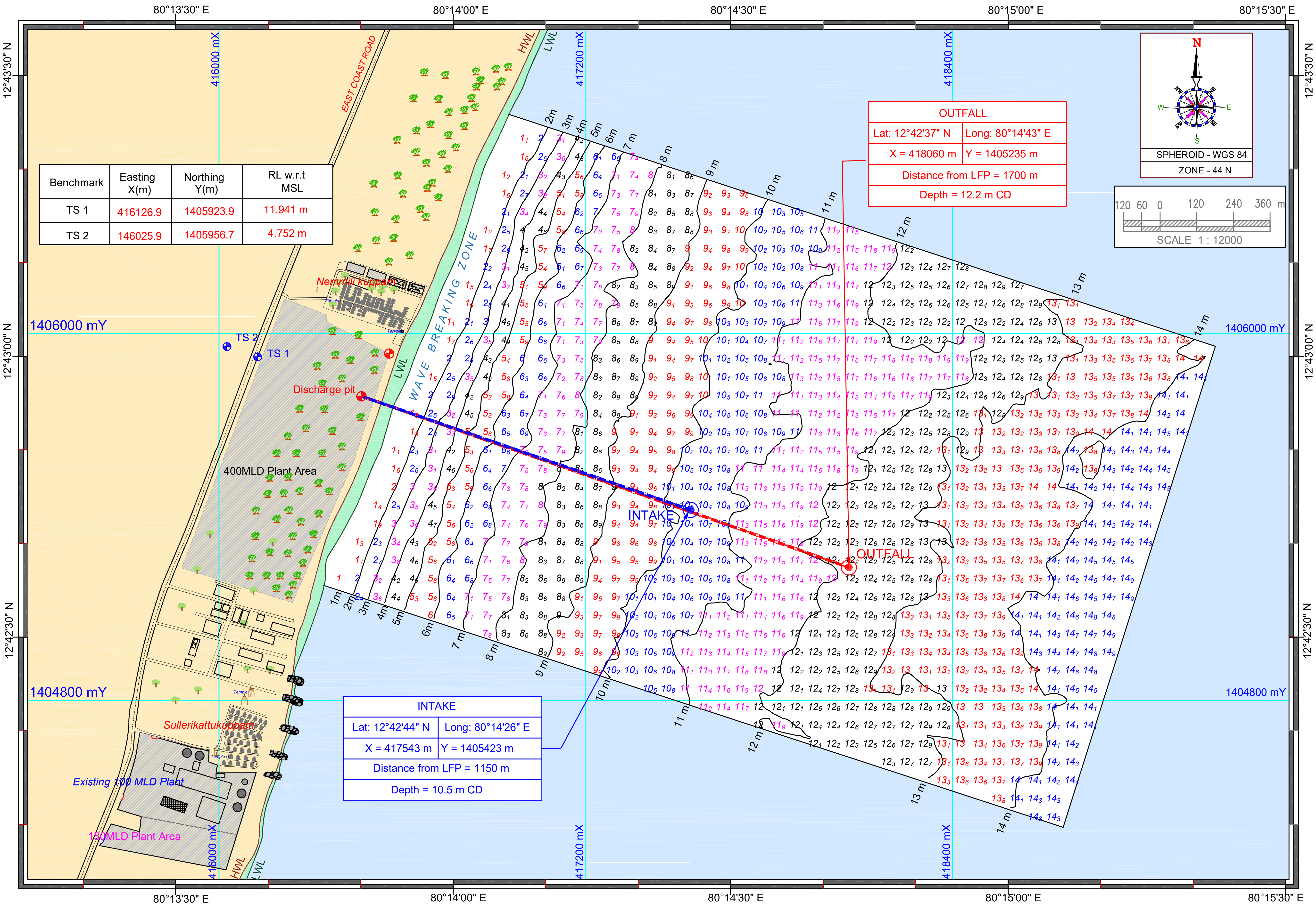
FIG. 5.1. BATHYMETRY



Benchmark	Easting X(m)	Northing Y(m)	RL w.r.t MSL
TS 1	416126.9	1405923.9	11.941 m
TS 2	146025.9	1405956.7	4.752 m

400 MLD - PERUR		
OUTFALL	INTAKE - 1	INTAKE - 2
X - 0417161 m Y - 1405584 m	X - 0417558 m Y - 1405252 m	X - 0417339 m Y - 1405010 m
LAT - 12°42'49" N LONG - 80°14'13" E	LAT - 12°42'38" N LONG - 80°14'26" E	LAT - 12°42'30.24" N LONG - 80°14'19.09" E
Distance = 700 m Depth = 8.2 m w.r.t CD	Distance = 1200 m Depth = 10.6 m w.r.t.CD	Distance = 1010 m Depth = 10.3 m w.r.t CD
DISCHARGE = 747 MLD	INTAKE = 573.5 MLD	INTAKE = 573.5 MLD

FIG. 5.2. LOCATIONS OF BRINE REJECT DISCHARGE - CASE I (GIVEN IN DPR)



Benchmark	Easting X(m)	Northing Y(m)	RL w.r.t MSL
TS 1	416126.9	1405923.9	11.941 m
TS 2	146025.9	1405956.7	4.752 m

OUTFALL	
Lat: 12°42'37" N	Long: 80°14'43" E
X = 418060 m	Y = 1405235 m
Distance from LFP = 1700 m	
Depth = 12.2 m CD	

INTAKE	
Lat: 12°42'44" N	Long: 80°14'26" E
X = 417543 m	Y = 1405423 m
Distance from LFP = 1150 m	
Depth = 10.5 m CD	

FIG.5.3. LOCATIONS OF BRINE REJECT DISCHARGE - CASE II (ADOPTED IN JICA STUDY)

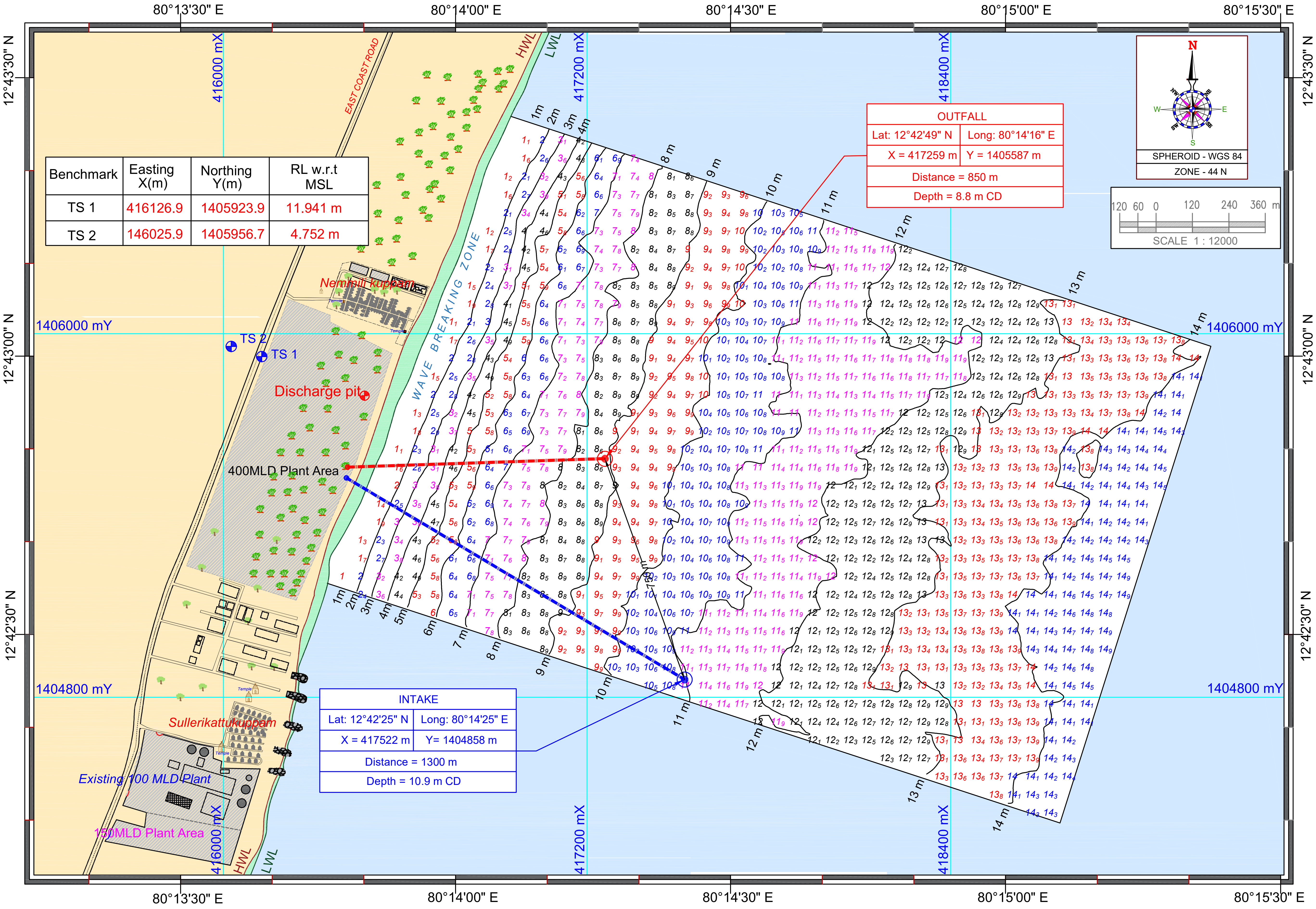


FIG. 5.4. LOCATIONS OF BRINE REJECT DISCHARGE - CASE III (SUGGESTED BY INDOMER)

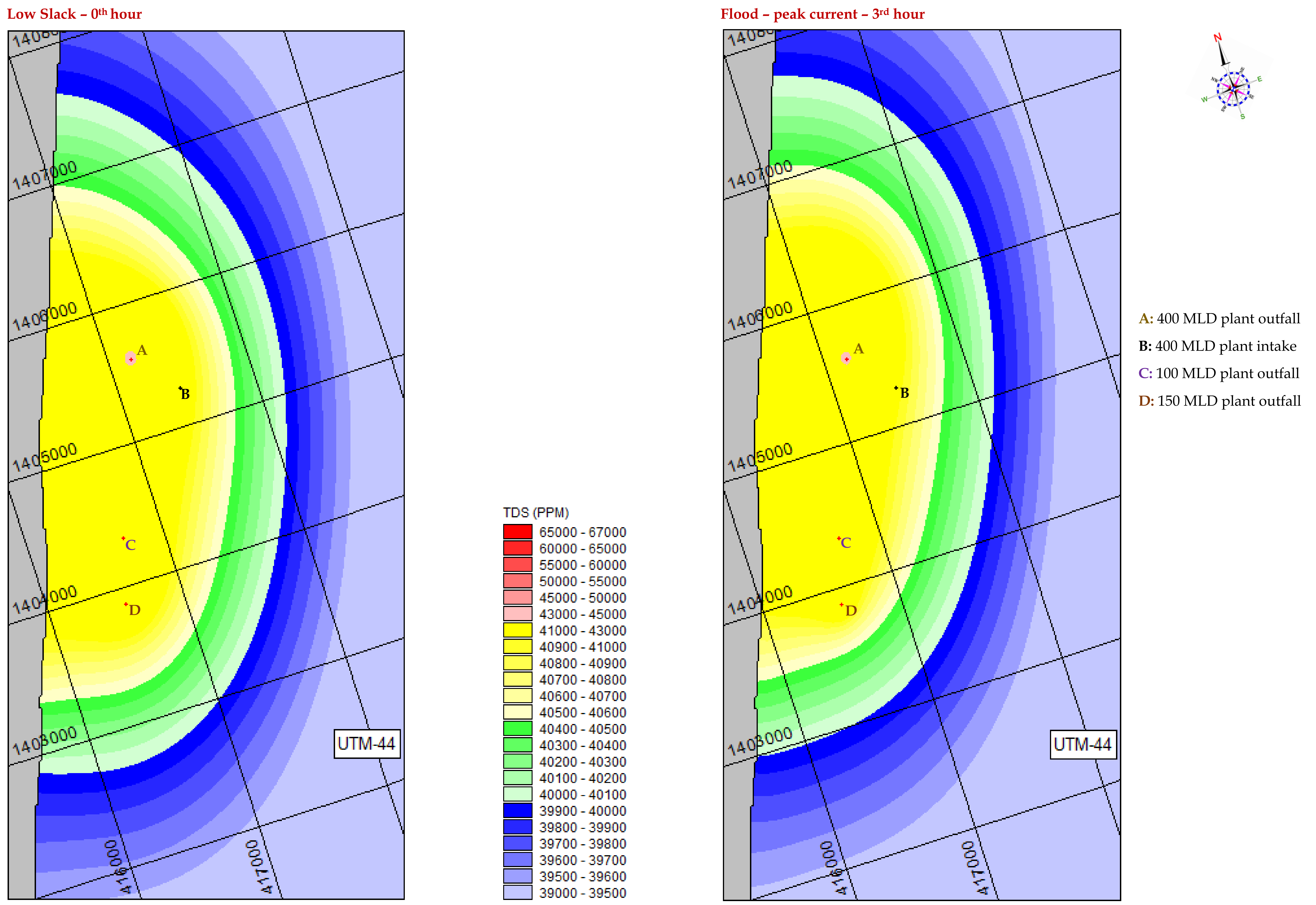


FIG. 5.5(A). SECONDARY DISPERSION – FAIR WEATHER - SPRING TIDE – CASE I (GIVEN IN DPR) – (TDS)

High Slack – 6th hour

Ebb – peak current – 9th hour

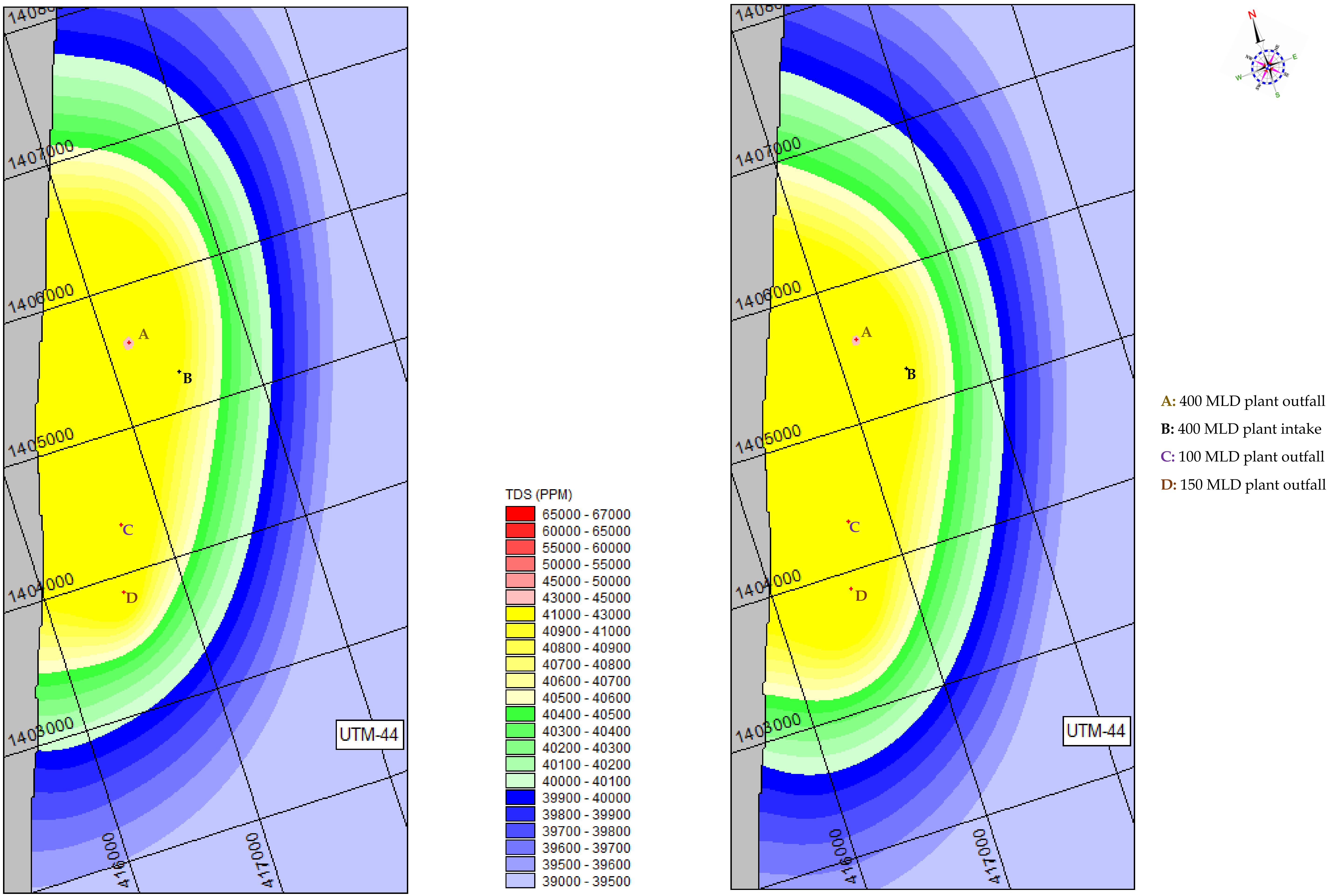


FIG. 5.5(B). SECONDARY DISPERSION – FAIR WEATHER - SPRING TIDE – CASE I (GIVEN IN DPR) – (TDS)

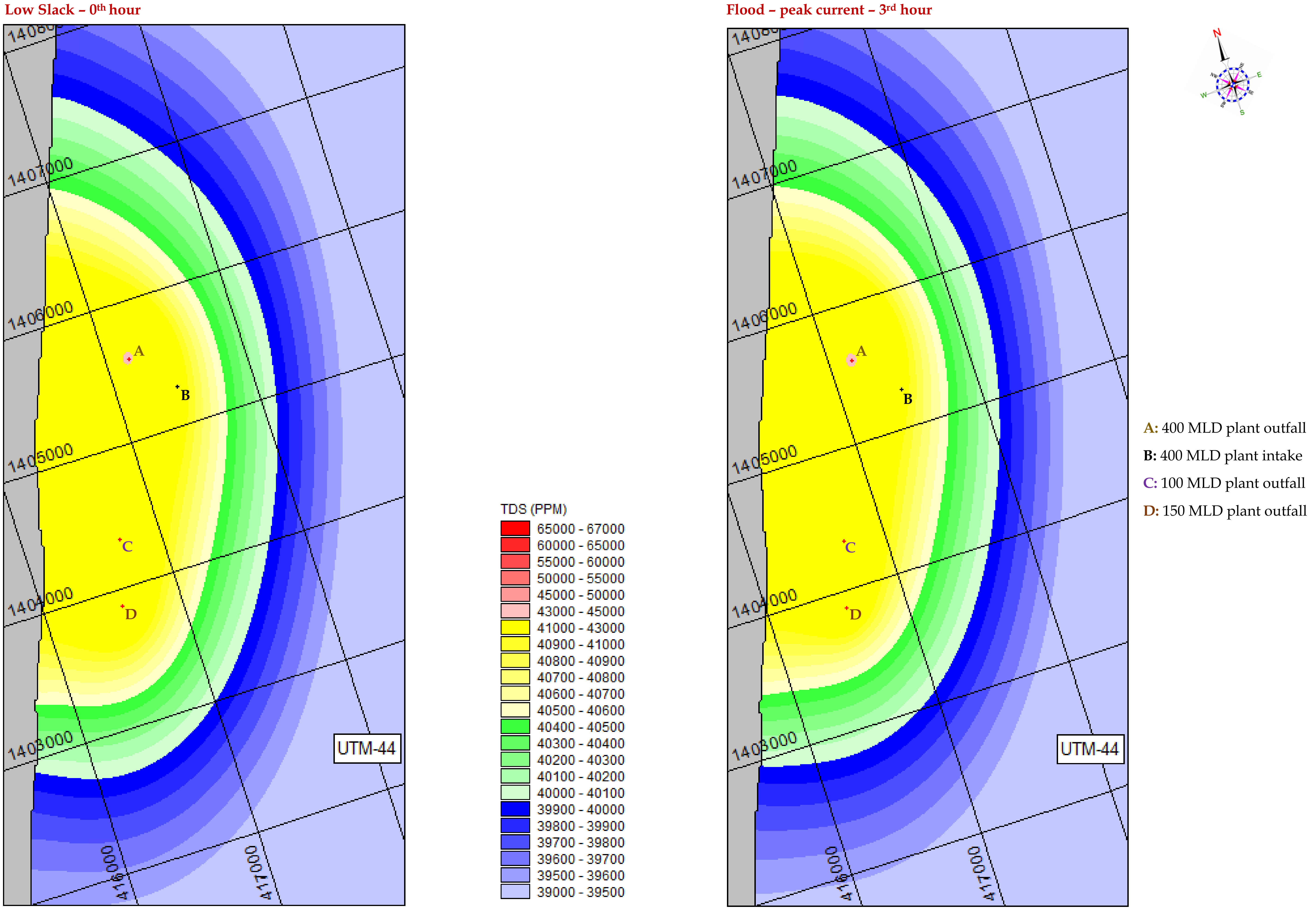


FIG. 5.6(A). SECONDARY DISPERSION – FAIR WEATHER - NEAP TIDE – CASE I (GIVEN IN DPR) – (TDS)

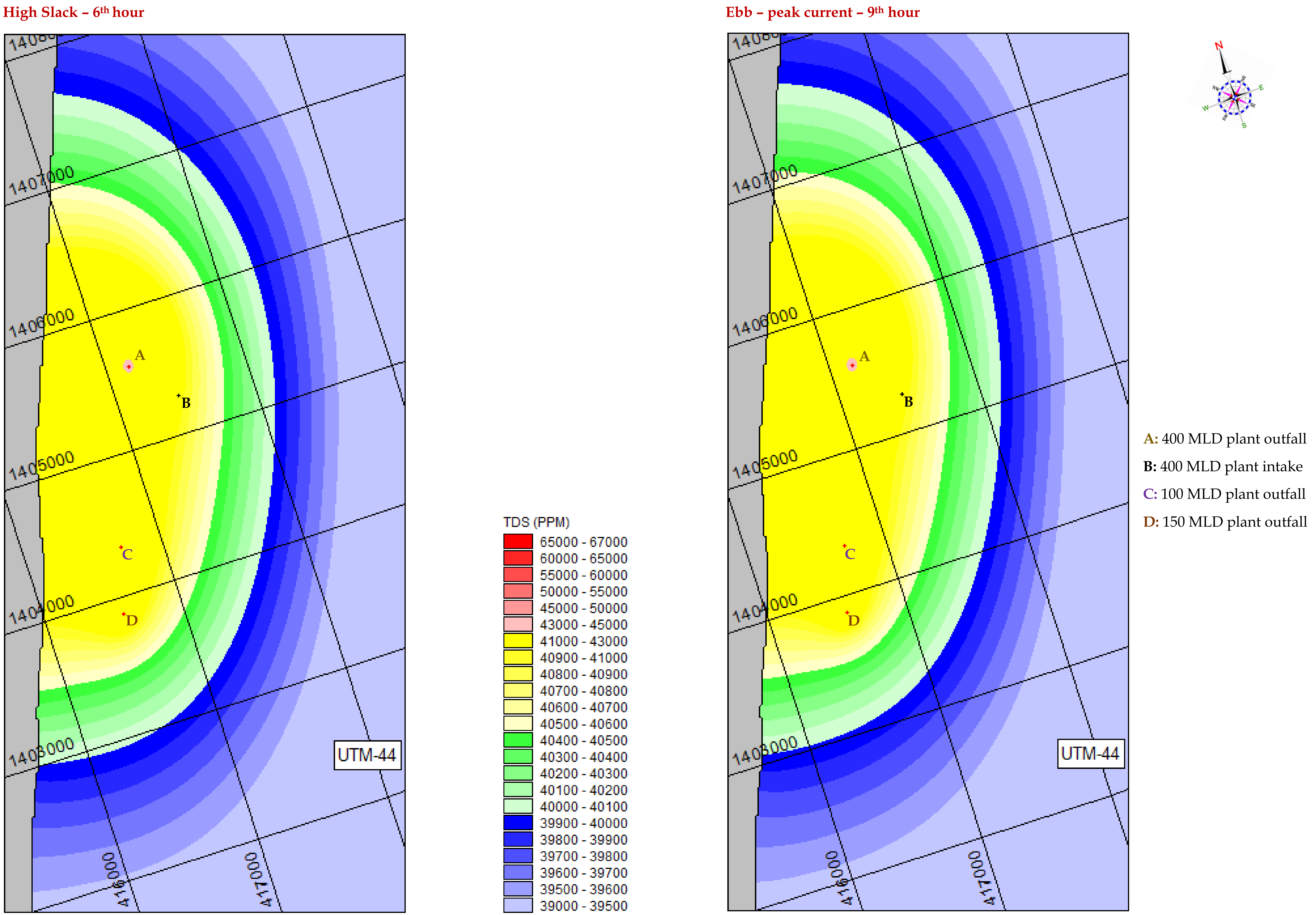


FIG. 5.6(B). SECONDARY DISPERSION – FAIR WEATHER - NEAP TIDE – CASE I (GIVEN IN DPR) – (TDS)

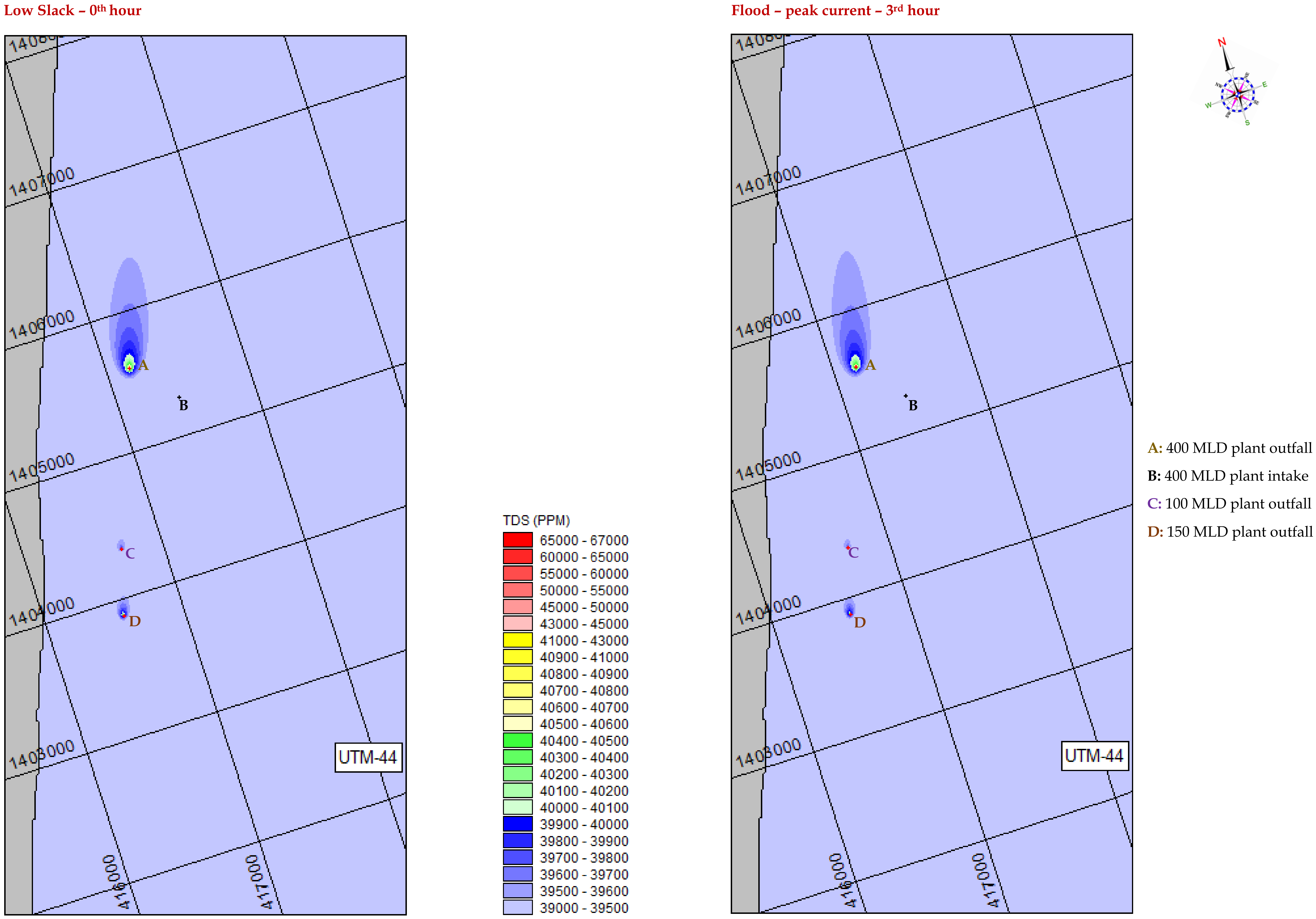


FIG. 5.7(A). SECONDARY DISPERSION – SW MONSOON - SPRING TIDE – CASE I (GIVEN IN DPR) – (TDS)

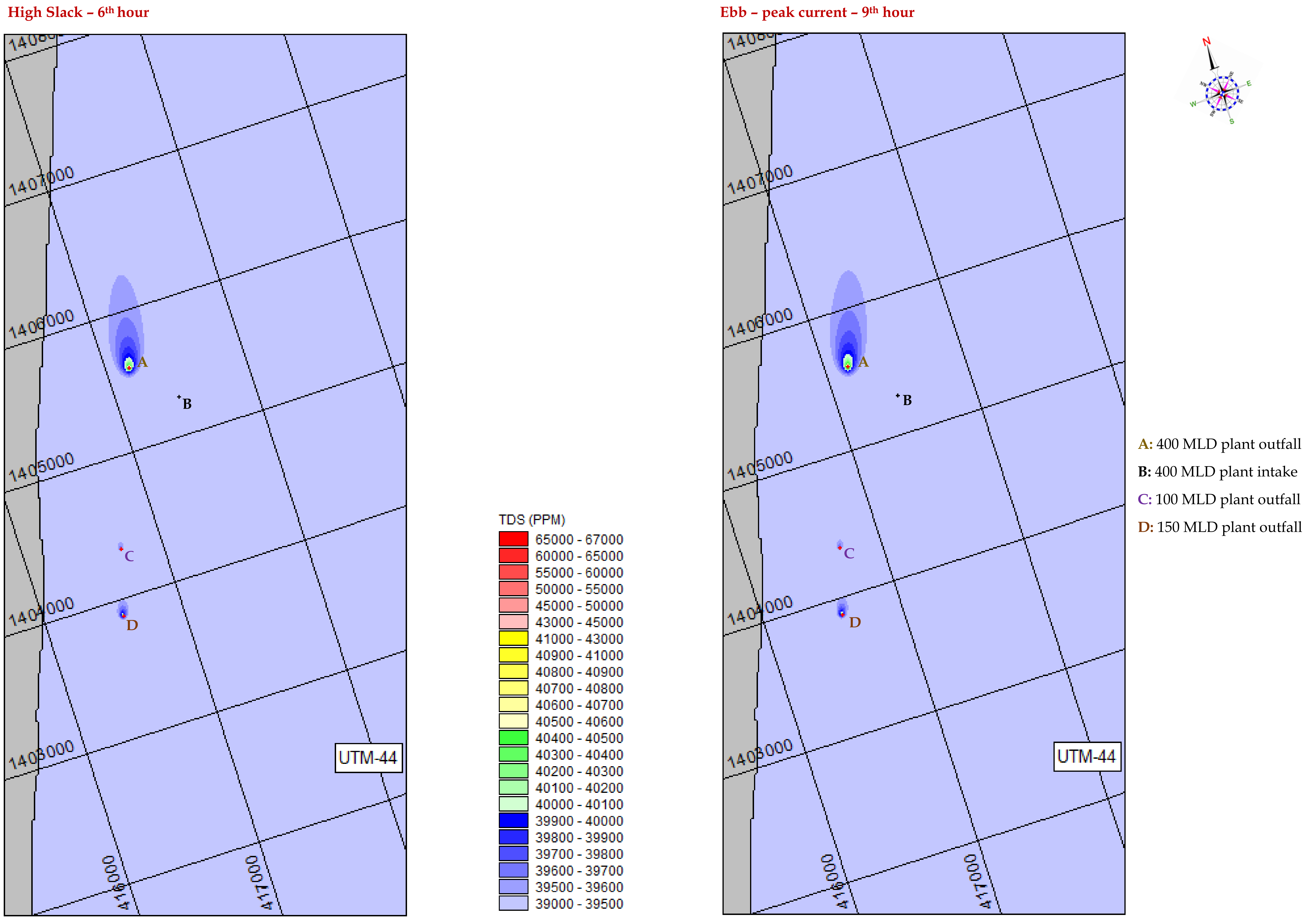


FIG. 5.7(B). SECONDARY DISPERSION – SW MONSOON - SPRING TIDE – CASE I (GIVEN IN DPR) – (TDS)

Low Slack – 0th hour

Flood – peak current - 3rd hour

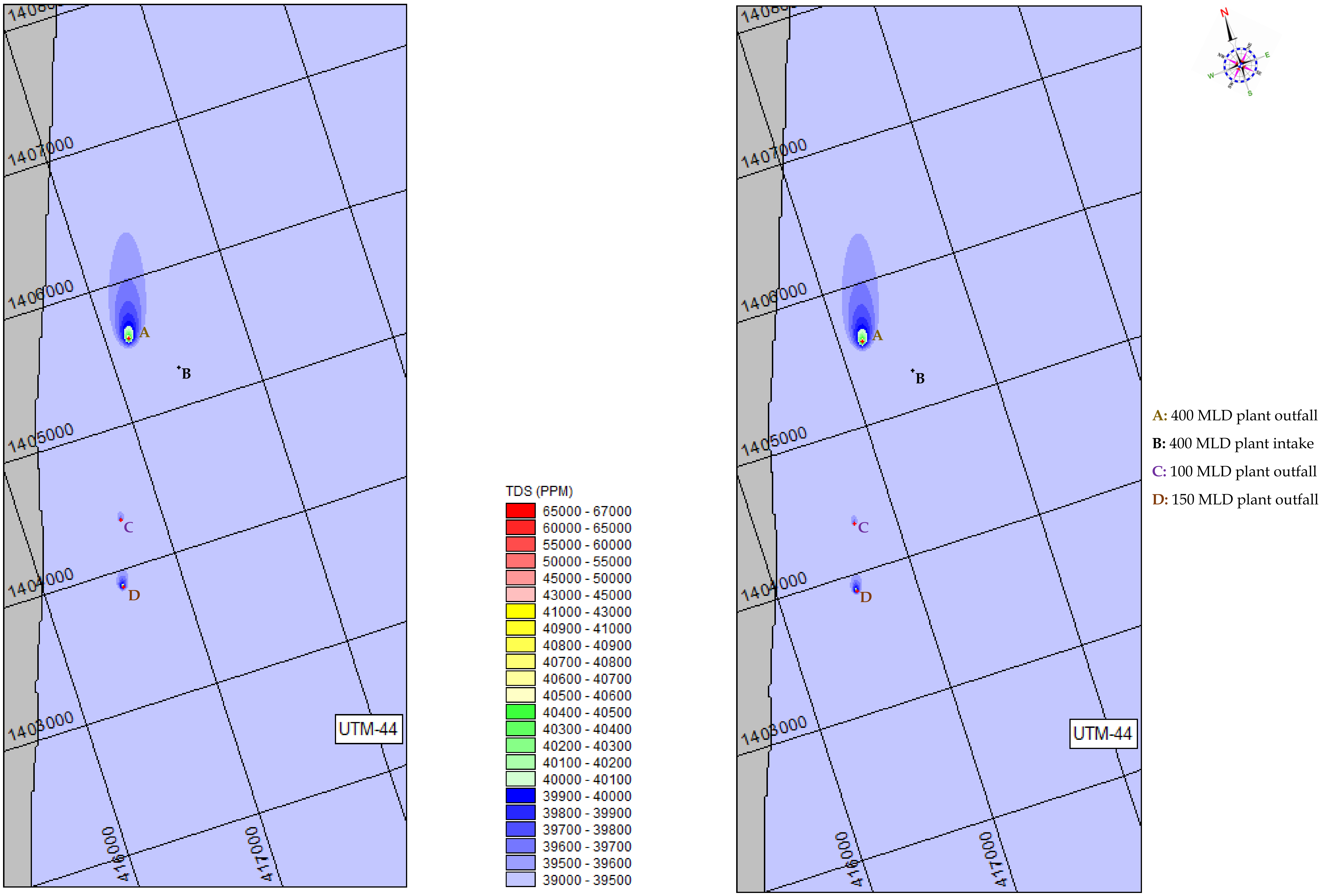


FIG. 5.8(A). SECONDARY DISPERSION – SW MONSOON - NEAP TIDE – CASE I (GIVEN IN DPR) – (TDS)

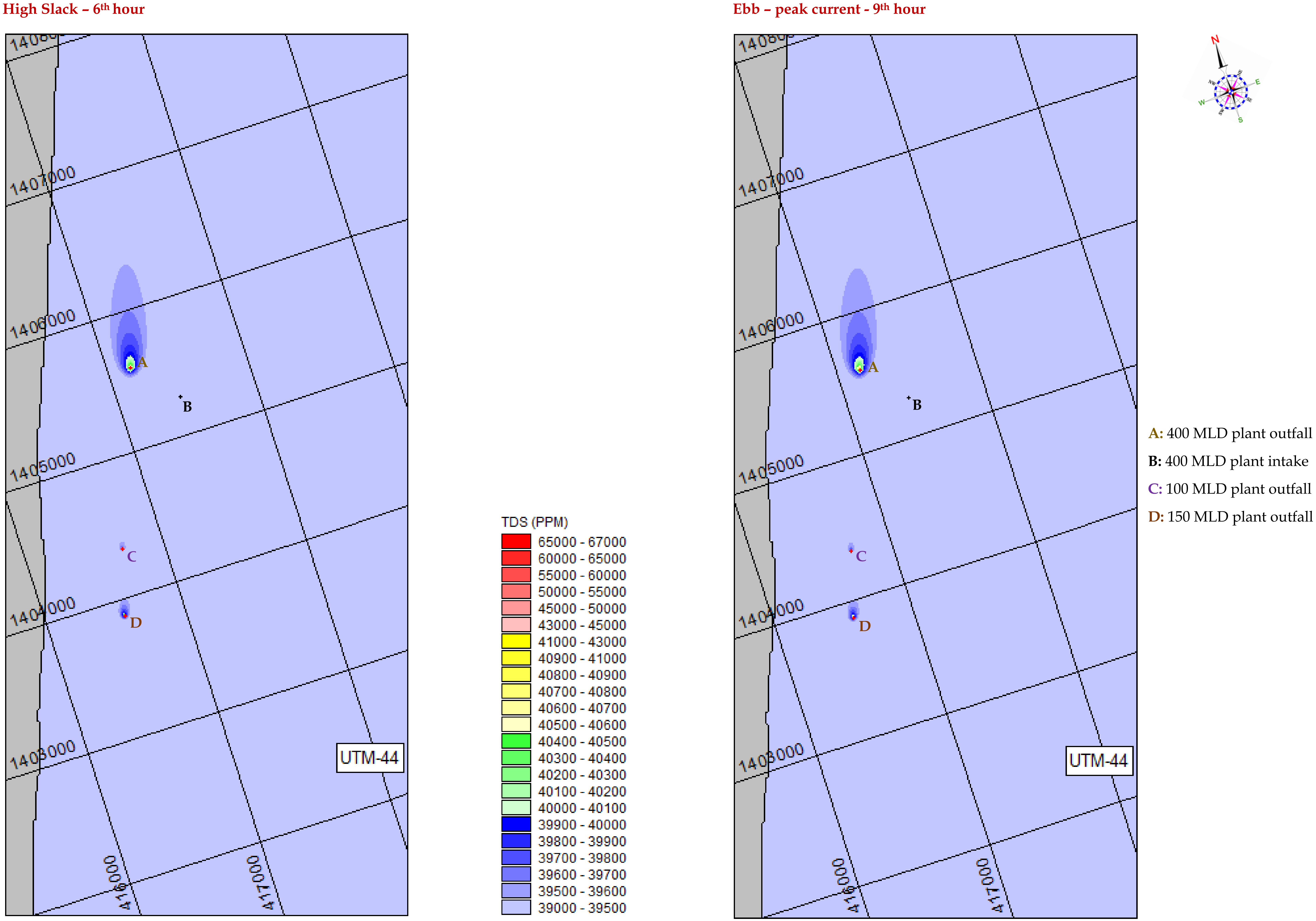
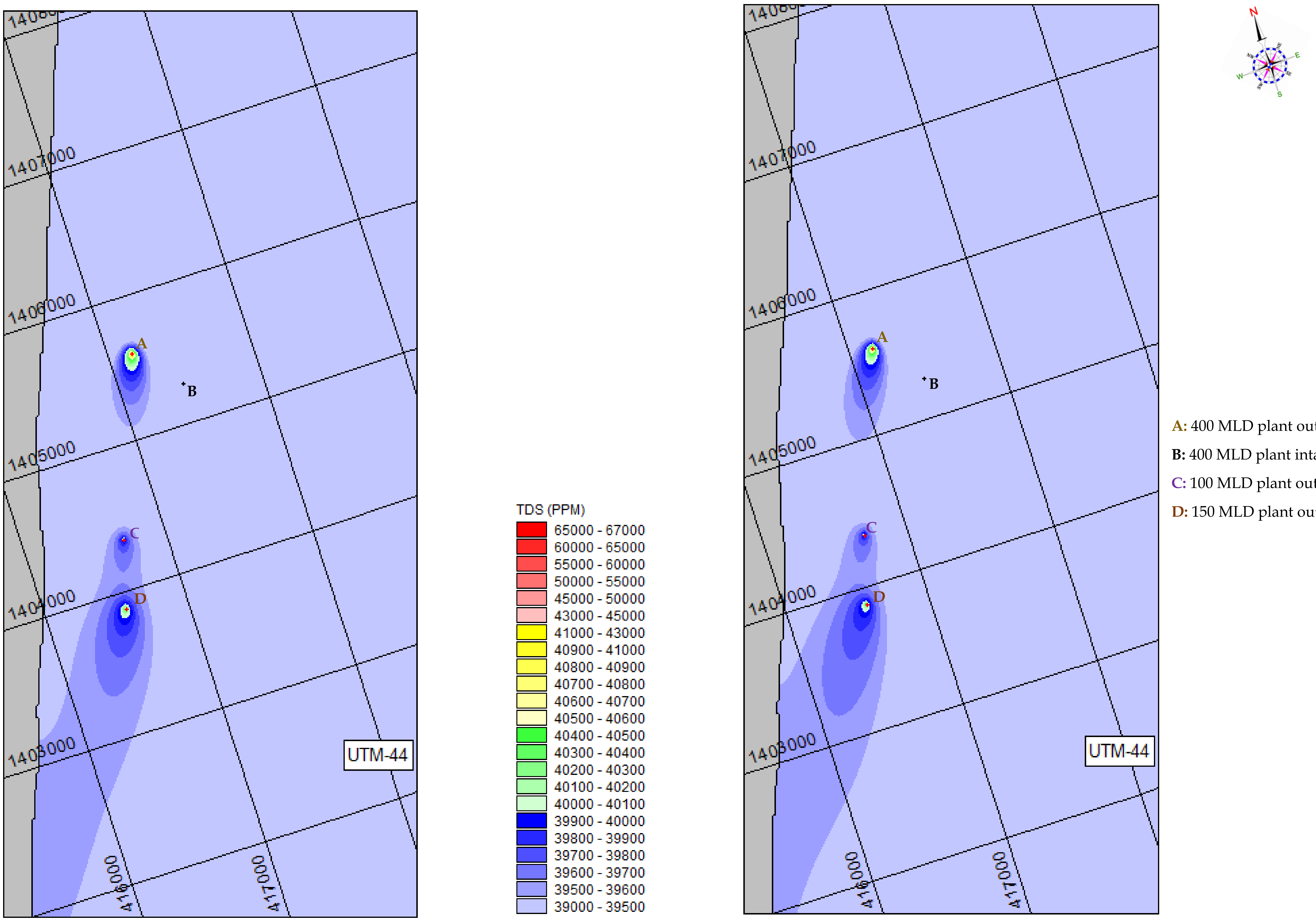


FIG. 5.8(B). SECONDARY DISPERSION – SW MONSOON - NEAP TIDE – CASE I (GIVEN IN DPR) – (TDS)

Low Slack – 0th hour

Flood – peak current - 3rd hour



A: 400 MLD plant outfall

B: 400 MLD plant intake

C: 100 MLD plant outfall

D: 150 MLD plant outfall

FIG. 5.9(A). SECONDARY DISPERSION – NE MONSOON - SPRING TIDE – CASE I (GIVEN IN DPR) – (TDS)

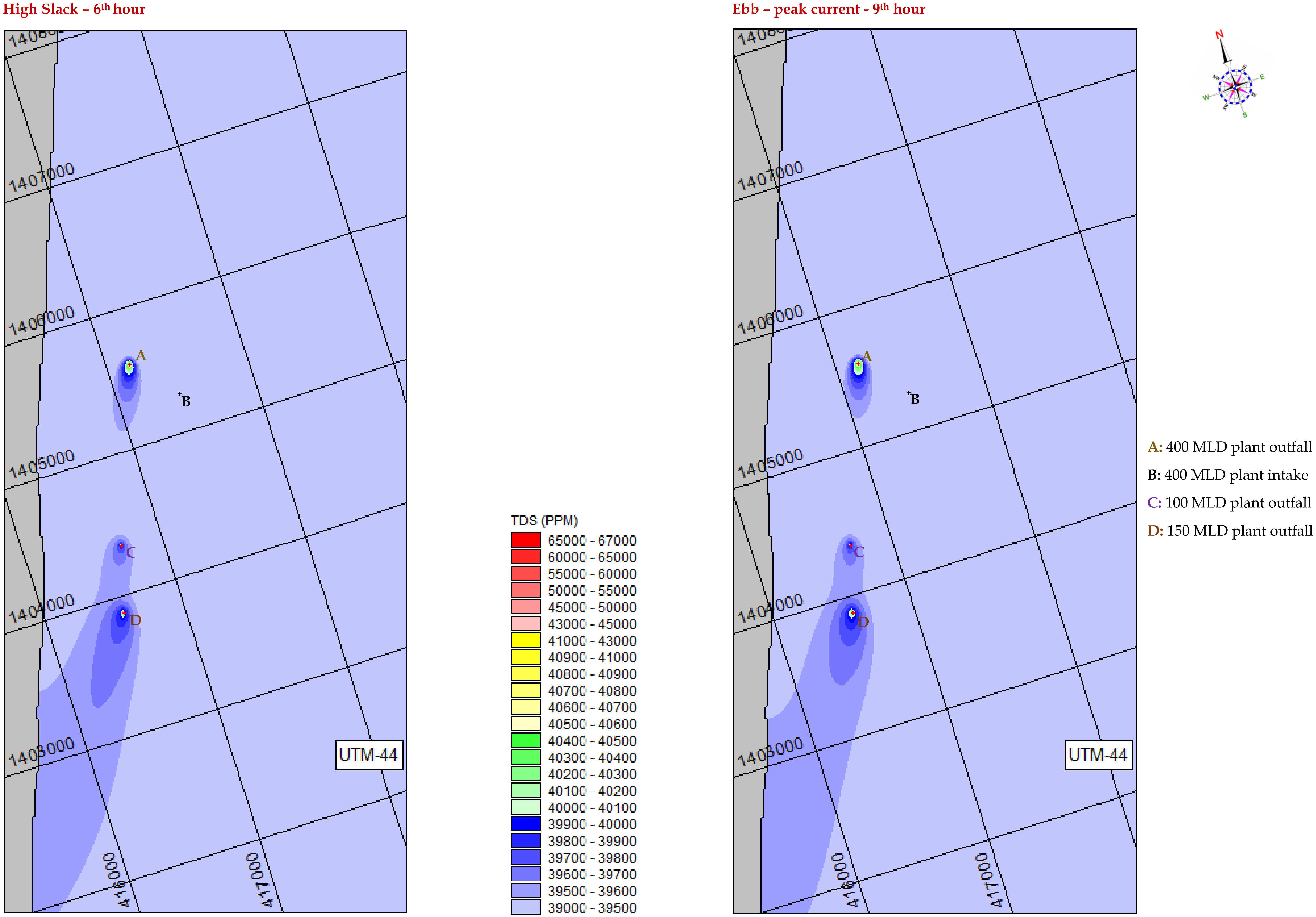


FIG. 5.9(B). SECONDARY DISPERSION – NE MONSOON - SPRING TIDE – CASE I (GIVEN IN DPR) – (TDS)

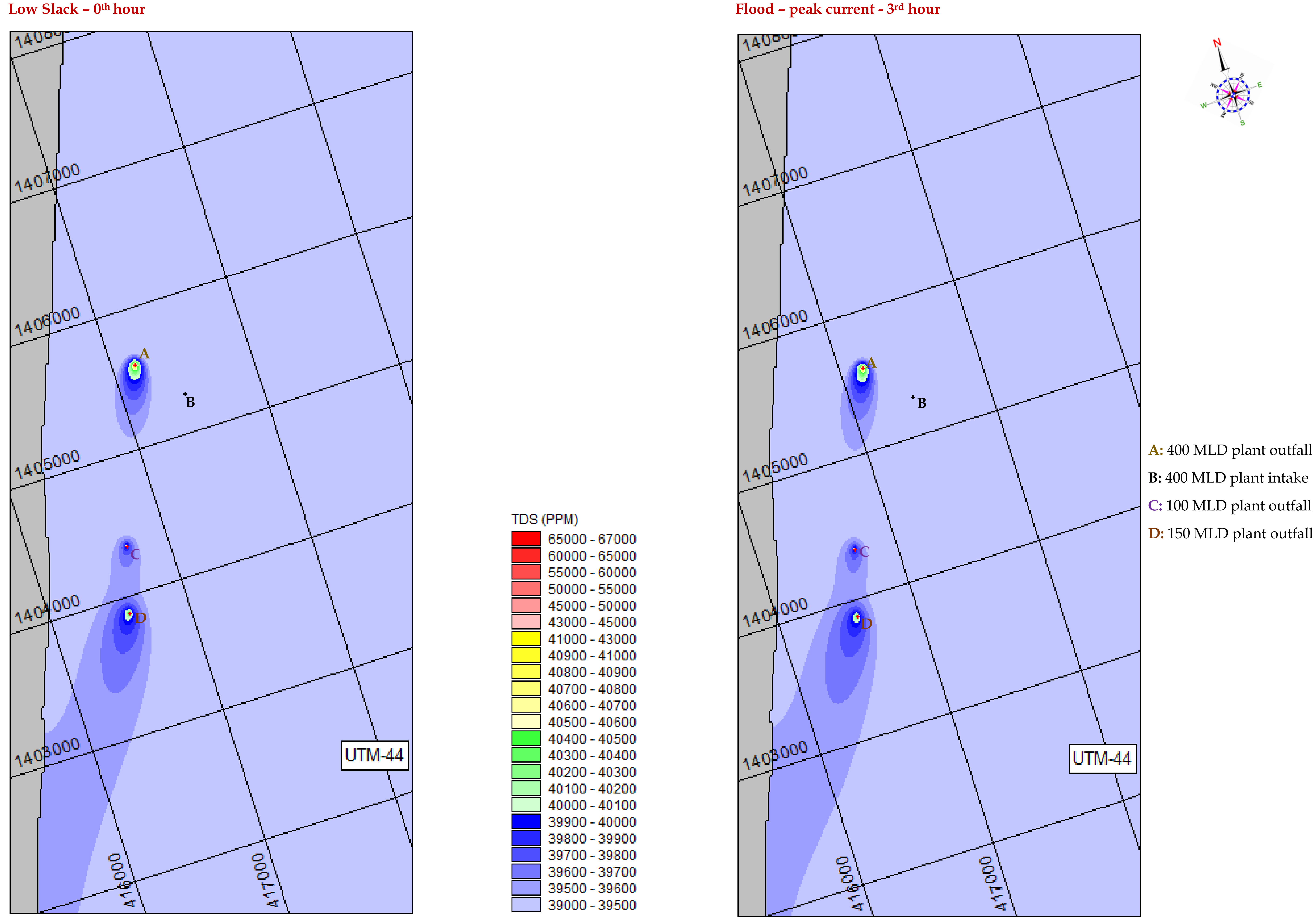


FIG. 5.10(A). SECONDARY DISPERSION – NE MONSOON - NEAP TIDE – CASE I (GIVEN IN DPR) – (TDS)

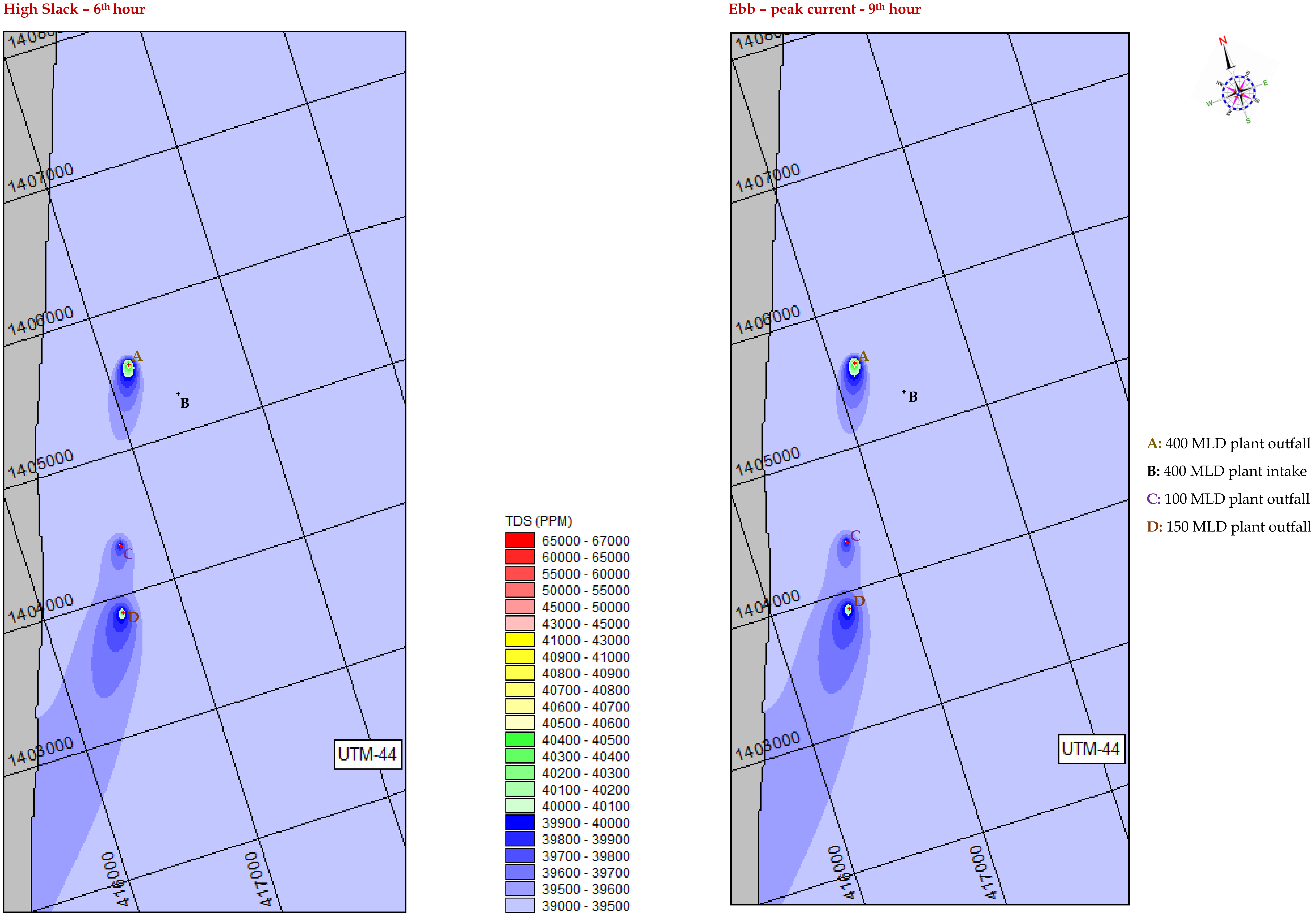


FIG. 5.10(B). SECONDARY DISPERSION – NE MONSOON - NEAP TIDE – CASE I (GIVEN IN DPR) – (TDS)

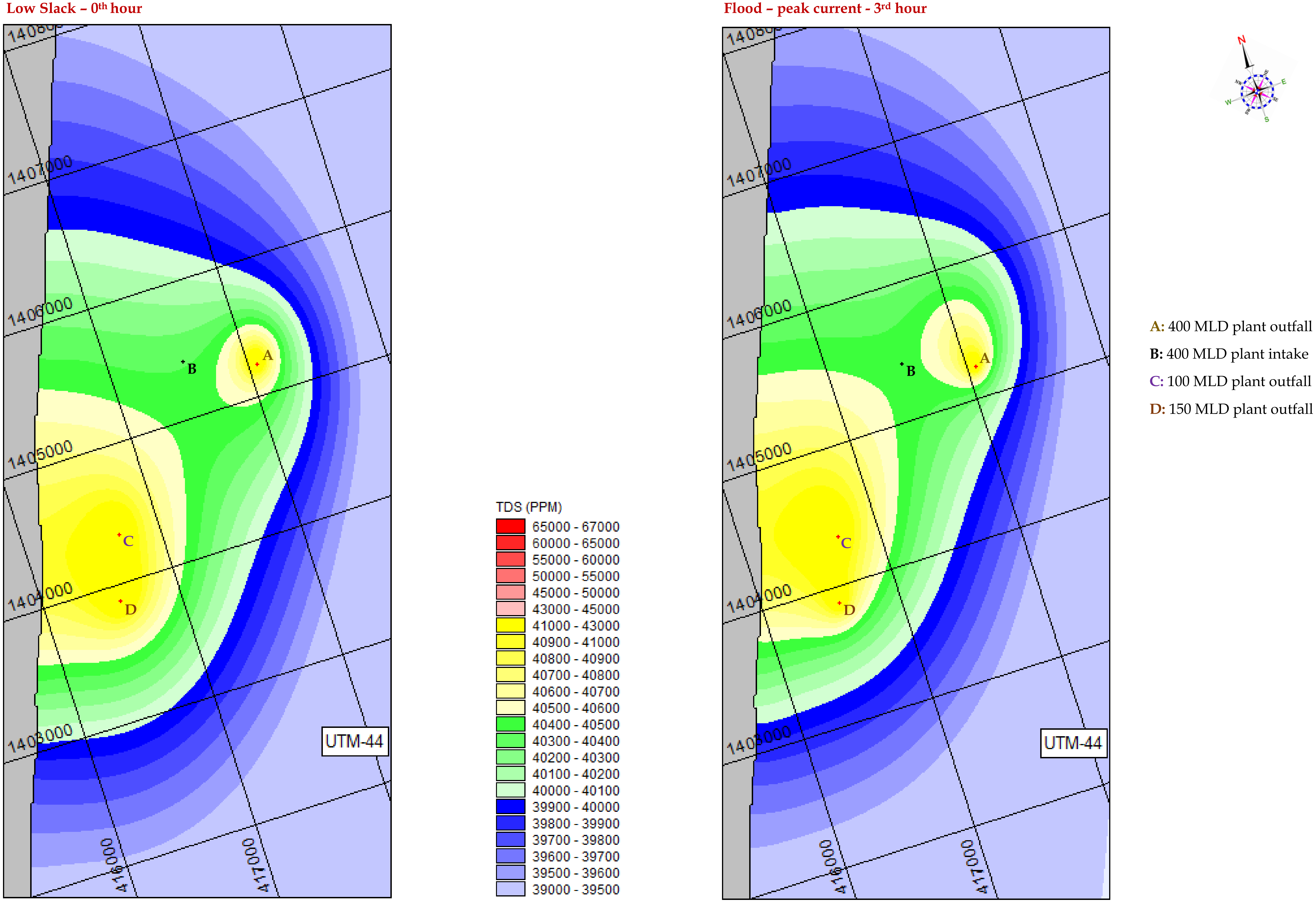


FIG. 5.11(A). SECONDARY DISPERSION – FAIR WEATHER - SPRING TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

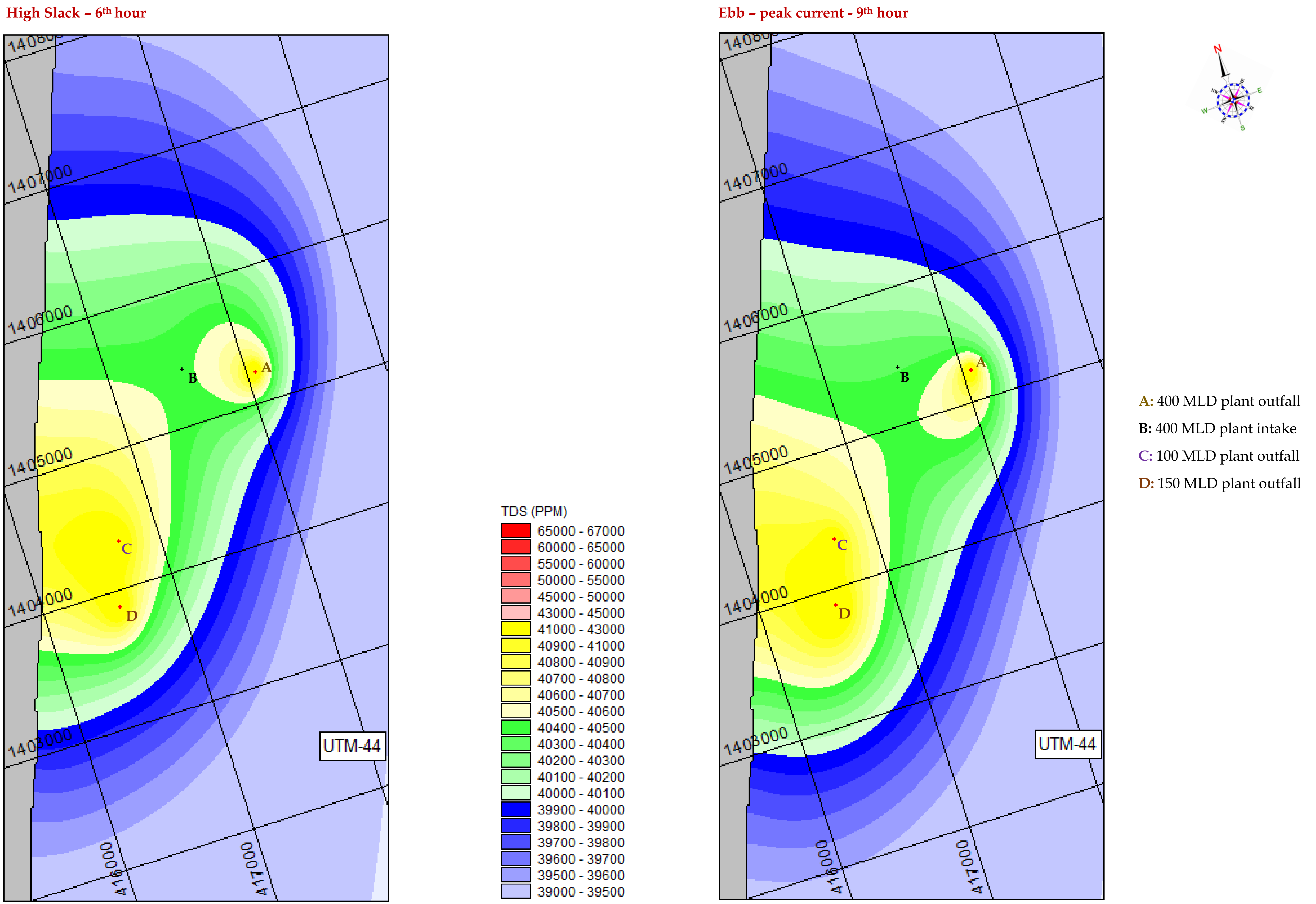


FIG. 5.11(B). SECONDARY DISPERSION – FAIR WEATHER - SPRING TIDE – CASE II (ADOPTED IN JICA STUDY)– (TDS)

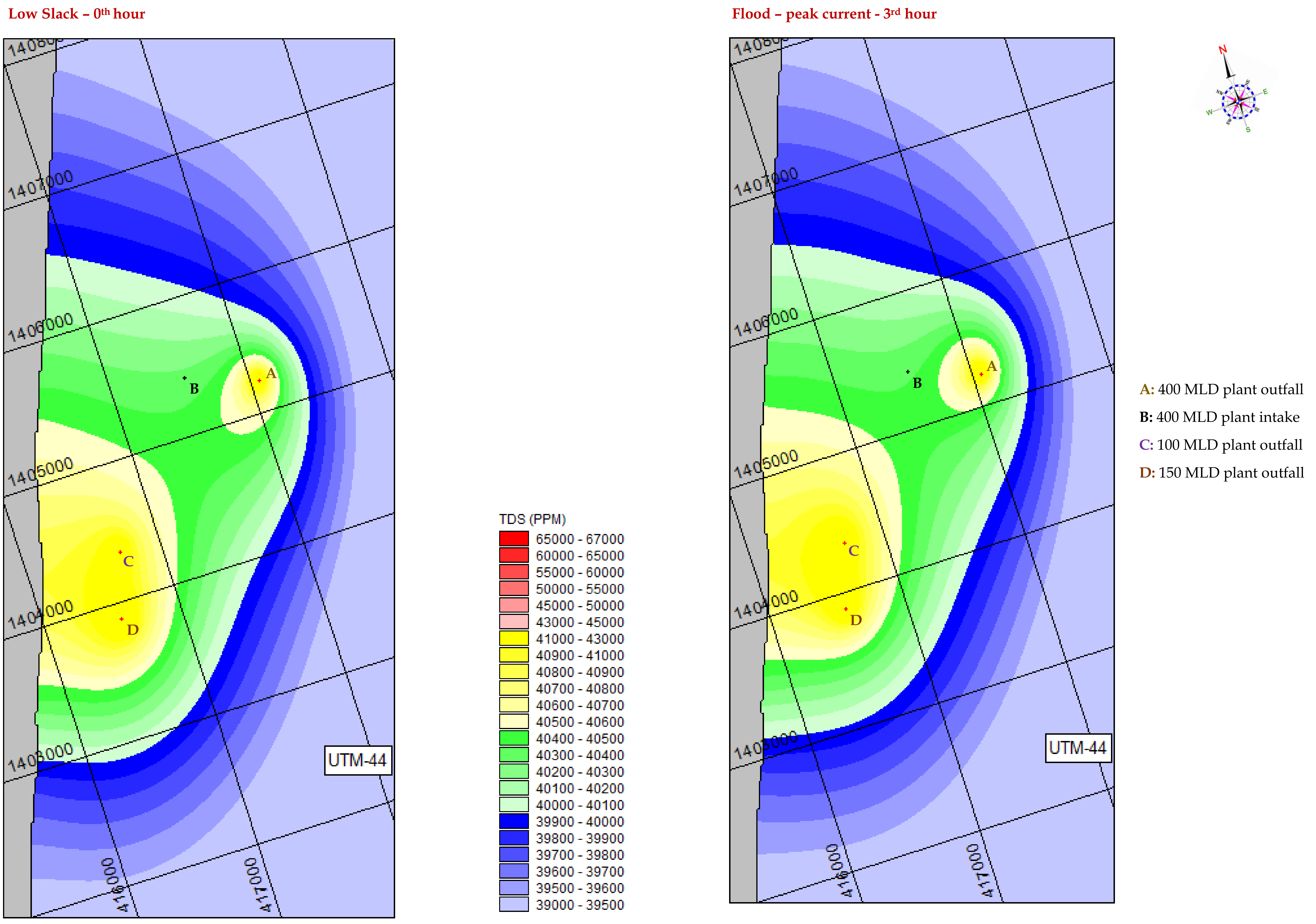


FIG. 5.12(A). SECONDARY DISPERSION – FAIR WEATHER - NEAP TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

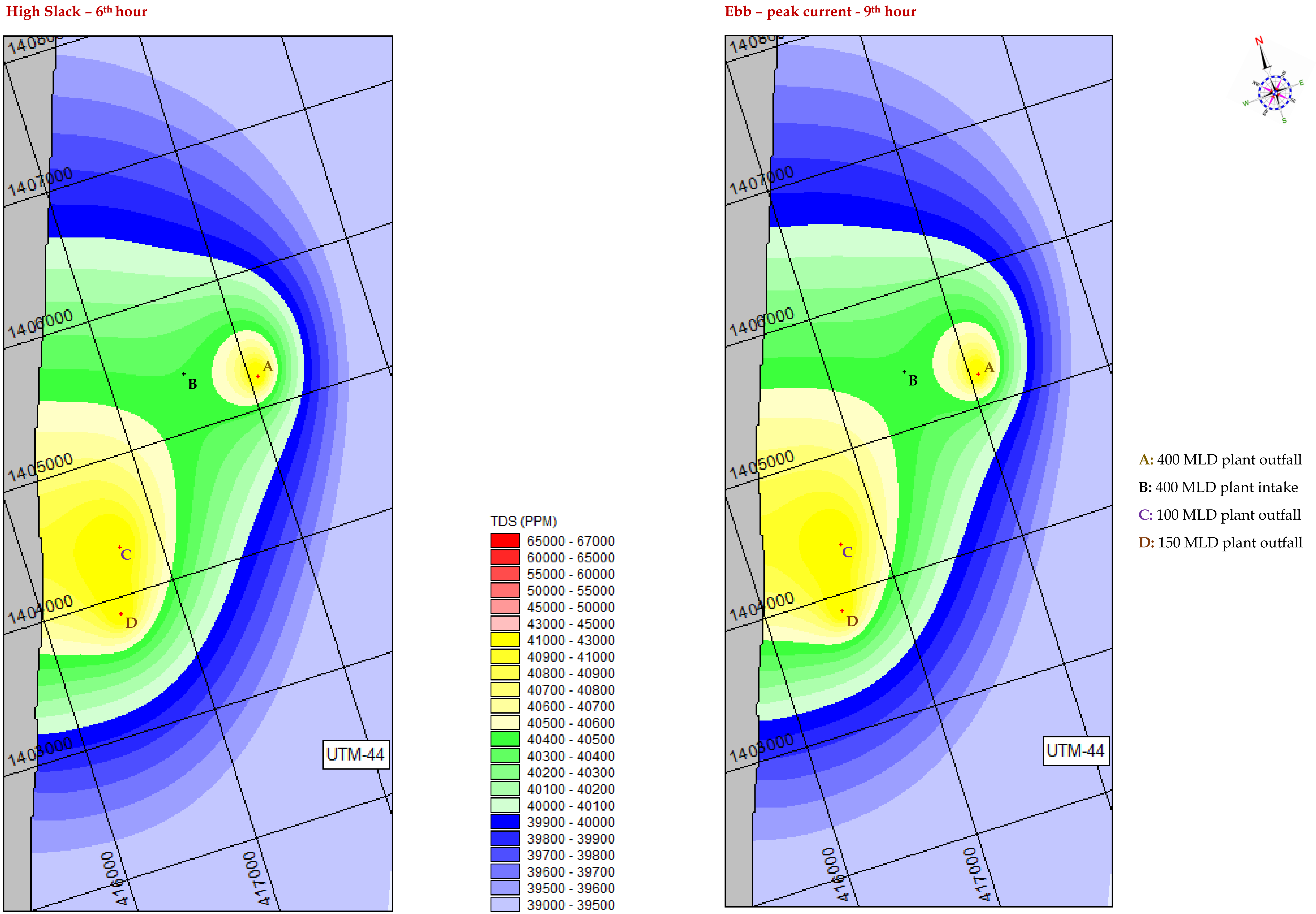


FIG. 5.12(B). SECONDARY DISPERSION – FAIR WEATHER - NEAP TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

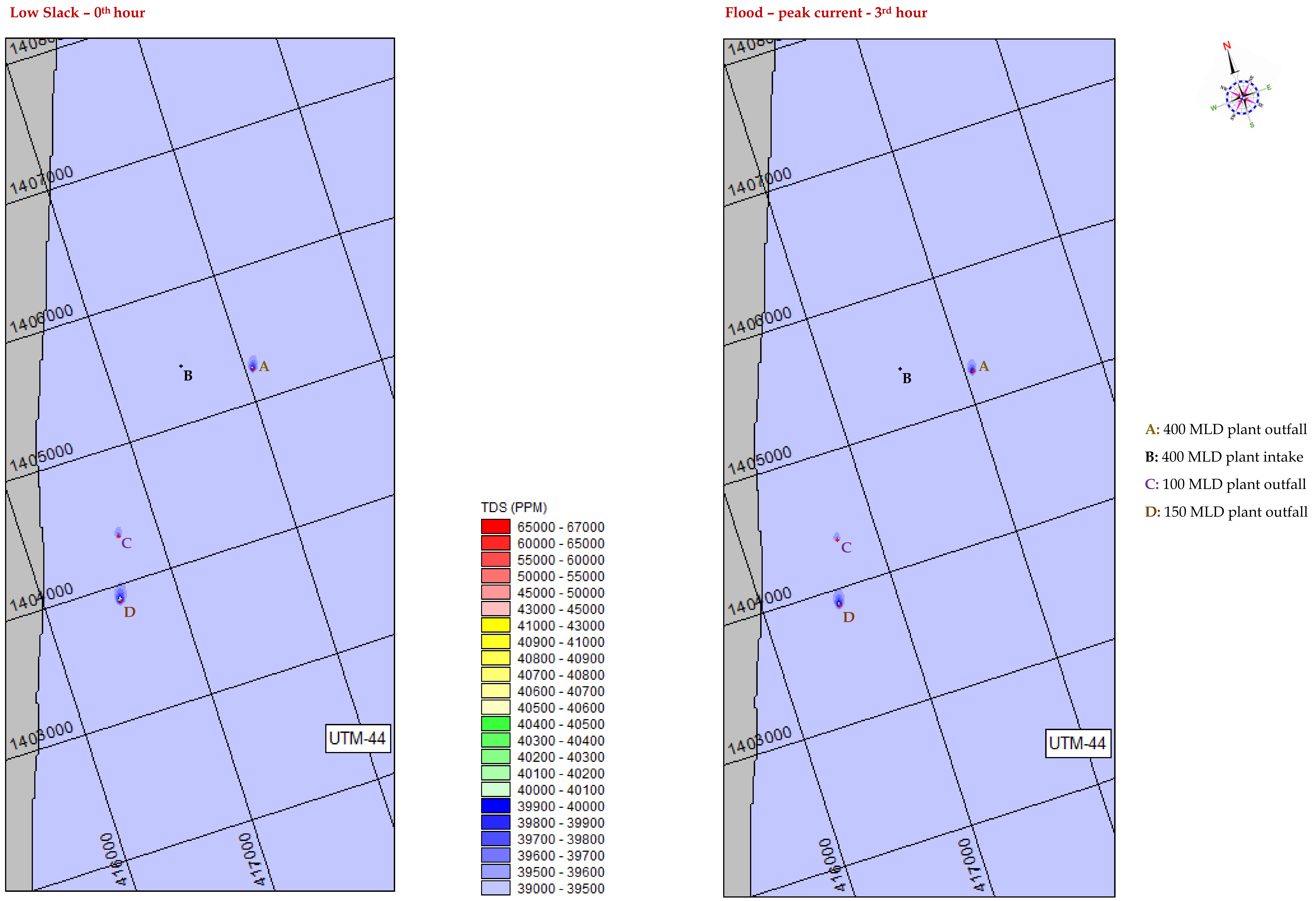


FIG. 5.13(A). SECONDARY DISPERSION – SW MONSOON - SPRING TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

High Slack – 6th hour

Ebb – peak current - 9th hour

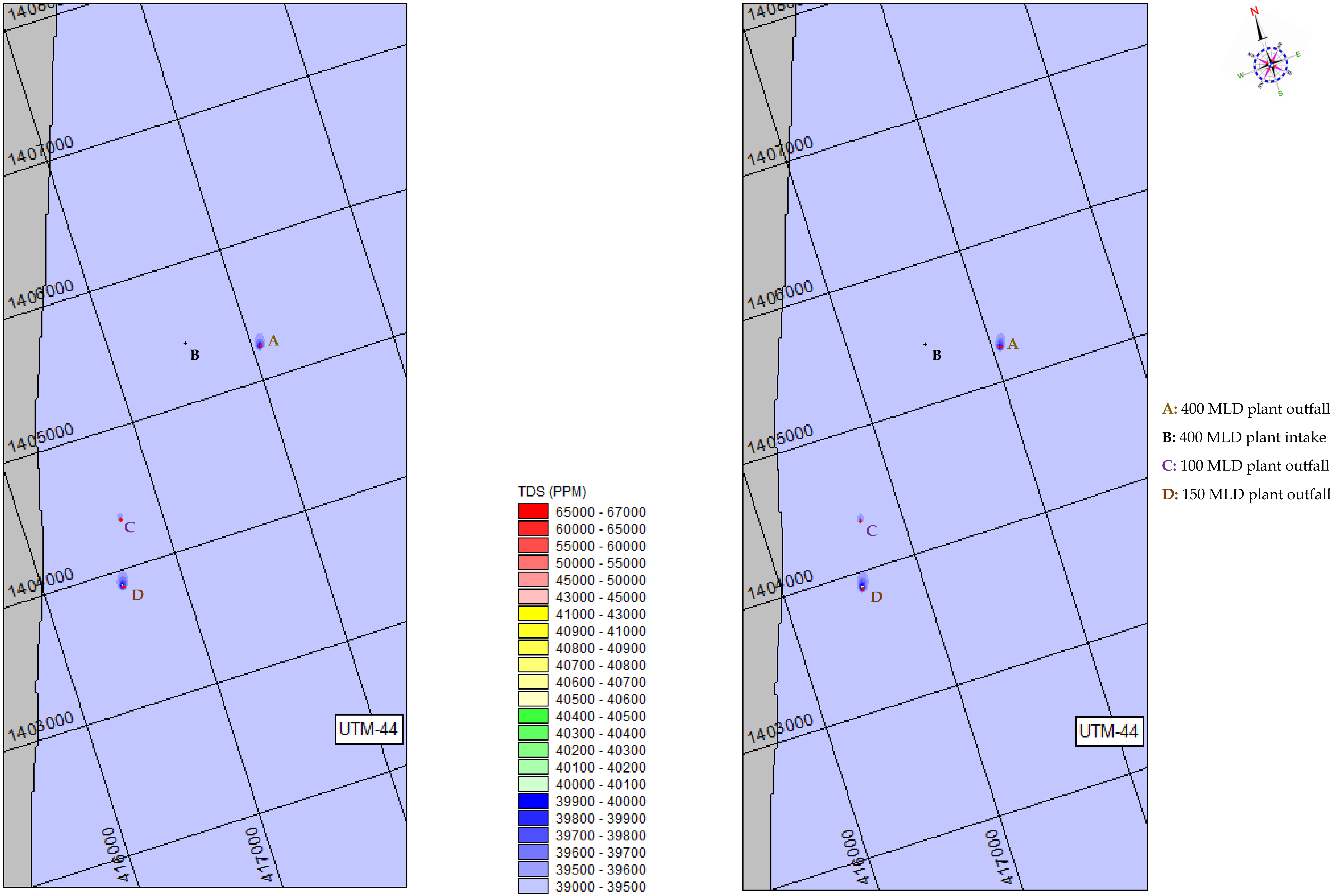


FIG. 5.13(B). SECONDARY DISPERSION – SW MONSOON - SPRING TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

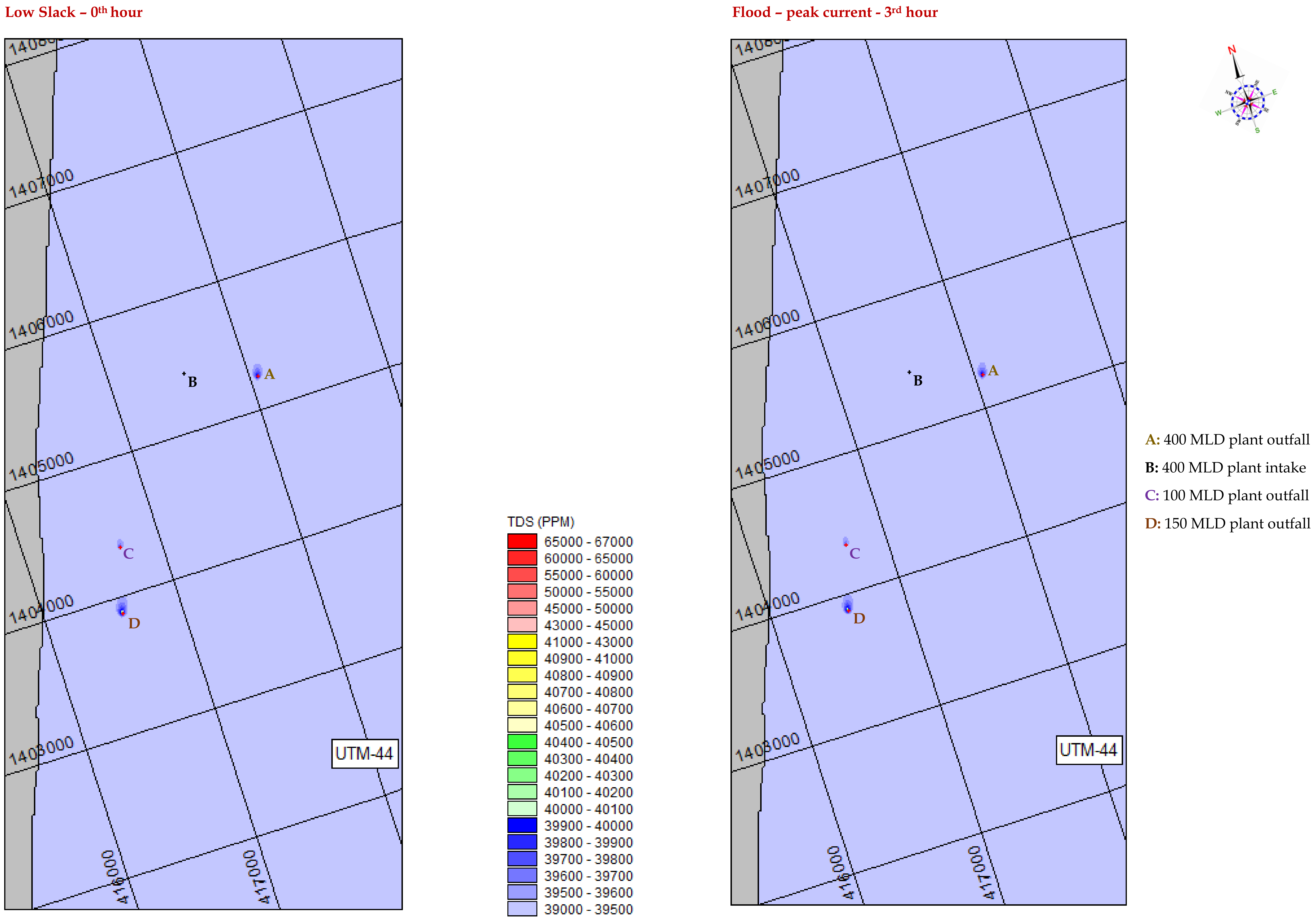


FIG. 5.14(A). SECONDARY DISPERSION – SW MONSOON - NEAP TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

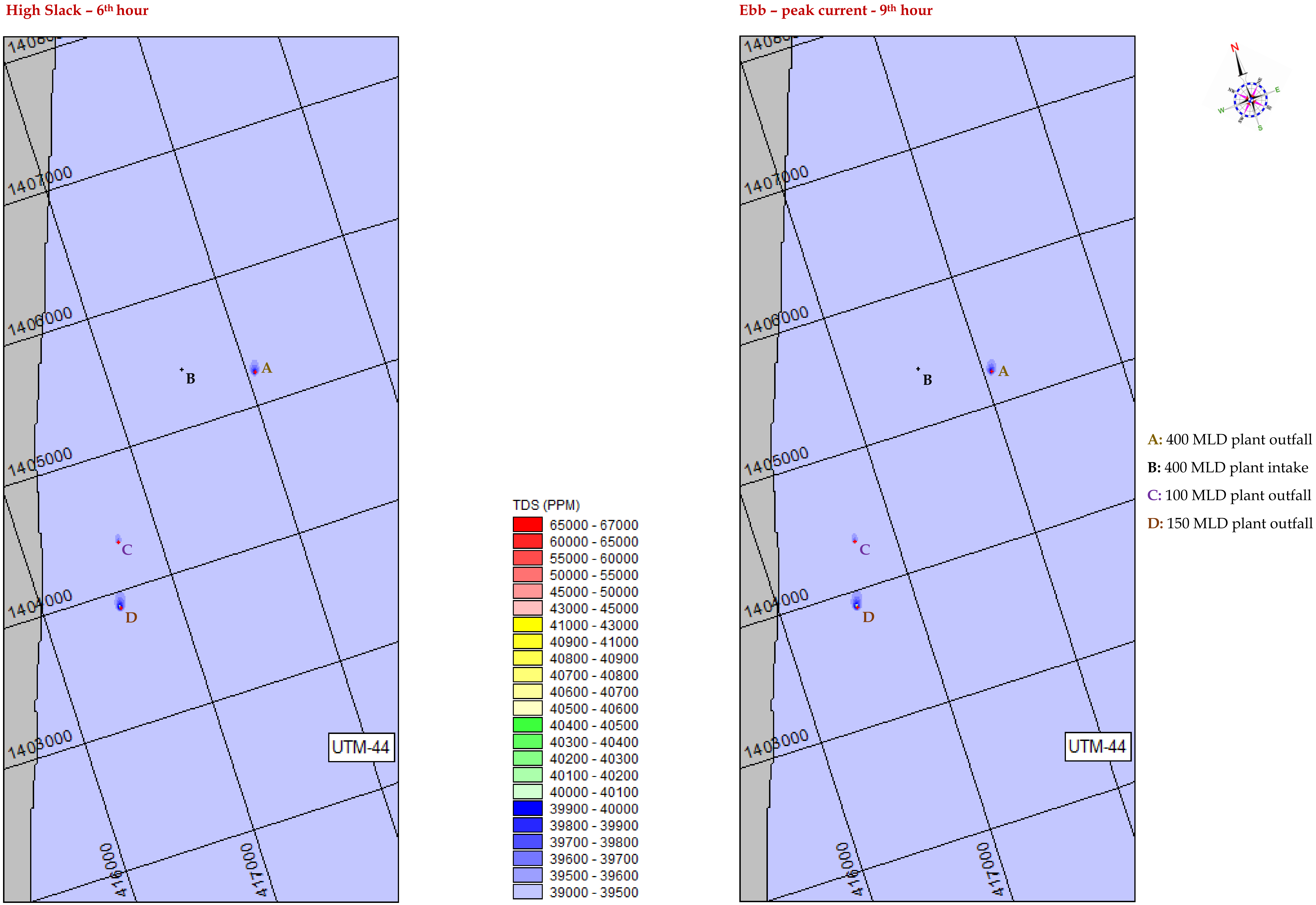


FIG. 5.14(B). SECONDARY DISPERSION – SW MONSOON - NEAP TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

Low Slack – 0th hour

Flood – peak current - 3rd hour

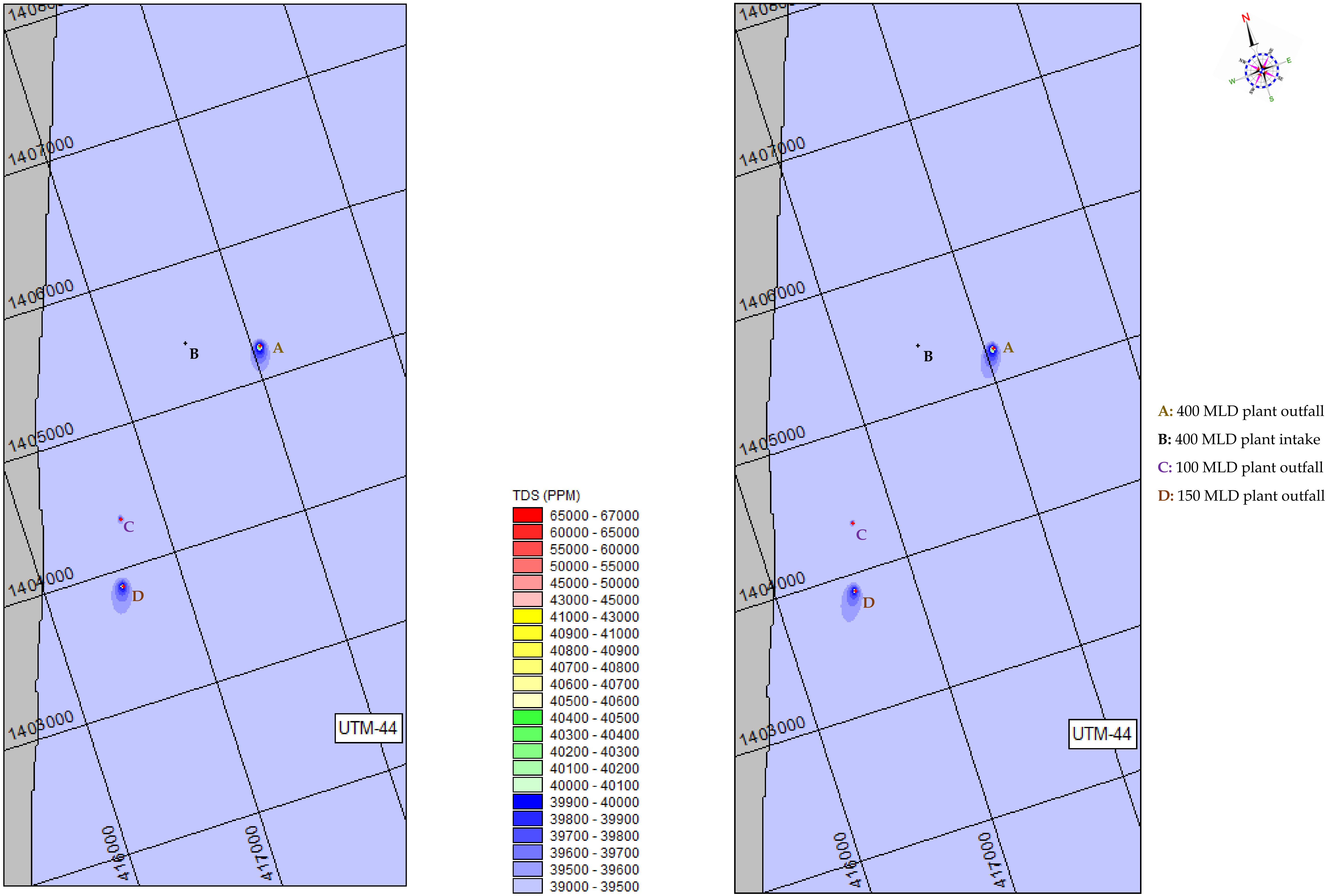


FIG. 5.15(A). SECONDARY DISPERSION – NE MONSOON - SPRING TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

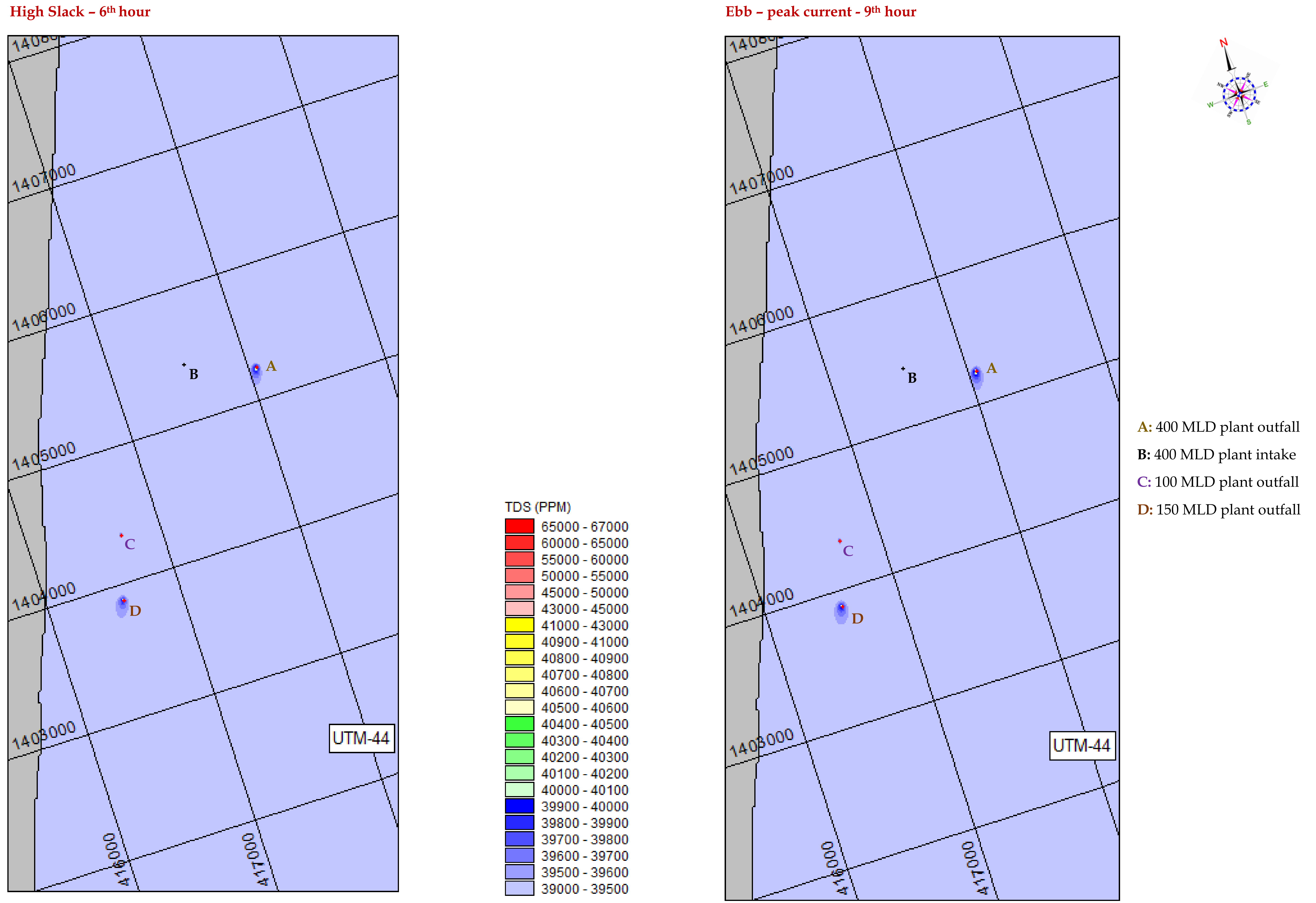


FIG. 5.15(B). SECONDARY DISPERSION – NE MONSOON - SPRING TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

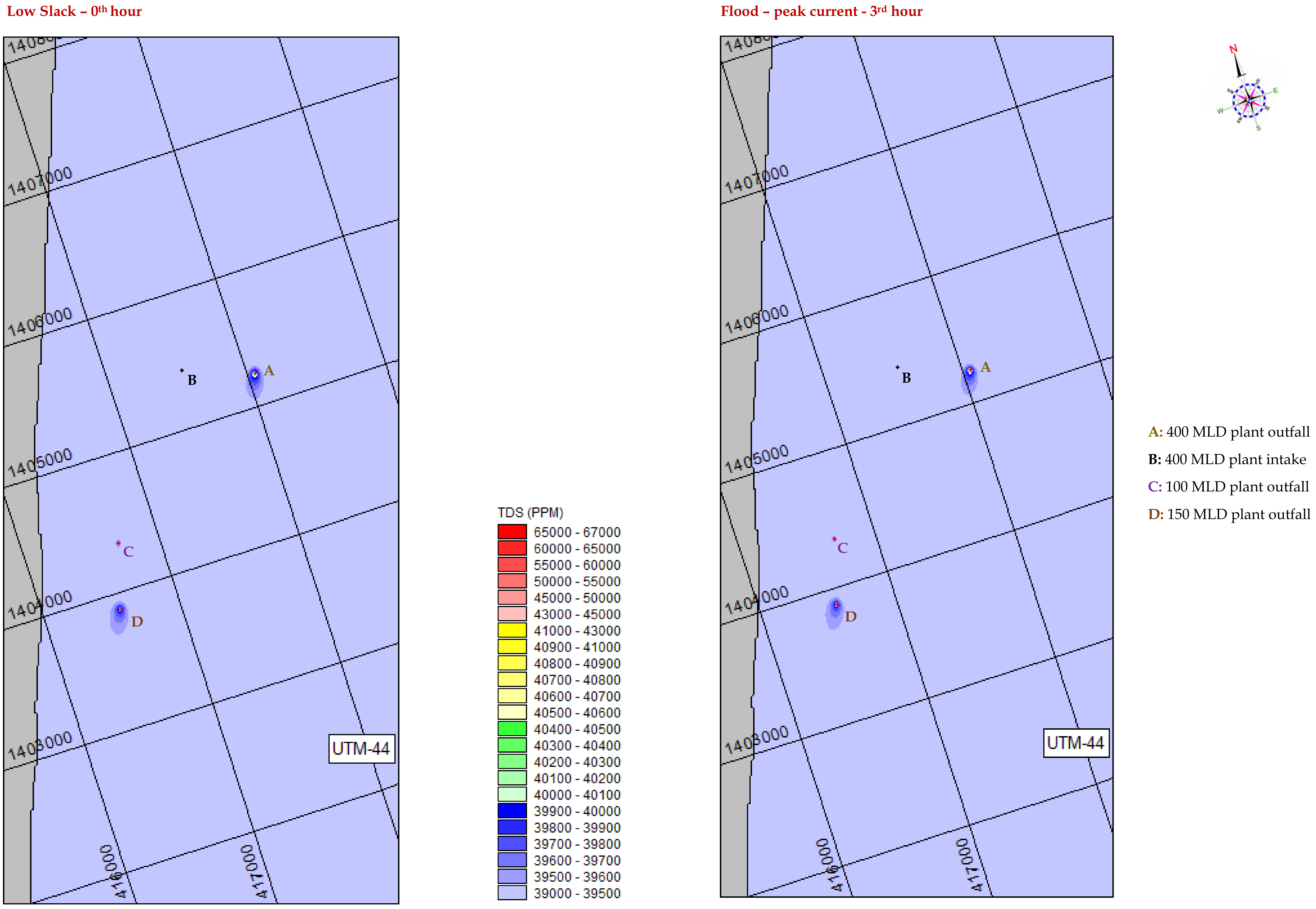


FIG. 5.16(A). SECONDARY DISPERSION – NE MONSOON - NEAP TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

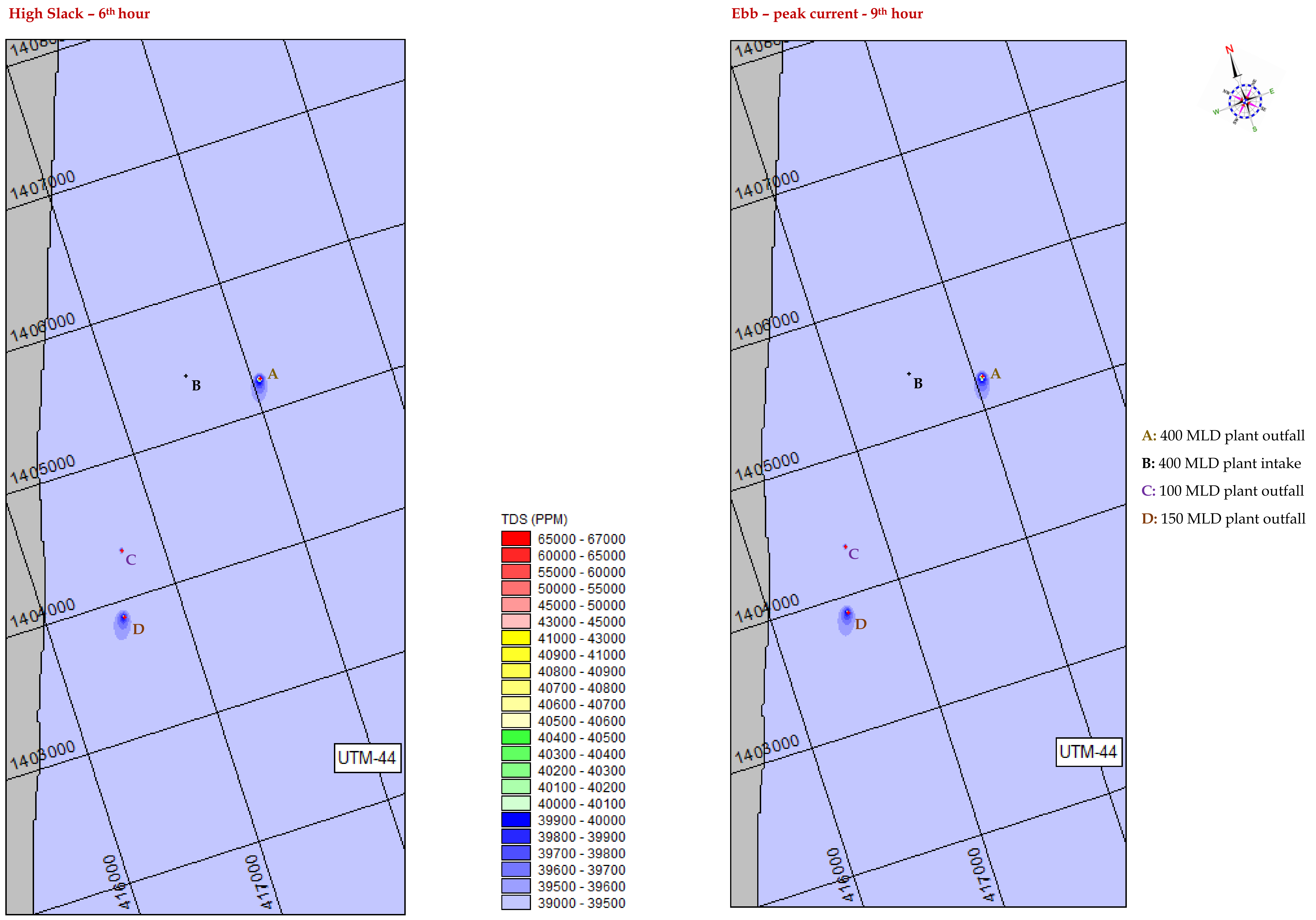


FIG. 5.16(B). SECONDARY DISPERSION – NE MONSOON - NEAP TIDE – CASE II (ADOPTED IN JICA STUDY) – (TDS)

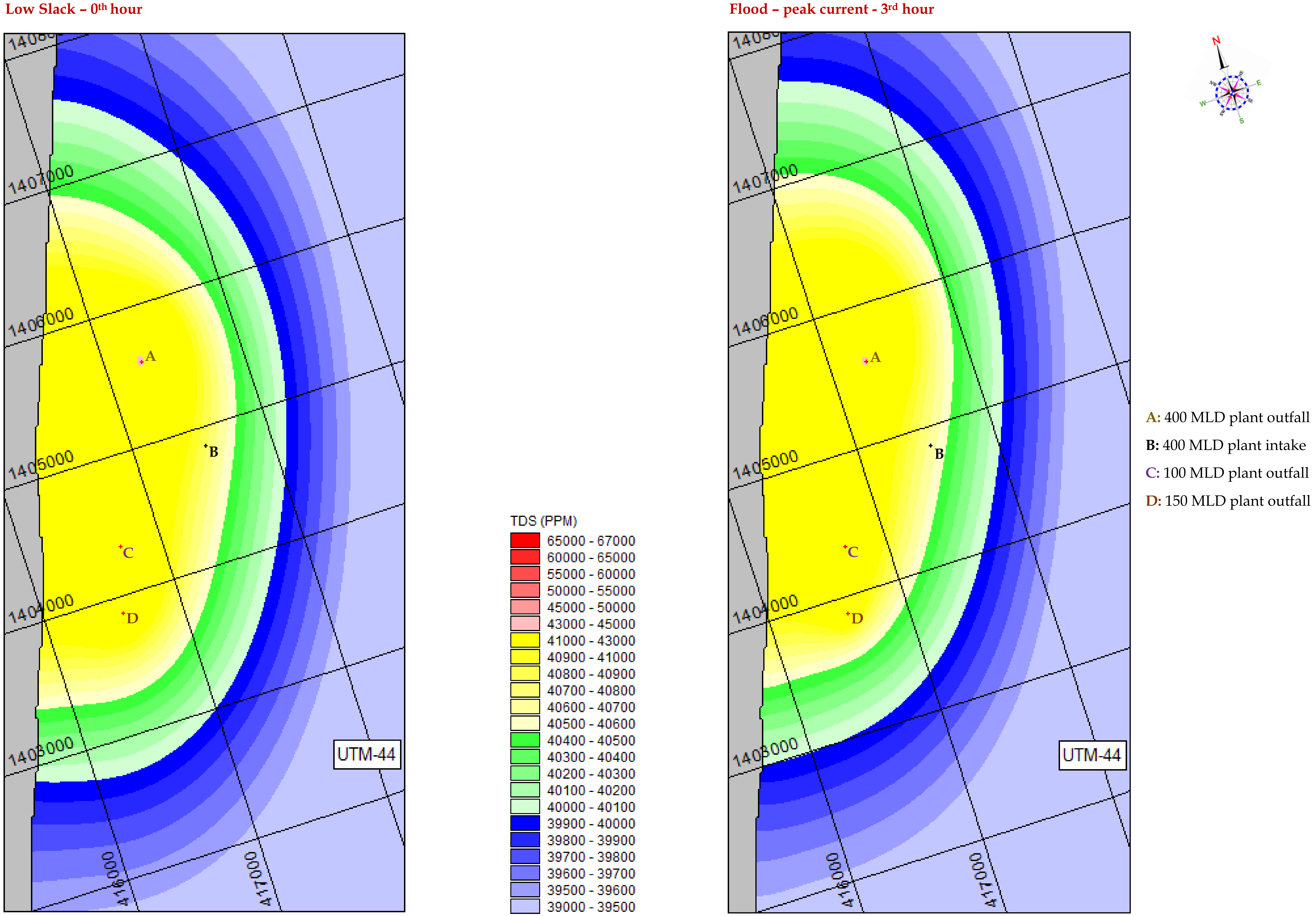


FIG. 5.17(A). SECONDARY DISPERSION – FAIR WEATHER - SPRING TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

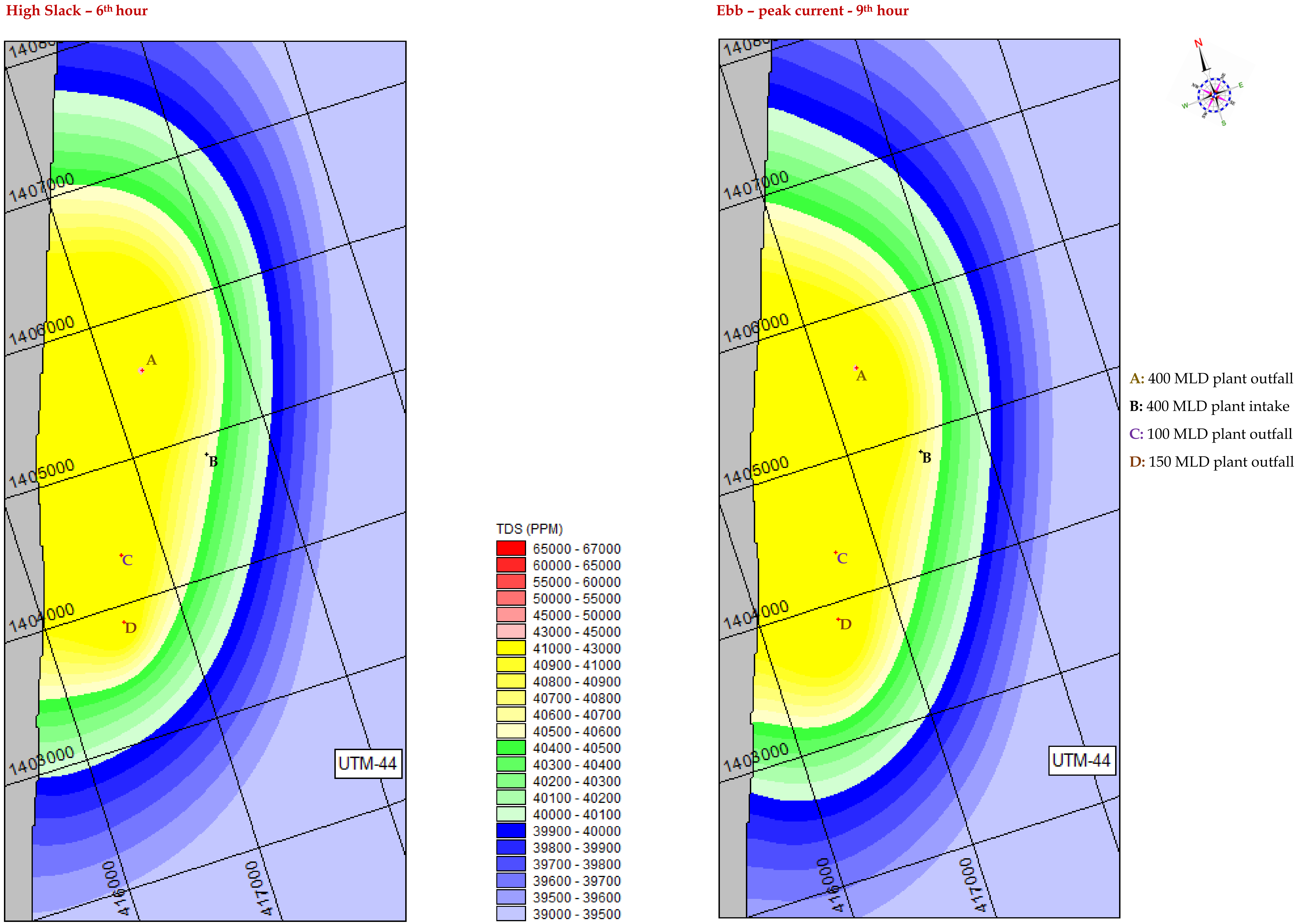


FIG. 5.17(B). SECONDARY DISPERSION – FAIR WEATHER - SPRING TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

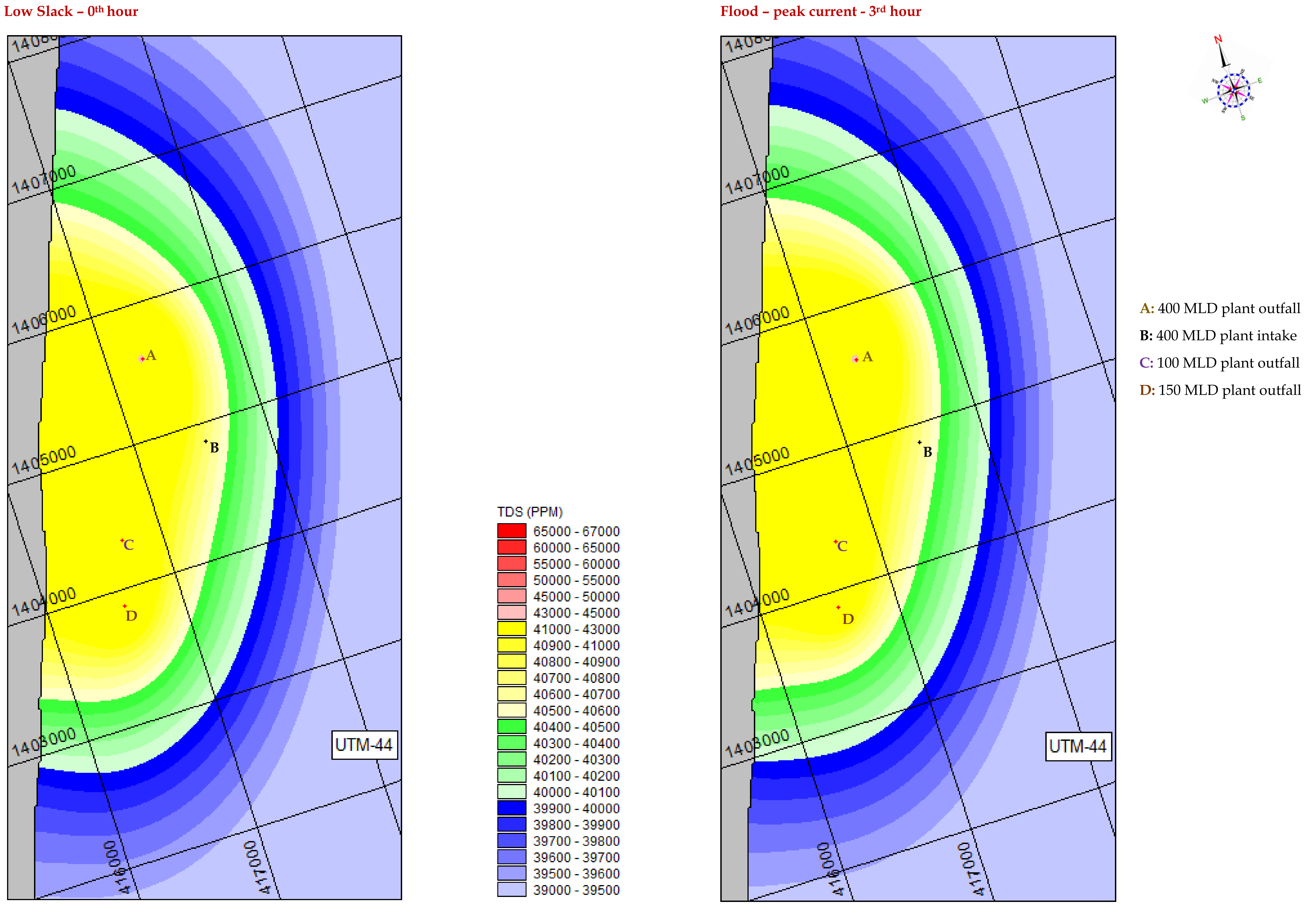


FIG. 5.18(A). SECONDARY DISPERSION – FAIR WEATHER - NEAP TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

High Slack – 6th hour

Ebb – peak current - 9th hour

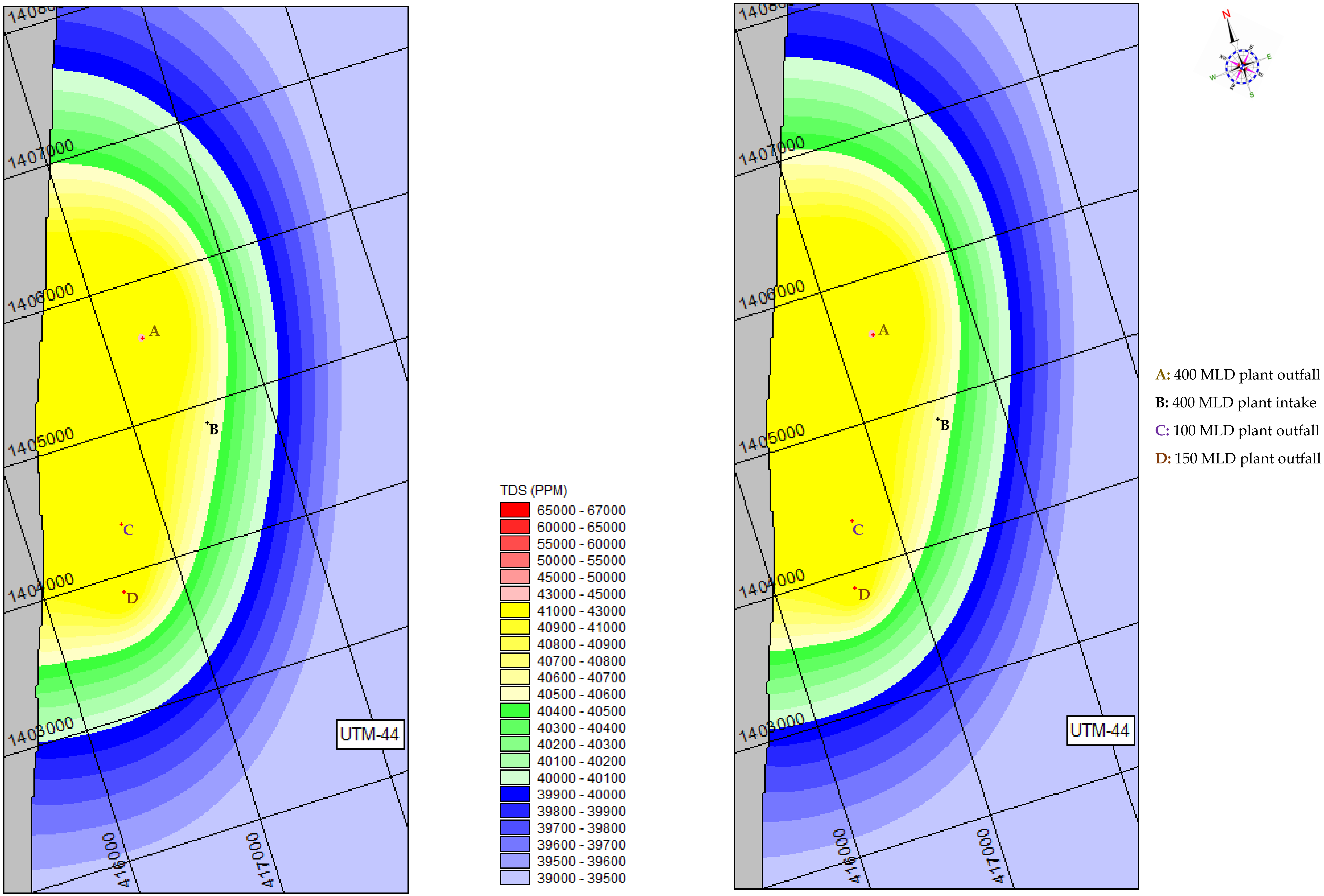


FIG. 5.18(B). SECONDARY DISPERSION – FAIR WEATHER - NEAP TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

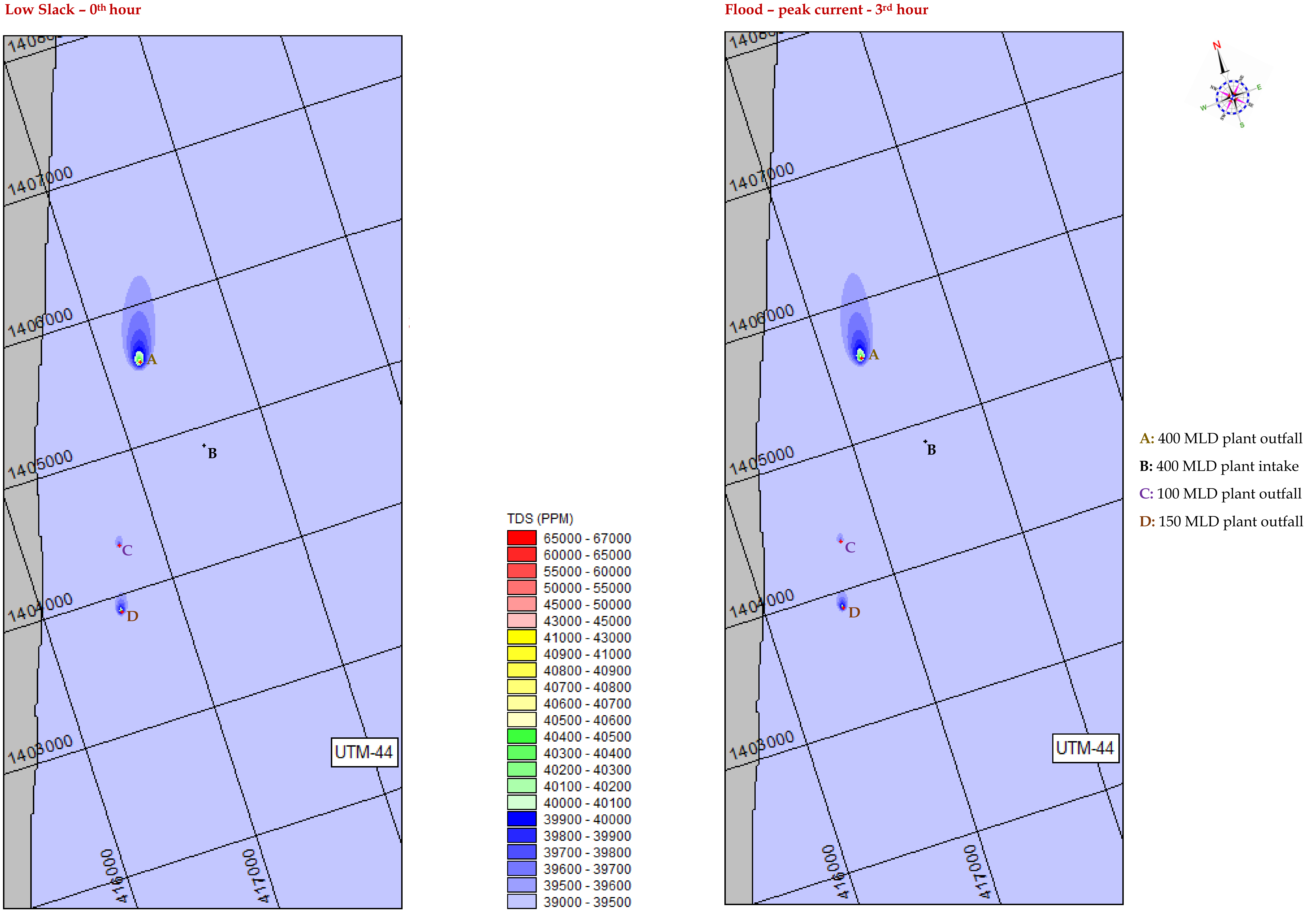


FIG. 5.19(A). SECONDARY DISPERSION – SW MONSOON - SPRING TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

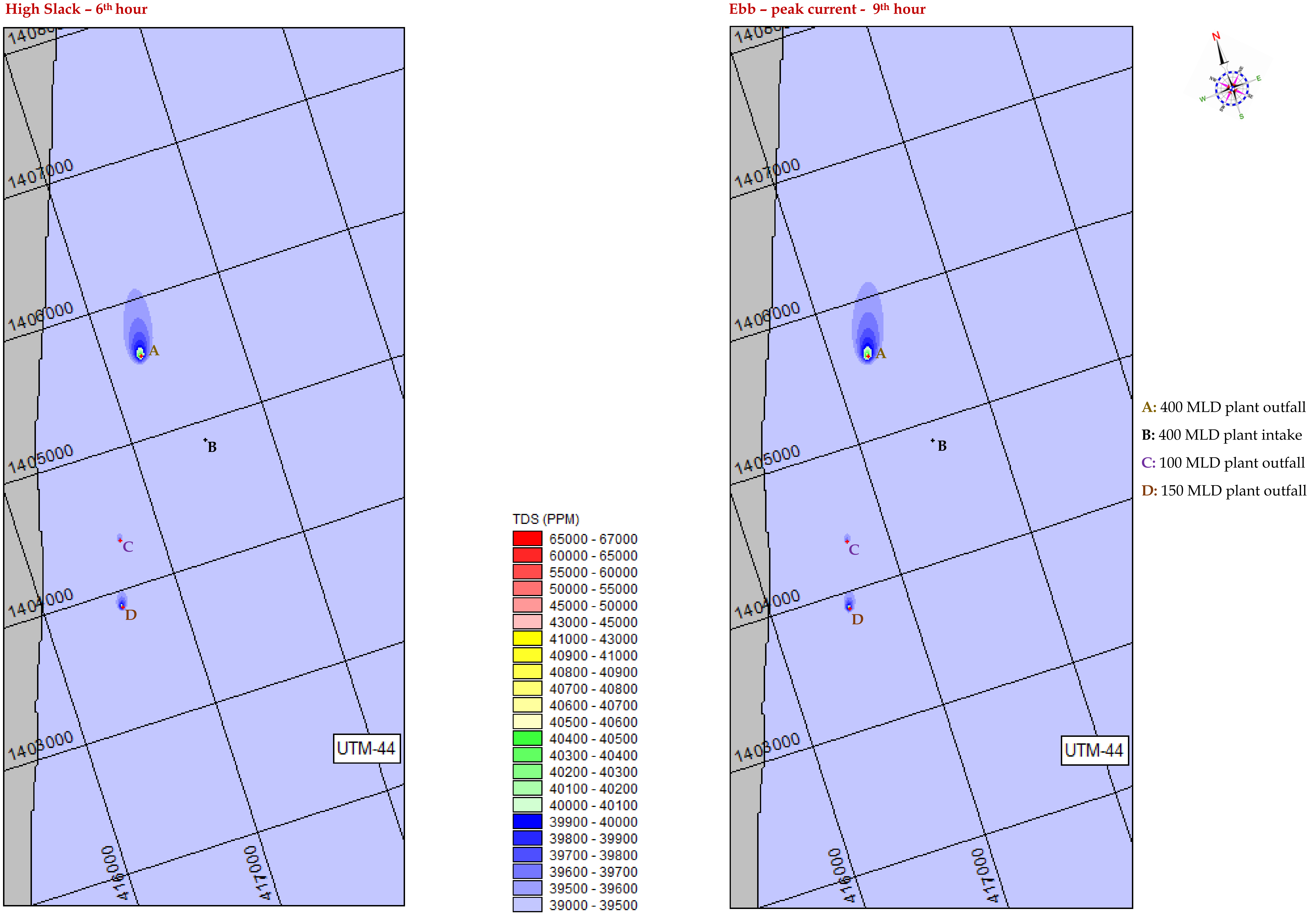


FIG. 5.19(B). SECONDARY DISPERSION – SW MONSOON - SPRING TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

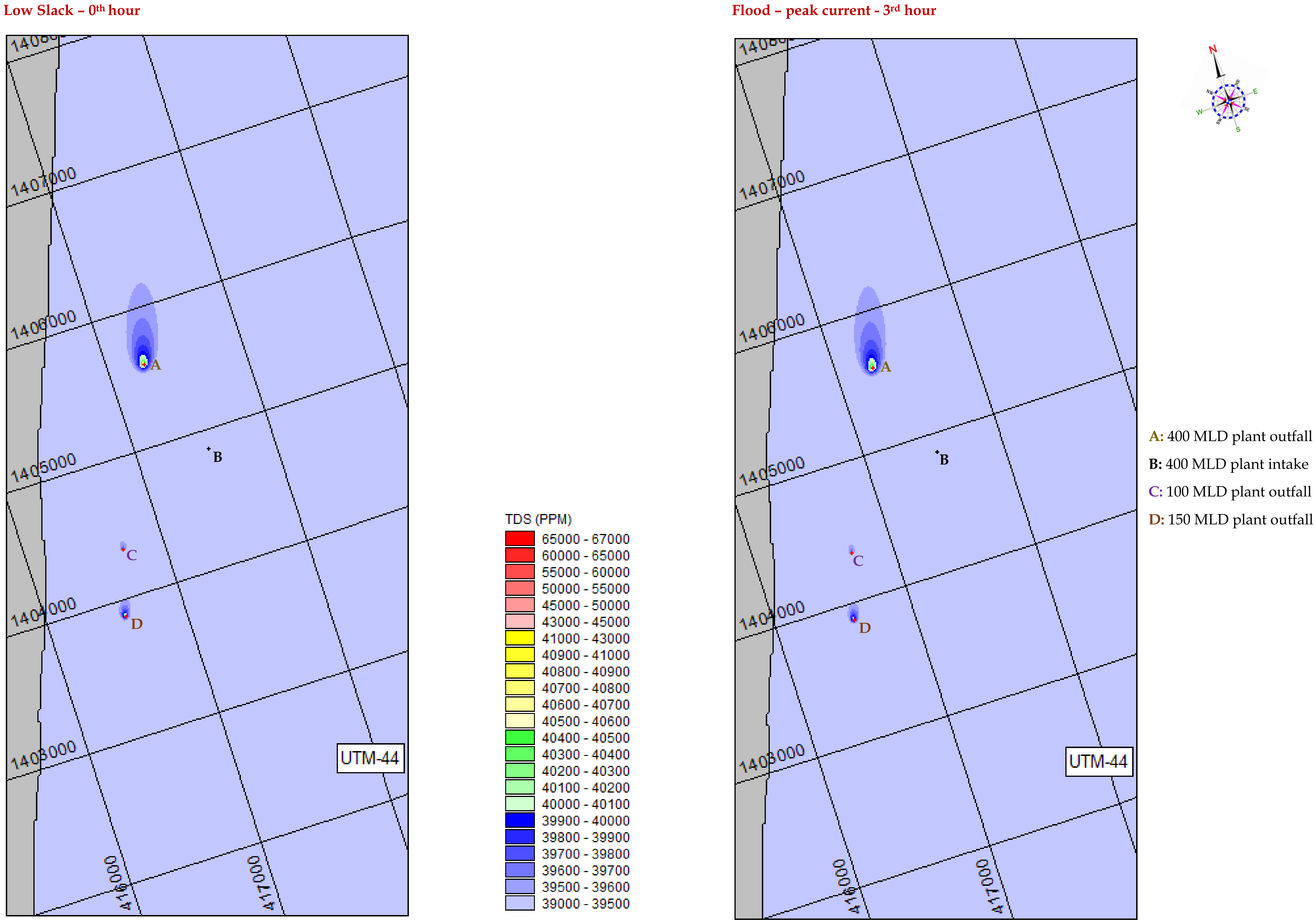


FIG. 5.20(A). SECONDARY DISPERSION – SW MONSOON - NEAP TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

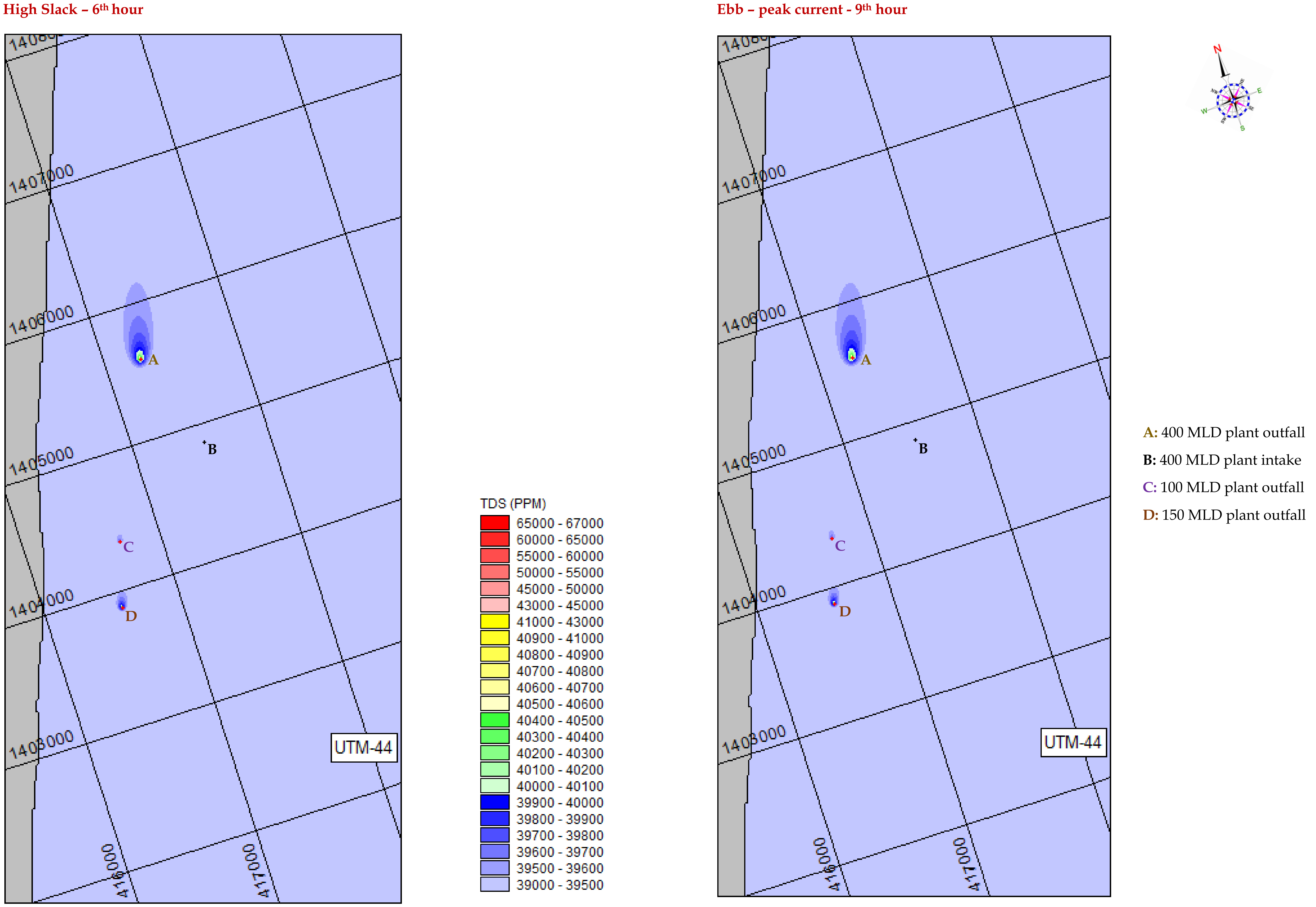


FIG. 5.20(B). SECONDARY DISPERSION – SW MONSOON - NEAP TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

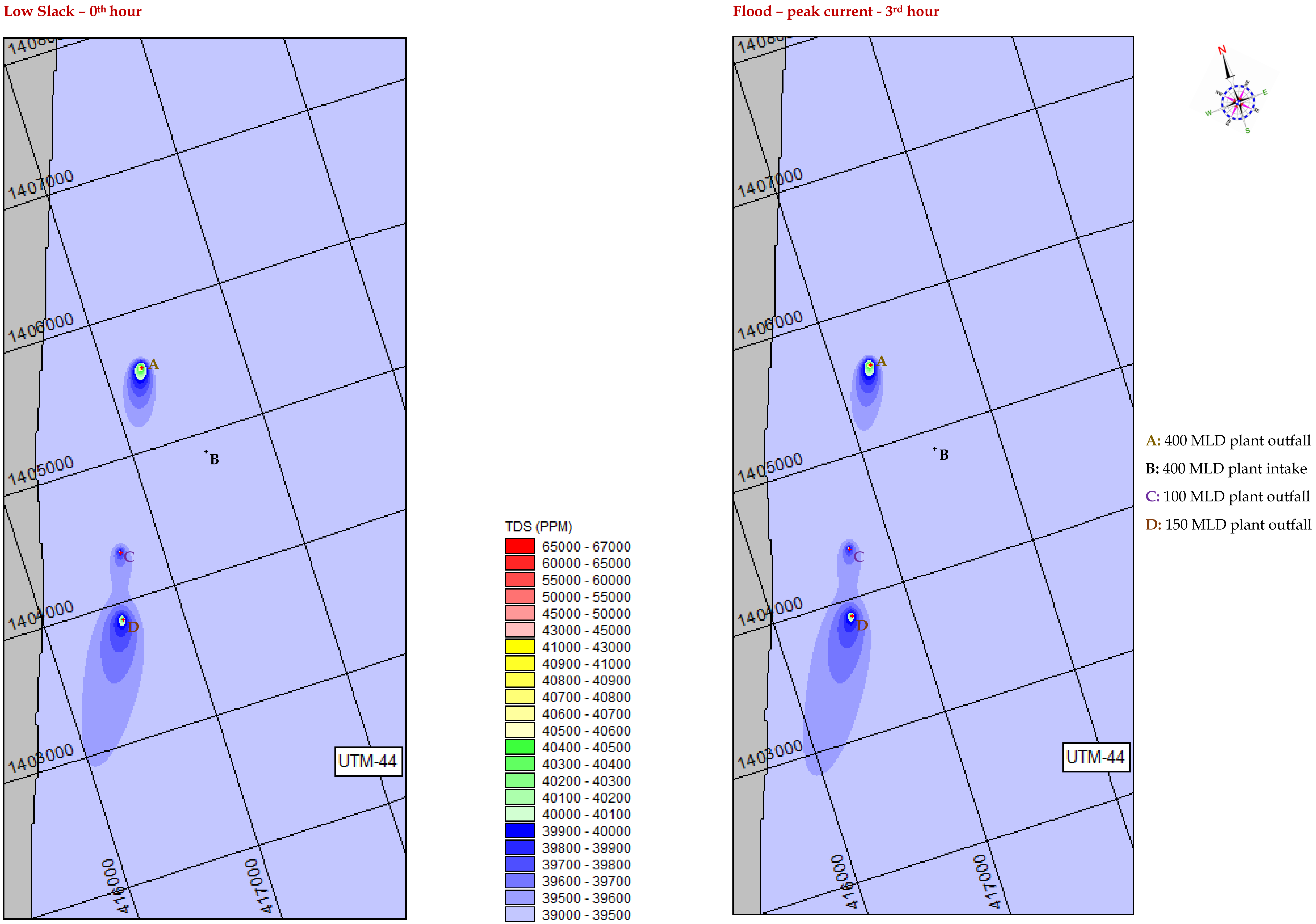


FIG. 5.21(A). SECONDARY DISPERSION – NE MONSOON - SPRING TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

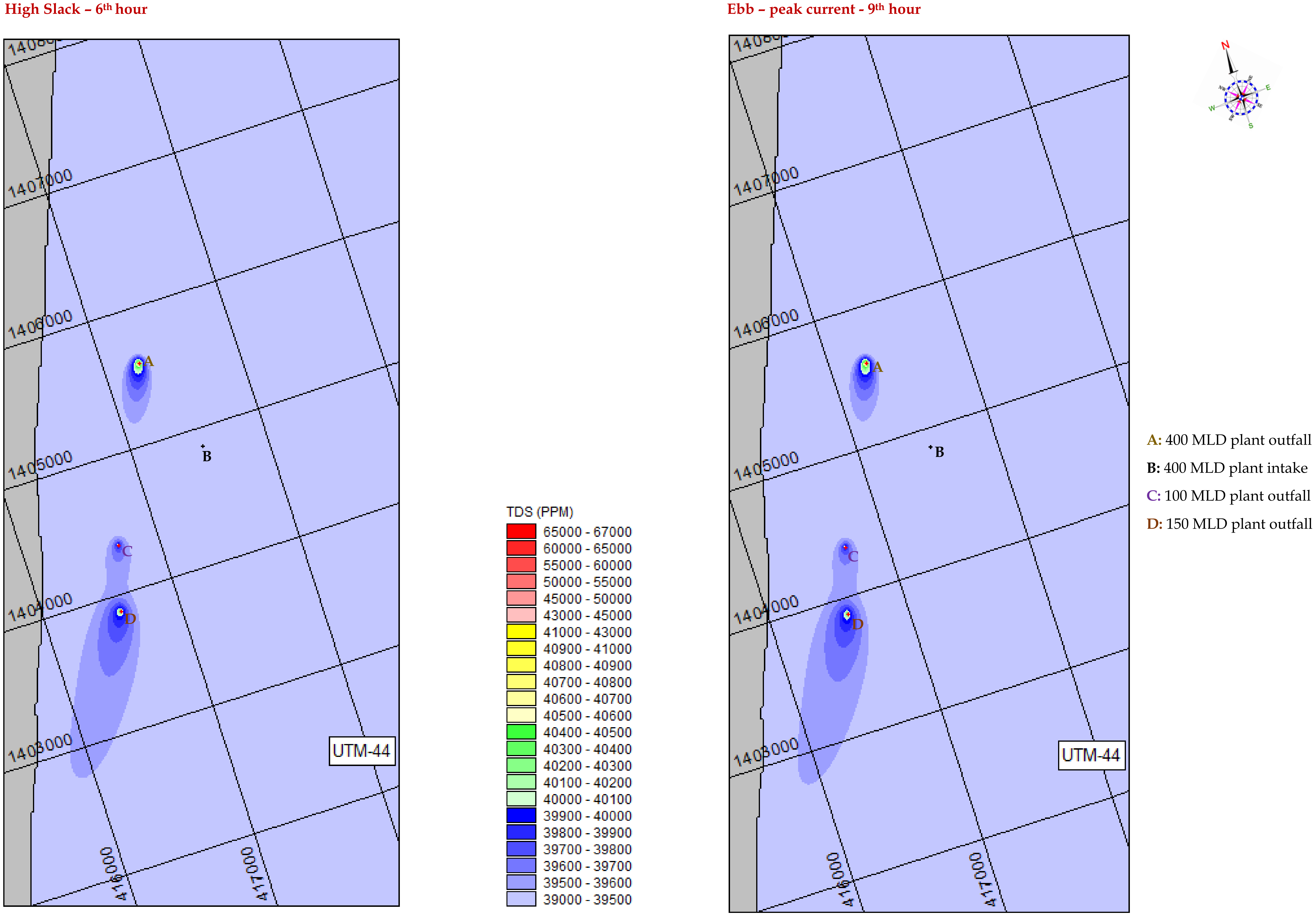


FIG. 5.21(B). SECONDARY DISPERSION – NE MONSOON - SPRING TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

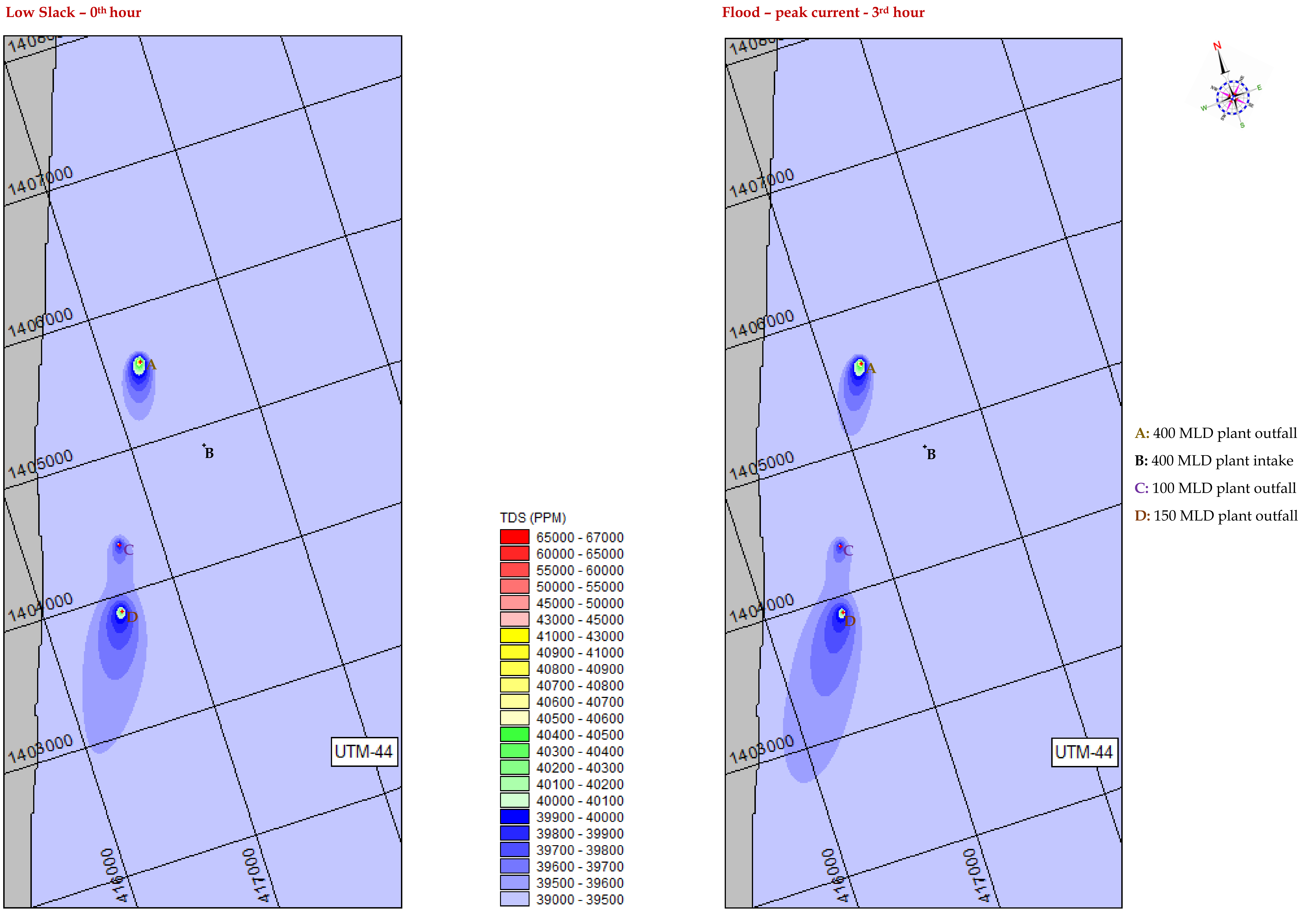


Fig. 5.22(A). SECONDARY DISPERSION – NE MONSOON - NEAP TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

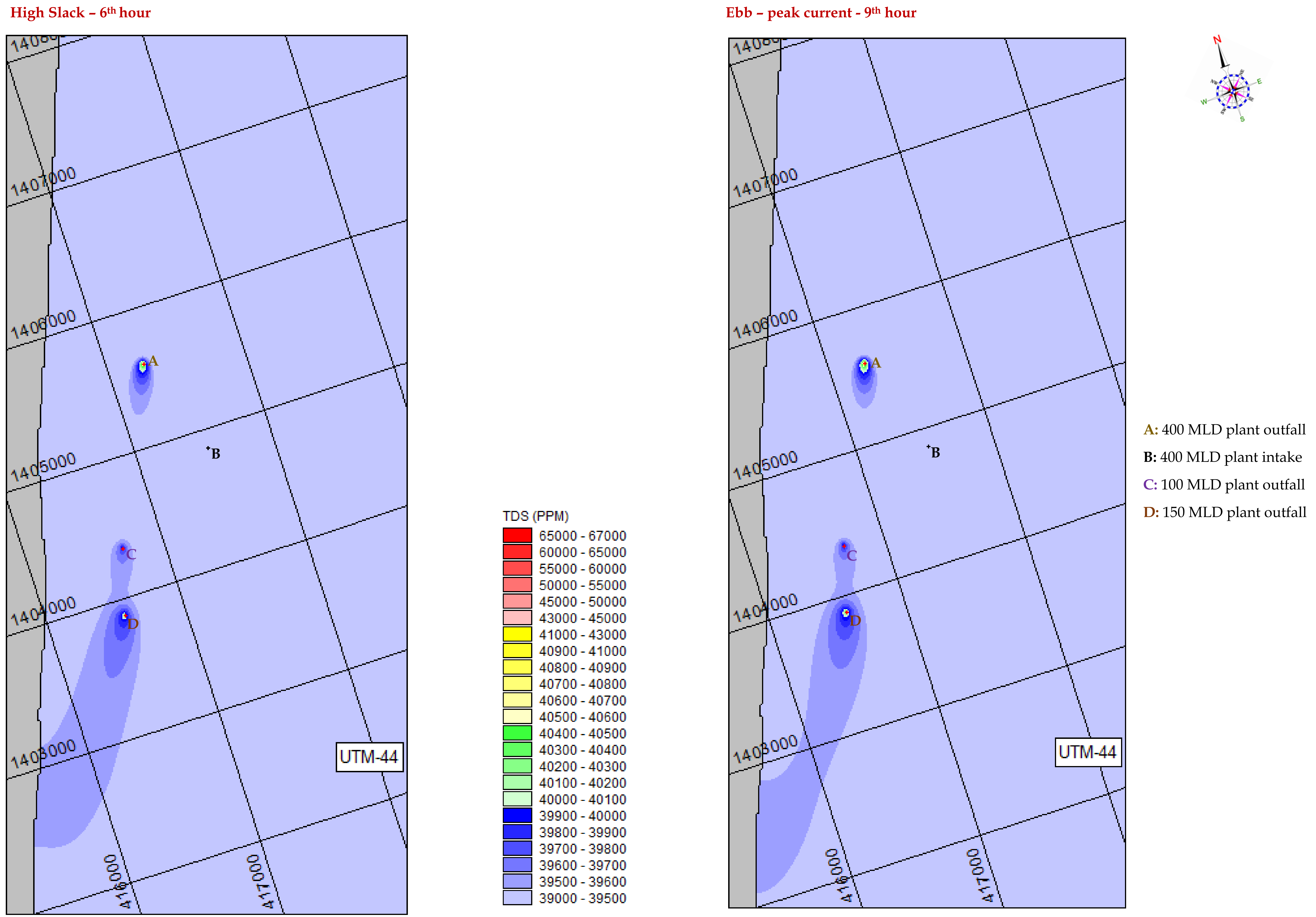
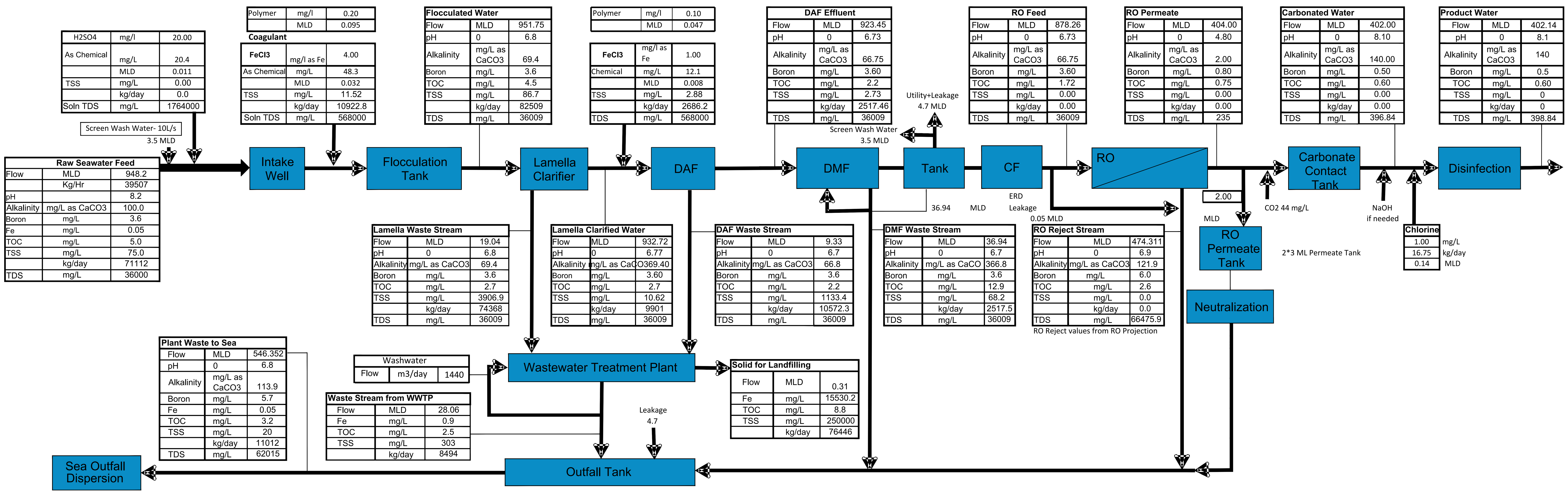


FIG. 5.22(B). SECONDARY DISPERSION – NE MONSOON - NEAP TIDE – CASE III (SUGGESTED BY INDOMER) – (TDS)

Project: Construction of 400MLD DSP at Perur, Chennai
Prepared by : Dr. G. Mustafa

Annexure 4(a) Mass Balance Diagram for Normal Flowrate for 400 MLD Desalination Plant at Perur, Chennai



Dispersion

Mass Balance Checks		Solids due to Seawater TSS + Coagulant	Sludge due to removal of DOC	Total Solid
Flow (MLD)		Solid Tonnes/day		
Inputs	948.49	84.721	0.0	84.7
Outputs	948.49	84.721	2.7	87.5

The following assumptions have been made based on experiences.

Assumptions

1	DOC content of total TOC	90	%
2	DOC removal in Lamella Filter	40	%
3	DOC removal in DAF	20	%
4	DOC removal in DMF	20	%
5	Lamella Clarifier recovery	98	%
6	Lamella Clarifier solid removal efficiency	88	%
7	DAF waste solid removal efficiency	80	%
8	DAF Recovery	99	%
9	DMF Recovery	96	%
10	RO Recovery	46	%
11	Poly purity	100	%
12	Poly solution concentration	0.2	%
13	Density of Poly solution	1000	kg/m3
14	DOC reduction in RO process	80	%
15	DOC reduction in Carbonate tank	20	%
16	Other Utility and Plant leakage - high feed water	0.5	%
17	Solid Recovery Rate in Thickener	90	%
18	Iron removed as solid in sludge treatment	99.5	%
19	TOC removed as solid in sludge treatment	98	%

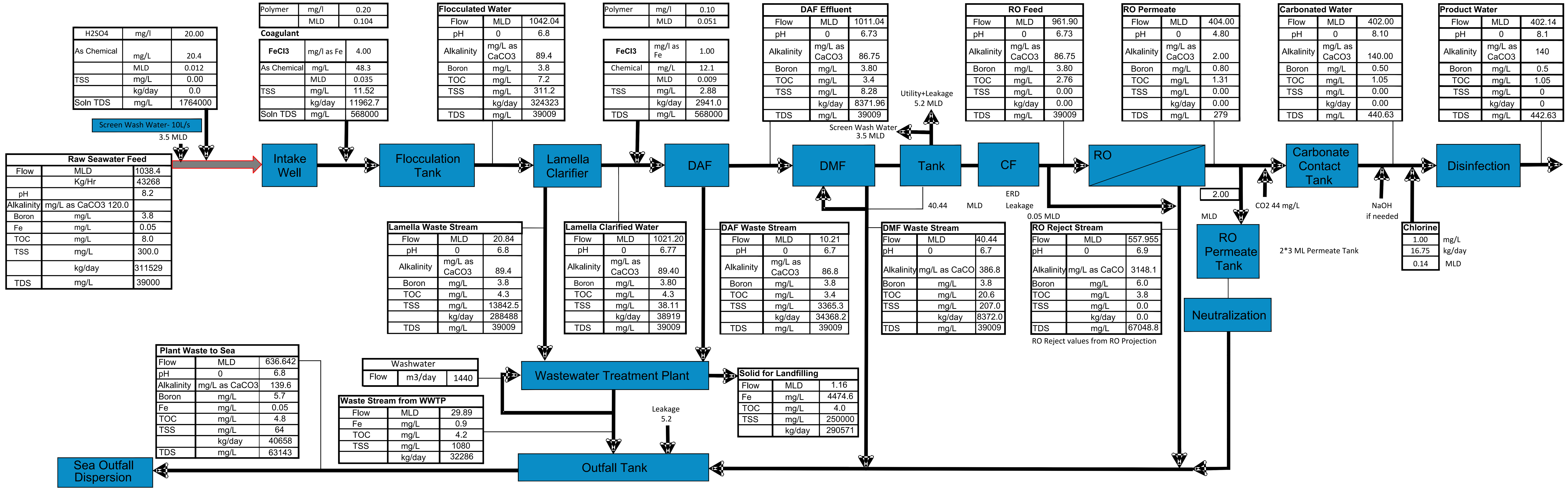
MASS BALANCE AT A GLANCE - NORMAL CASE

Process Stages			
Intake Pumps	948160		
Service Water	2000		
Utility and Leakage		4741	
Lamella + DAF waste		28363	
GMF Backwash		36938	
Pre-filtered water	878311		
Feed water RO+ERD	878311		
Feed to RO	878261		
HP pumps	404000		42.61%
Recir. Pump	474261		50.02%
Feed to ERD	474311		50.02%
RO permeate	404000		42.61%
RO Reject		474311	50.02%
CIP & Flushing		2000	0.21%
Total plant waste discharge		5,46,352	57.62%
Net Plant Product Water	4,02,000		
Overall Plant Recovery	42.4%		

MASS BALANCE DIAGRAM FOR NORMAL FLOWRATE

Project: Construction of 400MLD DSP at Perur, Chennai
Prepared by : Dr. G. Mustafa

Annexure 4(b) Mass Balance Diagram for Maximum Flowrate for 400 MLD Desalination Plant at Perur, Chennai



H2SO4	mg/l	20.00
As Chemical	mg/L	20.4
	MLD	0.012
TSS	mg/L	0.00
	kg/day	0.0
Soln TDS	mg/L	1764000

Polymer	mg/l	0.20
	MLD	0.104
Coagulant		
FeCl3	mg/l as Fe	4.00
As Chemical	mg/L	48.3
	MLD	0.035
TSS	mg/L	11.52
	kg/day	11962.7
Soln TDS	mg/L	568000

Flocculated Water		
Flow	MLD	1042.04
pH	0	6.8
Alkalinity	mg/L as CaCO3	89.4
Boron	mg/L	3.8
TOC	mg/L	7.2
TSS	mg/L	311.2
	kg/day	324323
TDS	mg/L	39009

Polymer	mg/l	0.10
	MLD	0.051
FeCl3	mg/l as Fe	1.00
Chemical	mg/L	12.1
	MLD	0.009
TSS	mg/L	2.88
	kg/day	2941.0
TDS	mg/L	568000

DAF Effluent		
Flow	MLD	1011.04
pH	0	6.73
Alkalinity	mg/L as CaCO3	86.75
Boron	mg/L	3.80
TOC	mg/L	3.4
TSS	mg/L	8.28
	kg/day	8371.96
TDS	mg/L	39009

RO Feed		
Flow	MLD	961.90
pH	0	6.73
Alkalinity	mg/L as CaCO3	86.75
Boron	mg/L	3.80
TOC	mg/L	2.76
TSS	mg/L	0.00
	kg/day	0.00
TDS	mg/L	39009

RO Permeate		
Flow	MLD	404.00
pH	0	4.80
Alkalinity	mg/L as CaCO3	2.00
Boron	mg/L	0.80
TOC	mg/L	1.31
TSS	mg/L	0.00
	kg/day	0.00
TDS	mg/L	279

Carbonated Water		
Flow	MLD	402.00
pH	0	8.10
Alkalinity	mg/L as CaCO3	140.00
Boron	mg/L	0.50
TOC	mg/L	1.05
TSS	mg/L	0.00
	kg/day	0.00
TDS	mg/L	440.63

Product Water		
Flow	MLD	402.14
pH	0	8.1
Alkalinity	mg/L as CaCO3	140
Boron	mg/L	0.5
TOC	mg/L	1.05
TSS	mg/L	0
	kg/day	0
TDS	mg/L	442.63

Raw Seawater Feed		
Flow	MLD	1038.4
	Kg/Hr	43268
pH		8.2
Alkalinity	mg/L as CaCO3 120.0	
Boron	mg/L	3.8
Fe	mg/L	0.05
TOC	mg/L	8.0
TSS	mg/L	300.0
	kg/day	311529
TDS	mg/L	39000

Lamella Waste Stream		
Flow	MLD	20.84
pH	0	6.8
Alkalinity	mg/L as CaCO3	89.4
Boron	mg/L	3.8
TOC	mg/L	4.3
TSS	mg/L	13842.5
	kg/day	288488
TDS	mg/L	39009

Lamella Clarified Water		
Flow	MLD	1021.20
pH	0	6.77
Alkalinity	mg/L as CaCO3	89.40
Boron	mg/L	3.80
TOC	mg/L	4.3
TSS	mg/L	38.11
	kg/day	38919
TDS	mg/L	39009

DAF Waste Stream		
Flow	MLD	10.21
pH	0	6.7
Alkalinity	mg/L as CaCO3	86.8
Boron	mg/L	3.8
TOC	mg/L	3.4
TSS	mg/L	3365.3
	kg/day	34368.2
TDS	mg/L	39009

DMF Waste Stream		
Flow	MLD	40.44
pH	0	6.7
Alkalinity	mg/L as CaCO3	386.8
Boron	mg/L	3.8
TOC	mg/L	20.6
TSS	mg/L	207.0
	kg/day	8372.0
TDS	mg/L	39009

RO Reject Stream		
Flow	MLD	557.955
pH	0	6.9
Alkalinity	mg/L as CaCO	3148.1
Boron	mg/L	6.0
TOC	mg/L	3.8
TSS	mg/L	0.0
	kg/day	0.0
TDS	mg/L	67048.8

RO Reject values from RO Projection

Chlorine	
1.00	mg/L
16.75	kg/day
0.14	MLD

Plant Waste to Sea		
Flow	MLD	636.642
pH	0	6.8
Alkalinity	mg/L as CaCO3	139.6
Boron	mg/L	5.7
Fe	mg/L	0.05
TOC	mg/L	4.8
TSS	mg/L	64
	kg/day	40658
TDS	mg/L	63143

Washwater		
Flow	m3/day	1440

Waste Stream from WWTP		
Flow	MLD	29.89
Fe	mg/L	0.9
TOC	mg/L	4.2
TSS	mg/L	1080
	kg/day	32286

Solid for Landfilling		
Flow	MLD	1.16
Fe	mg/L	4474.6
TOC	mg/L	4.0
TSS	mg/L	250000
	kg/day	290571

Dispersion

Mass Balance Checks		Solids due to Seawater TSS + Coagulant	Sludge due to removal of DOC	Total Solid
	Flow (MLD)	Solid Tonnes/day		
Inputs	1038.78	326.433	0.0	326.4
Outputs	1038.78	326.433	4.8	331.2

The following assumptions have been made based on experiences.

Assumptions

1	DOC content of total TOC	90	%
2	DOC removal in Lamella Filter	40	%
3	DOC removal in DAF	20	%
4	DOC removal in DMF	20	%
5	Lamella Clarifier recovery	98	%
6	Lamella Clarifier solid removal efficiency	88	%
7	DAF waste solid removal efficiency	80	%
8	DAF Recovery	99	%
9	DMF Recovery	96	%
10	RO Recovery	42	%
11	Poly purity	100	%
12	Poly solution concentration	0.2	%
13	Density of Poly solution	1000	kg/m3
14	DOC reduction in RO process	80	%
15	DOC reduction in Carbonate tank	20	%
16	Other Utility and Plant leakage - high feed water	0.5	%
17	Solid Recovery Rate in Thickener	90	%
18	Iron removed as solid in sludge treatment	99.5	%
19	TOC removed as solid in sludge treatment	98	%

Mass Balance at a glance - Max Case

Process Stages	Process water	Wastewater	Rate wrt Feed
Intake Pumps	1038431		100.00%
Service Water	2000		0.19%
Utility and Leakage		5192	0.50%
Lamella + DAF waste		31053	2.99%
GMF Backwash		40442	3.89%
Pre-filtered water	961955		92.64%
Feed water RO+ERD	0		0.00%
Feed to RO	961905		92.63%
HP pumps	404000		38.90%
Recir. Pump	0		0.00%
Feed to ERD	0		0.00%
RO permeate	404000		38.90%
RO Reject		557955	53.73%
CIP & Flushing		2000	0.19%
Total plant waste discharge		6,36,642	61.31%
Net Plant Product Water	4,02,000		
Overall Plant Recovery	38.7%		

MASS BALANCE DIAGRAM FOR MAXIMUM FLOWRATE

ANNEXURE 5
RO DESIGN PROJECTION

Calculated by	Dr. G. Mustafa		Permeate flow/train	25.250 mld
HP Pump flow	1064.33 m3/h		Raw water flow/train	57.386 mld
Feed pressure	64.5 bar		Permeate recovery	44.00 %
Feed temperature	31.5 °C(88.7°F)		Element age	3.5 years
Feed water pH	8.40		Flux decline %, per year	7.0
Chem dose, mg/l, 50 %	7.7 NaOH		Fouling factor	0.78
Leakage	1 %		SP increase, per year	10.0 %
Volumetric mixing	6 %			
H.P. differential	0.50 bar			
Boost pressure	2.39 bar			
Specific energy	2.36 kwh/m3			
Pass NDP	19.6 bar			
Average flux rate	13.4 lmh			
			Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	594.2	10	7.5	20.2	0.9	24.8	1.04	1.5	0	63.6	170.9	SWC4 MAX	720	240 x 3M
1-1-h	456.8	7.5	5.6	9.3	1	16.5	1.03	1.5	0	62.7	397.6	SWC5 MAX	1200	240 x 5M

Ion (mg/l)	Raw Water	Blended Water	Feed Water	Permeate Water	Concentrate	ERD Reject
Hardness, as CaCO3	6732.79	6919.25	6919.25	15.741	12334.1	11998.02
Ca	480.00	493.29	493.29	1.122	879.3	855.37
Mg	1350.00	1387.39	1387.39	3.156	2473.1	2405.74
Na	12905.00	13261.49	13261.49	144.508	23549.9	22911.29
K	409.00	420.19	420.19	5.720	745.3	725.11
NH4	0.20	0.18	0.18	0.003	0.3	0.31
Ba	0.450	0.462	0.462	0.001	0.8	0.80
Sr	0.100	0.103	0.103	0.000	0.2	0.18
H	0.00	0.00	0.00	0.000	0.0	0.00
CO3	15.05	32.91	32.91	0.002	67.8	65.66
HCO3	99.41	83.92	83.92	1.498	111.7	109.99
SO4	2972.00	3054.29	3054.29	7.601	5444.0	5295.68
Cl	22755.00	23380.23	23380.23	232.326	41536.4	40409.57
F	1.63	1.67	1.67	0.033	3.0	2.88
NO3	4.00	4.10	4.10	0.301	7.1	6.90
PO4	0.10	0.10	0.10	0.000	0.2	0.18
OH	0.20	0.51	0.51	0.004	0.8	0.78
SiO2	1.38	1.42	1.42	0.011	2.5	2.45
B	3.80	3.88	3.88	0.944	6.2	6.04
CO2	0.43	0.15	0.15	0.15	0.20	0.20
NH3	0.02	0.04	0.04	0.04	0.04	0.04
TDS	**40997.12**	**42125.64**	**42125.64**	**397.23**	**74827.84**	**72798.15**
pH	**8.00**	**8.40**	**8.40**	**7.15**	**8.44**	**8.44**

Saturations	**Raw Water**	**Feed Water**	**Concentrate**	**Limits**

Version : 2.228.86 %

CaSO4 / ksp * 100, %	23	24	50	400
SrSO4 / ksp * 100, %	0	0	1	1200
BaSO4 / ksp * 100, %	1750	1805	3497	10000
SiO2 saturation, %	1	1	1	140
CaF2 / ksp * 100, %	58	63	580	50000
Ca3(PO4)2 saturation index	0.2	0.6	1.5	2.4
CCPP, mg/l	20.45	17.62	36.27	850
Ionic strength	0.80	0.83	1.47	
Osmotic pressure, bar	30.8	31.6	56.2	

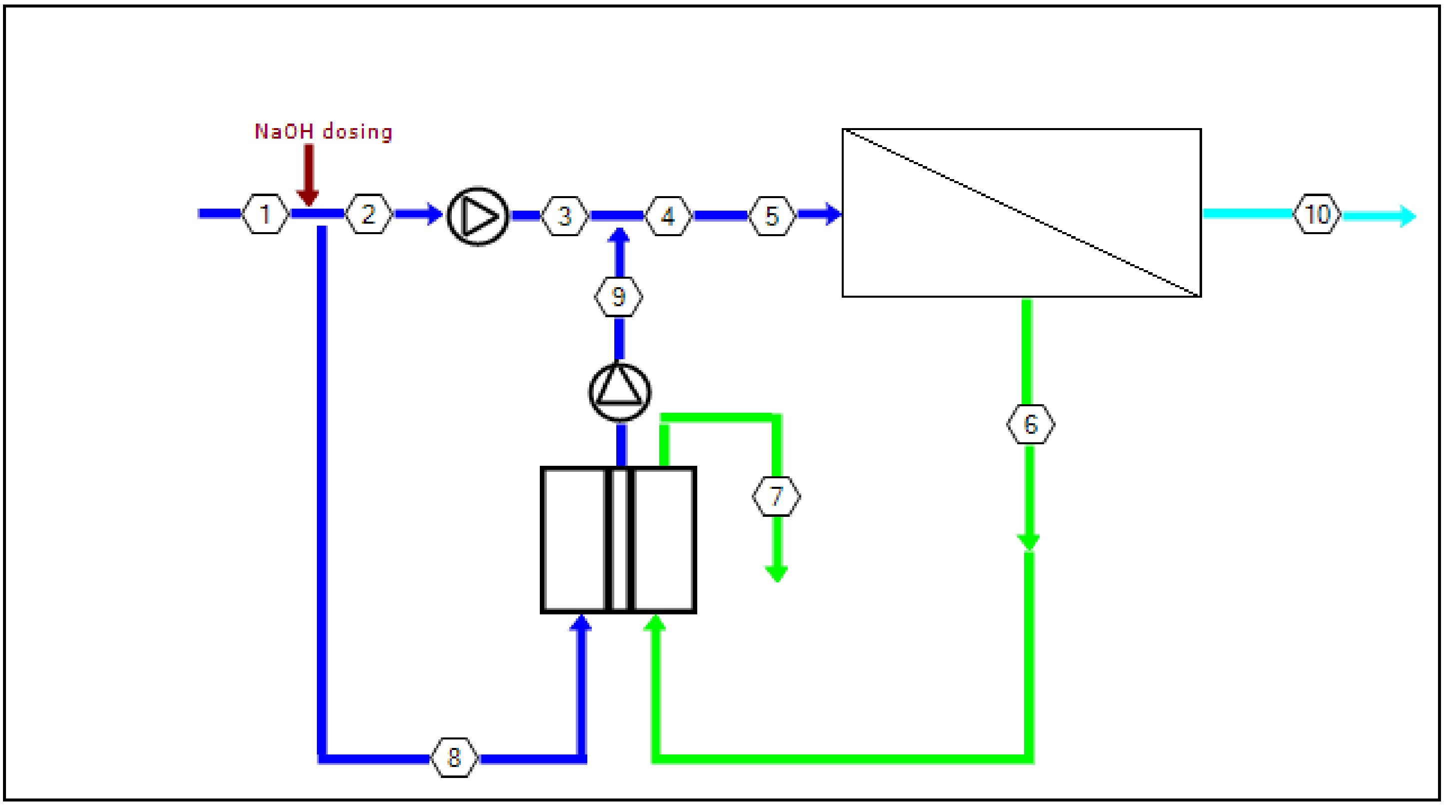
Calculated by	Dr. G. Mustafa	Permeate flow/train	25.250 mld
HP Pump flow	1064.33 m3/h	Raw water flow/train	57.386 mld
Feed pressure	64.5 bar	Permeate recovery	44.00 %
Feed temperature	31.5 °C(88.7°F)	Element age	3.5 years
Feed water pH	8.40	Flux decline %, per year	7.0
Chem dose, mg/l, 50 %	7.7 NaOH	Fouling factor	0.78
Leakage	1 %	SP increase, per year	10.0 %
Volumetric mixing	6 %		
H.P. differential	0.50 bar		
Boost pressure	2.39 bar		
Specific energy	2.36 kwh/m3		
Pass NDP	19.6 bar		
Average flux rate	13.4 lmh	Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	594.2	10	7.5	20.2	0.9	24.8	1.04	1.5	0	63.6	170.9	SWC4 MAX	720	240 x 3M
1-1-h	456.8	7.5	5.6	9.3	1	16.5	1.03	1.5	0	62.7	397.6	SWC5 MAX	1200	240 x 5M

Pass - Stage	Element No.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	Permeate (Stagewise cumulative) TDS	Ca	HCO3	Cl	NO3	B
1-1	1	64.5	0.36	35.2	28.7	1	24.8	1.04	126.9	0.358	0.479	74.21	0.097	0.314
1-1	2	64.2	0.31	38.7	24.6	0.8	20	1.03	147.3	0.416	0.556	86.128	0.113	0.364
1-1	3	63.9	0.27	42	20.8	0.6	15.8	1.03	170.9	0.482	0.645	99.932	0.131	0.414
1-1	4	63.6	0.24	46.1	16.6	0.7	16.5	1.03	208.5	0.588	0.787	121.935	0.159	0.521
1-1	5	63.4	0.21	49.6	12.9	0.5	11.7	1.03	250.5	0.707	0.945	146.46	0.191	0.626
1-1	6	63.2	0.18	52.4	9.8	0.3	8.3	1.02	296.5	0.837	1.119	173.397	0.225	0.731
1-1	7	63	0.17	54.5	7.5	0.2	5.9	1.01	345.7	0.976	1.304	202.149	0.262	0.838
1-1	8	62.8	0.16	56.2	5.7	0.2	4.2	1.01	397.6	1.123	1.499	232.55	0.301	0.945

Temperature : 31.5 °C

Element age, P1 : 3.5 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	Hardness as CaCO3	Cl	B	pH
1	2391	0	40997	6733	22755	3.80	8.00
2	1064	0	41000	6733	22755	3.80	8.40
3	1064	64.5	41000	6733	22755	3.80	8.40
4	2391	64.5	42126	6919	23380	3.88	8.40
5	2391	64.5	42126	6919	23380	3.88	8.40
6	1340	62.7	74828	12334	41536	6.18	8.44
7	1340	0	72798	11998	40410	6.04	8.44
8	1326	0	41000	6733	22755	3.80	8.40
9	1326	64.5	43029	7069	23882	3.94	8.40
10	1052	1.50	397	15.7	232	0.944	7.15

Calculated by	Dr. G. Mustafa	Permeate flow/train	25.250 mld
HP Pump flow	1064.33 m3/h	Raw water flow/train	57.386 mld
Feed pressure	64.5 bar	Permeate recovery	44.00 %
Feed temperature	31.5 °C(88.7°F)	Element age	3.5 years
Feed water pH	8.40	Flux decline %, per year	7.0
Chem dose, mg/l, 50 %	7.7 NaOH	Fouling factor	0.78
Leakage	1 %	SP increase, per year	10.0 %
Volumetric mixing	6 %		
H.P. differential	0.50 bar		
Boost pressure	2.39 bar		
Specific energy	2.36 kwh/m3		
Pass NDP	19.6 bar		
Average flux rate	13.4 lmh		
		Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow	Flow / Vessel Feed	Conc	Flux	DP	Flux Max	Beta	Stagewise Pressure Perm.	Boost	Conc	Perm. TDS	Element Type	Element Quantity	PV# x Elem #
	m3/h	m3/h	m3/h	lmh	bar	lmh		bar	bar	bar	mg/l			
1-1-h	594.2	10	7.5	20.2	0.9	24.8	1.04	1.5	0	63.6	170.9	SWC4 MAX	720	240 x 3M
1-1-h	456.8	7.5	5.6	9.3	1	16.5	1.03	1.5	0	62.7	397.6	SWC5 MAX	1200	240 x 5M

CALCULATION OF INVESTMENT AND WATER COST

Plant capacity as permeate	0.000 mld
Specific investment	0.00 INR/mld
Investment	000.00 INR
Plant life	0.0 years
Membrane life	0.0 years
Interest rate	0.0 %
Membrane cost	0.00 INR/element
Plant factor	0.0 %
Number of elements	1920.0
Power cost	0.000 INR/kwhr
Inhibitor cost	0.00
Power consumption	2.36 kwhr/m3
Inhibitor dosing	0.0
Maintenance(as % of investment)	0.0 %
Acid cost	0.00
Acid dosing	3.83

CALCULATION RESULTS

Capital cost	0.00 INR/m3
Power cost	0.00 INR/m3
Chemicals cost	0.00 INR/m3
Membrane replacement costs	0.00 INR/m3
Maintenance	0.00 INR/m3
Total water cost	0.00 INR/m3

400 MLD Perur DSP | Membrane – 3 SWC4MAX & 5 SWC5MAX | Max TDS-41000 mg/l, Temp 31.5C, Rec 46%

Calculated by	Dr. G. Mustafa		Permeate flow/train	25.250 mld
HP Pump flow		1063.58 m3/h	Raw water flow/train	54.891 mld
Feed pressure		66.3 bar	Permeate recovery	46.00 %
Feed temperature		31.5 °C(88.7°F)	Element age	3.5 years
Feed water pH		8.40	Flux decline %, per year	7.0
Chem dose, mg/l, 50 %		7.7 NaOH	Fouling factor	0.78
Leakage		1 %	SP increase, per year	10.0 %
Volumetric mixing		6 %		
H.P. differential		0.50 bar		
Boost pressure		2.21 bar		
Specific energy		2.41 kwh/m3		
Pass NDP		20.6 bar		
Average flux rate		13.4 lmh		
			Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Boost bar	Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	615.6	9.5	7	20.9	0.9	26	1.04	1.5	0	65.4	167.9	SWC4 MAX	720	240 x 3M
1-1-h	435.6	7	5.1	8.9	0.9	16.3	1.04	1.5	0	64.5	410.7	SWC5 MAX	1200	240 x 5M

Ion (mg/l)	Raw Water	Blended Water	Feed Water	Permeate Water	Concentrate	ERD Reject
Hardness, as CaCO3	6732.79	6927.77	6927.77	16.265	12807.8	12443.29
Ca	480.00	493.90	493.90	1.160	913.1	887.12
Mg	1350.00	1389.10	1389.10	3.261	2568.1	2495.02
Na	12905.00	13277.56	13277.56	149.295	24446.5	23754.11
K	409.00	420.70	420.70	5.909	773.6	751.71
NH4	0.20	0.18	0.18	0.003	0.3	0.32
Ba	0.450	0.463	0.463	0.001	0.9	0.83
Sr	0.100	0.103	0.103	0.000	0.2	0.18
H	0.00	0.00	0.00	0.000	0.0	0.00
CO3	15.05	33.00	33.00	0.002	71.9	69.53
HCO3	99.41	83.92	83.92	1.546	112.9	111.09
SO4	2972.00	3058.05	3058.05	7.854	5653.0	5492.17
Cl	22755.00	23408.60	23408.60	240.024	43119.4	41897.56
F	1.63	1.68	1.68	0.034	3.1	2.99
NO3	4.00	4.11	4.11	0.311	7.3	7.14
PO4	0.10	0.10	0.10	0.000	0.2	0.18
OH	0.20	0.51	0.51	0.004	0.9	0.83
SiO2	1.38	1.42	1.42	0.011	2.6	2.54
B	3.80	3.88	3.88	0.959	6.4	6.21
CO2	0.43	0.15	0.15	0.15	0.20	0.20
NH3	0.02	0.04	0.04	0.04	0.04	0.04
TDS	**40997.12**	**42176.76**	**42176.76**	**410.37**	**77679.48**	**75478.71**

pH	**8.00**	**8.40**	**8.40**	**7.17**	**8.46**	**8.46**

Saturations	**Raw Water**	**Feed Water**	**Concentrate**	**Limits**
CaSO4 / ksp * 100, %	23	24	52	400
SrSO4 / ksp * 100, %	0	0	1	1200
BaSO4 / ksp * 100, %	1750	1808	3651	10000
SiO2 saturation, %	1	1	1	140
CaF2 / ksp * 100, %	58	64	683	50000
Ca3(PO4)2 saturation index	0.2	0.6	1.6	2.4
CCPP, mg/l	20.45	17.63	37.49	850
Ionic strength	0.80	0.83	1.53	
Osmotic pressure, bar	30.8	31.7	58.3	

400 MLD Perur DSP | Membrane – 3 SWC4MAX & 5 SWC5MAX | Max TDS-41000 mg/l, Temp 31.5C, Rec 46%

Calculated by	Dr. G. Mustafa	Permeate flow/train	25.250 mld
HP Pump flow	1063.58 m3/h	Raw water flow/train	54.891 mld
Feed pressure	66.3 bar	Permeate recovery	46.00 %
Feed temperature	31.5 °C(88.7°F)	Element age	3.5 years
Feed water pH	8.40	Flux decline %, per year	7.0
Chem dose, mg/l, 50 %	7.7 NaOH	Fouling factor	0.78
Leakage	1 %	SP increase, per year	10.0 %
Volumetric mixing	6 %		
H.P. differential	0.50 bar		
Boost pressure	2.21 bar		
Specific energy	2.41 kwh/m3		
Pass NDP	20.6 bar		
Average flux rate	13.4 lmh		

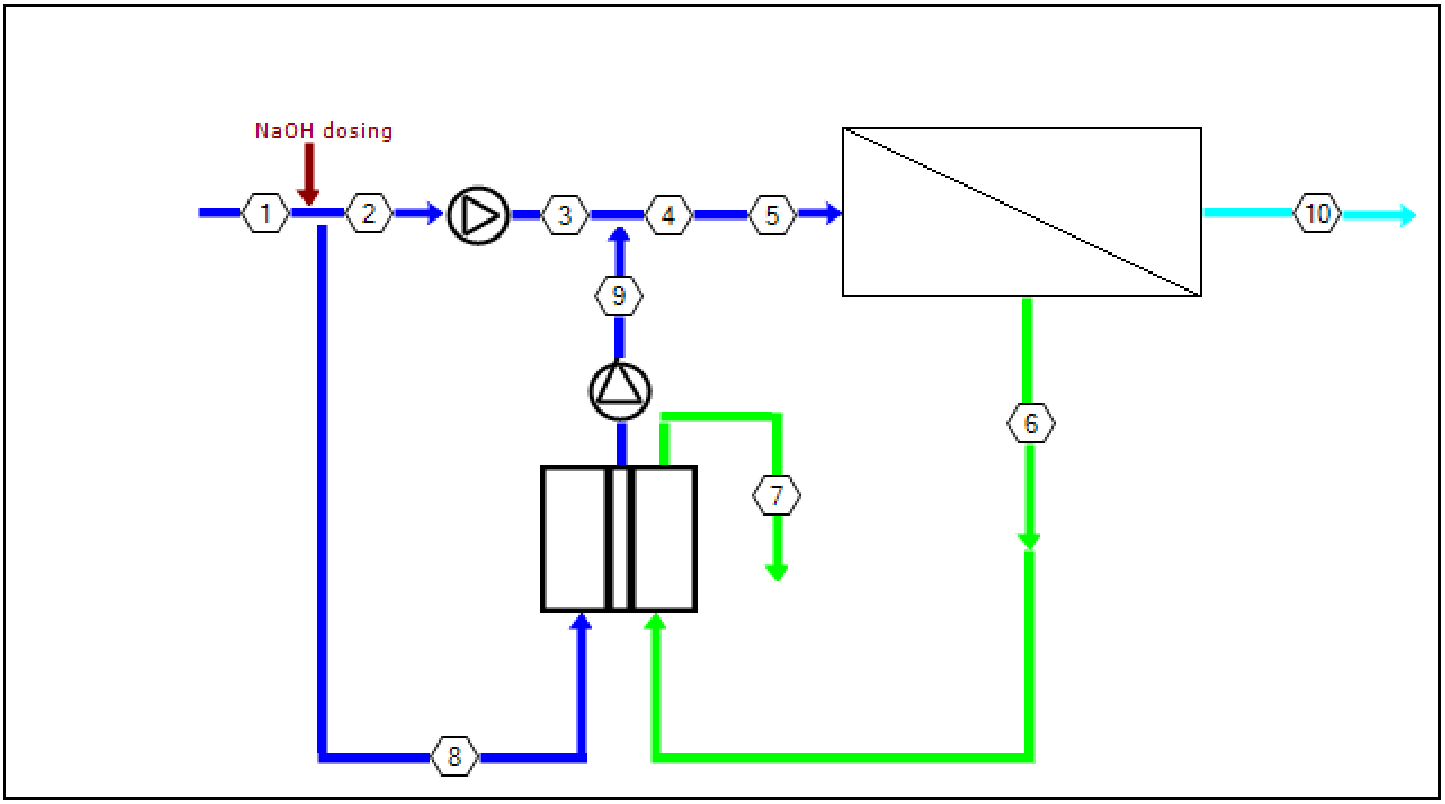
Feed type: Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	615.6	9.5	7	20.9	0.9	26	1.04	1.5	0	65.4	167.9	SWC4 MAX	720	240 x 3M
1-1-h	435.6	7	5.1	8.9	0.9	16.3	1.04	1.5	0	64.5	410.7	SWC5 MAX	1200	240 x 5M

Pass - Stage	Element No.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	Permeate (Stagewise cumulative) TDS	Ca	HCO3	Cl	NO3	B
1-1	1	66.3	0.33	35.6	30	1.1	26	1.04	122.4	0.345	0.462	71.58	0.094	0.302
1-1	2	65.9	0.28	39.5	25.6	0.8	20.5	1.03	143.7	0.405	0.542	84.029	0.11	0.354
1-1	3	65.6	0.24	43.3	21.7	0.7	16.3	1.03	167.9	0.474	0.633	98.157	0.128	0.405
1-1	4	65.4	0.21	47.8	16.9	0.7	16.3	1.04	208.1	0.587	0.784	121.685	0.159	0.516
1-1	5	65.2	0.18	51.5	12.8	0.5	11.2	1.03	253.1	0.715	0.954	148.01	0.193	0.626
1-1	6	65	0.16	54.4	9.6	0.3	7.6	1.02	302.6	0.854	1.14	176.94	0.23	0.737
1-1	7	64.8	0.15	56.6	7.3	0.2	5.4	1.01	355.2	1.003	1.338	207.723	0.269	0.848
1-1	8	64.7	0.14	58.3	5.4	0.2	3.7	1.01	410.7	1.16	1.547	240.19	0.311	0.96

400 MLD Perur DSP Membrane – 3 SWC4MAX & 5 SWC5MAX Max TDS-41000 mg/l, Temp 31.5C, Rec 46%

Temperature : 31.5 °C Element age, P1 : 3.5 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	Hardness as CaCO3	Cl	B	pH
1	2287	0	40997	6733	22755	3.80	8.00
2	1064	0	41000	6733	22755	3.80	8.40
3	1064	66.3	41000	6733	22755	3.80	8.40
4	2287	66.3	42177	6928	23409	3.88	8.40
5	2287	66.3	42177	6928	23409	3.88	8.40
6	1236	64.5	77679	12808	43119	6.37	8.46
7	1236	0	75479	12443	41898	6.21	8.46
8	1223	0	41000	6733	22755	3.80	8.40
9	1223	66.3	43200	7097	23977	3.95	8.40
10	1052	1.50	410	16.3	240	0.959	7.17

Calculated by	Dr. G. Mustafa		Permeate flow/train	25.250 mld
HP Pump flow		1063.58 m3/h	Raw water flow/train	54.891 mld
Feed pressure		66.3 bar	Permeate recovery	46.00 %
Feed temperature		31.5 °C(88.7°F)	Element age	3.5 years
Feed water pH		8.40	Flux decline %, per year	7.0
Chem dose, mg/l, 50 %		7.7 NaOH	Fouling factor	0.78
Leakage		1 %	SP increase, per year	10.0 %
Volumetric mixing		6 %		
H.P. differential		0.50 bar		
Boost pressure		2.21 bar		
Specific energy		2.41 kwh/m3		
Pass NDP		20.6 bar		
Average flux rate		13.4 lmh		
			Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	615.6	9.5	7	20.9	0.9	26	1.04	1.5	0	65.4	167.9	SWC4 MAX	720	240 x 3M
1-1-h	435.6	7	5.1	8.9	0.9	16.3	1.04	1.5	0	64.5	410.7	SWC5 MAX	1200	240 x 5M

CALCULATION OF INVESTMENT AND WATER COST

Plant capacity as permeate	0.000 mld
Specific investment	0.00 INR/mld
Investment	000.00 INR
Plant life	0.0 years
Membrane life	0.0 years
Interest rate	0.0 %
Membrane cost	0.00 INR/element
Plant factor	0.0 %
Number of elements	1920.0
Power cost	0.000 INR/kwhr
Inhibitor cost	0.00
Power consumption	2.41 kwhr/m3
Inhibitor dosing	0.0
Maintenance(as % of investment)	0.0 %
Acid cost	0.00
Acid dosing	3.83

CALCULATION RESULTS

Capital cost	0.00 INR/m3
Power cost	0.00 INR/m3
Chemicals cost	0.00 INR/m3
Membrane replacement costs	0.00 INR/m3
Maintenance	0.00 INR/m3
Total water cost	0.00 INR/m3

400 MLD Perur DSP Membrane – 3 SWC4MAX & 5 SWC5MAX Avg TDS-35942 mg/l, Temp 28.3C, Rec-44%

Calculated by	MORILLON	
HP Pump flow	1064.67	m3/h
Feed pressure	56.8	bar
Feed temperature	28.3	°C(82.9°F)
Feed water pH	8.20	
Chem dose, mg/l, 50 %	1.2	NaOH
Leakage	1	%
Volumetric mixing	4	%
H.P. differential	0.80	bar
Boost pressure	2.72	bar
Specific energy	2.11	kwh/m3
Pass NDP	18.1	bar
Average flux rate	13.4	lmh

Permeate flow/train	1052.00	m3/h
Total product flow	16832.00	m3/h
Number of trains	16	
Raw water flow/train	2390.91	m3/h
Permeate recovery	44.00	%
Element age	3.5	years
Flux decline %, per year	7.0	
Fouling factor	0.78	
SP increase, per year	10.0	%
Feed type	Sea Surface Conventional	

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Boost bar	Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	553.1	10	7.7	18.8	0.9	22.2	1.03	1.5	0	55.8	137.6	SWC4 MAX	720	240 x 3M
1-1-h	498.1	7.7	5.6	10.2	1	17	1.03	1.5	0	54.8	299.1	SWC5 MAX	1200	240 x 5M

Ion (mg/l)	Raw Water	Blended Water	Feed Water	Permeate Water	Concentrate	ERD Reject
Hardness, as CaCO3	6323.24	6437.65	6437.65	12.819	11479.6	11273.31
Ca	467.00	475.45	475.45	0.947	847.8	832.59
Mg	1258.00	1280.76	1280.76	2.550	2283.8	2242.81
Na	11089.00	11288.43	11288.43	107.695	20062.5	19703.60
K	391.00	398.00	398.00	4.744	706.6	693.99
NH4	0.20	0.20	0.20	0.003	0.4	0.34
Ba	0.450	0.458	0.458	0.001	0.8	0.80
Sr	0.100	0.102	0.102	0.000	0.2	0.18
H	0.00	0.00	0.00	0.000	0.0	0.00
CO3	20.77	24.65	24.65	0.001	61.1	59.57
HCO3	126.30	124.63	124.63	1.936	183.1	180.70
SO4	2878.00	2930.06	2930.06	6.342	5224.5	5130.61
Cl	19700.00	20054.02	20054.02	173.348	35655.4	35017.21
F	1.63	1.66	1.66	0.029	2.9	2.89
NO3	4.00	4.07	4.07	0.260	7.1	6.93
PO4	0.76	0.77	0.77	0.002	1.4	1.35
OH	0.19	0.22	0.22	0.002	0.4	0.35
SiO2	1.38	1.40	1.40	0.009	2.5	2.46
B	3.53	3.58	3.58	0.979	5.6	5.53
CO2	0.44	0.37	0.37	0.37	0.49	0.49
NH3	0.02	0.02	0.02	0.02	0.02	0.02
TDS	**35942.12**	**36588.25**	**36588.25**	**298.85**	**65045.68**	**63881.56**

pH	**8.13**	**8.20**	**8.20**	**6.88**	**8.25**	**8.25**

Saturations	Raw Water	Feed Water	Concentrate	Limits
CaSO4 / ksp * 100, %	25	25	52	400
SrSO4 / ksp * 100, %	0	0	1	1200
BaSO4 / ksp * 100, %	1883	1921	3722	10000
SiO2 saturation, %	1	1	2	140
CaF2 / ksp * 100, %	54	57	468	50000
Ca3(PO4)2 saturation index	0.9	1.0	1.8	2.4
CCPP, mg/l	30.28	30.39	69.38	850
Ionic strength	0.71	0.73	1.29	
Osmotic pressure, bar	26.5	27.0	47.9	

Calculated by	Laurent MORILLON	
HP Pump flow	1064.67	m3/h
Feed pressure	56.8	bar
Feed temperature	28.3	°C(82.9°F)
Feed water pH	8.20	
Chem dose, mg/l, 50 %	1.2	NaOH
Leakage	1	%
Volumetric mixing	4	%
H.P. differential	0.80	bar
Boost pressure	2.72	bar
Specific energy	2.11	kwh/m3
Pass NDP	18.1	bar
Average flux rate	13.4	lmh

Permeate flow/train	1052.00	m3/h
Total product flow	16832.00	m3/h
Number of trains	16	
Raw water flow/train	2390.91	m3/h
Permeate recovery	44.00	%
Element age	3.5	years
Flux decline %, per year	7.0	
Fouling factor	0.78	
SP increase, per year	10.0	%

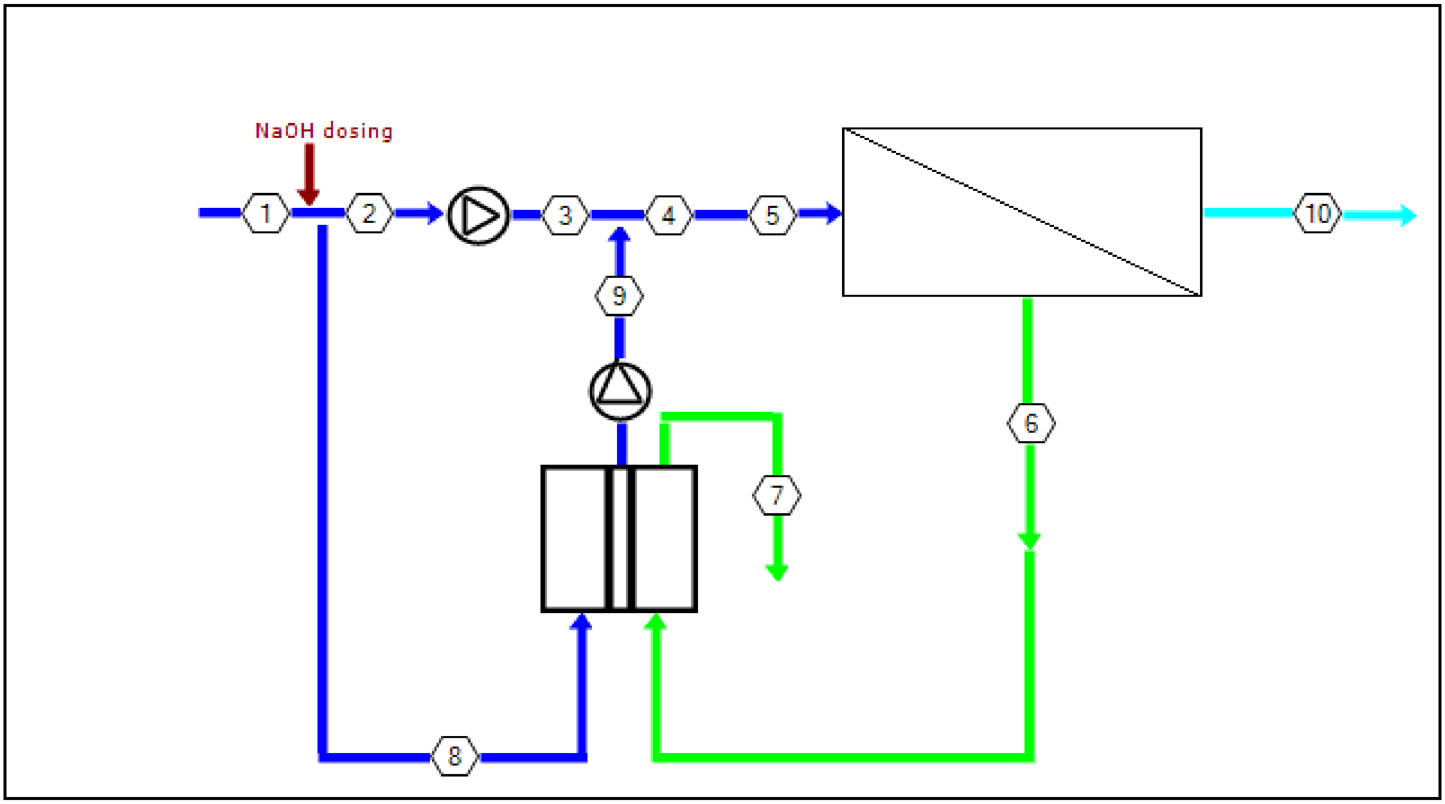
Feed type: Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	553.1	10	7.7	18.8	0.9	22.2	1.03	1.5	0	55.8	137.6	SWC4 MAX	720	240 x 3M
1-1-h	498.1	7.7	5.6	10.2	1	17	1.03	1.5	0	54.8	299.1	SWC5 MAX	1200	240 x 5M

Pass - Stage	Element No.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	TDS	Permeate (Stagewise cumulative) Ca	Mg	Na	Cl	B
1-1	1	56.8	0.36	29.7	26.2	0.9	22.2	1.03	106.5	0.337	0.908	38.379	61.766	0.349
1-1	2	56.4	0.31	32.4	22.9	0.8	18.7	1.03	121.3	0.384	1.034	43.724	70.368	0.396
1-1	3	56.1	0.27	35	19.9	0.6	15.6	1.03	137.6	0.436	1.173	49.608	79.839	0.443
1-1	4	55.8	0.24	38.5	16.4	0.7	17	1.03	164	0.519	1.398	59.086	95.096	0.55
1-1	5	55.6	0.21	41.6	13	0.5	12.6	1.03	193.6	0.613	1.65	69.742	112.25	0.655
1-1	6	55.4	0.19	44.1	10.2	0.4	9.3	1.02	226.2	0.716	1.929	81.489	131.159	0.761
1-1	7	55.2	0.17	46.3	7.9	0.3	7	1.02	261.4	0.828	2.23	94.19	151.606	0.87
1-1	8	55	0.16	47.9	6	0.2	5.1	1.01	299.1	0.947	2.552	107.768	173.467	0.98

400 MLD Perur DSP Membrane – 3 SWC4MAX & 5 SWC5MAX Avg TDS-35942 mg/l, Temp 28.3C, Rec-44%

Temperature : 28.3 °C Element age, P1 : 3.5 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	Hardness as CaCO3	Cl	B	pH
1	2391	0	35942	6323	19700	3.53	8.13
2	1065	0	35943	6323	19700	3.53	8.20
3	1065	56.8	35943	6323	19700	3.53	8.20
4	2391	56.8	36588	6438	20054	3.58	8.20
5	2391	56.8	36588	6438	20054	3.58	8.20
6	1340	54.8	65046	11480	35655	5.61	8.25
7	1340	0	63882	11273	35017	5.53	8.25
8	1326	0	35943	6323	19700	3.53	8.20
9	1326	56.8	37107	6529	20338	3.61	8.20
10	1052	1.50	299	12.8	173	0.979	6.88

Calculated by	Laurent MORILLON
HP Pump flow	1064.67 m3/h
Feed pressure	56.8 bar
Feed temperature	28.3 °C(82.9°F)
Feed water pH	8.20
Chem dose, mg/l, 50 %	1.2 NaOH
Leakage	1 %
Volumetric mixing	4 %
H.P. differential	0.80 bar
Boost pressure	2.72 bar
Specific energy	2.11 kwh/m3
Pass NDP	18.1 bar
Average flux rate	13.4 lmh

Permeate flow/train	1052.00 m3/h
Total product flow	16832.00 m3/h
Number of trains	16
Raw water flow/train	2390.91 m3/h
Permeate recovery	44.00 %
Element age	3.5 years
Flux decline %, per year	7.0
Fouling factor	0.78
SP increase, per year	10.0 %
Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow	Flow / Vessel Feed	Conc	Flux	DP	Flux Max	Beta	Stagewise Pressure Perm.	Boost	Conc	Perm. TDS	Element Type	Element Quantity	PV# x Elem #
	m3/h	m3/h	m3/h	lmh	bar	lmh		bar	bar	bar	mg/l			
1-1-h	553.1	10	7.7	18.8	0.9	22.2	1.03	1.5	0	55.8	137.6	SWC4 MAX	720	240 x 3M
1-1-h	498.1	7.7	5.6	10.2	1	17	1.03	1.5	0	54.8	299.1	SWC5 MAX	1200	240 x 5M

CALCULATION OF INVESTMENT AND WATER COST

Plant capacity as permeate	0.00 m3/h
Specific investment	22,151.90 USD/m3/h
Investment	000.00 USD
Plant life	15.0 years
Membrane life	5.0 years
Interest rate	4.5 %
Membrane cost	500.00 USD/element
Plant factor	90.0 %
Number of elements	1920.0
Power cost	0.200 USD/kwhr
Inhibitor cost	2.20
Power consumption	2.11 kwhr/m3
Inhibitor dosing	3.0 mg/l
Maintenance(as % of investment)	3.0 %
Acid cost	1.50
Acid dosing	0.58 mg/l

CALCULATION RESULTS

Capital cost	0.00 USD/m3
Power cost	0.42 USD/m3
Chemicals cost	0.00 USD/m3
Membrane replacement costs	0.00 USD/m3
Maintenance	0.00 USD/m3
Total water cost	0.42 USD/m3

Calculated by	MORILLON	Permeate flow/train	1052.00 m3/h
HP Pump flow	1063.82 m3/h	Total product flow	16832.00 m3/h
Feed pressure	57.4 bar	Number of trains	16
Feed temperature	28.3 °C(82.9°F)	Raw water flow/train	2337.78 m3/h
Feed water pH	8.20	Permeate recovery	45.00 %
Chem dose, mg/l, 50 %	1.2 NaOH	Element age	3.5 years
Leakage	1 %	Flux decline %, per year	7.0
Volumetric mixing	4 %	Fouling factor	0.78
H.P. differential	0.80 bar	SP increase, per year	10.0 %
Boost pressure	2.63 bar		
Specific energy	2.12 kwh/m3		
Pass NDP	18.4 bar		
Average flux rate	13.4 lmh		
		Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	561.3	9.7	7.4	19	0.9	22.6	1.03	1.5	0	56.5	136.7	SWC4 MAX	720	240 x 3M
1-1-h	489.7	7.4	5.4	9.9	0.9	16.8	1.03	1.5	0	55.6	303.7	SWC5 MAX	1200	240 x 5M

Ion (mg/l)	Raw Water	Blended Water	Feed Water	Permeate Water	Concentrate	ERD Reject
Hardness, as CaCO3	6323.24	6440.21	6440.21	13.014	11689.4	11474.75
Ca	467.00	475.64	475.64	0.961	863.3	847.46
Mg	1258.00	1281.27	1281.27	2.589	2325.6	2282.89
Na	11089.00	11292.86	11292.86	109.325	20426.6	20053.06
K	391.00	398.16	398.16	4.815	719.4	706.27
NH4	0.20	0.20	0.20	0.003	0.4	0.35
Ba	0.450	0.458	0.458	0.001	0.8	0.82
Sr	0.100	0.102	0.102	0.000	0.2	0.18
H	0.00	0.00	0.00	0.000	0.0	0.00
CO3	20.77	24.68	24.68	0.001	63.2	61.63
HCO3	126.30	124.64	124.64	1.964	184.8	182.35
SO4	2878.00	2931.23	2931.23	6.439	5319.9	5222.27
Cl	19700.00	20061.91	20061.91	175.972	36302.9	35638.84
F	1.63	1.66	1.66	0.029	3.0	2.94
NO3	4.00	4.07	4.07	0.264	7.2	7.05
PO4	0.76	0.77	0.77	0.002	1.4	1.38
OH	0.19	0.22	0.22	0.002	0.4	0.36
SiO2	1.38	1.41	1.41	0.009	2.5	2.50
B	3.53	3.58	3.58	0.988	5.7	5.60
CO2	0.44	0.37	0.37	0.37	0.49	0.49
NH3	0.02	0.02	0.02	0.02	0.02	0.02
TDS	**35942.12**	**36602.64**	**36602.64**	**303.36**	**66226.95**	**65015.59**
pH	**8.13**	**8.20**	**8.20**	**6.88**	**8.26**	**8.26**

Version : 2.228.86 %

Saturations	Raw Water	Feed Water	Concentrate	Limits
CaSO4 / ksp * 100, %	25	25	53	400
SrSO4 / ksp * 100, %	0	0	1	1200
BaSO4 / ksp * 100, %	1883	1922	3800	10000
SiO2 saturation, %	1	1	2	140
CaF2 / ksp * 100, %	54	57	504	50000
Ca3(PO4)2 saturation index	0.9	1.0	1.8	2.4
CCPP, mg/l	30.28	30.40	70.78	850
Ionic strength	0.71	0.73	1.31	
Osmotic pressure, bar	26.5	27.0	48.8	

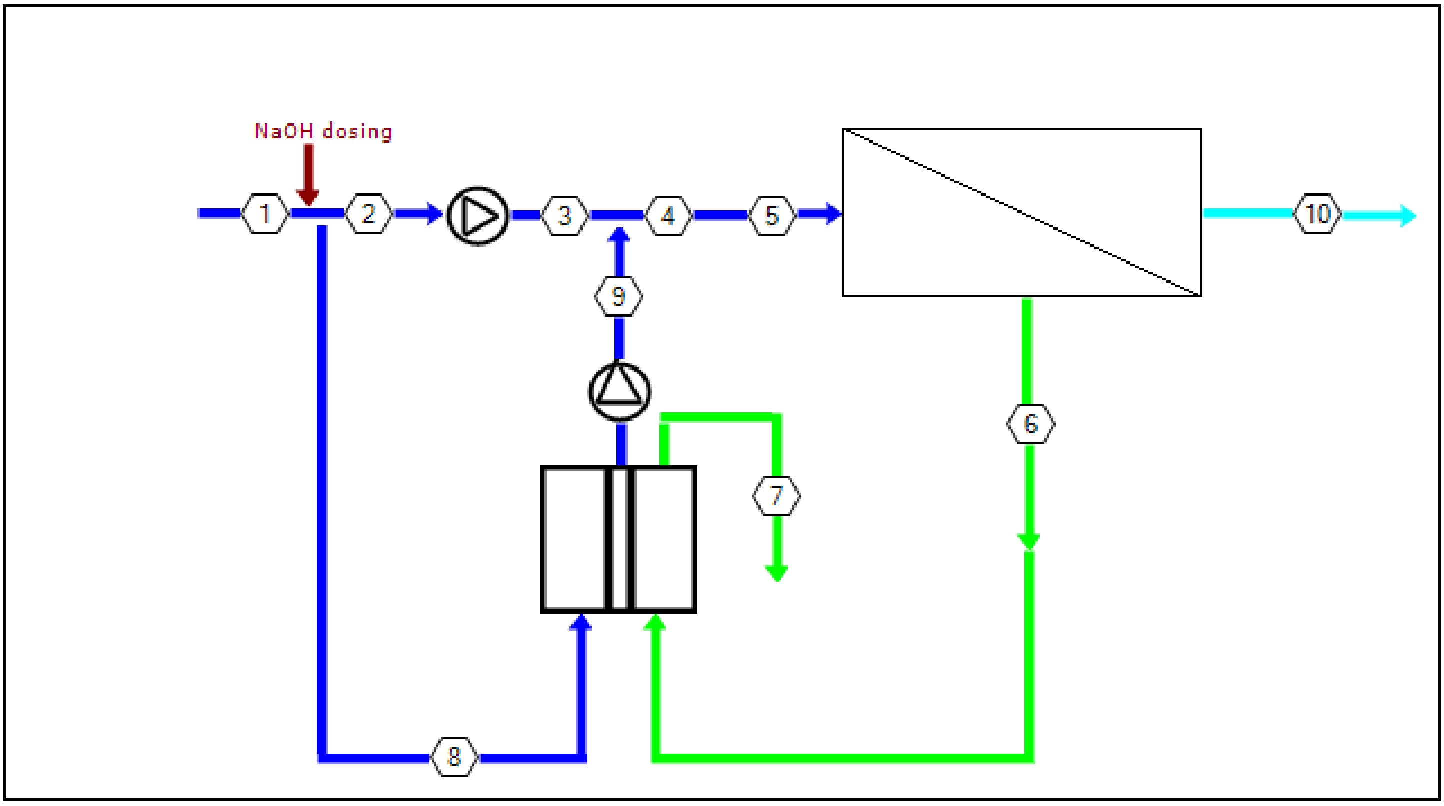
Calculated by	Laurent MORILLON	Permeate flow/train	1052.00 m3/h
HP Pump flow	1063.82 m3/h	Total product flow	16832.00 m3/h
Feed pressure	57.4 bar	Number of trains	16
Feed temperature	28.3 °C(82.9°F)	Raw water flow/train	2337.78 m3/h
Feed water pH	8.20	Permeate recovery	45.00 %
Chem dose, mg/l, 50 %	1.2 NaOH	Element age	3.5 years
Leakage	1 %	Flux decline %, per year	7.0
Volumetric mixing	4 %	Fouling factor	0.78
H.P. differential	0.80 bar	SP increase, per year	10.0 %
Boost pressure	2.63 bar		
Specific energy	2.12 kwh/m3		
Pass NDP	18.4 bar		
Average flux rate	13.4 lmh	Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Boost bar	Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	561.3	9.7	7.4	19	0.9	22.6	1.03	1.5	0	56.5	136.7	SWC4 MAX	720	240 x 3M
1-1-h	489.7	7.4	5.4	9.9	0.9	16.8	1.03	1.5	0	55.6	303.7	SWC5 MAX	1200	240 x 5M

Pass - Stage	Element No.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	Permeate (Stagewise cumulative) TDS	Ca	Mg	Na	Cl	B
1-1	1	57.4	0.35	29.8	26.7	0.9	22.6	1.03	104.9	0.332	0.894	37.812	60.852	0.343
1-1	2	57	0.3	32.6	23.2	0.8	18.8	1.03	120	0.38	1.023	43.249	69.604	0.391
1-1	3	56.7	0.26	35.5	20.2	0.6	15.6	1.03	136.7	0.433	1.166	49.28	79.311	0.439
1-1	4	56.5	0.23	39.1	16.5	0.7	16.8	1.03	163.8	0.519	1.397	59.041	95.024	0.548
1-1	5	56.3	0.2	42.3	13	0.5	12.4	1.03	194.4	0.616	1.658	70.063	112.766	0.656
1-1	6	56.1	0.18	44.9	10.1	0.4	9.2	1.02	228.2	0.723	1.947	82.229	132.352	0.765
1-1	7	55.9	0.16	47.1	7.8	0.3	6.6	1.02	264.7	0.838	2.258	95.381	153.523	0.876
1-1	8	55.7	0.15	48.8	5.9	0.2	4.8	1.01	303.7	0.962	2.592	109.433	176.146	0.989

Temperature : 28.3 °C

Element age, P1 : 3.5 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	Hardness as CaCO3	Cl	B	pH
1	2338	0	35942	6323	19700	3.53	8.13
2	1064	0	35943	6323	19700	3.53	8.20
3	1064	57.4	35943	6323	19700	3.53	8.20
4	2338	57.4	36603	6440	20062	3.58	8.20
5	2338	57.4	36603	6440	20062	3.58	8.20
6	1287	55.6	66227	11689	36303	5.69	8.26
7	1287	0	65016	11475	35639	5.60	8.26
8	1274	0	35943	6323	19700	3.53	8.20
9	1274	57.4	37154	6538	20364	3.62	8.20
10	1052	1.50	303	13.0	176	0.988	6.88

Version : 2.228.86 %

Calculated by	Laurent MORILLON	Permeate flow/train	1052.00 m3/h
HP Pump flow	1063.82 m3/h	Total product flow	16832.00 m3/h
Feed pressure	57.4 bar	Number of trains	16
Feed temperature	28.3 °C(82.9°F)	Raw water flow/train	2337.78 m3/h
Feed water pH	8.20	Permeate recovery	45.00 %
Chem dose, mg/l, 50 %	1.2 NaOH	Element age	3.5 years
Leakage	1 %	Flux decline %, per year	7.0
Volumetric mixing	4 %	Fouling factor	0.78
H.P. differential	0.80 bar	SP increase, per year	10.0 %
Boost pressure	2.63 bar		
Specific energy	2.12 kwh/m3		
Pass NDP	18.4 bar		
Average flux rate	13.4 lmh		
		Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow	Flow / Vessel Feed	Flow / Vessel Conc	Flux	DP	Flux Max	Beta	Stagewise Pressure Perm.	Stagewise Pressure Boost	Stagewise Pressure Conc	Perm. TDS	Element Type	Element Quantity	PV# x Elem #
	m3/h	m3/h	m3/h	lmh	bar	lmh		bar	bar	bar	mg/l			
1-1-h	561.3	9.7	7.4	19	0.9	22.6	1.03	1.5	0	56.5	136.7	SWC4 MAX	720	240 x 3M
1-1-h	489.7	7.4	5.4	9.9	0.9	16.8	1.03	1.5	0	55.6	303.7	SWC5 MAX	1200	240 x 5M

CALCULATION OF INVESTMENT AND WATER COST

Plant capacity as permeate	0.00 m3/h
Specific investment	22,151.90 USD/m3/h
Investment	000.00 USD
Plant life	15.0 years
Membrane life	5.0 years
Interest rate	4.5 %
Membrane cost	500.00 USD/element
Plant factor	90.0 %
Number of elements	1920.0
Power cost	0.200 USD/kwhr
Inhibitor cost	2.20
Power consumption	2.12 kwhr/m3
Inhibitor dosing	3.0 mg/l
Maintenance(as % of investment)	3.0 %
Acid cost	1.50
Acid dosing	0.58 mg/l

CALCULATION RESULTS

Capital cost	0.00 USD/m3
Power cost	0.42 USD/m3
Chemicals cost	0.00 USD/m3
Membrane replacement costs	0.00 USD/m3
Maintenance	0.00 USD/m3
Total water cost	0.42 USD/m3

400 MLD Perur DSP Membrane - 3-SWC4MAX & 5 SWC5MAX Avg TDS-35942 mg/l, Temp 28.3C – Rec 46%

Calculated by	MORILLON	
HP Pump flow	1063.42	m3/h
Feed pressure	58.1	bar
Feed temperature	28.3	°C(82.9°F)
Feed water pH	8.25	
Chem dose, mg/l, 50 %	2.0	NaOH
Leakage	1	%
Volumetric mixing	4	%
H.P. differential	0.80	bar
Boost pressure	2.55	bar
Specific energy	2.13	kwh/m3
Pass NDP	18.8	bar
Average flux rate	13.4	lmh

Permeate flow/train	1052.00	m3/h
Total product flow	16832.00	m3/h
Number of trains	16	
Raw water flow/train	2286.96	m3/h
Permeate recovery	46.00	%
Element age	3.5	years
Flux decline %, per year	7.0	
Fouling factor	0.78	
SP increase, per year	10.0	%
Feed type	Sea Surface Conventional	

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	570.7	9.5	7.2	19.4	0.9	23.1	1.04	1.5	0	57.2	135.4	SWC4 MAX	720	240 x 3M
1-1-h	480.3	7.2	5.1	9.8	0.9	16.8	1.04	1.5	0	56.3	308.3	SWC5 MAX	1200	240 x 5M

Ion (mg/l)	Raw Water	Blended Water	Feed Water	Permeate Water	Concentrate	ERD Reject
Hardness, as CaCO3	6323.24	6442.81	6442.81	13.219	11910.8	11687.32
Ca	467.00	475.83	475.83	0.976	879.7	863.16
Mg	1258.00	1281.79	1281.79	2.630	2369.6	2325.18
Na	11089.00	11297.63	11297.63	111.038	20811.1	20422.26
K	391.00	398.32	398.32	4.890	732.9	719.22
NH4	0.20	0.20	0.20	0.003	0.4	0.35
Ba	0.450	0.459	0.459	0.001	0.8	0.83
Sr	0.100	0.102	0.102	0.000	0.2	0.18
H	0.00	0.00	0.00	0.000	0.0	0.00
CO3	20.77	27.14	27.14	0.001	69.3	67.62
HCO3	126.30	122.21	122.21	1.956	180.4	178.04
SO4	2878.00	2932.42	2932.42	6.541	5420.7	5319.00
Cl	19700.00	20069.93	20069.93	178.751	36986.2	36294.73
F	1.63	1.66	1.66	0.030	3.0	2.99
NO3	4.00	4.07	4.07	0.268	7.3	7.17
PO4	0.76	0.77	0.77	0.002	1.4	1.40
OH	0.19	0.25	0.25	0.002	0.4	0.41
SiO2	1.38	1.41	1.41	0.010	2.6	2.54
B	3.53	3.58	3.58	0.955	5.8	5.72
CO2	0.44	0.33	0.33	0.33	0.44	0.43
NH3	0.02	0.02	0.02	0.02	0.02	0.02
TDS	**35942.12**	**36617.50**	**36617.50**	**308.05**	**67471.56**	**66210.43**

pH	**8.13**	**8.25**	**8.25**	**6.94**	**8.30**	**8.30**

Saturations	**Raw Water**	**Feed Water**	**Concentrate**	**Limits**
$CaSO_4$ / ksp * 100, %	25	25	54	400
$SrSO_4$ / ksp * 100, %	0	0	1	1200
$BaSO_4$ / ksp * 100, %	1883	1923	3882	10000
SiO_2 saturation, %	1	1	2	140
CaF_2 / ksp * 100, %	54	57	545	50000
$Ca_3(PO_4)_2$ saturation index	0.9	1.0	1.9	2.4
CCPP, mg/l	30.28	29.79	69.27	850
Ionic strength	0.71	0.73	1.34	
Osmotic pressure, bar	26.5	27.0	49.7	

400 MLD Perur DSP　Membrane - 3-SWC4MAX & 5 SWC5MAX　Avg TDS-35942 mg/l, Temp 28.3C – Rec 46%

Calculated by	Laurent MORILLON	
HP Pump flow	1063.42	m3/h
Feed pressure	58.1	bar
Feed temperature	28.3	°C(82.9°F)
Feed water pH	8.25	
Chem dose, mg/l, 50 %	2.0	NaOH
Leakage	1	%
Volumetric mixing	4	%
H.P. differential	0.80	bar
Boost pressure	2.55	bar
Specific energy	2.13	kwh/m3
Pass NDP	18.8	bar
Average flux rate	13.4	lmh

Permeate flow/train	1052.00	m3/h
Total product flow	16832.00	m3/h
Number of trains	16	
Raw water flow/train	2286.96	m3/h
Permeate recovery	46.00	%
Element age	3.5	years
Flux decline %, per year	7.0	
Fouling factor	0.78	
SP increase, per year	10.0	%
Feed type	Sea Surface Conventional	

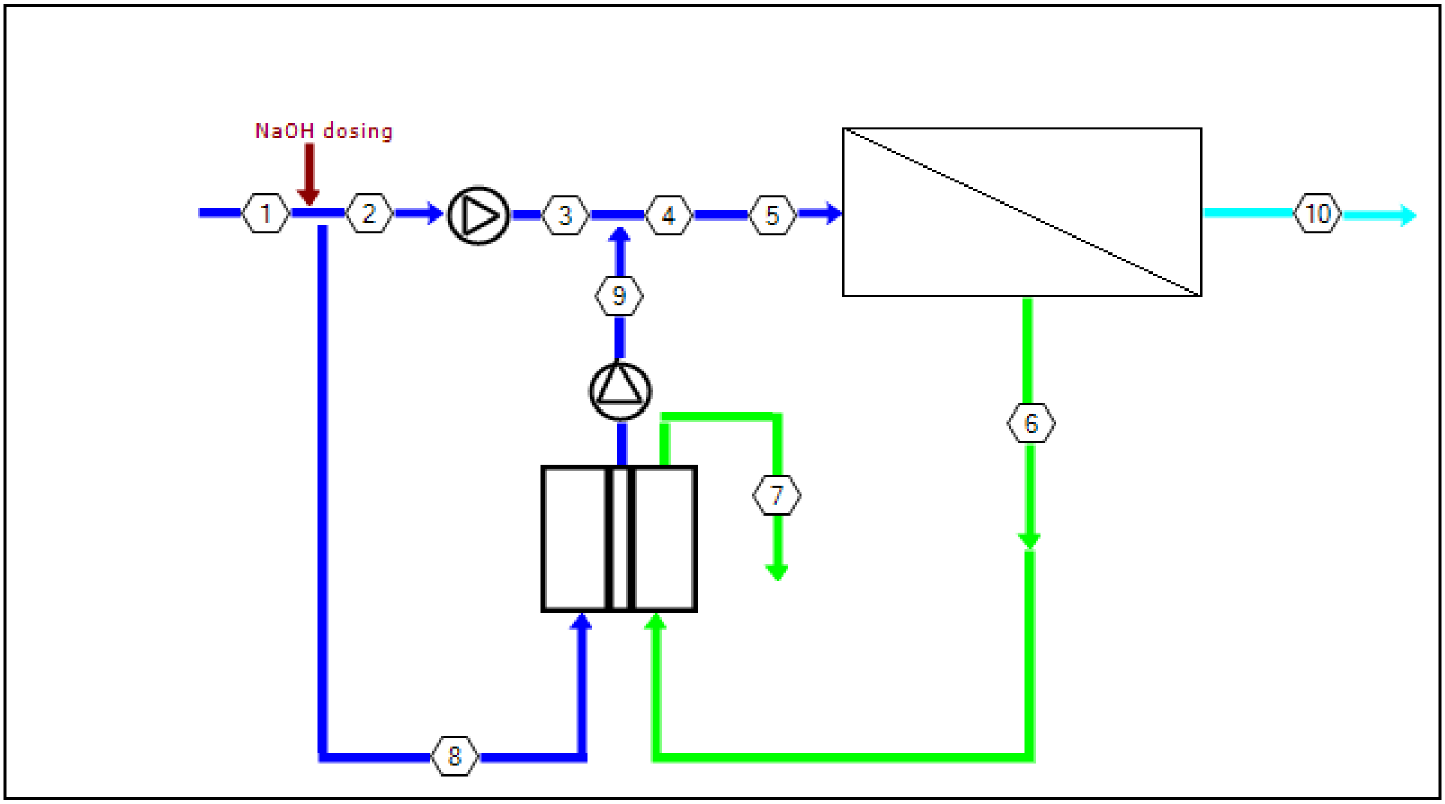
Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	570.7	9.5	7.2	19.4	0.9	23.1	1.04	1.5	0	57.2	135.4	SWC4 MAX	720	240 x 3M
1-1-h	480.3	7.2	5.1	9.8	0.9	16.8	1.04	1.5	0	56.3	308.3	SWC5 MAX	1200	240 x 5M

Pass - Stage	Element No.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	Permeate (Stagewise cumulative) TDS	Ca	Mg	Na	Cl	B
1-1	1	58.1	0.33	29.9	27.3	0.9	23.1	1.04	103.2	0.327	0.88	37.202	59.878	0.325
1-1	2	57.7	0.29	33	23.8	0.8	19.4	1.03	118.1	0.374	1.007	42.573	68.524	0.37
1-1	3	57.4	0.25	35.9	20.4	0.6	15.8	1.03	135.4	0.429	1.155	48.821	78.581	0.418
1-1	4	57.2	0.22	39.7	16.6	0.7	16.8	1.04	163.5	0.518	1.394	58.918	94.835	0.525
1-1	5	57	0.19	43	12.9	0.5	12.2	1.03	195.2	0.618	1.665	70.343	113.23	0.63
1-1	6	56.8	0.17	45.8	10	0.4	8.8	1.02	230.2	0.729	1.964	82.962	133.546	0.737
1-1	7	56.6	0.15	48	7.6	0.3	6.5	1.02	268	0.849	2.287	96.59	155.487	0.846
1-1	8	56.5	0.14	49.7	5.7	0.2	4.6	1.01	308.3	0.977	2.632	111.137	178.91	0.956

400 MLD Perur DSP Membrane - 3-SWC4MAX & 5 SWC5MAX Avg TDS-35942 mg/l, Temp 28.3C – Rec 46%

Temperature : 28.3 °C

Element age, P1 : 3.5 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	Hardness as CaCO3	Cl	B	pH
1	2287	0	35942	6323	19700	3.53	8.13
2	1063	0	35943	6323	19700	3.53	8.25
3	1063	58.1	35943	6323	19700	3.53	8.25
4	2287	58.1	36618	6443	20070	3.58	8.25
5	2287	58.1	36618	6443	20070	3.58	8.25
6	1236	56.3	67472	11911	36986	5.81	8.30
7	1236	0	66210	11687	36295	5.72	8.30
8	1224	0	35943	6323	19700	3.53	8.25
9	1224	58.1	37204	6547	20391	3.62	8.25
10	1052	1.50	308	13.2	179	0.955	6.94

Calculated by	Laurent MORILLON	
HP Pump flow	1063.42	m3/h
Feed pressure	58.1	bar
Feed temperature	28.3	°C(82.9°F)
Feed water pH	8.25	
Chem dose, mg/l, 50 %	2.0	NaOH
Leakage	1	%
Volumetric mixing	4	%
H.P. differential	0.80	bar
Boost pressure	2.55	bar
Specific energy	2.13	kwh/m3
Pass NDP	18.8	bar
Average flux rate	13.4	lmh

Permeate flow/train	1052.00	m3/h
Total product flow	16832.00	m3/h
Number of trains	16	
Raw water flow/train	2286.96	m3/h
Permeate recovery	46.00	%
Element age	3.5	years
Flux decline %, per year	7.0	
Fouling factor	0.78	
SP increase, per year	10.0	%
Feed type	Sea Surface Conventional	

Pass - Stage	Perm. Flow	Flow / Vessel Feed	Flow / Vessel Conc	Flux	DP	Flux Max	Beta	Stagewise Pressure Perm.	Stagewise Pressure Boost	Stagewise Pressure Conc	Perm. TDS	Element Type	Element Quantity	PV# x Elem #
	m3/h	m3/h	m3/h	lmh	bar	lmh		bar	bar	bar	mg/l			
1-1-h	570.7	9.5	7.2	19.4	0.9	23.1	1.04	1.5	0	57.2	135.4	SWC4 MAX	720	240 x 3M
1-1-h	480.3	7.2	5.1	9.8	0.9	16.8	1.04	1.5	0	56.3	308.3	SWC5 MAX	1200	240 x 5M

CALCULATION OF INVESTMENT AND WATER COST

Plant capacity as permeate	0.00	m3/h
Specific investment	22,151.90	USD/m3/h
Investment	000.00	USD
Plant life	15.0	years
Membrane life	5.0	years
Interest rate	4.5	%
Membrane cost	500.00	USD/element
Plant factor	90.0	%
Number of elements	1920.0	
Power cost	0.200	USD/kwhr
Inhibitor cost	2.20	
Power consumption	2.13	kwhr/m3
Inhibitor dosing	3.0	mg/l
Maintenance (as % of investment)	3.0	%
Acid cost	1.50	
Acid dosing	1.01	mg/l

CALCULATION RESULTS

Capital cost	0.00	USD/m3
Power cost	0.43	USD/m3
Chemicals cost	0.00	USD/m3
Membrane replacement costs	0.00	USD/m3
Maintenance	0.00	USD/m3
Total water cost	0.43	USD/m3

400 MLD Perur DSP Membrane – 3 SWC4MAX & 5 SWC5MAX Avg TDS-39000 mg/l, Temp 31.5C, Rec 44%

Calculated by	MORILLON	
HP Pump flow	1064.52	m3/h
Feed pressure	61.0	bar
Feed temperature	31.5	°C(88.7°F)
Feed water pH	8.40	
Chem dose, mg/l, 50 %	7.7	NaOH
Leakage	1	%
Volumetric mixing	4	%
H.P. differential	0.80	bar
Boost pressure	2.69	bar
Specific energy	2.25	kwh/m3
Pass NDP	18.6	bar
Average flux rate	13.4	lmh

Permeate flow/train	1052.00	m3/h
Total product flow	16832.00	m3/h
Number of trains	16	
Raw water flow/train	2390.91	m3/h
Permeate recovery	44.00	%
Element age	3.5	years
Flux decline %, per year	7.0	
Fouling factor	0.78	
SP increase, per year	10.0	%
Feed type	Sea Surface Conventional	

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	586.1	10	7.5	19.9	0.9	24.1	1.04	1.5	0	60.1	162.8	SWC4 MAX	720	240 x 3M
1-1-h	465	7.5	5.6	9.5	1	16.6	1.03	1.5	0	59.1	374.1	SWC5 MAX	1200	240 x 5M

Ion (mg/l)	Raw Water	Blended Water	Feed Water	Permeate Water	Concentrate	ERD Reject
Hardness, as CaCO3	6323.24	6437.60	6437.60	14.589	11476.8	11270.61
Ca	467.00	475.45	475.45	1.077	847.6	832.39
Mg	1258.00	1280.75	1280.75	2.903	2283.3	2242.27
Na	12299.00	12521.74	12521.74	135.924	22238.9	21841.42
K	391.00	397.99	397.99	5.397	706.0	693.39
NH4	0.20	0.18	0.18	0.003	0.3	0.31
Ba	0.450	0.458	0.458	0.001	0.8	0.80
Sr	0.100	0.102	0.102	0.000	0.2	0.18
H	0.00	0.00	0.00	0.000	0.0	0.00
CO3	18.46	39.90	39.90	0.002	83.0	81.24
HCO3	126.30	106.87	106.87	1.907	144.3	142.78
SO4	2878.00	2930.04	2930.04	7.288	5223.1	5129.27
Cl	21560.00	21946.88	21946.88	217.971	38994.1	38296.76
F	1.63	1.66	1.66	0.033	2.9	2.88
NO3	4.00	4.07	4.07	0.298	7.0	6.90
PO4	0.76	0.77	0.77	0.002	1.4	1.35
OH	0.19	0.49	0.49	0.004	0.7	0.73
SiO2	1.38	1.40	1.40	0.011	2.5	2.45
B	3.80	3.85	3.85	0.962	6.1	6.03
CO2	0.56	0.19	0.19	0.19	0.26	0.26
NH3	0.02	0.04	0.04	0.04	0.04	0.04
TDS	**39010.08**	**39712.11**	**39712.11**	**373.78**	**70541.61**	**69280.45**
pH	**8.00**	**8.40**	**8.40**	**7.15**	**8.42**	**8.42**

Saturations	**Raw Water**	**Feed Water**	**Concentrate**	**Limits**

CaSO4 / ksp * 100, %	23	23	48	400
SrSO4 / ksp * 100, %	0	0	1	1200
BaSO4 / ksp * 100, %	1771	1807	3500	10000
SiO2 saturation, %	1	1	1	140
CaF2 / ksp * 100, %	55	58	507	50000
Ca3(PO4)2 saturation index	0.8	1.3	2.1	2.4
CCPP, mg/l	29.44	25.03	50.95	850
Ionic strength	0.76	0.78	1.39	
Osmotic pressure, bar	29.3	29.8	52.9	

400 MLD Perur DSP   Membrane – 3 SWC4MAX & 5 SWC5MAX Avg TDS-39000 mg/l, Temp 31.5C, Rec 44%

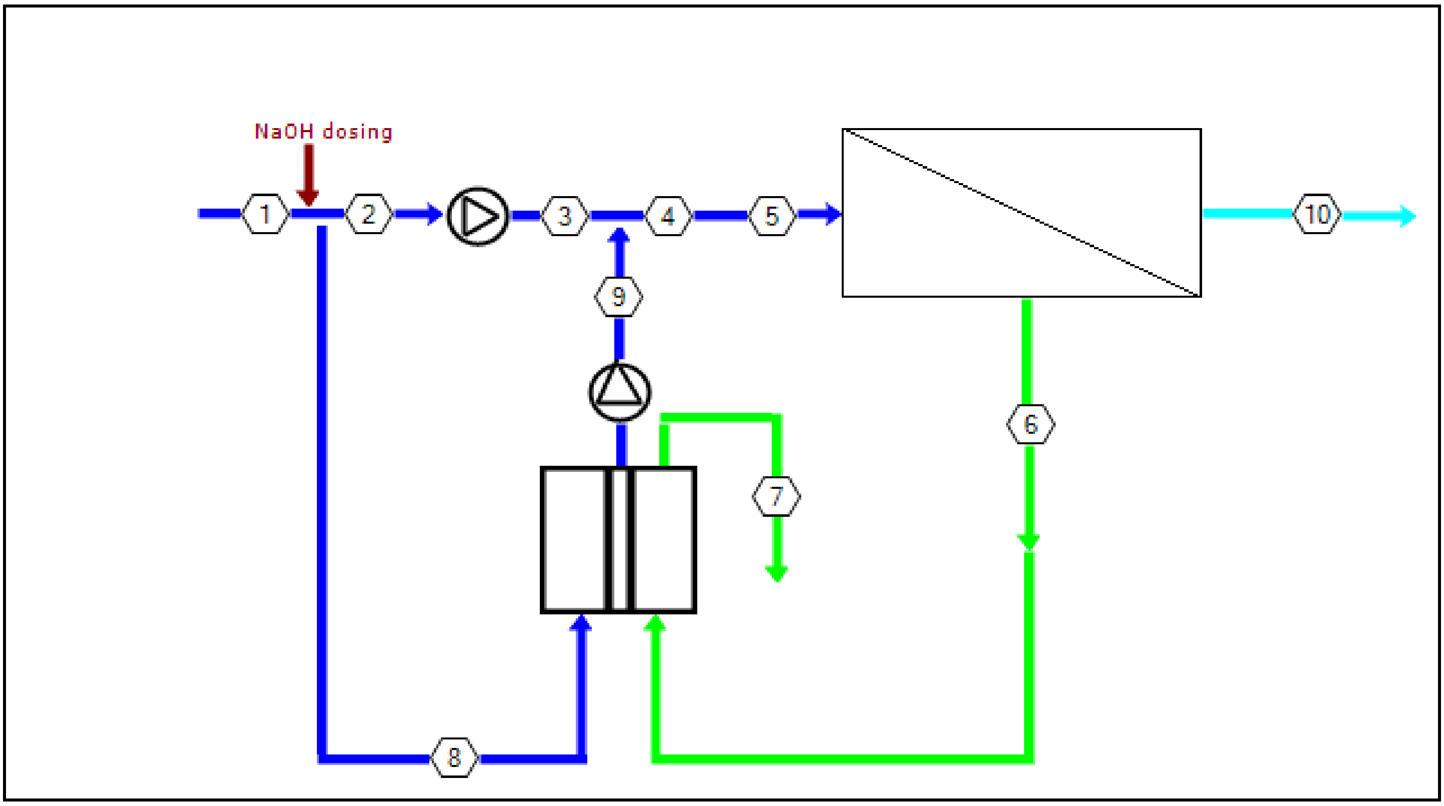
Calculated by	MORILLON	Permeate flow/train	1052.00 m3/h
HP Pump flow	1064.52 m3/h	Total product flow	16832.00 m3/h
Feed pressure	61.0 bar	Number of trains	16
Feed temperature	31.5 °C(88.7°F)	Raw water flow/train	2390.91 m3/h
Feed water pH	8.40	Permeate recovery	44.00 %
Chem dose, mg/l, 50 %	7.7 NaOH	Element age	3.5 years
Leakage	1 %	Flux decline %, per year	7.0
Volumetric mixing	4 %	Fouling factor	0.78
H.P. differential	0.80 bar	SP increase, per year	10.0 %
Boost pressure	2.69 bar		
Specific energy	2.25 kwh/m3		
Pass NDP	18.6 bar		
Average flux rate	13.4 lmh	Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	586.1	10	7.5	19.9	0.9	24.1	1.04	1.5	0	60.1	162.8	SWC4 MAX	720	240 x 3M
1-1-h	465	7.5	5.6	9.5	1	16.6	1.03	1.5	0	59.1	374.1	SWC5 MAX	1200	240 x 5M

Pass - Stage	Element No.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	Permeate (Stagewise cumulative) TDS	Ca	Mg	Na	Cl
1-1	1	61	0.36	33	27.2	1	24.1	1.04	122.1	0.352	0.947	44.415	71.213
1-1	2	60.7	0.31	36.3	23.4	0.8	19.7	1.03	141	0.406	1.093	51.27	82.206
1-1	3	60.3	0.27	39.4	19.9	0.6	15.8	1.03	162.8	0.469	1.263	59.206	94.931
1-1	4	60.1	0.24	43.3	15.9	0.7	16.6	1.03	197.7	0.569	1.534	71.885	115.265
1-1	5	59.8	0.21	46.6	12.3	0.5	11.9	1.03	236.8	0.682	1.837	86.112	138.081
1-1	6	59.6	0.19	49.2	9.4	0.3	8.5	1.02	279.6	0.806	2.17	101.677	163.043
1-1	7	59.4	0.17	51.3	7.2	0.2	6.1	1.02	325.5	0.938	2.527	118.351	189.786
1-1	8	59.3	0.16	52.9	5.4	0.2	4.4	1.01	374.1	1.078	2.905	136.037	218.153

400 MLD Perur DSP   Membrane – 3 SWC4MAX & 5 SWC5MAX Avg TDS-39000 mg/l, Temp 31.5C, Rec 44%

Temperature : 31.5 °C   Element age, P1 : 3.5 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	Hardness as CaCO3	Cl	B	pH
1	2391	0	39010	6323	21560	3.80	8.00
2	1065	0	39012	6323	21560	3.80	8.40
3	1065	61.0	39012	6323	21560	3.80	8.40
4	2391	61.0	39712	6438	21947	3.85	8.40
5	2391	61.0	39712	6438	21947	3.85	8.40
6	1340	59.1	70542	11477	38994	6.12	8.42
7	1340	0	69280	11271	38297	6.03	8.42
8	1326	0	39012	6323	21560	3.80	8.40
9	1326	61.0	40274	6529	22257	3.89	8.40
10	1052	1.50	374	14.6	218	0.962	7.15

Calculated by	MORILLON		Permeate flow/train	1052.00 m3/h
HP Pump flow		1064.52 m3/h	Total product flow	16832.00 m3/h
Feed pressure		61.0 bar	Number of trains	16
Feed temperature		31.5 °C(88.7°F)	Raw water flow/train	2390.91 m3/h
Feed water pH		8.40	Permeate recovery	44.00 %
Chem dose, mg/l, 50 %		7.7 NaOH	Element age	3.5 years
Leakage		1 %	Flux decline %, per year	7.0
Volumetric mixing		4 %	Fouling factor	0.78
H.P. differential		0.80 bar	SP increase, per year	10.0 %
Boost pressure		2.69 bar		
Specific energy		2.25 kwh/m3		
Pass NDP		18.6 bar		
Average flux rate		13.4 lmh		
			Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow	Flow / Vessel Feed	Conc	Flux	DP	Flux Max	Beta	Stagewise Pressure Perm.	Boost	Conc	Perm. TDS	Element Type	Element Quantity	PV# x Elem #
	m3/h	m3/h	m3/h	lmh	bar	lmh		bar	bar	bar	mg/l			
1-1-h	586.1	10	7.5	19.9	0.9	24.1	1.04	1.5	0	60.1	162.8	SWC4 MAX	720	240 x 3M
1-1-h	465	7.5	5.6	9.5	1	16.6	1.03	1.5	0	59.1	374.1	SWC5 MAX	1200	240 x 5M

CALCULATION OF INVESTMENT AND WATER COST

Plant capacity as permeate	0.00 m3/h
Specific investment	22,151.90 USD/m3/h
Investment	000.00 USD
Plant life	15.0 years
Membrane life	5.0 years
Interest rate	4.5 %
Membrane cost	500.00 USD/element
Plant factor	90.0 %
Number of elements	1920.0
Power cost	0.200 USD/kwhr
Inhibitor cost	2.20
Power consumption	2.25 kwhr/m3
Inhibitor dosing	3.0 mg/l
Maintenance(as % of investment)	3.0 %
Acid cost	1.50
Acid dosing	3.86 mg/l

CALCULATION RESULTS

Capital cost	0.00 USD/m3
Power cost	0.45 USD/m3
Chemicals cost	0.00 USD/m3
Membrane replacement costs	0.00 USD/m3
Maintenance	0.00 USD/m3
Total water cost	0.45 USD/m3

Calculated by	MORILLON	***Permeate flow/train***	***1052.00 m3/h***
HP Pump flow	1064.44 m3/h	***Total product flow***	***16832.00 m3/h***
Feed pressure	61.8 bar	***Number of trains***	***16***
Feed temperature	31.5 °C(88.7°F)	***Raw water flow/train***	***2337.78 m3/h***
Feed water pH	8.40	***Permeate recovery***	***45.00 %***
Chem dose, mg/l, 50 %	7.7 NaOH	***Element age***	***3.5 years***
Leakage	1 %	***Flux decline %, per year***	***7.0***
Volumetric mixing	4 %	***Fouling factor***	***0.78***
H.P. differential	0.80 bar	***SP increase, per year***	***10.0 %***
Boost pressure	2.60 bar		
Specific energy	2.27 kwh/m3		
Pass NDP	19.0 bar		
Average flux rate	13.4 lmh		
		Feed type	*Sea Surface Conventional*

Pass - Stage	***Perm. Flow m3/h***	***Flow / Vessel Feed m3/h***	***Flow / Vessel Conc m3/h***	***Flux lmh***	***DP bar***	***Flux Max lmh***	***Beta***	***Stagewise Pressure Perm. bar***	***Stagewise Pressure Boost bar***	***Stagewise Pressure Conc bar***	***Perm. TDS mg/l***	***Element Type***	***Element Quantity***	***PV# x Elem #***
1-1-h	***595.8***	***9.7***	***7.3***	***20.3***	***0.9***	***24.8***	***1.04***	***1.5***	***0***	***60.9***	***161.6***	***SWC4 MAX***	***720***	***240 x 3M***
1-1-h	***455.8***	***7.3***	***5.4***	***9.2***	***0.9***	***16.5***	***1.03***	***1.5***	***0***	***60***	***379.9***	***SWC5 MAX***	***1200***	***240 x 5M***

Ion (mg/l)	Raw Water	Blended Water	Feed Water	Permeate Water	Concentrate	ERD Reject
Hardness, as CaCO3	6323.24	6440.24	6440.24	14.824	11693.6	11478.73
Ca	467.00	475.64	475.64	1.095	863.6	847.76
Mg	1258.00	1281.28	1281.28	2.949	2326.4	2283.68
Na	12299.00	12526.81	12526.81	138.096	22655.6	22241.39
K	391.00	398.15	398.15	5.483	719.2	706.06
NH4	0.20	0.18	0.18	0.003	0.3	0.31
Ba	0.450	0.458	0.458	0.001	0.8	0.82
Sr	0.100	0.102	0.102	0.000	0.2	0.18
H	0.00	0.00	0.00	0.000	0.0	0.00
CO3	18.46	39.93	39.93	0.002	85.5	83.63
HCO3	126.30	106.87	106.87	1.936	145.2	143.62
SO4	2878.00	2931.24	2931.24	7.405	5321.7	5223.97
Cl	21560.00	21955.77	21955.77	221.455	39725.3	38998.71
F	1.63	1.66	1.66	0.033	3.0	2.93
NO3	4.00	4.07	4.07	0.303	7.1	7.02
PO4	0.76	0.77	0.77	0.002	1.4	1.38
OH	0.19	0.49	0.49	0.004	0.8	0.75
SiO2	1.38	1.41	1.41	0.011	2.5	2.50
B	3.80	3.85	3.85	0.969	6.2	6.11
CO2	0.56	0.19	0.19	0.19	0.26	0.26
NH3	0.02	0.04	0.04	0.04	0.04	0.04
TDS	**39010.08**	**39728.20**	**39728.20**	**379.74**	**71864.15**	**70550.08**
pH	**8.00**	**8.40**	**8.40**	**7.16**	**8.43**	**8.43**

Saturations	***Raw Water***	***Feed Water***	***Concentrate***	***Limits***

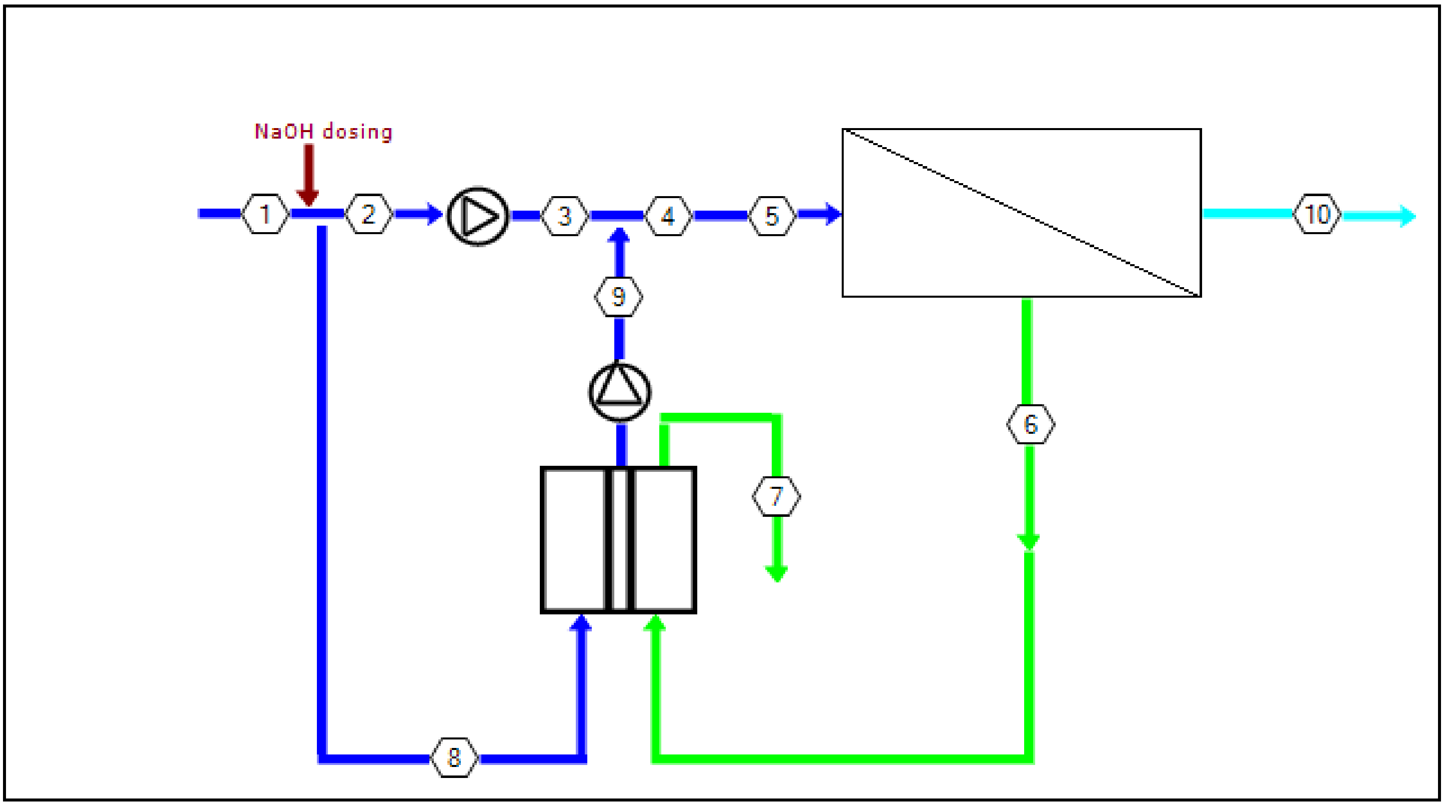
CaSO4 / ksp * 100, %	***23***	***23***	***50***	***400***
SrSO4 / ksp * 100, %	***0***	***0***	***1***	***1200***
BaSO4 / ksp * 100, %	***1771***	***1807***	***3576***	***10000***
SiO2 saturation, %	***1***	***1***	***1***	***140***
CaF2 / ksp * 100, %	***55***	***58***	***549***	***50000***
Ca3(PO4)2 saturation index	***0.8***	***1.3***	***2.1***	***2.4***
CCPP, mg/l	***29.44***	***25.04***	***51.79***	***850***
Ionic strength	***0.76***	***0.78***	***1.41***	
Osmotic pressure, bar	***29.3***	***29.8***	***53.9***	

Calculated by	MORILLON	Permeate flow/train	1052.00 m3/h
HP Pump flow	1064.44 m3/h	Total product flow	16832.00 m3/h
Feed pressure	61.8 bar	Number of trains	16
Feed temperature	31.5 °C(88.7°F)	Raw water flow/train	2337.78 m3/h
Feed water pH	8.40	Permeate recovery	45.00 %
Chem dose, mg/l, 50 %	7.7 NaOH	Element age	3.5 years
Leakage	1 %	Flux decline %, per year	7.0
Volumetric mixing	4 %	Fouling factor	0.78
H.P. differential	0.80 bar	SP increase, per year	10.0 %
Boost pressure	2.60 bar		
Specific energy	2.27 kwh/m3		
Pass NDP	19.0 bar		
Average flux rate	13.4 lmh	Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	595.8	9.7	7.3	20.3	0.9	24.8	1.04	1.5	0	60.9	161.6	SWC4 MAX	720	240 x 3M
1-1-h	455.8	7.3	5.4	9.2	0.9	16.5	1.03	1.5	0	60	379.9	SWC5 MAX	1200	240 x 5M

Pass - Stage	Element No.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	Permeate (Stagewise cumulative) TDS	Ca	Mg	Na	Cl
1-1	1	61.8	0.35	33.2	27.8	1	24.8	1.04	120	0.345	0.93	43.634	69.961
1-1	2	61.4	0.29	36.6	23.9	0.8	20	1.03	139.2	0.401	1.08	50.633	81.184
1-1	3	61.1	0.26	39.9	20.2	0.7	16	1.03	161.6	0.465	1.254	58.776	94.241
1-1	4	60.9	0.23	44	16.1	0.7	16.5	1.03	197.6	0.569	1.533	71.842	115.195
1-1	5	60.7	0.2	47.4	12.4	0.5	11.7	1.03	237.8	0.685	1.845	86.471	138.656
1-1	6	60.5	0.18	50.2	9.3	0.3	8.1	1.02	282.2	0.813	2.19	102.608	164.536
1-1	7	60.3	0.16	52.3	7	0.2	5.8	1.02	329.7	0.95	2.559	119.867	192.218
1-1	8	60.1	0.15	53.9	5.3	0.2	4.1	1.01	379.9	1.095	2.95	138.151	221.544

Temperature : 31.5 °C Element age, P1 : 3.5 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	Hardness as CaCO3	Cl	B	pH
1	2338	0	39010	6323	21560	3.80	8.00
2	1064	0	39012	6323	21560	3.80	8.40
3	1064	61.8	39012	6323	21560	3.80	8.40
4	2338	61.8	39728	6440	21956	3.85	8.40
5	2338	61.8	39728	6440	21956	3.85	8.40
6	1286	60.0	71864	11694	39725	6.21	8.43
7	1286	0	70550	11479	38999	6.11	8.43
8	1273	0	39012	6323	21560	3.80	8.40
9	1273	61.8	40327	6538	22287	3.90	8.40
10	1052	1.50	380	14.8	221	0.969	7.16

Calculated by	MORILLON	
HP Pump flow	1064.44	m3/h
Feed pressure	61.8	bar
Feed temperature	31.5	°C(88.7°F)
Feed water pH	8.40	
Chem dose, mg/l, 50 %	7.7	NaOH
Leakage	1	%
Volumetric mixing	4	%
H.P. differential	0.80	bar
Boost pressure	2.60	bar
Specific energy	2.27	kwh/m3
Pass NDP	19.0	bar
Average flux rate	13.4	lmh

Permeate flow/train	1052.00	m3/h
Total product flow	16832.00	m3/h
Number of trains	16	
Raw water flow/train	2337.78	m3/h
Permeate recovery	45.00	%
Element age	3.5	years
Flux decline %, per year	7.0	
Fouling factor	0.78	
SP increase, per year	10.0	%
Feed type	Sea Surface Conventional	

Pass - Stage	Perm. Flow	Flow / Vessel Feed	Flow / Vessel Conc	Flux	DP	Flux Max	Beta	Stagewise Pressure Perm.	Stagewise Pressure Boost	Stagewise Pressure Conc	Perm. TDS	Element Type	Element Quantity	PV# x Elem #
	m3/h	m3/h	m3/h	lmh	bar	lmh		bar	bar	bar	mg/l			
1-1-h	595.8	9.7	7.3	20.3	0.9	24.8	1.04	1.5	0	60.9	161.6	SWC4 MAX	720	240 x 3M
1-1-h	455.8	7.3	5.4	9.2	0.9	16.5	1.03	1.5	0	60	379.9	SWC5 MAX	1200	240 x 5M

CALCULATION OF INVESTMENT AND WATER COST

Plant capacity as permeate	0.00	m3/h
Specific investment	22,151.90	USD/m3/h
Investment	000.00	USD
Plant life	15.0	years
Membrane life	5.0	years
Interest rate	4.5	%
Membrane cost	500.00	USD/element
Plant factor	90.0	%
Number of elements	1920.0	
Power cost	0.200	USD/kwhr
Inhibitor cost	2.20	
Power consumption	2.27	kwhr/m3
Inhibitor dosing	3.0	mg/l
Maintenance(as % of investment)	3.0	%
Acid cost	1.50	
Acid dosing	3.86	mg/l

CALCULATION RESULTS

Capital cost	0.00	USD/m3
Power cost	0.45	USD/m3
Chemicals cost	0.00	USD/m3
Membrane replacement costs	0.00	USD/m3
Maintenance	0.00	USD/m3
Total water cost	0.45	USD/m3

400 MLD Perur DSP Membrane – 3 SWC4MAX & 5 SWC5MAX Max TDS-39000 mg/l, Temp 31.5C, Rec 46%

Calculated by	MORILLON		Permeate flow/train	1052.00 m3/h
HP Pump flow		1063.71 m3/h	Total product flow	16832.00 m3/h
Feed pressure		62.6 bar	Number of trains	16
Feed temperature		31.5 °C(88.7°F)	Raw water flow/train	2286.96 m3/h
Feed water pH		8.40	Permeate recovery	46.00 %
Chem dose, mg/l, 50 %		7.7 NaOH	Element age	3.5 years
Leakage		1 %	Flux decline %, per year	7.0
Volumetric mixing		4 %	Fouling factor	0.78
H.P. differential		0.80 bar	SP increase, per year	10.0 %
Boost pressure		2.52 bar		
Specific energy		2.29 kwh/m3		
Pass NDP		19.4 bar		
Average flux rate		13.4 lmh		
			Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Boost bar	Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	605.4	9.5	7	20.6	0.9	25.3	1.04	1.5	0	61.7	160.6	SWC4 MAX	720	240 x 3M
1-1-h	445.9	7	5.1	9.1	0.9	16.5	1.04	1.5	0	60.8	386.2	SWC5 MAX	1200	240 x 5M

Ion (mg/l)	Raw Water	Blended Water	Feed Water	Permeate Water	Concentrate	ERD Reject
Hardness, as CaCO3	6323.24	6442.81	6442.81	15.066	11912.1	11688.58
Ca	467.00	475.83	475.83	1.113	879.8	863.26
Mg	1258.00	1281.79	1281.79	2.997	2369.9	2325.43
Na	12299.00	12531.74	12531.74	140.342	23075.4	22644.45
K	391.00	398.31	398.31	5.572	732.5	718.82
NH4	0.20	0.18	0.18	0.003	0.3	0.32
Ba	0.450	0.459	0.459	0.001	0.8	0.83
Sr	0.100	0.102	0.102	0.000	0.2	0.18
H	0.00	0.00	0.00	0.000	0.0	0.00
CO3	18.46	39.97	39.97	0.002	88.1	86.11
HCO3	126.30	106.87	106.87	1.967	146.1	144.46
SO4	2878.00	2932.41	2932.41	7.526	5421.2	5319.45
Cl	21560.00	21964.42	21964.42	225.058	40462.2	39706.12
F	1.63	1.66	1.66	0.034	3.0	2.99
NO3	4.00	4.07	4.07	0.308	7.3	7.14
PO4	0.76	0.77	0.77	0.002	1.4	1.40
OH	0.19	0.49	0.49	0.004	0.8	0.78
SiO2	1.38	1.41	1.41	0.011	2.6	2.54
B	3.80	3.85	3.85	0.977	6.3	6.20
CO2	0.56	0.19	0.19	0.19	0.26	0.26
NH3	0.02	0.04	0.04	0.04	0.04	0.04
TDS	**39010.08**	**39743.83**	**39743.83**	**385.91**	**73197.09**	**71829.71**
pH	**8.00**	**8.40**	**8.40**	**7.16**	**8.44**	**8.44**

Saturations	**Raw Water**	**Feed Water**	**Concentrate**	**Limits**

Version : 2.228.86 %

CaSO4 / ksp * 100, %	23	23	51	400
SrSO4 / ksp * 100, %	0	0	1	1200
BaSO4 / ksp * 100, %	1771	1808	3652	10000
SiO2 saturation, %	1	1	1	140
CaF2 / ksp * 100, %	55	59	594	50000
Ca3(PO4)2 saturation index	0.8	1.3	2.2	2.4
CCPP, mg/l	29.44	25.04	52.65	850
Ionic strength	0.76	0.78	1.44	
Osmotic pressure, bar	29.3	29.8	54.9	

400 MLD Perur DSP Membrane – 3 SWC4MAX & 5 SWC5MAX Max TDS-39000 mg/l, Temp 31.5C, Rec 46%

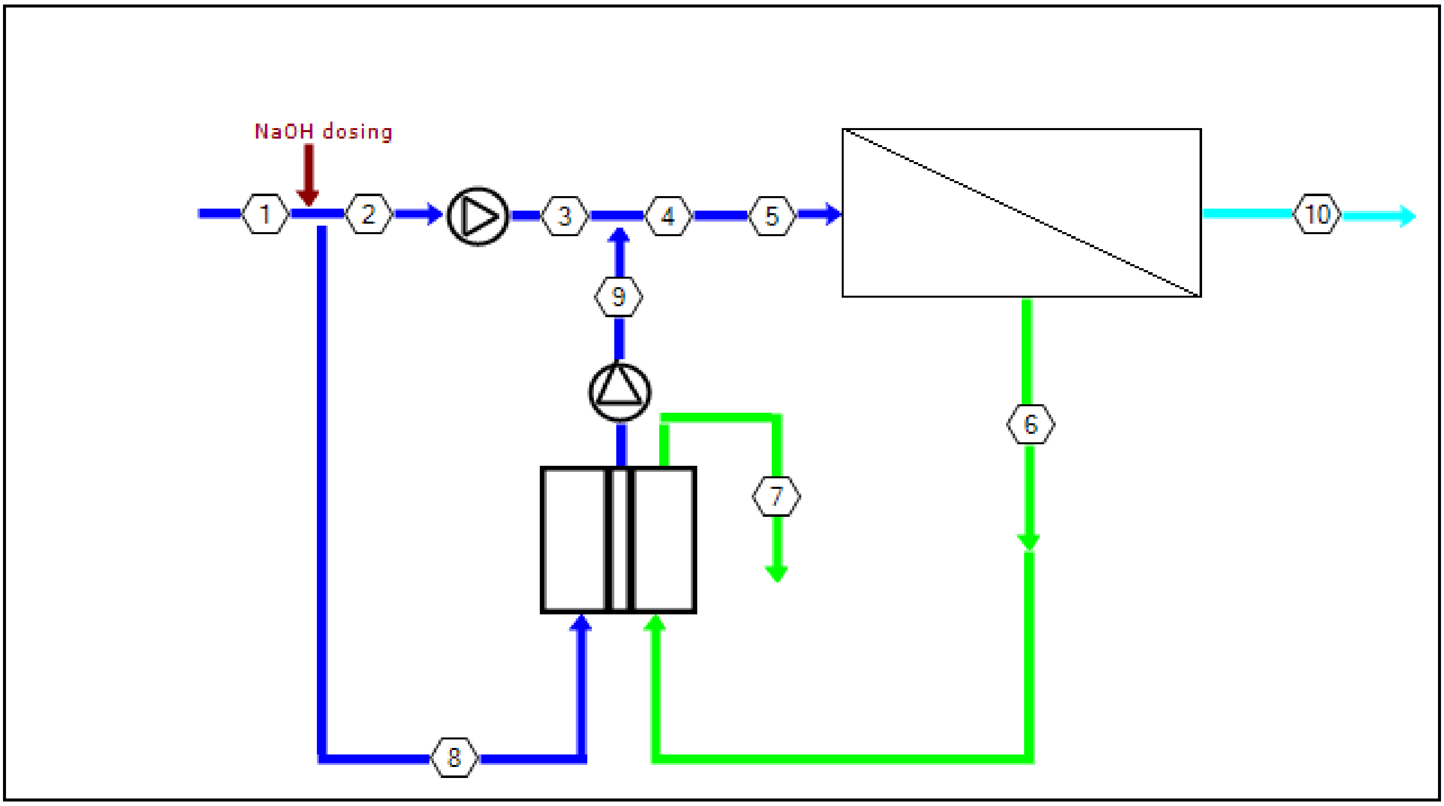
Calculated by	MORILLON		Permeate flow/train	1052.00	m3/h
HP Pump flow	1063.71	m3/h	Total product flow	16832.00	m3/h
Feed pressure	62.6	bar	Number of trains	16	
Feed temperature	31.5	°C(88.7°F)	Raw water flow/train	2286.96	m3/h
Feed water pH	8.40		Permeate recovery	46.00	%
Chem dose, mg/l, 50 %	7.7	NaOH	Element age	3.5	years
Leakage	1	%	Flux decline %, per year	7.0	
Volumetric mixing	4	%	Fouling factor	0.78	
H.P. differential	0.80	bar	SP increase, per year	10.0	%
Boost pressure	2.52	bar			
Specific energy	2.29	kwh/m3			
Pass NDP	19.4	bar			
Average flux rate	13.4	lmh			
			Feed type	Sea Surface Conventional	

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	605.4	9.5	7	20.6	0.9	25.3	1.04	1.5	0	61.7	160.6	SWC4 MAX	720	240 x 3M
1-1-h	445.9	7	5.1	9.1	0.9	16.5	1.04	1.5	0	60.8	386.2	SWC5 MAX	1200	240 x 5M

Pass - Stage	Element No.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	Permeate (Stagewise cumulative) TDS	Ca	Mg	Na	Cl
1-1	1	62.6	0.33	33.4	28.5	1	25.3	1.04	117.9	0.339	0.914	42.872	68.74
1-1	2	62.2	0.28	37	24.3	0.8	20.4	1.03	137.6	0.396	1.067	50.021	80.204
1-1	3	61.9	0.24	40.5	20.5	0.7	16.1	1.03	160.6	0.462	1.245	58.382	93.611
1-1	4	61.7	0.21	44.7	16.2	0.7	16.5	1.04	197.6	0.569	1.533	71.853	115.214
1-1	5	61.5	0.18	48.3	12.3	0.5	11.5	1.03	239.2	0.689	1.856	86.981	139.475
1-1	6	61.3	0.17	51.1	9.2	0.3	8	1.02	285.2	0.822	2.213	103.689	166.271
1-1	7	61.1	0.15	53.3	6.9	0.2	5.6	1.02	334.2	0.963	2.595	121.537	194.897
1-1	8	61	0.14	54.9	5.1	0.2	3.9	1.01	386.2	1.113	2.999	140.427	225.194

400 MLD Perur DSP Membrane – 3 SWC4MAX & 5 SWC5MAX Max TDS-39000 mg/l, Temp 31.5C, Rec 46%

Temperature : 31.5 °C Element age, P1 : 3.5 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	Hardness as CaCO3	Cl	B	pH
1	2287	0	39010	6323	21560	3.80	8.00
2	1064	0	39012	6323	21560	3.80	8.40
3	1064	62.6	39012	6323	21560	3.80	8.40
4	2287	62.6	39744	6443	21964	3.85	8.40
5	2287	62.6	39744	6443	21964	3.85	8.40
6	1236	60.8	73197	11912	40462	6.30	8.44
7	1236	0	71830	11689	39706	6.20	8.44
8	1223	0	39012	6323	21560	3.80	8.40
9	1223	62.6	40380	6547	22316	3.90	8.40
10	1052	1.50	386	15.1	225	0.977	7.16

400 MLD Perur DSP Membrane – 3 SWC4MAX & 5 SWC5MAX Max TDS-39000 mg/l, Temp 31.5C, Rec 46%

Calculated by	MORILLON		Permeate flow/train	1052.00	m3/h
HP Pump flow	1063.71	m3/h	Total product flow	16832.00	m3/h
Feed pressure	62.6	bar	Number of trains	16	
Feed temperature	31.5	°C(88.7°F)	Raw water flow/train	2286.96	m3/h
Feed water pH	8.40		Permeate recovery	46.00	%
Chem dose, mg/l, 50 %	7.7	NaOH	Element age	3.5	years
Leakage	1	%	Flux decline %, per year	7.0	
Volumetric mixing	4	%	Fouling factor	0.78	
H.P. differential	0.80	bar	SP increase, per year	10.0	%
Boost pressure	2.52	bar			
Specific energy	2.29	kwh/m3			
Pass NDP	19.4	bar			
Average flux rate	13.4	lmh			
			Feed type	Sea Surface Conventional	

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1-h	605.4	9.5	7	20.6	0.9	25.3	1.04	1.5	0	61.7	160.6	SWC4 MAX	720	240 x 3M
1-1-h	445.9	7	5.1	9.1	0.9	16.5	1.04	1.5	0	60.8	386.2	SWC5 MAX	1200	240 x 5M

CALCULATION OF INVESTMENT AND WATER COST

Plant capacity as permeate	0.00	m3/h
Specific investment	22,151.90	USD/m3/h
Investment	000.00	USD
Plant life	15.0	years
Membrane life	5.0	years
Interest rate	4.5	%
Membrane cost	500.00	USD/element
Plant factor	90.0	%
Number of elements	1920.0	
Power cost	0.200	USD/kwhr
Inhibitor cost	2.20	
Power consumption	2.29	kwhr/m3
Inhibitor dosing	3.0	mg/l
Maintenance(as % of investment)	3.0	%
Acid cost	1.50	
Acid dosing	3.86	mg/l

CALCULATION RESULTS

Capital cost	0.00	USD/m3
Power cost	0.46	USD/m3
Chemicals cost	0.00	USD/m3
Membrane replacement costs	0.00	USD/m3
Maintenance	0.00	USD/m3
Total water cost	0.46	USD/m3

Calculated by	MORILLON	Permeate flow/train	1052.00 m3/h
HP Pump flow	1063.76 m3/h	Total product flow	16832.00 m3/h
Feed pressure	60.9 bar	Number of trains	16
Feed temperature	28.3 °C(82.9°F)	Raw water flow/train	2286.96 m3/h
Feed water pH	8.13	Permeate recovery	46.00 %
Chem dose, mg/l, -	None	Element age	3.5 years
Leakage	1 %	Flux decline %, per year	7.0
Volumetric mixing	4 %	Fouling factor	0.78
H.P. differential	0.80 bar	SP increase, per year	10.0 %
Boost pressure	2.53 bar		
Specific energy	2.23 kwh/m3		
Pass NDP	21.6 bar		
Average flux rate	13.4 lmh		
		Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Boost bar	Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1	1051.4	9.5	5.1	13.4	1.7	25.3	1.04	1.5	0	59.2	245	SWC4 MAX	1920	240 x 8M

Ion (mg/l)	Raw Water	Blended Water	Feed Water	Permeate Water	Concentrate	ERD Reject
Hardness, as CaCO3	6323.24	6442.90	6442.90	10.501	11916.6	11692.88
Ca	467.00	475.84	475.84	0.776	880.1	863.57
Mg	1258.00	1281.81	1281.81	2.089	2370.8	2326.28
Na	11089.00	11297.53	11297.53	88.245	20836.1	20446.25
K	391.00	398.34	398.34	3.887	734.0	720.28
NH4	0.20	0.20	0.20	0.002	0.4	0.36
Ba	0.450	0.459	0.459	0.001	0.8	0.83
Sr	0.100	0.102	0.102	0.000	0.2	0.18
H	0.00	0.00	0.00	0.000	0.0	0.00
CO3	20.77	21.61	21.61	0.001	60.3	58.71
HCO3	126.30	127.77	127.77	1.625	194.9	192.12
SO4	2878.00	2932.46	2932.46	5.195	5423.4	5321.62
Cl	19700.00	20070.75	20070.75	142.022	37029.2	36336.05
F	1.63	1.66	1.66	0.023	3.1	3.00
NO3	4.00	4.07	4.07	0.214	7.4	7.22
PO4	0.76	0.77	0.77	0.001	1.4	1.41
OH	0.19	0.19	0.19	0.001	0.3	0.33
SiO2	1.38	1.41	1.41	0.008	2.6	2.55
B	3.53	3.58	3.58	0.748	6.0	5.90
CO2	0.44	0.45	0.45	0.45	0.59	0.58
NH3	0.02	0.02	0.02	0.02	0.02	0.02
TDS	**35942.12**	**36618.36**	**36618.36**	**244.84**	**67550.66**	**66286.34**
pH	**8.13**	**8.13**	**8.13**	**6.72**	**8.21**	**8.21**

Saturations	**Raw Water**	**Feed Water**	**Concentrate**	**Limits**
CaSO4 / ksp * 100, %	25	25	54	400

Version : 2.228.86 %

SrSO4 / ksp * 100, %	0	0	1	1200
BaSO4 / ksp * 100, %	1883	1923	3883	10000
SiO2 saturation, %	1	1	2	140
CaF2 / ksp * 100, %	54	57	548	50000
Ca3(PO4)2 saturation index	0.9	0.9	1.8	2.4
CCPP, mg/l	30.28	31.15	76.25	850
Ionic strength	0.71	0.73	1.34	
Osmotic pressure, bar	26.5	27.0	49.8	

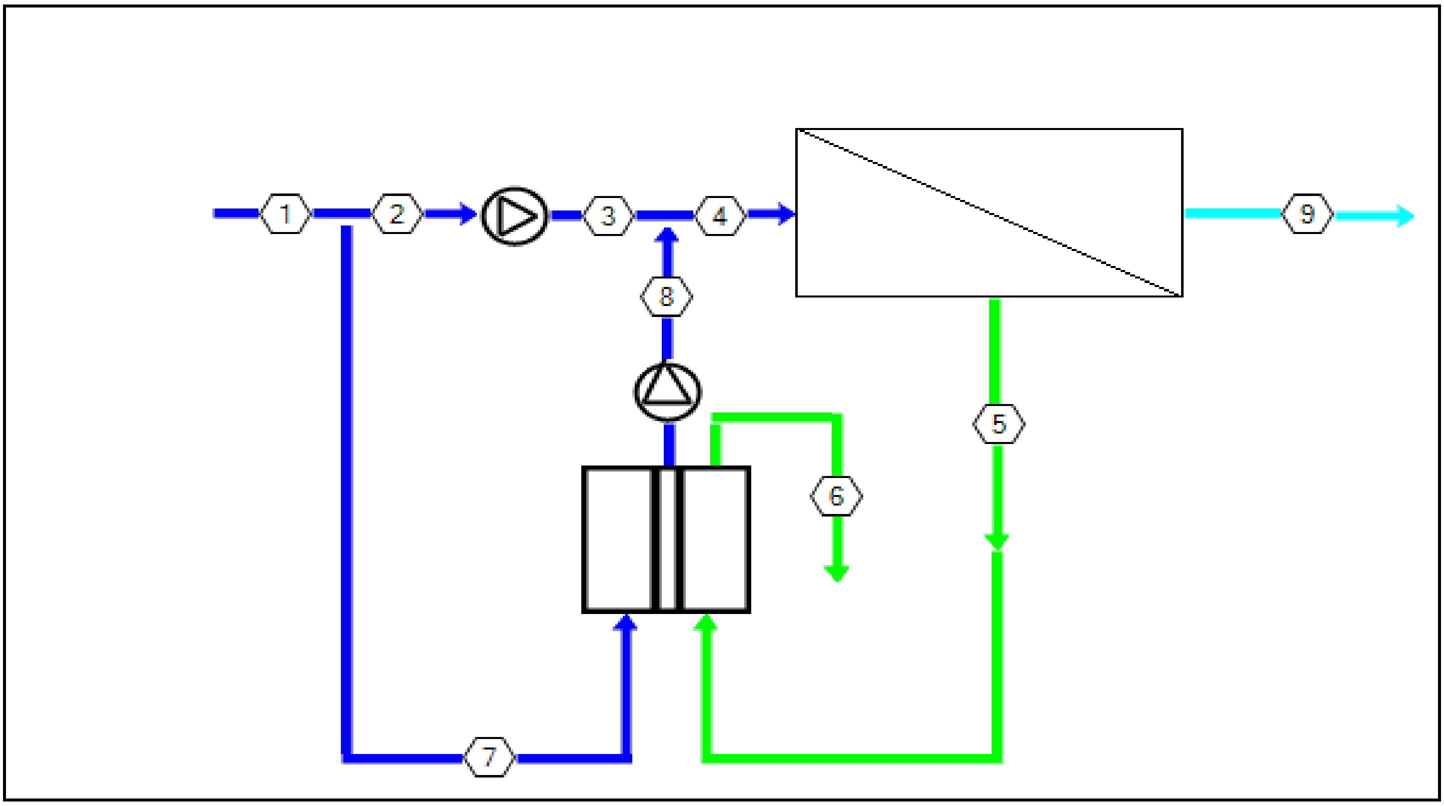
Calculated by	MORILLON	Permeate flow/train	1052.00 m3/h
HP Pump flow	1063.76 m3/h	Total product flow	16832.00 m3/h
Feed pressure	60.9 bar	Number of trains	16
Feed temperature	28.3 °C(82.9°F)	Raw water flow/train	2286.96 m3/h
Feed water pH	8.13	Permeate recovery	46.00 %
Chem dose, mg/l, -	None	Element age	3.5 years
Leakage	1 %	Flux decline %, per year	7.0
Volumetric mixing	4 %	Fouling factor	0.78
H.P. differential	0.80 bar	SP increase, per year	10.0 %
Boost pressure	2.53 bar		
Specific energy	2.23 kwh/m3		
Pass NDP	21.6 bar		
Average flux rate	13.4 lmh		
		Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1	1051.4	9.5	5.1	13.4	1.7	25.3	1.04	1.5	0	59.2	245	SWC4 MAX	1920	240 x 8M

Pass - Stage	Element No.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	Permeate (Stagewise cumulative) TDS	Ca	Mg	Na	Cl
1-1	1	60.9	0.33	30.3	29.8	1	25.3	1.04	95.3	0.301	0.812	34.329	55.243
1-1	2	60.6	0.28	33.6	26	0.9	21	1.03	109.8	0.347	0.936	39.571	63.679
1-1	3	60.3	0.24	37	22.3	0.7	17	1.03	127	0.402	1.083	45.766	73.648
1-1	4	60.1	0.21	40.2	18.9	0.6	13.6	1.03	146.4	0.463	1.248	52.767	84.916
1-1	5	59.9	0.19	43.1	15.7	0.4	10.7	1.03	168.1	0.532	1.434	60.579	97.49
1-1	6	59.7	0.17	45.7	12.9	0.3	8.3	1.02	191.9	0.607	1.636	69.141	111.271
1-1	7	59.5	0.15	47.9	10.5	0.3	6.5	1.02	217.6	0.689	1.856	78.407	126.186
1-1	8	59.3	0.14	49.8	8.5	0.2	4.9	1.01	245	0.776	2.09	88.295	142.102

Temperature : 28.3 °C

Element age, P1 : 3.5 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	Hardness as CaCO3	Cl	B	pH
1	2287	0	35942	6323	19700	3.53	8.13
2	1064	0	35942	6323	19700	3.53	8.13
3	1064	60.9	35942	6323	19700	3.53	8.13
4	2287	60.9	36618	6443	20071	3.58	8.13
5	1236	59.2	67551	11917	37029	5.99	8.21
6	1236	0	66286	11693	36336	5.90	8.21
7	1223	0	35942	6323	19700	3.53	8.13
8	1223	60.9	37206	6547	20393	3.63	8.13
9	1052	1.50	245	10.5	142	0.748	6.72

Calculated by	MORILLON		Permeate flow/train	1052.00 m3/h
HP Pump flow		1063.76 m3/h	Total product flow	16832.00 m3/h
Feed pressure		60.9 bar	Number of trains	16
Feed temperature		28.3 °C(82.9°F)	Raw water flow/train	2286.96 m3/h
Feed water pH		8.13	Permeate recovery	46.00 %
Chem dose, mg/l, -		None	Element age	3.5 years
Leakage		1 %	Flux decline %, per year	7.0
Volumetric mixing		4 %	Fouling factor	0.78
H.P. differential		0.80 bar	SP increase, per year	10.0 %
Boost pressure		2.53 bar		
Specific energy		2.23 kwh/m3		
Pass NDP		21.6 bar		
Average flux rate		13.4 lmh		
			Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1	1051.4	9.5	5.1	13.4	1.7	25.3	1.04	1.5	0	59.2	245	SWC4 MAX	1920	240 x 8M

CALCULATION OF INVESTMENT AND WATER COST

Plant capacity as permeate	0.00 m3/h
Specific investment	22,151.90 USD/m3/h
Investment	000.00 USD
Plant life	15.0 years
Membrane life	5.0 years
Interest rate	4.5 %
Membrane cost	500.00 USD/element
Plant factor	90.0 %
Number of elements	1920.0
Power cost	0.200 USD/kwhr
Inhibitor cost	2.20
Power consumption	2.23 kwhr/m3
Inhibitor dosing	3.0 mg/l
Maintenance(as % of investment)	3.0 %
Acid cost	1.50
Acid dosing	0.00 mg/l

CALCULATION RESULTS

Capital cost	0.00 USD/m3
Power cost	0.45 USD/m3
Chemicals cost	0.00 USD/m3
Membrane replacement costs	0.00 USD/m3
Maintenance	0.00 USD/m3
Total water cost	0.45 USD/m3

Calculated by	MORILLON	Permeate flow/train	1052.00 m3/h
HP Pump flow	1063.61 m3/h	Total product flow	16832.00 m3/h
Feed pressure	65.2 bar	Number of trains	16
Feed temperature	31.5 °C(88.7°F)	Raw water flow/train	2286.96 m3/h
Feed water pH	8.00	Permeate recovery	46.00 %
Chem dose, mg/l, -	None	Element age	3.5 years
Leakage	1 %	Flux decline %, per year	7.0
Volumetric mixing	4 %	Fouling factor	0.78
H.P. differential	0.80 bar	SP increase, per year	10.0 %
Boost pressure	2.50 bar		
Specific energy	2.38 kwh/m3		
Pass NDP	22.1 bar		
Average flux rate	13.4 lmh		
		Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1	1051.3	9.5	5.1	13.4	1.7	27.3	1.04	1.5	0	63.5	307	SWC4 MAX	1920	240 x 8M

Ion (mg/l)	Raw Water	Blended Water	Feed Water	Permeate Water	Concentrate	ERD Reject
Hardness, as CaCO3	6323.24	6442.86	6442.86	11.959	11913.9	11690.25
Ca	467.00	475.83	475.83	0.883	879.9	863.38
Mg	1258.00	1281.80	1281.80	2.379	2370.3	2325.76
Na	12299.00	12530.00	12530.00	111.437	23094.9	22663.05
K	391.00	398.33	398.33	4.426	733.4	719.73
NH4	0.20	0.20	0.20	0.003	0.4	0.36
Ba	0.450	0.459	0.459	0.001	0.8	0.83
Sr	0.100	0.102	0.102	0.000	0.2	0.18
H	0.00	0.00	0.00	0.000	0.0	0.00
CO3	18.46	19.29	19.29	0.001	57.5	55.95
HCO3	126.30	127.78	127.78	1.867	195.5	192.76
SO4	2878.00	2932.44	2932.44	5.969	5422.1	5320.33
Cl	21560.00	21965.26	21965.26	178.552	40500.0	39742.37
F	1.63	1.66	1.66	0.027	3.1	2.99
NO3	4.00	4.07	4.07	0.245	7.3	7.19
PO4	0.76	0.77	0.77	0.002	1.4	1.40
OH	0.19	0.20	0.20	0.001	0.4	0.38
SiO2	1.38	1.41	1.41	0.009	2.6	2.55
B	3.80	3.85	3.85	0.987	6.3	6.19
CO2	0.56	0.56	0.56	0.56	0.72	0.71
NH3	0.02	0.02	0.02	0.02	0.02	0.02
TDS	**39010.08**	**39743.26**	**39743.26**	**306.79**	**73275.66**	**71905.04**
pH	**8.00**	**8.00**	**8.00**	**6.67**	**8.13**	**8.13**

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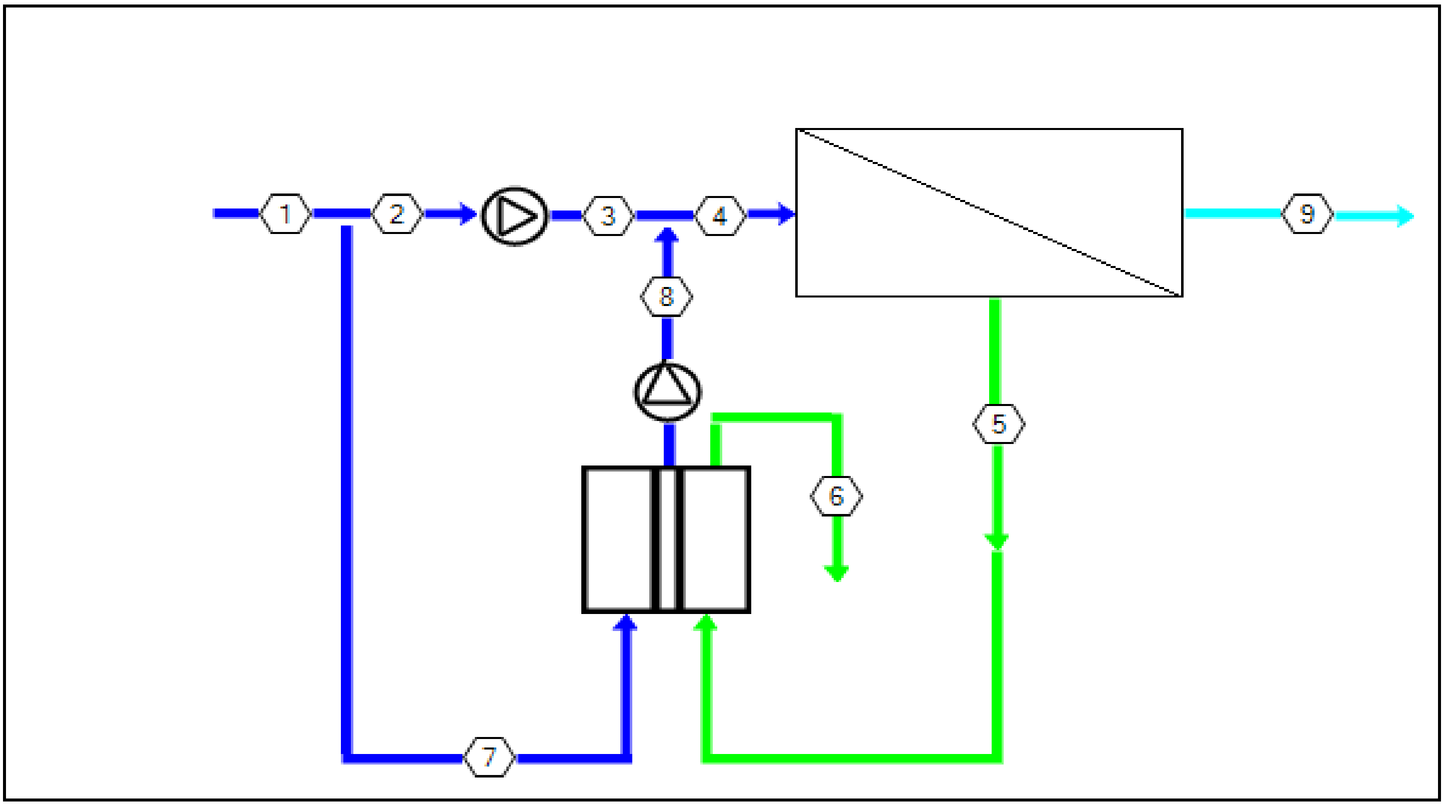
Saturations	Raw Water	Feed Water	Concentrate	Limits
CaSO4 / ksp * 100, %	23	23	51	400
SrSO4 / ksp * 100, %	0	0	1	1200
BaSO4 / ksp * 100, %	1771	1809	3653	10000
SiO2 saturation, %	1	1	2	140
CaF2 / ksp * 100, %	55	59	597	50000
Ca3(PO4)2 saturation index	0.8	0.8	1.8	2.4
CCPP, mg/l	29.44	30.32	76.10	850
Ionic strength	0.76	0.78	1.44	
Osmotic pressure, bar	29.3	29.8	55.0	

Calculated by	MORILLON	Permeate flow/train	1052.00 m3/h
HP Pump flow	1063.61 m3/h	Total product flow	16832.00 m3/h
Feed pressure	65.2 bar	Number of trains	16
Feed temperature	31.5 °C(88.7°F)	Raw water flow/train	2286.96 m3/h
Feed water pH	8.00	Permeate recovery	46.00 %
Chem dose, mg/l, -	None	Element age	3.5 years
Leakage	1 %	Flux decline %, per year	7.0
Volumetric mixing	4 %	Fouling factor	0.78
H.P. differential	0.80 bar	SP increase, per year	10.0 %
Boost pressure	2.50 bar		
Specific energy	2.38 kwh/m3		
Pass NDP	22.1 bar		
Average flux rate	13.4 lmh	Feed type	Sea Surface Conventional

Pass - Stage	Perm. Flow m3/h	Flow / Vessel Feed m3/h	Flow / Vessel Conc m3/h	Flux lmh	DP bar	Flux Max lmh	Beta	Stagewise Pressure Perm. bar	Stagewise Pressure Boost bar	Stagewise Pressure Conc bar	Perm. TDS mg/l	Element Type	Element Quantity	PV# x Elem #
1-1	1051.3	9.5	5.1	13.4	1.7	27.3	1.04	1.5	0	63.5	307	SWC4 MAX	1920	240 x 8M

Pass - Stage	Element No.	Feed Pressure bar	Pressure Drop bar	Conc Osmo. bar	NDP bar	Permeate Water Flow m3/h	Permeate Water Flux lmh	Beta	Permeate (Stagewise cumulative) TDS	Ca	Mg	Na	Cl
1-1	1	65.2	0.33	33.7	30.8	1.1	27.3	1.04	110.1	0.317	0.853	39.978	64.047
1-1	2	64.9	0.28	37.8	26.3	0.9	21.9	1.04	129.4	0.372	1.002	46.987	75.278
1-1	3	64.6	0.24	41.6	22.3	0.7	17.3	1.03	151.7	0.436	1.175	55.075	88.237
1-1	4	64.4	0.21	45.2	18.2	0.5	13.1	1.03	177.7	0.511	1.377	64.535	103.394
1-1	5	64.2	0.18	48.3	14.9	0.4	10	1.02	206.5	0.594	1.601	75.006	120.173
1-1	6	64	0.17	51	12.1	0.3	7.5	1.02	237.8	0.684	1.844	86.382	138.401
1-1	7	63.8	0.15	53.2	9.7	0.2	5.8	1.02	271.5	0.781	2.105	98.592	157.967
1-1	8	63.7	0.14	54.9	7.7	0.2	4.2	1.01	307	0.884	2.381	111.515	178.678

Temperature : 31.5 °C Element age, P1 : 3.5 years



Stream No.	Flow (m3/h)	Pressure (bar)	TDS (mg/l)	Hardness as CaCO3	Cl	B	pH
1	2287	0	39010	6323	21560	3.80	8.00
2	1064	0	39010	6323	21560	3.80	8.00
3	1064	65.2	39010	6323	21560	3.80	8.00
4	2287	65.2	39743	6443	21965	3.85	8.00
5	1236	63.5	73276	11914	40500	6.29	8.13
6	1236	0	71905	11690	39742	6.19	8.13
7	1223	0	39010	6323	21560	3.80	8.00
8	1223	65.2	40381	6547	22318	3.90	8.00
9	1052	1.50	307	12.0	179	0.987	6.67

Calculated by	MORILLON		Permeate flow/train	1052.00	m3/h
HP Pump flow	1063.61	m3/h	Total product flow	16832.00	m3/h
Feed pressure	65.2	bar	Number of trains	16	
Feed temperature	31.5	°C(88.7°F)	Raw water flow/train	2286.96	m3/h
Feed water pH	8.00		Permeate recovery	46.00	%
Chem dose, mg/l, -	None		Element age	3.5	years
Leakage	1	%	Flux decline %, per year	7.0	
Volumetric mixing	4	%	Fouling factor	0.78	
H.P. differential	0.80	bar	SP increase, per year	10.0	%
Boost pressure	2.50	bar			
Specific energy	2.38	kwh/m3			
Pass NDP	22.1	bar			
Average flux rate	13.4	lmh			
			Feed type	Sea Surface Conventional	

Pass - Stage	Perm. Flow	Flow / Vessel Feed	Flow / Vessel Conc	Flux	DP	Flux Max	Beta	Stagewise Pressure Perm.	Stagewise Pressure Boost	Stagewise Pressure Conc	Perm. TDS	Element Type	Element Quantity	PV# x Elem #
	m3/h	m3/h	m3/h	lmh	bar	lmh		bar	bar	bar	mg/l			
1-1	1051.3	9.5	5.1	13.4	1.7	27.3	1.04	1.5	0	63.5	307	SWC4 MAX	1920	240 x 8M

CALCULATION OF INVESTMENT AND WATER COST

Plant capacity as permeate	0.00	m3/h
Specific investment	22,151.90	USD/m3/h
Investment	000.00	USD
Plant life	15.0	years
Membrane life	5.0	years
Interest rate	4.5	%
Membrane cost	500.00	USD/element
Plant factor	90.0	%
Number of elements	1920.0	
Power cost	0.200	USD/kwhr
Inhibitor cost	2.20	
Power consumption	2.38	kwhr/m3
Inhibitor dosing	3.0	mg/l
Maintenance(as % of investment)	3.0	%
Acid cost	1.50	
Acid dosing	0.00	mg/l

CALCULATION RESULTS

Capital cost	0.00	USD/m3
Power cost	0.48	USD/m3
Chemicals cost	0.00	USD/m3
Membrane replacement costs	0.00	USD/m3
Maintenance	0.00	USD/m3
Total water cost	0.48	USD/m3

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Annexure: 6 Details of Sludge Treatment System Design for 400 MLD Perur Desalination Plant

Sl.No.	Description		Value	Unit	Remarks
1	**Lamella Sludge Calculation**				
	Inflow from seawater	=	1040.00	MLD	
	TSS in Seawater	=	300	ppm	
	Sludge load from seawater	=	312000	kg/day	
	Inflow for band screen cleaning	=	3.500	MLD	
	Ferric flow rate	=	0.04	MLD	
	Poly flow rate	=	0.21	MLD	
	Total Inflow into Lamella	=	1043.75	MLD	
		=	43490	m3/hr	
	Sludge due to $FeCl_3$ addition		14.4	ppm	2.88 times the Fe metal
	Sludge load due to $FeCl_3$ addition	=	15030	kg/day	
	Total sludge load into Lamella	=	327030	kg/day	
	Suspended solids in Lamella inlet calculated	=	313.32	ppm	
	Recovery in Lamella assumed	=	98.00	%	
	Lamella supernant water	=	1022.877	MLD	
	TSS in Lamella supernant water	=	38.36	ppm	
	Sludge removal efficiency in Lamella		88.00	%	
	Sludge load in Lamella supernant water	=	39244	kg/day	
	Hence sludge load removed in Lamella from under flow arrived	=	287788	kg/day	
	Lamella under flow sludge flow rate arrived	=	20.88	MLD	
	Lamella under flow sludge concentration arrived	=	13784.33	ppm	
	Lamella under flow sludge consistency arrived	=	1.378	%	up to 2% as per CPHEEO sewage manual Chapter 5, page 5-55, clause No 5.7.4.2.6.1
	TSS in Lamella supernant water	=	38.36	ppm	
	Hence sludge load removed from Lamella	=	287788	kg/day	
	Total Solids load	=	11991	kg/hr	
2	**DAF Sludge Calculation**				
	Effluent of Lamella	=	1022.88	MLD	
	TSS in feed to DAF	=	38.37	ppm	
	Sludge load into DAF	=	39244	kg/day	
	Ferric flow rate	=	0.02	MLD	
	Poly flow rate	=	0.051	MLD	
	Total Inflow into DAF	=	1023	MLD	

Sl.No.	Description		Value	Unit	Remarks
		=	42623	m3/hr	
	Sludge due to $FeCl_3$ addition		5.8	ppm	2.88 times the Fe metal
	Sludge load due to FeCl3 addition	=	5892	kg/day	0.4 times the FeCl3 consumption
	Total sludge load into DAF	=	45136	kg/day	
	Suspended solids in DAF inlet calculated	=	44.12	ppm	
	Recovery in DAF assumed	=	99.00	%	
	DAF supernant water	=	1012.716	MLD	
	TSS in DAF supernant water	=	3.57	ppm	
	Sludge removal efficiency in DAF		92.00	%	
	Sludge load in DAF supernant water	=	3611	kg/day	
	Hence sludge load removed in DAF from under flow arrived	=	41525	kg/day	
	DAF under flow sludge flow rate arrived	=	10.23	MLD	
	DAF under flow sludge concentration arrived	=	4058.88	ppm	
	DAF under flow sludge consistency arrived	=	0.406	%	
	TSS in DAF supernant water	=	3.57	ppm	
	Hence sludge load removed from DAF	=	41525.00	kg/day	
	Total Solids load	=	1730	kg/hr	
3	**Sludge Balancing Tank Design**				
	Total inflow into sludge balancing tank	=	31.10	MLD	
		=	1296.02	m3/hr	
	Sludge load into Sludge balancing tank	=	329311	kg/day	
	Tank volume considered (100% extra)	=	2592	m3	
	retention time arrived for average flow	=	2.00	hrs	
	Number of tanks	=	1	No	
	Tank depth as per contract	=	3.5	m	
	Tank area required	=	740.6	m2	
	Tank diameter arrived	=	30.7	m	
	Tank diameter considered	=	31	m	
	Tank size	**=**	**31m dia x 3.5m SWD**		
	Volume	=	2641.7	m3	
	MOC	=	RCC		
	Retention time arrived	=	2.04	hrs	
	Sludge collection pit sizing				
	Diameter of tank provided	=	31.00	m	
	Width provided	=	5.00	m	

Sl.No.	Description		Value	Unit	Remarks
	Depth provided	=	2.00	m	
	Size of sludge pit provided	=	5m x 3m x 2m Deep		
	Slope provided in spent backwash tank floor for sludge collection	=	1 in 12		As per CPHEEO Manual on Water Supply and Treatment, Cl.7.5.8, Pg. no. 230
4	**Submersible mixers**				
	No of working mixers	=	3	No	1 mixer on self
	Mixing power required	=	10	W/m3	
	Required power per mixer	=	8.8	kW	
	Motor rating considered	=	10	kW	
	Type of mixers	=	Submersible		
	Note: Details indicated above may vary based on suppliers' details.				
5	**Static mixer**				
	No of mixers	=	1	No	
	Installation	=	Pump discharge line		
6	**Thickener feed pumps**				
	Capacity of pumps required (10% extra)	=	1425.82	m3/hr	
	Pump capacity considered	=	1500	m3/hr	
	Quantity	=	2	No (1W+1S)	
	Type of pumps	=	Submersible non clog type		
7	**Thickener Design**				
	No of Thickeners	=	2	No	
	Solid loading in to Thickeners	=	329314	kg/day	
		=	13721.4	kg/hr	
	In Flow rate	=	1296.20	m3/hr	
	Design flow rate	=	1500.00	m3/hr	
	TSS in inflow of Thickener	=	9148	ppm	
	Solids recovery rate in Thickener	=	96	%	up to 90 % as per CPHEEO sewage manual Chapter 6, page 6-4, Table 6.3. Retention time is increased to achieve 96% solids recovery.
	Solid carry over in supernant of Thickener	=	548.86	kg/hr	
	TSS in Thickener supernant water	=	470	ppm	

Sl.No.	Description		Value	Unit	Remarks
	Solid loading rate	=	100-150	kg/day/m2	as per Metcalf & Eddy, table 14-19, page 1492
	Solid loading rate considered	=	86	kg/day/m2	Due to presence of high organics
		=	3.58	kg/hr/m2	
	Surface area of Thickener required	=	3829.2	m2	
	Diameter of each Thickener arrived (a)	=	34.912	m	
	Surface loading rate required	=	0.7	m3/hr/m2	
	Surface area of Thickener required	=	2142.9	m2	
	Diameter of each Thickener arrived (b)	=	26.117	m	
	Thickener diameter (max of a,b)	=	34.912	m	
	Diameter of Thickener considered	=	**35.0**	m	
	Liquid depth in Thickener	=	**4**	m	
	Type of Thickener	=	**Full bridge, central driven**		
	Size of Thickener	=	**35m dia x 4m SWD**		
	Weir load				
	Peak flow per hour into a Thickener	=	750	m3/hr	
	Flow per day per	=	18000	m3/day	
	Weir load	=	163.8	m3/day/m	
	Weir load	=	< 300	m3/day/m	as per CPHEEO page 230, Clause No 7.5.8
			Hence OK		
	Provide Thickener size - 2 x 35m dia x 4.0m SWD				
	V- Notch weir				
	Provide 90^0 V-Notch weirs at	=	175	c/c distance	
	Length of weir plate	=	109.900	m	
	No. of V-notch	=	628.00	No	
	Flow per each notch	=	0.332	lps	
		=	1.194	m3/hr	
		=	0.00033	m3/sec	
	Flow through V - Notch				
	$Q = 2.362\ C_e\ h^{2.5}$				
	Ce for head of 60 mm to 377 mm	=	0.603 to 0.686		
	Consider Ce	=	0.613		
	Consider h	=	0.035	m	
	Q	=	0.00033	m3/s	
		=	1.195	m3/hr	
	Total flow	=	750.192	m3/hr	Check for flow
	Weir plate size: 150 mm wide, 90 degree V Notch of 60 mm depth, C/C 175mm				
	Q	=	$1.402 \times 10^{-2} \times (h)^{5/2}$		

Sl.No.	Description		Value	Unit	Remarks
	Q	=	Flow per notch in lps		
	h	=	Water depth in cm		
	h	=	3.55	cm	
		=	4	cm	
		=	41	mm	<60 mm depth
8	**Thickened Sludge holding tank**				
	Sludge load removed in Thickener	=	13172.6	kg/hr	
	Concentration of solids in underflow	=	3 to 5	%	
	Solid concentration considered	=	5.00%		
	Formula to calculate Specific gravity of slurry				
	1/Ss	=	$(M_f/S_f) + M_v/S_v)$		
	S_s	=	Overall specific gravity of slurry		
	M_f	=	Mass of fixed solids, 0.05kg		
	S_f	=	Specific gravity of fixed solids, 2.5		
	M_v	=	Mass of volatile solids, 0.95 kg		
	S_v	=	Specific gravity of volatile solids, 1		
	Therefore Ss	=	1.0309		
	Thickener underflow slurry density	=	1030.93	kg/m^3	
	Thickener Underflow per unit	=	127.77	m^3/h	
	Total sludge from Thickener into sludge holding tank	=	255.55	m^3/h	
		=	6.13	MLD	
	Hydraulic retention time	=	4.00	hr	
	Volume of Sludge holding tank required	=	1022.19	m3	
	Depth of tank	=	3.0	m	
	Length of tank	=	28.0	m	
	Width of tank arrived	=	12.2	m	
	Width of tank considered	=	14.0	m	
	Size of tank	=	**28m L x 14.0 m W x 3.0m SWD**		
	Number of tanks	=	1	No	
	MOC	=	RCC		
9	**Agitators in Sludge holding tank**				
	No of Agitators in the tank	=	2	No	
	No of working mixers	=	2	No	

Sl.No.	Description		Value	Unit	Remarks
	Type of mixers	=	Vertical top mounted suspended type		
	Design of agitators				
A	**Power requirement**				
	Formulae for Total Power input to agitator, P	=	G^2 μ (Vol)		
	Velocity gradient (G)	=	75	s^{-1}	10-75 As per CPHEEO Manual on Water Supply and Treatment, page 213
	Absolute viscosity of water (μ)	=	0.0008	NS/m2	As per CPHEEO Manual, Table 7.4.3 of page 207
		=	0.001236	NS/m2 @ 12 deg c	
	Volume of tank (V)	=	1176.0	m3	
	Input power in water (P)	=	4.1	kW	
	Efficiency of Gear box	=	85	%	
	Efficiency of Motor	=	75	%	
	Motor rating required	=	6.41	kW	
	Motor rating for agitator considered	=	7.5	kW	
	* Motor rating for the agitator shall be finalized as per the selected vendor.				
B	**Design of No of blades**				
	Power input, (Watt)	=	1/2 x Cd x ρ x Ap $(V-v)^3$		As per CPHEEO Manual on Water Supply and Treatment, Cl.7.4.3.1 (2), Pg. no. 213
	Where, **Value considered :**				
	Cd, Newton coefficient of drag	=	1.80		0.8-1.9 As per CPHEEO Manual, Cl.7.4.3.1 (2), Pg. no. 213
	ρ, Density of water	=	1000.00	kg/m^3	
	V, Velocity of the tip of Blades	=	0.55	m/sec	0.2-0.6 As per CPHEEO Manual, Cl.7.4.3.1 (2), Pg. no. 213
	v, Velocity of water at tip of Blade	=	25% of V	m/sec	
		=	0.138	m/sec	
	Total Power input to Agitator	=	4088.07	watts	
	Hence Ap	=	64.715	m2	

Sl.No.	Description		Value	Unit	Remarks
	total area of paddles to cross section area of tank	=	19.0	%	10-25% As per CPHEEO Manual, Cl.7.4.3.1 (2), Pg. no. 213
	*The dimensions of Blades for the agitator shall be finalized as per the selected vendor.				
10	**Filter press feed pumps**				
	Sludge flow rate	=	255.5	m3/hr	
		=	6133	m3/day	
	No of hours of operation of filter presses	=	16	hours	
	Feed to filter presses	=	383	m3/hr	
	No of working pumps for filter press feed	=	15	No	
	No of stand by pumps	=	1	No	
	Capacity of each pump	=	25.6	m3/hr	
	Capacity of each pump considered	=	27.0	m3/hr	
	Type of pump	=	Progressive cavity pumps		
11	**Belt Filter Press**				
	Type of Filter press	=	Belt filter press		
	No of hours of operation of Filter presses per day	=	16	hours	
	Total sludge flow rate from Thickener	=	6133	m3/day	
		=	383	m3/hr	
	Total sludge load from Thickener	=	316142	kg/day	
		=	19759	kg/hr	
	No of working filter presses	=	15	No.	
	No of stand by filter presses	=	3	No.	
	Capacity of each filter press	**=**	**25.55**	**m3/hr**	
	Solids load to each filter press	=	1317.26	kg/hr	
	Dry solids to each filter press	=	1317	kg/h	
	Dryness of cake (Solid consistency)	=	25	%	
	Bulk density of particles	=	2500	kg/m^3	
	Formula to calculate Specific gravity of slurry				
	$1/S_s$	=	$(M_f/S_f) + M_v/S_v)$		
	S_s	=	Overall sp. gravity of slurry		
	M_f	=	Mass of fixed solids, 0.25 kg		
	S_f	=	Sp. gravity of fixed solids, 2.5		
	M_v	=	Mass of volatile solids, 0.75 kg		

Sl.No.	Description		Value	Unit	Remarks
	S_v	=	Sp. gravity of volatile solids, 1		
	Therefore Ss	=	1176.47	kg/m^3	
	Volume of cake	=	4.48	m^3/hr	
	Total sludge generated for all filter presses	=	67.2	m^3/hr	
		=	1075	m^3/day	
		=	1.075	MLD	
	Filtrate generated from all filter presses	=	316.14	m^3/hr	
			5058	m^3/day	
			5.058	MLD	
12	**Belt filter press washing pumps**				
	Total number of pumps	=	4	No	
	No of working pumps	=	3	No	
	No of stand by pumps	=	1	No	
	Capacity of each pump	=	30	m3/hr	5 m3/hr for each BFP
13	**Polymer dosing pumps for Thickener**				
	Type of polymer	=	Non-food grade		
	Solids load into Thickener	=	13721.42	kg/hr	
		=	13.72	tons/hr	
	Dosage considered for sizing	=	4.0	kg/ton SS	4 kg/ton SS as per Metcalf & Eddy, page 1496
	Quantity of chemical required	=	54.89	kg/hr	
		=	1317.26	kg/day	
	Purity of the chemical	=	100.0	%	
	Quantity of chemical required	=	54.89	kg/hr	
	Concentration of the solution	=	0.5	%	
	Pump Capacity	=	10977.14	LPH	
	No of pumps working	=	1	No	
	Capacity of pump required	=	10977	LPH	
	Capacity of pump provided	=	0-15000	LPH	
	Type	=	Diaphragm metering pump		
	Quantity	=	2	(1W + 1S)	
	Size & MOC of Poly dosing piping	=	63	HDPE / uPVC	

Sl.No.	Description		Value	Unit	Remarks
	Size & MOC of Poly dosing Valves	=	63	NB PP / PTFE	
14	**De water Polymer dosing pumps for BFP**				
	Type of polymer	=	Non Food grade		
	Solids load into BFP	=	19758.85	kg/hr	
		=	19.76	tons per hr	
	Dosage considered for sizing	=	4.0	kg/ton SS	4 kg/ton SS as per Metcalf & Eddy, page 1496
	Quantity of chemical required	=	79.04	kg/hr	
		=	1896.85	kg/day	
	Purity of the chemical	=	100.0	%	
	Quantity of chemical required	=	79.04	kg/hr	
	Concentration of the solution	=	0.5	%	
	Pump Capacity	=	15807.08	LPH	
	No of pumps working	=	15	No	
	Capacity of pump required	=	1054	LPH	
	Capacity of pump provided	=	0-1500	LPH	
	Type	=	Diaphragm metering pump		
	Quantity	=	18	(15W + 3S)	
	Size & MOC of Poly dosing piping	=	25	HDPE / uPVC	
	Size & MOC of Poly dosing Valves	=	25	NB PP / PTFE	
15	**Polymer Dosing Tanks for Sludge Treatment**				
	Storage time of chemicals	=	12	hr	
	Volume of solution required / 12 hrs	=	321411	liters	
	Volume of each tank required	=	321411	liters	
	No of tanks considered	=	2	No	
	Volume of tank required	=	321411	liters	
	Volume of tank provided	=	321411	liters	
	Quantity	=	4	(2W+2S)	
	MOC of tank	=	RCC with chemical resistant tiling		
	Volume	=	321.41	m3	
	Volume of each tank required		160.71		
	Side water depth	=	4.0	m	
	Side required	=	6.3	m	
	Side Considered		6.5	m	

Sl.No.	Description		Value	Unit	Remarks
	Size	=	6.5x 6.5m x 4m SWD+0.5m FB		
16	**Agitator for Poly Dosing tanks for Sludge Treatment**				
	Type	=	Turbine type, Motor driven		
	Agitator for chemical tank	=	60	rpm	40-125 rpm as per Metcalf & Eddy Page 356, table 5-13
	Quantity	=	4	No.	
	MOC of agitator	=	SS 316		
17	**Design of Agitator in the Poly dosing tank for Sludge Treatment**				
A	**Power requirement**				
	Formulae for Total Power input to agitator, P	=	G^2 μ (Vol)		
	Velocity gradient (G)	=	120	s^{-1}	
	Absolute viscosity of water (μ)	=	0.0008	NS/m2	As per CPHEEO Manual on Water Supply and Treatment, Table 7.4.3 of page 207
		=	0.001236	NS/m2 @ 12 deg C	
	Volume of tank (V)	=	169.0	m3	
	Input power in water (P)	=	3.0079	kW	
	Efficiency of Gear box	=	85	%	
	Efficiency of Motor	=	78.5	%	
	Motor rating required	=	4.5079	kW	
	Motor rating for agitator considered	=	5	kW	

Annexure - 7

Graphs

- **Open offshore intake and discharge pipes**

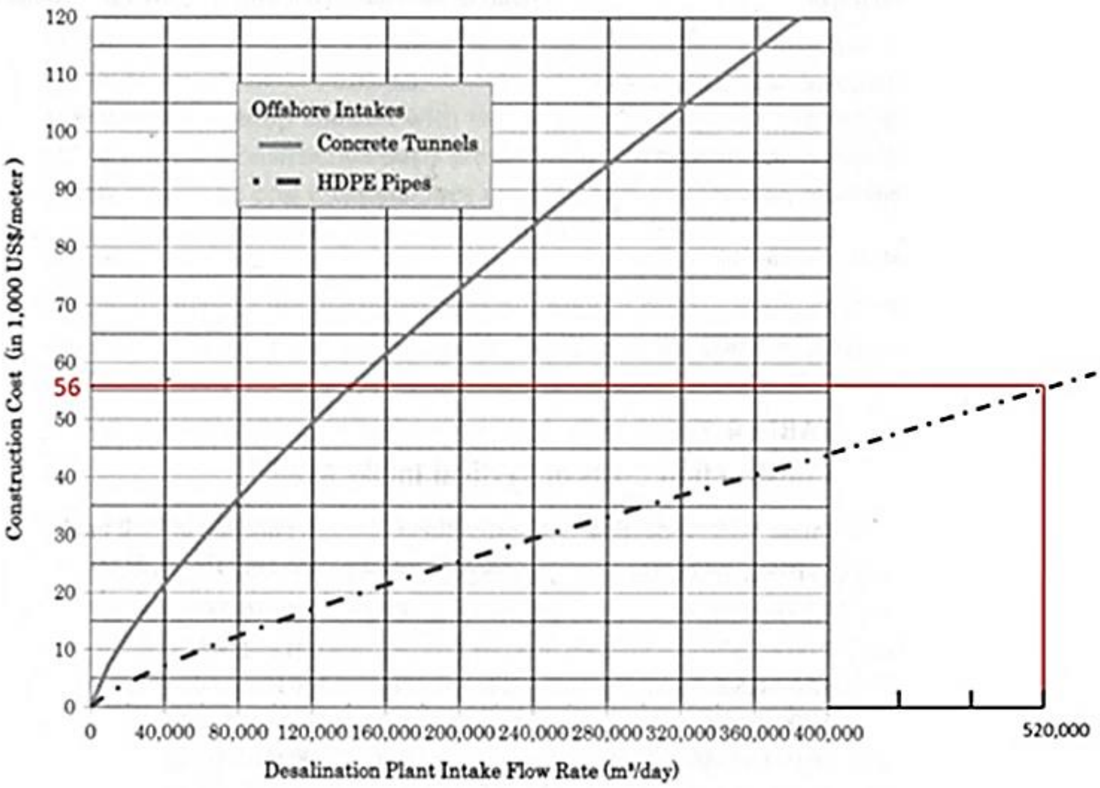

Figure 1: Construction cost for open offshore intakes

- The folowing data and coefficient are used :
  - Half plant intake flow : 520000 m3/d
  - Intake pipe length : 1800m
  - Outfall pipe length : 800m

NB The Brine pipe is not considered for 200 MLD then derived to 400 MLD plant capacity; the total plant discharge (627 MLD) will be not considered either ; since same pipe diameter than intake (2500 mm) will be implemented for discharge, the same unit cost (56,000USD/m) will be used used.

- **Intake pumping station**

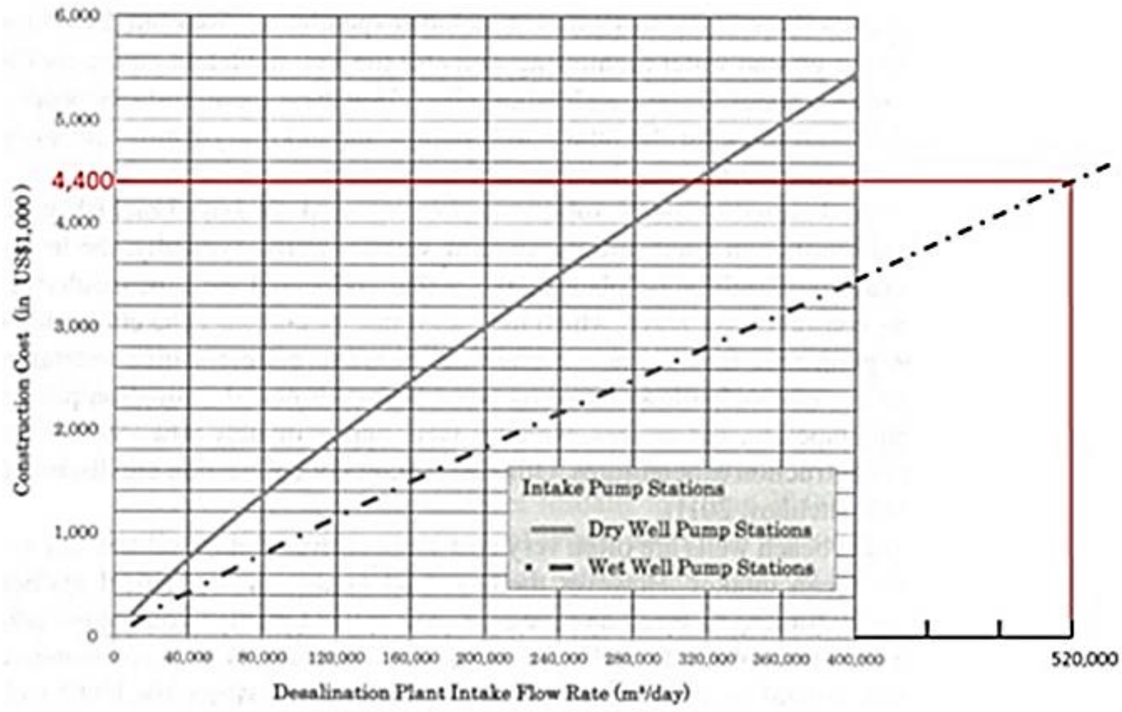

Figure 2: Construction cost for intake pump stations

- **Band screens**

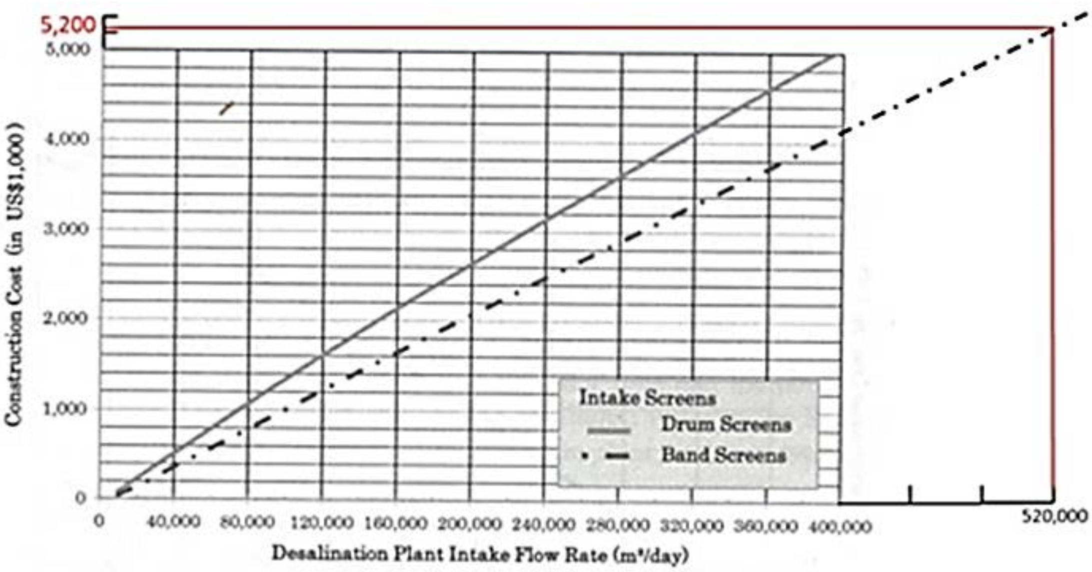

Figure 3: **Contruction cost for drum and band intake screens**

- **DAF and lamella settlers**

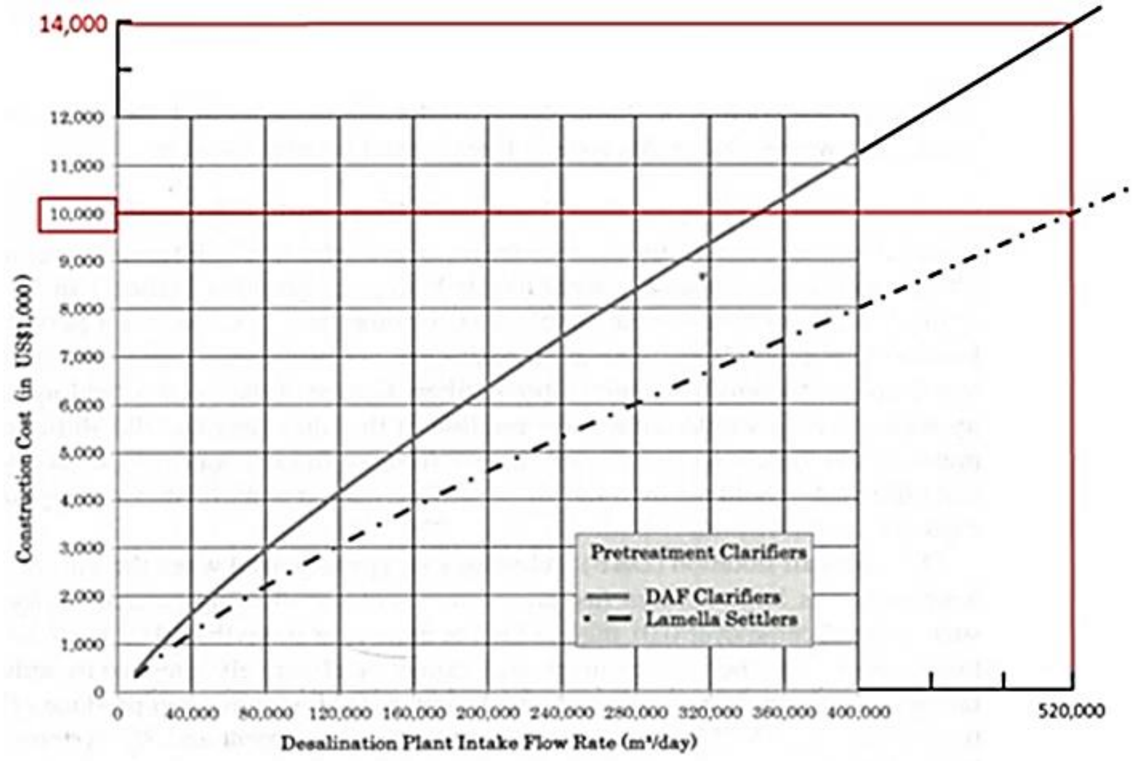

Figure 4: Construction cost for DAF and Lamella Clarifier

- **Granular Media filters**

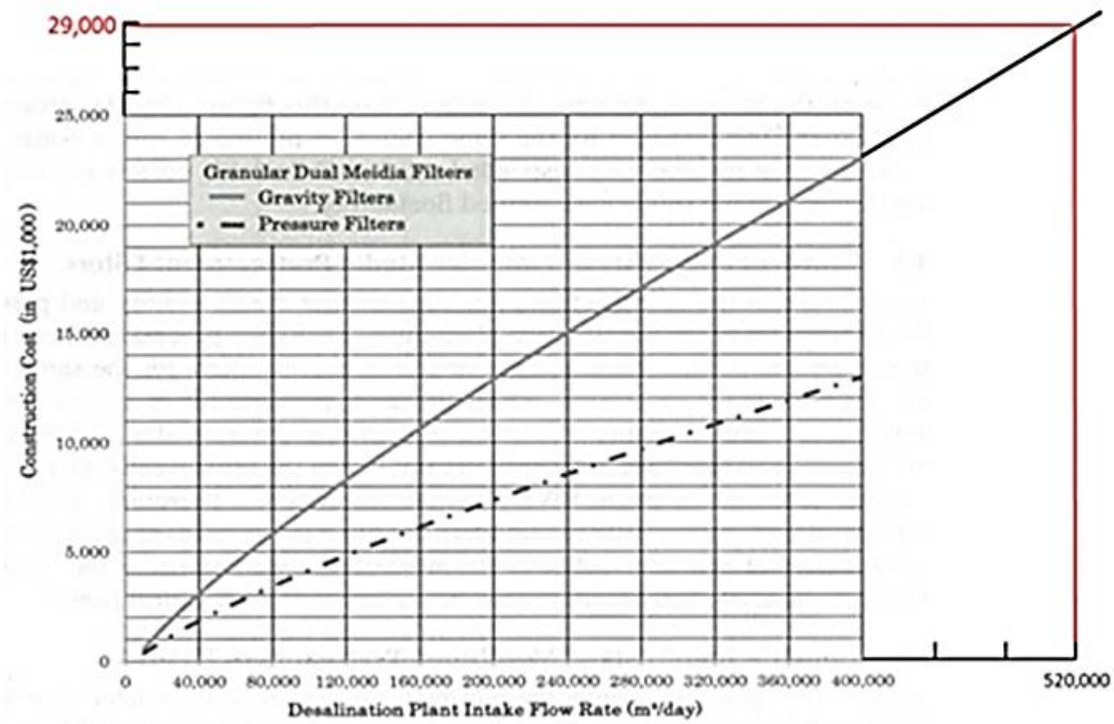

Figure 5: Construction cost for Granular Dual Media Filter

- **Cartridge filters**

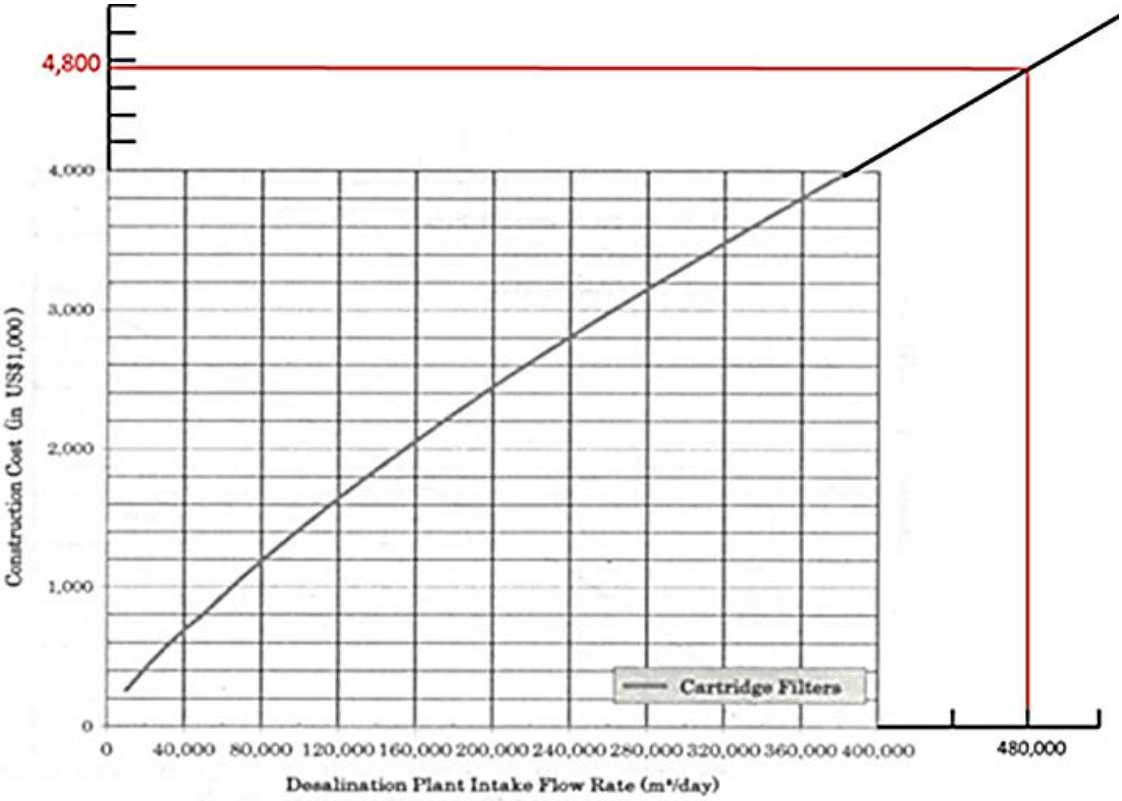

Figure 6: Construction cost for Cartridge Filters

- **Single pass SWRO**

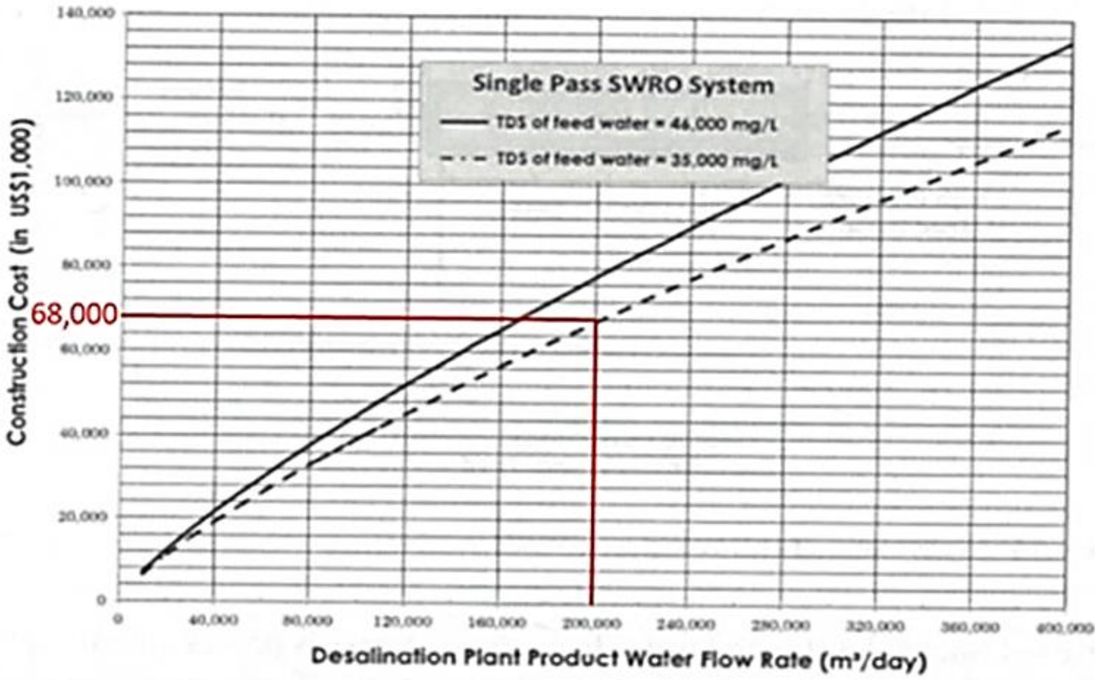

Figure 7: Construction cost for single pass SWRO system

- **Post treatment**

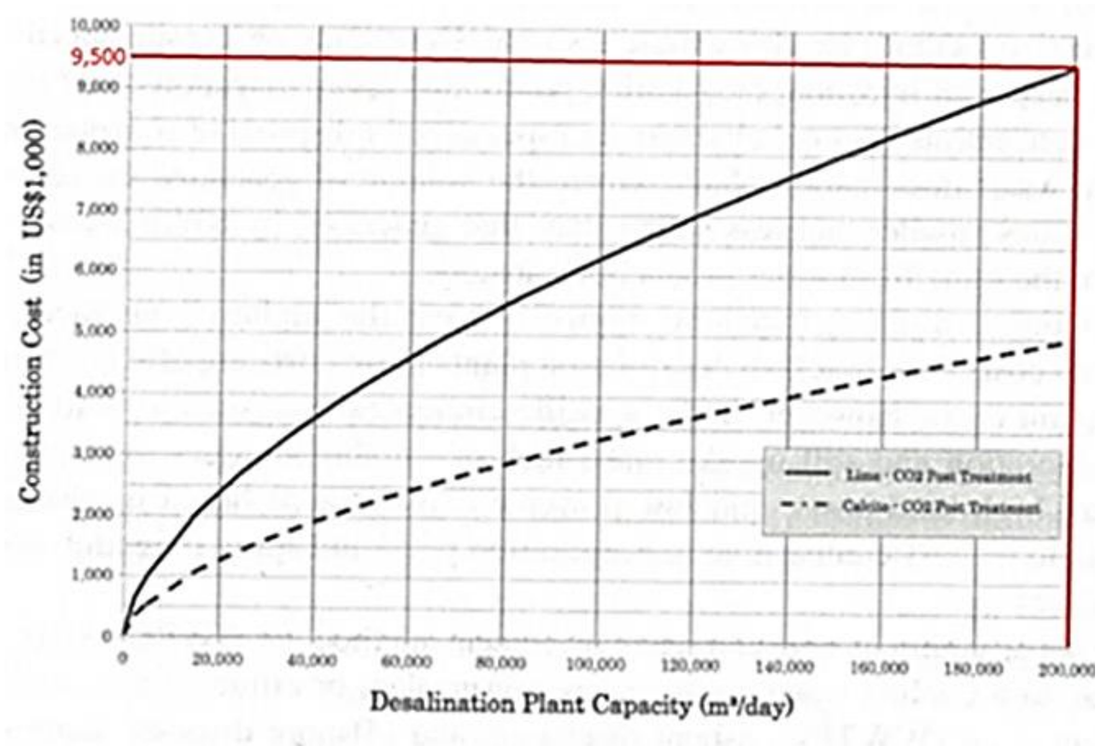

Figure 8: Constrution cost for Lime and Calcite post treatment system

- **Sodium hypochlorite disinfection**

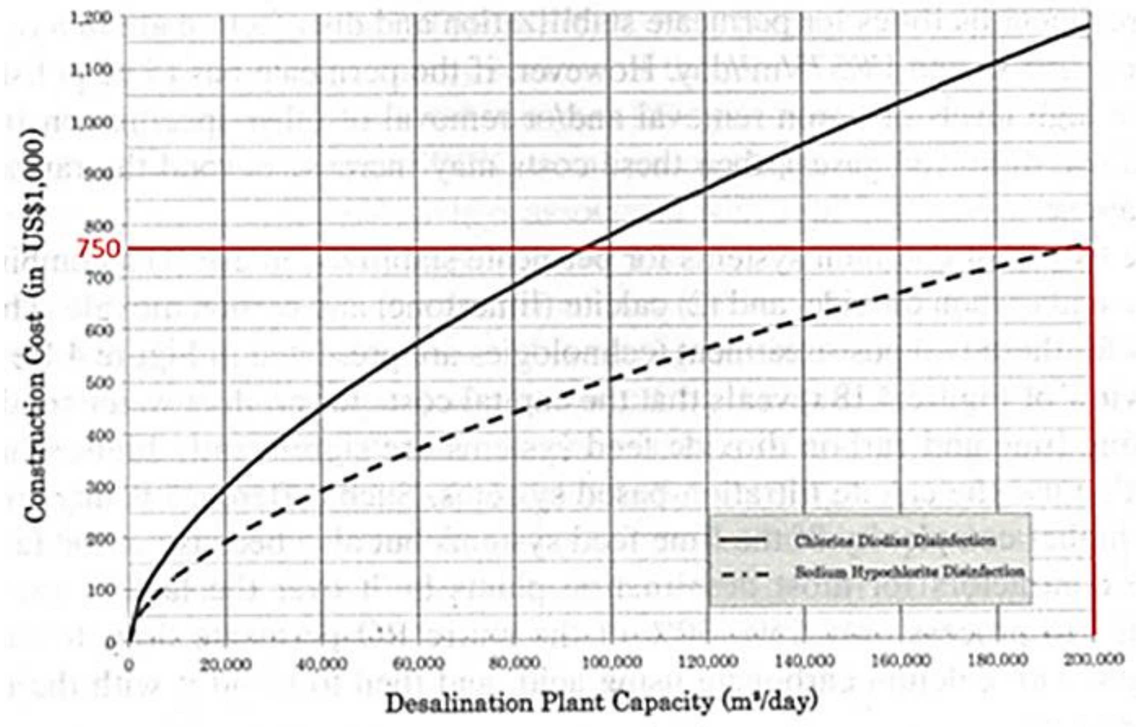

Figure 9: **Construction cost for carbon dioxide and sodium hypochlorite disinfection**

CHENNAI METROPOLITAN WATER SUPPLY & SEWERAGE BOARD
(CMWSSB)

PMC FOR CHENNAI PERUR 400 MLD DESALINATION PLANT AND ALLIED WORKS

Concept Design Report for 400 MLD Desalination Plant (CP1) at Perur

Reference No. Loan ID-P267
Contract No.: CNT/ CON/DESAL /ICB/GoI/016/2018-19

Submitted on 23 April 2021

VOLUME II
ANNEXURES

SMEC International Pty. Ltd. *in consortium with*
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TATA Consulting Engineers Limited,
SMEC (India) Private Limited

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0	8 July 2020	Dr.Ghulam Mustafa Mr.Michel Morillon Mr.Guilbert Z Gonzales & PMC team	Dr.P.Dharmabalan & PMC team	Dr.P.Dharmabalan
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This report is confidential and is provided solely for the purposes of briefing the Client on the planned activities to be undertaken by the Project Management Consultant ("PMC") during the course of the Consulting Services under the Chennai 400 MLD Desalination Plant project]. This report is provided pursuant to a Consultancy Agreement between PMC consisting of SMEC International Pty Ltd ("SMEC"), as lead consultant with Joint venture partners, consisting of TATA Consulting Engineers Ltd. (TCE), NJS Engineers India Pvt. Ltd. (NJSEI) and SMEC (India) Private Limited and CMWSSB, under which PMC undertook to perform a specific and limited task for CMWSSB.

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TABLE OF CONTENTS

Annexure 1

CHENNAI METROPOLITAN WATER SUPPLY & SEWERAGE BOARD (CMWSSB)

BATHYMETRY SURVEY REPORT

PMC for Chennai Perur 400 MLD Desalination Plant and Allied Works

Reference No.: Loan ID-P267
Contract No. : CNT/ CON/DESAL /ICB/GoI/016/2018-19
9 December 2020

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IMPORTANT NOTICE

This report is confidential and is provided solely to report the Bathymetry Survey of the Project Management Consultant ("PMC") on the Consulting Services to be delivered under the Chennai Perur 400 MLD Desalination Plant and Allied Works project]. This report is provided according to a Contract Agreement between SMEC International Pty Limited ("SMEC"), as lead consultant in the PMC, and CMWSSB, under which SMEC undertook to perform a specific and limited task for CMWSSB.

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BATHYMETRY SURVEY FOR SETTING UP OF 400 MLD DESALINATION PLANT AT PERUR, CHENNAI, TAMIL NADU

BATHYMETRY REPORT

PROJECT CODE: 696082021

For
SMEC India Pvt Ltd.
Gurugram

September 2020

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Client	SMEC India Pvt Ltd., Gurugram.
Project Title	Bathymetry survey for setting up of 400 MLD desalination plant at Perur, Chennai, Tamil Nadu.
Project Code	696082021
Abstract	CMWSSB has planned to set up a 400 MLD desalination plant at Perur. CMWSSB has nominated SMEC India Pvt Ltd., Gurugram as Project Consultant. SMEC has in turn asked to Indomer Coastal Hydraulics (P) Ltd., Chennai, to carry out the bathymetry survey over the proposed nearshore planned for providing seawater intake and brine reject outfall. Indomer has carried out the survey in August 2020 and this report presents the methodology and the bathymetry map.
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References	SMEC India Pvt Ltd.- SCA4 Rev00 10051/dt.19th August, 2020

Date	Report Type	Originator	Checked by	Approved by	Approver's sign
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	Project Code	696082021		Text pages	22
	File Location	F:/2020 Projects/Aug -20/Perur 400MLD		Figures	6

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LIST OF FIGURES

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List of Abbreviations

BM	Bench Mark
CD	Chart Datum
DGPS	Differential Global Position System
GNSS & GLONASS	Global Navigation Satellite System
GPS	Global Position System
GRS	GPS Range Residuals
GSA	Overall Satellite data
GST	GPS Pseudo range Noise Statistics
GSV	Detailed Satellite data
Hz	Hertz
kHz	Kilohertz
km	Kilometer
m	Meter
MSL	Mean Sea Level
RMC	Recommended Minimum Data for GPS
RS	Recommended Standard
RTCM	Radio Technical Commission for Maritime Services
RTK	Real- time Kinematic
SBAS	Satellite Based Augmentation Systems
UTM	Universal Transverse Mercator
VHF	Very High Frequency communication
w.r.t	with respect to
WGS	World Geodetic System

1. INTRODUCTION

Chennai Metropolitan Water Supply & Sewerage Board (CMWSSB) has appointed SMEC India Pvt. Ltd., Gurugram for the preparation of Detailed Project Report for the proposed 400 MLD desalination plant Perur, Chennai. In order to prepare the initial plan, SMEC has asked Indomer Coastal Hydraulics (P) Ltd., Chennai to conduct the bathymetry survey at nearshore which has been planned for the selection of seawater intake and brine reject outfall corridor. Accordingly, Indomer has carried out the surveys in August 2020.This report presents the methodology and results of the survey. The location map is shown in **Fig. 1.1.**

All calendar dates are referred in Indian style as dd.mm.yy. (eg. 28.08.20 for 28th August 2020) and the time is referred to Indian Standard Time in 24-hour clock, eg. 3 PM is written as 1500 hrs. SI units are followed for all fundamental and derived units. The depths are referred with respect to Chart Datum. The UTM coordinates are indicated in WGS 84 spheroid - Zone 44N.

2. SCOPE OF WORK

i. *to carry out the bathymetry survey for about 1000 m along the coast and 2000 m into the sea. (However, Indomer has carried out additional area covering 1650 m along coast and 2500 m into the sea)*

ii. *to prepare and submit the report.*

3. METHADOLOGY

3.1. Reference spheroid

World Geodetic System (WGS84) spheroid – Zone 44N has been followed for entire surveys and for the presentation in the chart.

3.2. Horizontal control

Reference station: The DGPS Beacon Transmitter installed by Department of Lighthouse and Navigation at *Pondicherry* has been taken as reference station. The transmitting frequency of this reference station DGPS Beacon transmitter is 315 kHz.

Mobile station: The horizontal positioning of the mobile unit was carried out using **Hemisphere R100** Series DGPS Beacon Receiver. It combines high-performance GPS reception with a DGPS-capable receiver in a lightweight, durable housing and comes with a separate antenna. It gives the horizontal position to an accuracy of close to 1 m. The GPS receiver also contains technology enabling *WAAS/EGNOS*, *Omni STAR* or *Beacon* real time differential capabilities. When used with a Real- time Kinematic (RTK) Base station, the GPS receiver provides RTK positioning for high-accuracy, centimeter-level applications. A standard GPS receiver provides the following features:

- 10 Hz (10 positions per second) output rate
- 12 GPS (C/A-code L1, C/A code L2 (for the Omni STAR XP/HP and RTK models)) tracking channels, code carrier channels
- Sub meter differential accuracy (RMS), assuming at least five satellites and a PDOP (Position Dilution of Precision) of less than four (when used with Satellite Based Augmentation Systems (SBAS) correction).

The system configuration is enabled with:

- LED display and keypad

- Outputs a 1 PPS (pulse per second) strobe signal on both ports. This signal enables an external instrument to synchronize its internal time with a time derived from the very accurate GPS system time.
- SBAS such as WAAS (Wide Area Augmentation System) differential correction 1
- Beacon differential correction
- Omni STAR VBS capability
- Omni STAR XP/HP capability in the XP/HP and RTK models
- RTK positioning capability, In the RTK model only
- E V E R E S T ™ mu l t i p a t h r e j e c t i o n t e c h n o l o g y
- Two connectors that support both CAN 2.0B and RS-232:
- CAN: J1939 and NMEA 2000 messages
- RS 232
- NMEA-0183 output: GGA, GLL, GRS, GST, GSA, GSV, MSS, RMC, VTG, ZDA (the default NMEA messages are GGA, GSA, VTG, and RMC).

3.3. Tide Measurements

The tide measurements were carried out at Kasimedu Fishing Harbour, Chennai using Aanderaa Tide Recorder (WTR 9). The measurements were done for 5 days from 25.08.20 to 29.08.20. The tide data were recorded at 15 minute interval. The measured tide levels were reduced to Chart Datum (CD) and used for tidal correction in the collected bathymetry data. The details of tide measurements are given in below.

Location details of Tide recorder

Location	Geographical Coordinates (WGS – 84)		UTM Coordinates (Zone 44N)		Duration	
	Latitude, N	Longitude, E	X (m)	Y (m)	From	To
Kasimedu Fishing Harbour	13° 07 ' 5 3	8 0 ° 1 7	0423987	1451773	25.08.20	29.08.20

Instrument: The Aanderaa Tide Recorder (WTR 9) manufactured by Aanderaa Data Instruments, Norway. It is a high precision recording instrument for measuring the variation of water level in the sea. The Pressure sensor 4647 is a compact, yet intelligent sensor designed to be used in this measuring systems. The sensor is based on a silicon piezo-resistive bridge sampled and temperature

compensated by an advanced Digital Signal Processor. The tide measurement is an average of the hydrostatic pressure measured over a time period of 10 seconds to 8 minutes (Optional). The recoding interval is selected between 2 seconds and 2 Hrs. The output parameters are Tide pressure, Tide level, Pressure and Temperature. Tide levels are preliminary, internally calculated estimates, based on fixed, selectable values of atmospheric pressure. Tide pressure is an average of hydrostatic pressure over the integration time. The data are stored on DSU. The instrument is housed in a pressure case that is closed by two C-clamps. All external and internal parts are fastened to the top end plate so that the whole instrument can be removed from the pressure case as one unit. In addition to carrying the combined handle and protection ring, the acoustic transducer and sensor inlet, the top end plate is furnished with a watertight receptacle. This terminal permits remote triggering and real-time reading of data by connecting cable.

Technical Specifications:

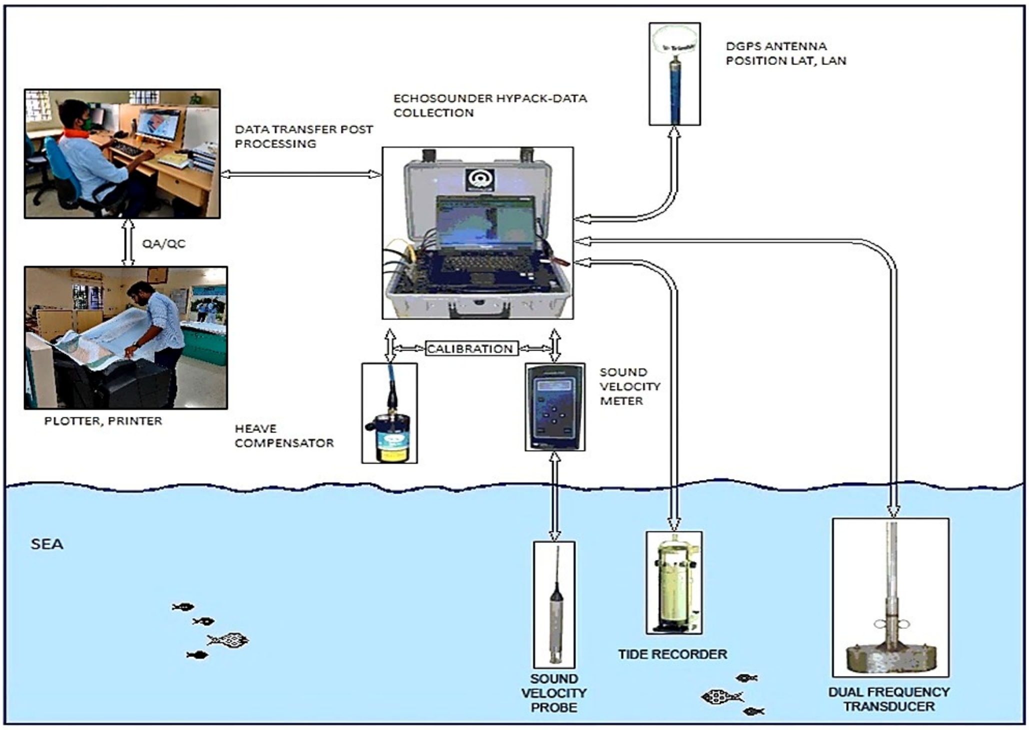
Top-End Plate	:	Multiparameter platform
Recording system	:	Data Storage on DSU
Storage Capacity	:	≤ 2GB
Battery	:	2 batteries inside the instrument
	:	Alkaline 3988 9V, 15Ah (nominal 12.5Ah; 20W down to 6V at 4°C) or Lithium 4002: 7V, 30Ah
Supply voltage	:	6 to 14VDC
	:	Parallel 2 Alkaline battery (each 9.0 VDC)
Operating temperature	:	-5 – + 4 0(23∈1 0 4) ° F
Deployment depth	:	Up to 300 m depending on sensor
Dimensions	:	OD: 139mm; H: 356mm
Weight in air	:	6.3kg
Weight in water	:	1.8kg
Materials	:	PET, Titanium, Stainless Steel 316, Epoxy
Pressure	:	4647B Range: 0 – 700kPa (101 psia) 60 m depth
	:	Resolution: 0.0001% FSO
	:	Accuracy: ±0.04% FSO
	:	Pressure connection: Swagelok™
	:	Inlet port (reference): top of the pressure port
	:	Pressure parameters: Pressure in kPa, Pressure raw data in LSB
Temperature	:	Range: 0 – 36°C (32 – 96.8°F)
	:	Resolution: 0.001°C (0.0018°F)
	:	Accuracy: ±0.4°C (0.72°F)
	:	Response Time (63%): < 2 min
	:	Temperature parameters: Temperature in °C, Temperature raw data in LSB
Tide	:	Integration time: 10s - 8 minutes
	:	Tide parameters: Tide pressure in kPa,
	:	Tide level in meter

3.4. Bathymetry survey

Area of survey: The bathymetry survey covers an area of 1650 m distance along the coast and 2500 m distance into the sea. The survey transects were planned perpendicular to coastline at 50 m spacing. In addition, the shore parallel tie up lines were planned at 250 m spacing. The surveyed bathymetry lines are shown **in Fig.3.1.**

Methodology

Instrument arrangement: The configuration of various devices and arrangements for conducting the bathymetry survey is shown below.



CONFIGURATION OF BATHYMETRY FLOW CHART

The survey vessel ***"MFV SRI DHURGAI"*** was used for the survey. The Echosounder transducer was mounted on the starboard side of the vessel by positioning it at 1.0 m below the sea surface. The DGPS receiver antenna was mounted on the mast vertically in line with the transducer, so that it represents the exact coordinates of the location where the depth is simultaneously measured by the transducer. The Heave Sensor was attached close to transducer stem on the boat deck in order to measure the residual vertical displacement of the boat induced by external disturbances and to carry out the correction.

The DIGIBAR-PRO sound velocity meter was used to measure the sound velocity across the vertical and entered as input for calibrating the transmitting part of the instrument. The bar check was also carried out by lowering the rigid plate at different depths and comparing with the displayed depth. The necessary inputs were given in HYPACK data collection software before the commencement of the survey. The planned track lines were displayed on the monitor at wheel for navigation. Watch guards were positioned at bow, transducer/antenna, and heave compensator at rear end. The data were continuously collected at onboard PC along each transect. After that day data collection was made, entire data were downloaded to external hard disc and stored. The recorded the data included: date, time, latitude, longitude, X coordinate, Y coordinate and heave. The depth data was recorded at 0.2 sec interval

Echosounder: ODOM Echotrac CVM Digital Dual Frequency Echo sounder manufactured by ODOM Hydrographic Systems; USA was used for the survey. This Echosounder has incorporated the cutting-edge technology, features and reliability of the Echotrac MKIII, plus the ease and flexibility of operation of a networked Windows interface. It operates in dual frequency consisting of 200 kHz on higher band and 33 kHz in lower band. It can be operated from 0.2 m to 1500 m water depth with 0.01 m accuracy. The Echotrac CVM transceiver units are compact rack mount package that is ideally suited to survey vessel installations. It supports Chart-functionality in one optional format and a laptop with a full size colour LCD as an electronic chart. The optional color LCD laptop offers internal data storage (in .XTF format) and playback of the analog return signal digitized to full 16-bit resolution. It contains a dual channel board. All channels feature a robust design and frequency agility enabling the operator to precisely match the transceiver to almost any existing transducer. Operator selectable TVG curves serve to optimize the Echotrac for both shallow and Deepwater bottom detection tasks and for Sonar imaging. The Echotrac CVM features unsurpassed interfacing flexibility, offering 2 serial ports that can be configured to interface with computers and motion reference units. It has an Ethernet port that outputs the 16-bit samples of the acoustic data for further processing and supports a number of output formats that are compatible with most common Echo Sounder strings.

Technical specifications

Frequency	:	High Band: 200 kHz Low Band: 33 kHz
Input Power	:	110 or 220 V AC or 24 VDC 50 watts

Resolution	:	0.01m / 0.1 ft.
Accuracy	:	m / 0.10 ft. +/-0.1% of depth @ 200 kHz 0.01 m / 0.30 ft. +/- 0.1% of depth @ 33 kHz
Depth range	:	0.2 – 200 m / 0.5 – 600 ft. @ 200 kHz 0.5 – 1500 m / 1.5 – 4500 ft. @ 33 kHz
Sound Velocity	:	1370 – 1700 m/s
Resolution	:	1 m/s
Depth Display	:	On control PC
Clock	:	Internal battery backed time, elapsed time, and date clock
Annotation	:	Internal – date, time, GPS position External – from RS232 Port or Ethernet
Interfaces	:	2 x RS232 serial ports, baud rate selectable 4800-19200. Input from external computer, motion sensor, and sound velocity. Outputs to external computer. Ethernet interface. Heave – TSS1 and sounder sentence
Software	:	Echotrac Control supplied. Chart View display and logging software.

Heave Compensator: TSS HS-50 Dynamic Motion Heave Sensor manufactured by TSS (UK) Ltd., UK was installed onboard. This will measure the component of the heave induced at echosounder transducer. The measured heave is then corrected from the depth values and the true depth was recorded in computer. The system is connected via. RS232 communication to the computer onboard enabled through HYPACK data collection software.

Hydrographic Survey Software: HYPACK survey software was used for data collection and processing. It is integrated, first generation hydrographic survey software developed by Coastal Oceanographical INC., USA. It works in MS Windows operating environment. The HYPACK's design program allows importing background map in CAD's DFX or Microsoft's DGN format. It enables to quickly create planned survey lines, plotting sheets and bottom coverage grids in a graphical environment. It gives the flexibility to support multiple navigational systems (GPS, range/range, range/azimuth), echo sounders (single and dual frequency, multiple transducer and multi-beam), magnetometers, ROV-tracking systems, telemetry tide systems and many other devices. It contains the post processing module to analyse and prepare the chart. The survey tracks were planned using this software for accurate manoeuvring of the vessel and to keep the accuracy of the track. The post processing of the survey data and preparation of map were carried out using this software.

Data recording: The Echo sounder, heave compensator and Beacon DGPS receiver was interfaced through HYPACK software with onboard PC. The entire system was supported by AC Power

Generator installed onboard. The position and depth were recorded along the pre-planned transect at 200 millisecond intervals continuously.

Calibration for Sound Velocity: ODOM DIGIPRO SVM has been used to measure the velocity of sound across the vertical and the mean value was fed in the echo sounder during calibration before the commencement of survey on each day.

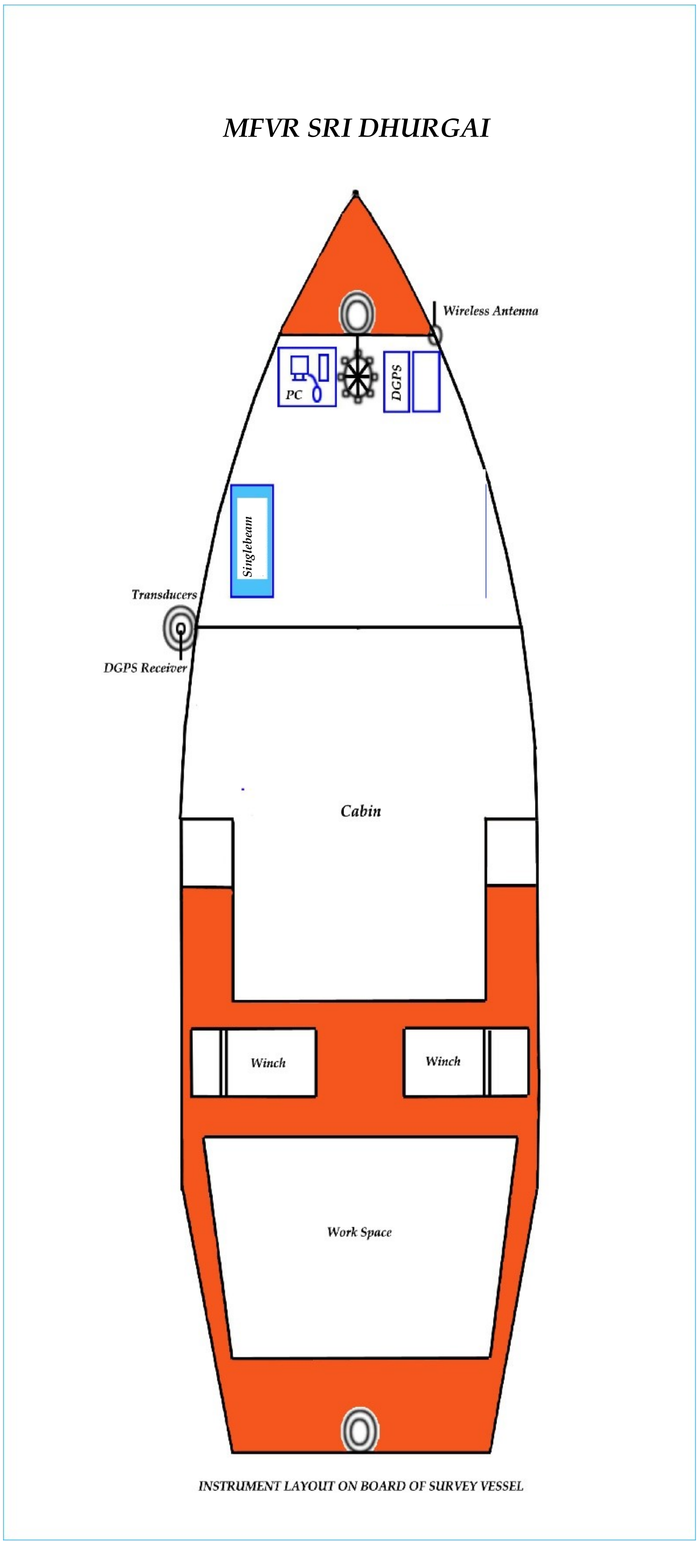
Calibration by Bar Check: Bar check was performed before starting of the surveys every day. It was done by lowering a bar plate at known depth below the transducer. The correction coefficients for known depth were noted and entered on the data collection software.

Tidal correction: The collected data were processed in the laboratory by applying corrections for tides and immersion depth of the transducer.

3.5. Survey boat and instrument arrangements

The bathymetry surveys were carried out using the survey vessel ***'MFV SRI DHURGA'I*** fitted with Multi-channel VHFR/T, Ship-to-Shore R/T, Gyro compass, Marine radar, Loud hailer, additional hull mounted Echo sounder, GPS positioning system and the VHF communication system. In addition, a smaller surf landing cum life boat was also put in place throughout the survey period for the safety and to transport surveyors to and for the survey vessel anchored at offshore.

SURVEY VESSEL - SRI DHURGAI



Survey vessel and Instruments arrangement

4. RESULTS

4.1. Tides

The variation of design tide levels with respect to Chart Datum for Chennai as presented in Indian Tide Table 2020, published by Survey of India are given below:

Mean High Water Spring	+ 1.15 m
Mean High Water Neap	+ 0.84 m
Mean Sea Level	*+ 0.65 m*
Mean Low Water Neap	+ 0.43 m
Mean Low Water Spring	+ 0.14 m

The variation of measured tide levels are reduced to chart datum for the period 25.08.20 to 29.08.20. is shown in **Fig. 4.1**.

Deployment of tide recorder

4.2. Bathymetry

The bathymetry map was prepared in WGS84 spheroid with UTM (Zone 44N) coordinates supplemented by Geographical coordinates indicating the latitude and longitude. The bathymetry map is prepared in 1:4000 scale and is presented in **Fig. 4.2** (see Pouch)**.** The depths w.r.t. chart datum is presented in 20 m x 20 m grid. Another bathymetry map was prepared in 1:12000 scale and presented in **Fig. 4.3.** The depths are presented in 60 m x 60 m grid. The tentative intake and outfall corridors and their locations as suggested by SMEC are shown in these charts.

The variation of water depth with distance from shore is shown below.

Water depth vs Distance

Depth w.r.t. CD (m)	Distance from shore (m)
wave breaking zone	
1	170
2	220
3	270
4	330
5	380
6	460
7	520
8	715
9	880
10	1050
11	1270
12	1560
13	1980
14	2150

The digital values (X,Y,Z) of bathymetry data are given in excel format and enclosed separately in DVD.

Heave compensator

Bar Check

Sound Velocity Meter

Onboard data collection

5. ADDITIONAL STUDIES

5.1. Collection of sediment sample

Seabed samples were collected using Van veen grab, in order to understand the nature of the geology of the seabed. The locations of sediment sample collection are shown in **Fig. 5.1.** The details of sediment sampling locations and sediment size distributions are given in below.

The nearshore in this region consists of scattered terraces of rock outcrops which is evidenced through the earlier survey conducted in the adjacent region. Planning of buried pipelines for intake and outfall needs top 4 m with sand and without any rocks thereupon.

Therefore, it is suggested to carry out shallow seismic survey in conjunction with side scan survey and magnetometer survey to identify the presence of rocks if any and to accordingly delineate a most suitable corridor for laying pipelines.




Collection of seabed sediment samples

Sediment size distribution

Stations	UTM Coordinates (WGS 84)		Water depth (m)	Classification of Soil	D_{50} (mm)	Sand			Silt & Clay %
	Easting (m)	Northing (m)				Coarse (%)	Medium (%)	Fine (%)	
SB1	416828	1405667	5.0	Fine sand	0.18	1.2	3.9	94.5	0.4
SB2	417053	1405591	7.5	Fine sand	0.17	1.4	3.9	93.8	0.8
SB3	417431	1405459	10.0	Fine sand	0.17	2.9	3.8	91.8	1.5
SB4	417809	1405328	11.5	Medium sand	0.41	38.3	31.5	30.0	0.2
SB5	418126	1405211	12.4	Medium sand	0.35	32.5	25.4	41.9	0.2
SB6	418452	1405104	13.6	Fine sand	0.14	4.5	4.8	88.1	2.6
SB7	418733	1405008	14.3	Fine sand	0.11	0.7	1.0	96.5	1.8
SB8	416978	1405405	7.7	Fine sand	0.11	2.1	2.5	90.4	5.0
SB9	417546	1405208	10.5	Medium Sand	0.40	28.4	46.4	25.1	0.1
SB10	418113	1405011	12.8	Coarse Sand	0.59	62.3	23.9	13.0	0.8
SB11	418683	1404820	14.0	Coarse Sand	0.55	63.6	26.5	9.5	0.5
SB12	417127	1405776	7.7	Medium Sand	0.37	35.1	25.3	39.3	0.3
SB13	417695	1405580	11.0	Medium Sand	0.44	37.1	44.5	18.2	0.2
SB14	418262	1405383	13.0	Medium Sand	0.35	31.2	27.7	40.3	0.7
SB15	418825	1405187	14.5	Medium Sand	0.45	26.8	62.3	10.6	0.3

GALLERY


Perur coastal front

crossing surfzone


Client inspection on board the vessel

Installation of Transducer

Client inspecting bathymetry data collection

SMEC officials with Indomer team

Discussing with CMWSSB Officals

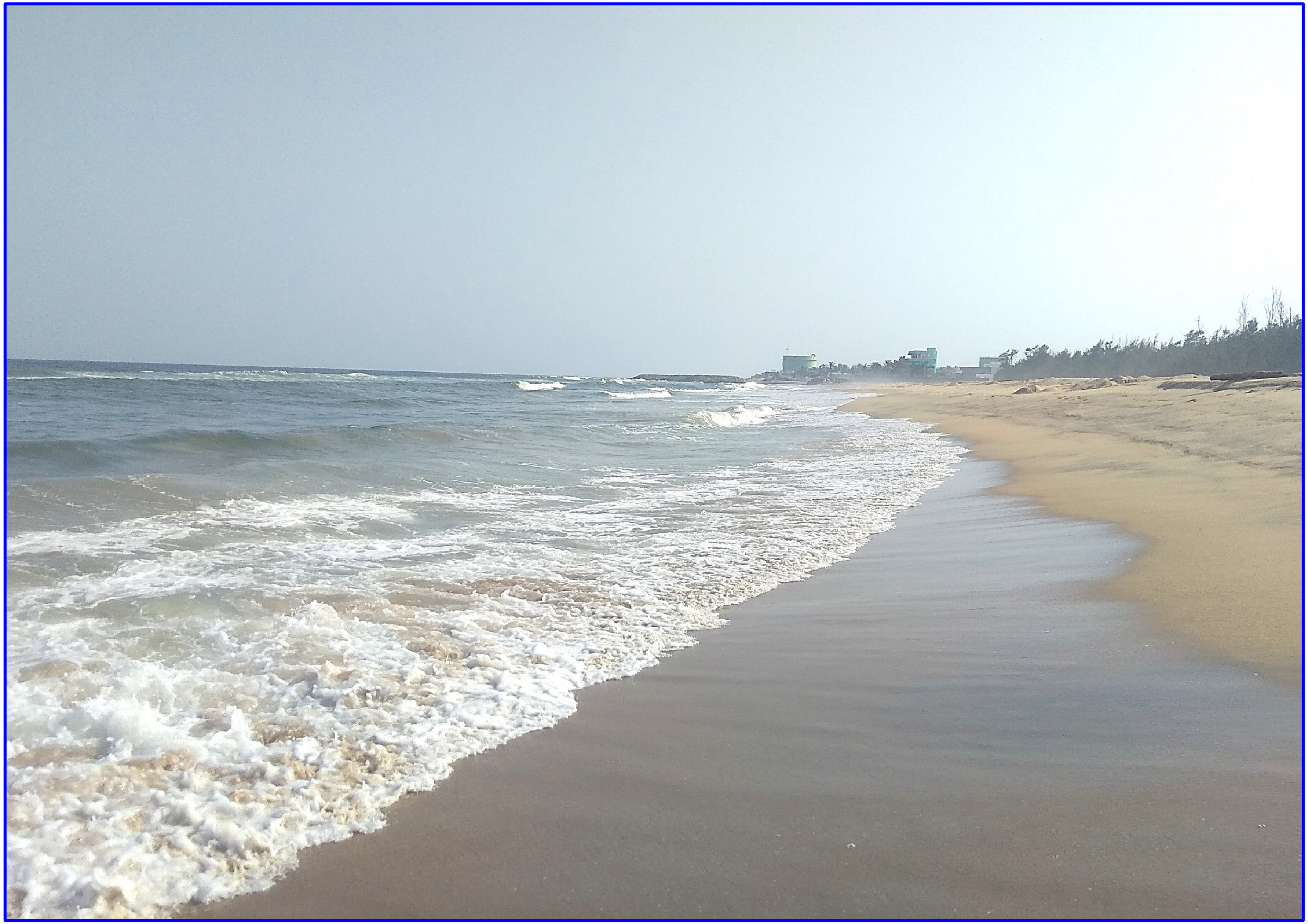


FIG. 1.1. LOCATION MAP

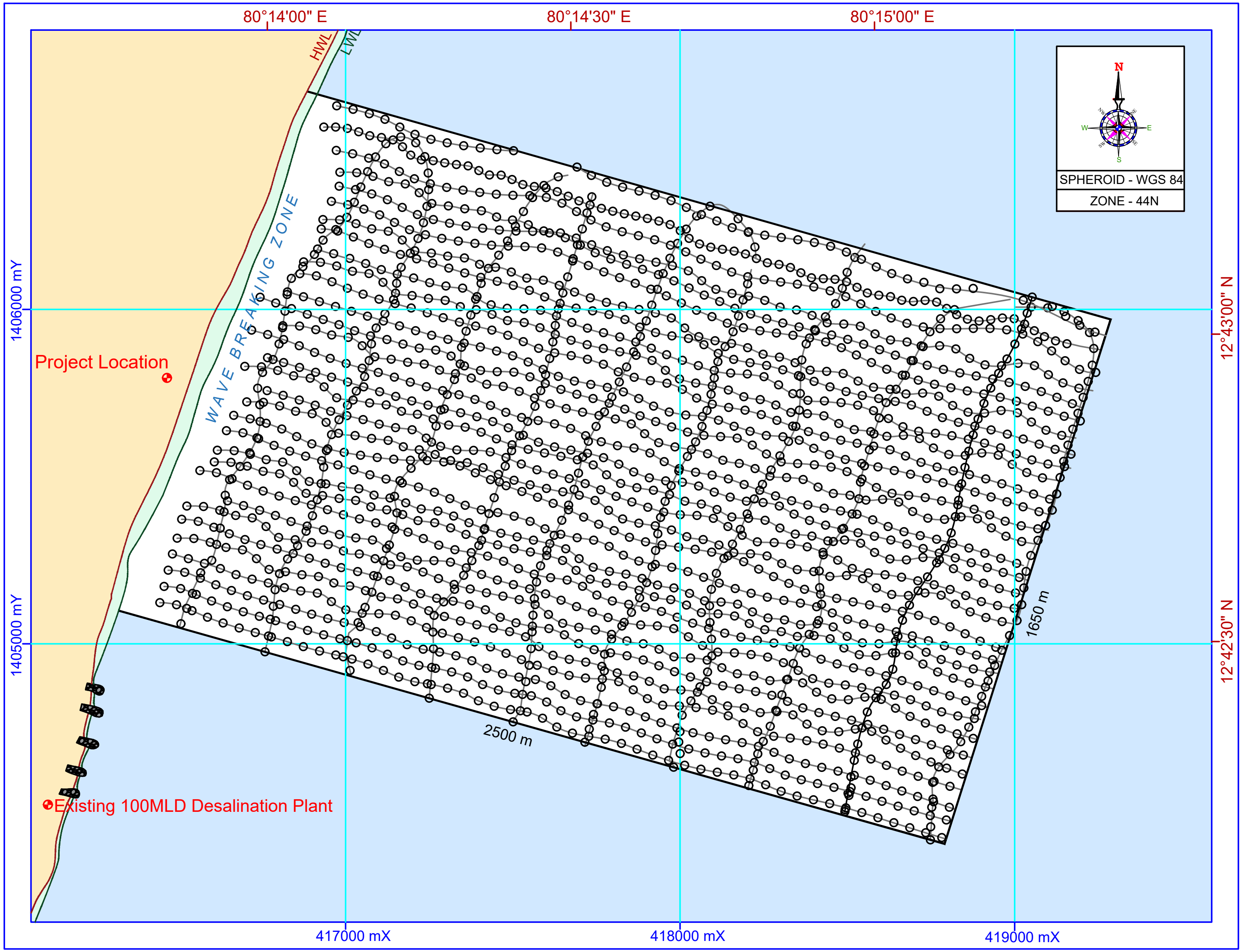


FIG.3.1. SURVEYED BATHYMETRY LINES

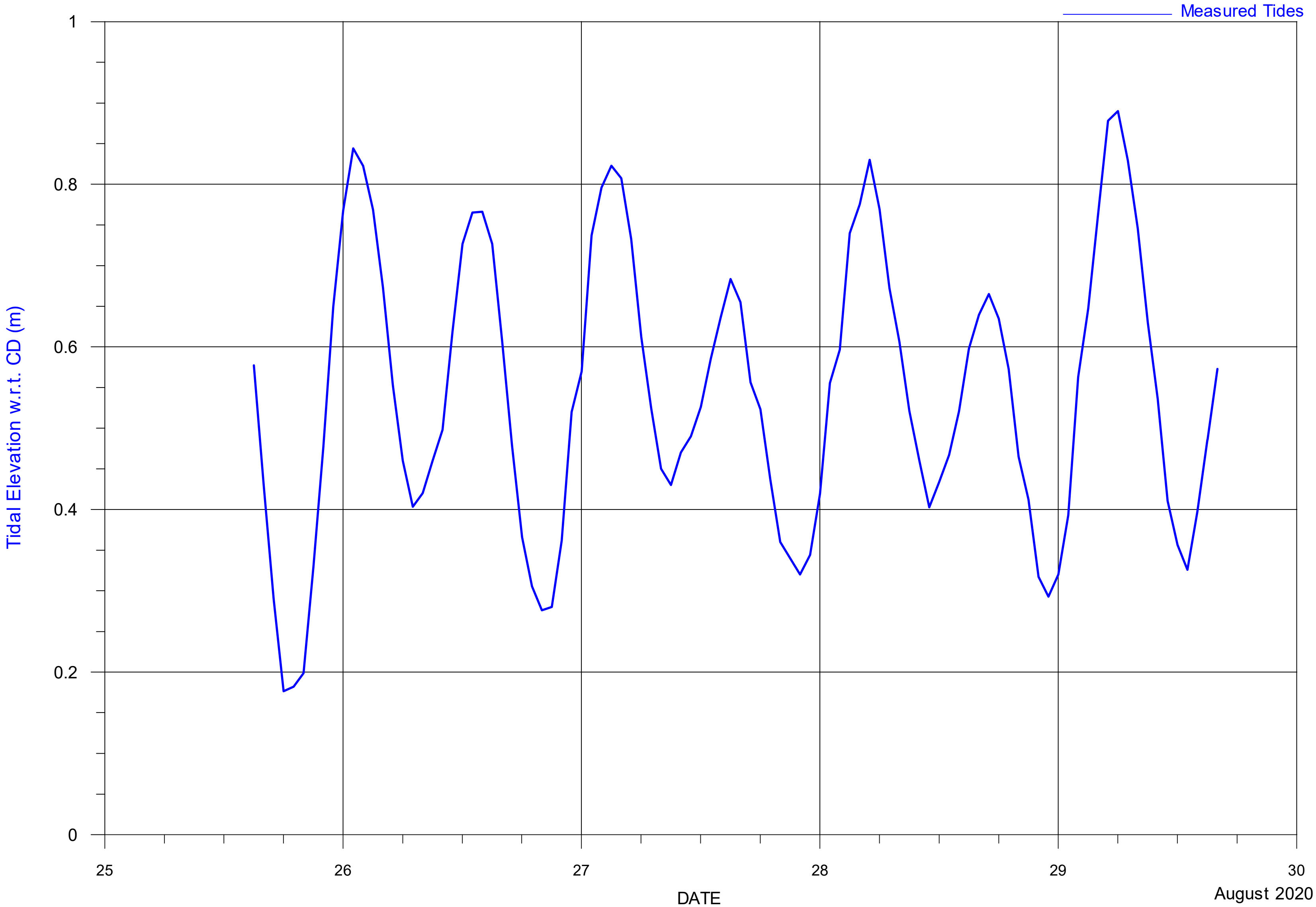
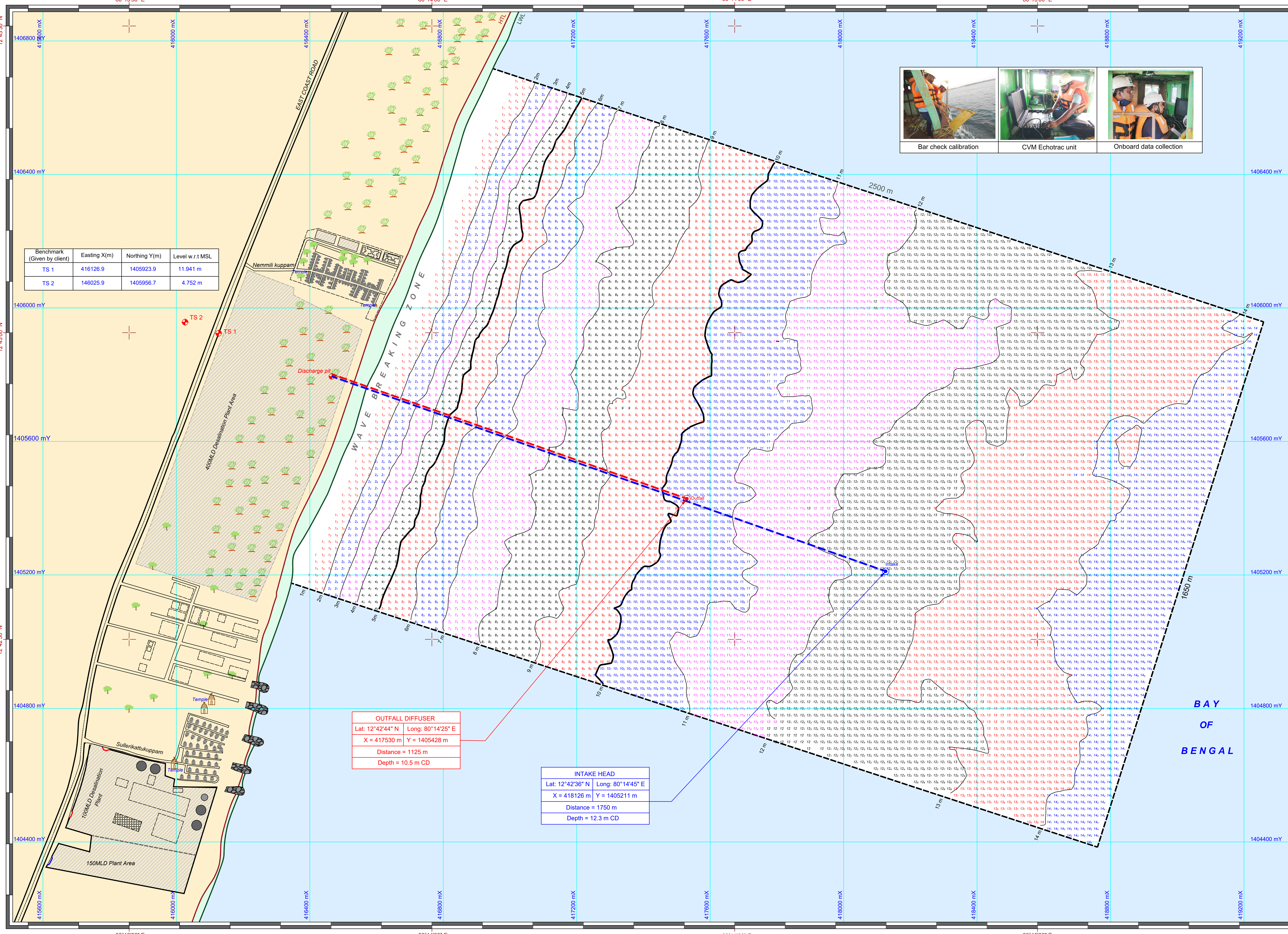
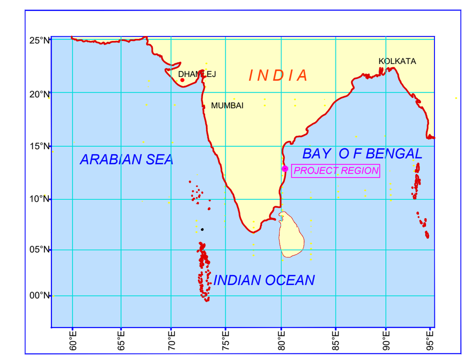


FIG.4.1. VARATION OF MEASURED TIDES



LOCATION MAP :



Notes :

1. Water depths are reduced to CD using measured tides.
2. Horizontal positioning acquired using Hemisphere DGPS Beacon Receiver.
3. Bathymetry acquired using Odom Echotrac CVM Dual frequency Echosounder.
4. Annotations are in metres and suffix in decimetres.
5. Contours depths are in Metres.
6. Soundings Intervals 20 m x 20m.
7. Coastal configuration based on Hemisphere DGPS Beacon Receiver.

LEGEND:

General

Geographical Grid Intersection

UTM Grid Intersection

Bathymetry

13 ,14 Depth in metres & decimetres below Chart Datum

GEODETIC DETAILS :

Spheroid	:	WGS 84
Semi major axis (a)	:	6378137.00 m
Inversed Flattening (1/f)	:	298.2572
Grid Projection	:	U.T.M. Zone 44 N
Latitude of origin	:	0° equator
Longitude of origin (CM)	:	81° East
Scale factor on CM	:	0.9996
False easting	:	500000m E
False northing	:	0m N
Unit	:	International Metre

DEPTHS IN METRES

SCALE:

40 20 0 40 80 120 160 200metres

SCALE 1 : 4000

Survey Period : 26.08.2020 to 28.08.2020

TIDAL INFORMATION :

PLACE	POSITION		HEIGHT ABOVE CHART DATUM				
	Latitude	Longitude	MHWS Metre	MHWN Metre	MLWN Metre	MLWS Metre	MSL (m)
CHENNAI	12° 52' N	80°41' E	1.15	0.84	0.43	0.14	0.65

CLIENT :

SMEC
Member of the Surbana Jurong Group

SMEC INDIA, CHENNAI.

SURVEYED BY :

ISO 9001
NABET

Ph. 91-44-24862482 ; WEB: www.indomer.com, Chennai.

PROJECT TITLE :

BATHYMETRY SURVEY, SEAWATER SAMPLE COLLECTION, TESTING, ANALYSIS AND BRINE DIFFUSION MODELING STUDY FOR SETTING UP 400 MLD DESALINATION PLANT AT PERUR, TAMILNADU

DRAWING TITLE :

BATHYMETRY MAP - PERUR

Surveyed by	:	J. Vinothkumar/M. Sharath/S. Vijay	FIG. 4.2.
Processed by	:	J. Vinothkumar/S. Vijay	
Drawn by	:	J. Vinothkumar/S. Vijay	
Checked by	:	Dr. P. Chandramohan	

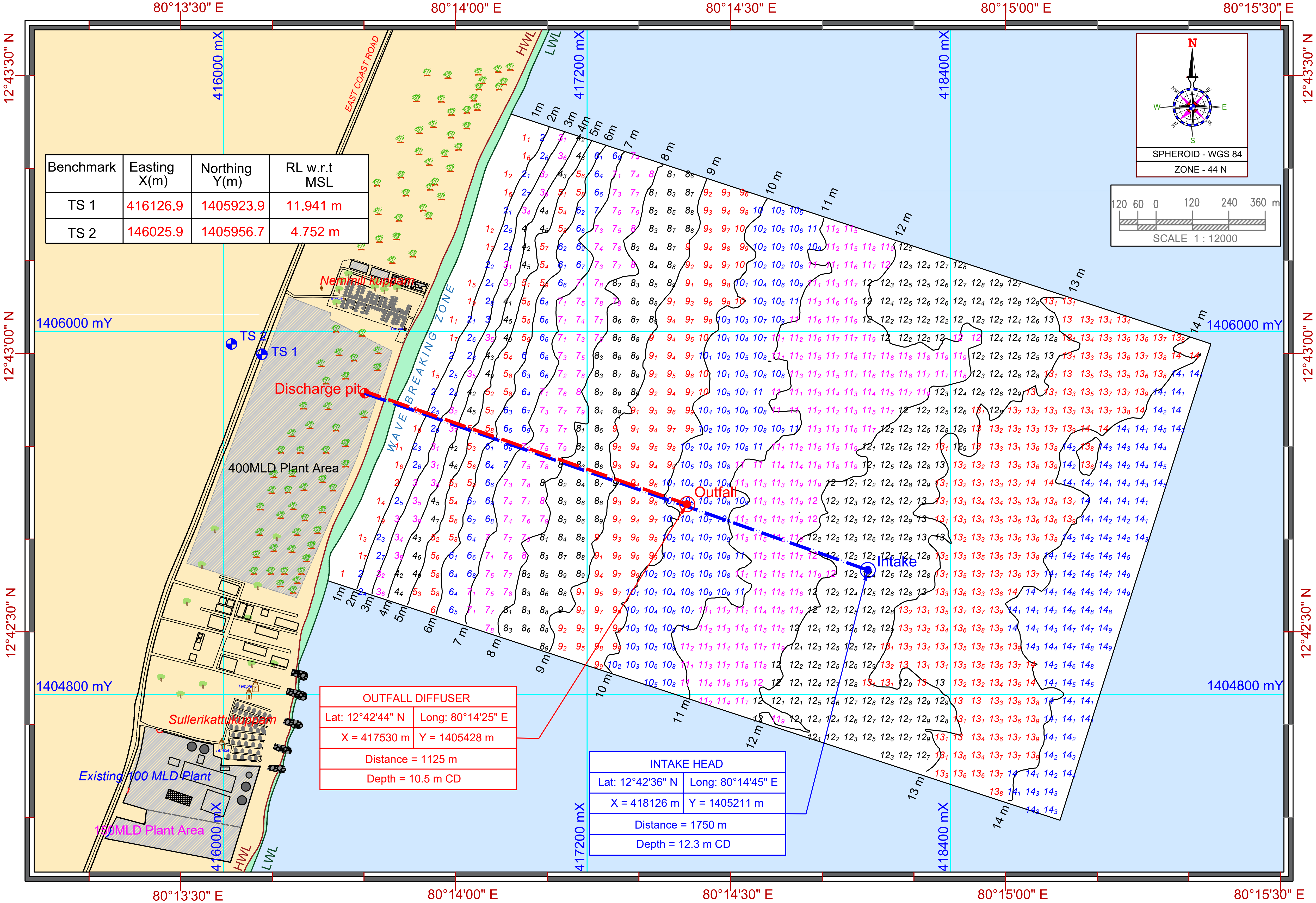


FIG. 4.3. BATHYMETRY MAP (1:12000 SCALE)

SAMPLING LOCATIONS

Stations	UTM Coordinates (Zone 44N)	
	Easting (Xm)	Northing (Ym)
SB1	416828	1405667
SB2	417053	1405591
SB3	417431	1405459
SB4	417809	1405328
SB5	418126	1405211
SB6	418452	1405104
SB7	418733	1405008
SB8	416978	1405405
SB9	417546	1405208
SB10	418113	1405011
SB11	418683	1404820
SB12	417127	1405776
SB13	417695	1405580
SB14	418262	1405383
SB15	418825	1405187

FIG.5.1. LOCATIONS OF SEABED SEDIMENT SAMPLE COLLECTION

Annexure 2

CHENNAI METROPOLITAN WATER SUPPLY & SEWERAGE BOARD (CMWSSB)

SEAWATER ANALYSIS REPORT

PMC for Chennai Perur 400 MLD Seawater Desalination Plant and allied works

Reference No.: Loan ID-P267
Contract No. : CNT/ CON/DESAL /ICB/GoI/016/2018-19
18 March 2021

SMEC International Pty. Ltd., Australia in consortium with
NJS Engineers India Private Limited, Pune
Tata Consulting Engineers Limited, Mumbai
SMEC (India) Private Limited, Haryana

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0	18 March 2021	Mr.S.M.Karthikaeswaran & PMC Team	Dr.Ghulam Mustafa	Dr.P.Dharmabalan

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CONTENTS

Tables

Figures

1. INTRODUCTION

1.1 Background

Chennai is currently experiencing a chronic water shortage due to the impacts of climate changes and failure of recent monsoons to deliver enough rainfall and associated stream flow to refill the existing water supply system's surface water sources.

To improve the current water supply situation, the Chennai Metropolitan Water Supply and Sewerage Board ("CMWSSB" or "the Client") has obtained loan from the Japan International Cooperation Agency ("JICA") through the Government of India and through Government of Tamil Nadu, to implement a 400 MLD Sea Water Reverse Osmosis Desalination Plant at Perur in Chennai.

CMWSSB has selected a Project Management Consultant ("PMC") through a competitive bidding process to support the CMWSSB Project Implementation Unit ("PIU") for implementation of the 400 MLD Seawater Desalination Plant and its components. A Consultancy Contract agreement was signed on January 09, 2020 for Project Management Consulting Services.

PMC started working on the project in Chennai from January 20, 2020. As part of the Term of Reference (TOR), PMC investigated the raw seawater quality conducted in 2017 and presented in the Detailed Project Report (DPR) and Feasibility Report prepared by JICA. The seawater quality data presented in the above reports include all important seawater parameters except the content of TOC and DOC.

Since early 2019 persistent occurrence of white fibre particles in the raw seawater was reported by the operating agency of 100 MLD Nemmeli Desalination plant. It was informed that the white fibrous particles are in huge quantity and that it clogs even the Energy Recovery Devices (ERDs) and the RO membranes resulting in maintenance at ERDs and frequent RO membranes cleaning through Clean In Place (CIP).

With the deteriorated seawater quality, it was important to examine the quality of the present raw seawater and to confirm the TOC/DOC concentration at and around offshore intake point. Subsequently, PMC engaged the following two laboratories by the end of June 2020 to analyse the seawater at the proposed seawater intake location:

a) Indian Institute of Technology (IIT), Madras

b) M/s. Indomer Coastal Hydraulics Pvt. Ltd., Chennai

M/s. Indomer Coastal Hydraulics (P) Ltd., Chennai, carried out the task of seawater sample collection at four selected locations – details of the locations are provided below in Table-1. The seawater analysis for all important parameters including the TOC and DOC were carried out by the above two laboratories. Due to possible variation in TOC/DOC analysed values resulting due to variation in analysis techniques, it was decided to engage two more reputed laboratories for only TOC/ DOC analysis in raw seawater. However, after thorough search we realised that very few laboratories in India conduct TOC/DOC analysis based on the recommended high temperature combustion (HTC) technique. An effort was also made to send the seawater samples to a Singaporean or Australian laboratory for TOC/DOC analysis, but it did not materialise due to custom issues in India during Covid-19 pandemic. After consistent efforts, PMC contacted only one laboratory, Eurofins (Unwelt West GmBH (Wessling) in Bangalore who agreed to conduct TOC/DOC analysis in Germany based on HTC technique. Later on, the sample was also supplied to National Environmental Engineering Research Institute (NEERI) for TOC/DOC analysis in seawater.

Finally, the TOC and DOC characterisation of seawater was carried out by four different laboratories namely:

a) IIT, Madras

b) M/s. Indomer Coastal Hydraulics (P) Ltd., Chennai

c) Eurofins (Unwelt West GmBH (Wessling), Germany

d) NEERI, Chennai

The seawater analysis reports submitted by the above four laboratories are appended as Annexures in this report.

M/s Indomer Coastal Hydraulics (P) Ltd., Chennai did the sample collection in August 2020. PMC was fully involved in conducting the sample collection at all the selected four locations. This report presents the details of the seawater sampling, analytical results, comparison of results among laboratories and that of DPR with discussion and inference.

1.2 Objectives of this Report

The objectives of this report are as follows:

- to carry out the raw seawater characterisation including analysis of TOC and DOC.
- To compare the analysis results with the DPR specified raw seawater design values.
- to arrive at the design parameters to be adopted for Process design of Perur DSP and ultimate inclusion in Bid specifications as the indicative design criteria.

2. SAMPLING PROGRAMME

With respect to the proposed intake and outfall positions in the sea, the seawater samples were collected at four locations (SP1, SP2, SP3 and SP4) for the proposed desalination plant at Perur, Chennai. The details of sampling locations with UTM (Universal Transverse Mercator) coordinates are presented in Table 1 below.

Table 1: Details of Seawater Sampling Locations

Station Number	UTM Coordinates (WGS 84) Zone 44 N		Distance from Shore (m)	Sampling Depth (m)
	X (m)	Y (m)		
SP1	415950	1404525	100 MLD Nemmeli DSP pumping Station	Pump Discharge
SP2	417536	1405436	1140	3 m above the seabed
SP3	418126	1405211	1800	3 m above the seabed
SP4	418733	1405008	2400	3 m above the seabed

The aerial view of the four sampling locations is illustrated in the Figure-1 below.

SAMPLING LOCATIONS				
Locations	Geographical Coordinates (WGS 84)		UTM Coordinates (Zone 44N)	
	Latitude, N	Longitude, E	Easting (Xm)	Northing (Ym)
Discharge pit	12°42'55"	80°13'50"	416465	1405794
SP1	12°42'14"	80°13'33"	415950	1404525
SP2	12°42'44"	80°14'25"	417536	1405436
SP3	12°42'36"	80°14'45"	418126	1405211
SP4	12°42'31"	80°15'05"	418733	1405008
NS1	12°42'31"	80°15'05"	417000	1406000
NS2	12°42'31"	80°15'05"	416833	1405399

Figure 1: Aerial View of the Seawater Sampling Locations

During the sampling period, the sea conditions were observed to be calm with moderate sea conditions which typical during the month of August. The season during the sampling period was retreating southwest monsoon with normal wind speed. There was no rain during the sampling period.

3. CORRESPONDENCE WITH LABORATORIES

PMC prepared the Terms of Reference (ToR) and raised work order for sampling and analysis of seawater. The results provided by the laboratories were reviewed, commented and virtual meetings were conducted with the laboratories for finalisation of the seawater analysis results. A chronology of the activities with respect to the task of seawater analysis by three different laboratories is given below in Table 2.

Table 2: Details of Activities for Seawater Analysis by Three Different Laboratories

Sl. No.	Details of Activities	Date of Activities
M/s Indomer Coastal Hydraulics (P) Ltd.		
1.	Release of Work order for sampling collection and analysis of Seawater, Bathymetric survey and Brine Dispersion Model	19 August 2020
2.	Date of sample collection/ Bathymetry survey	26 - 28 August 2020
3.	Submission of Seawater quality report by M/s Indomer	19 September 2020
4.	PMC Comments on the report submitted to M/s Indomer. The major issue was mismatch in TDS and analysed ionic strength.	21 September 2020
5.	A meeting with M/s Indomer and PMC team to discuss the comments.	22 September 2020
6.	Response from M/s Indomer to carry out the additional tests	28 September 2020
7.	A meeting with M/s. Indomer and PMC team for review of Seawater analysis report/ Bathymetry and Modelling. – The Ionic balance of TDS was not matching with the cations and anions analysed. Hence PMC requested M/s. Indomer to repeat the cations and anions analysis.	29 September 2020
8.	M/s Indomer provided the revised seawater analysis report	5 October 2020
9.	Virtual meeting with M/s. Indomer and PMC team for review of revised Seawater analysis report and Modelling report. The gap of a month was due to M/s Indomer undergoing internal QCI Assessment.	5 November 2020
10.	Submission of Final report for Seawater analysis by M/s Indomer	30 November 2020

Sl. No.	Details of Activities	Date of Activities
IIT Madras		
11.	Release of Work order for Seawater quality analysis	25 August 2020
12.	Receipt of analysis results with IIT, Madras without Heavy metals analysis	16 September 2020
13.	PMC comments on the analysis results – mainly for high values of TOC, DOC, BOD and Oil & Grease contents. Mismatch in the reported values. Difference of TOC and DOC was reported higher than TSS.	16 September 2020
14.	Receipt of final Seawater analysis report from IIT Madras. The test for TOC and DOC was repeated and found the values the same.	11 November 2020
M/s. Eurofins (Unwelt West GmBH (Wessling), Germany		
15.	Release of Work order for TOC/DOC analysis	18 November 2020
16.	Receipt of analysis results for TOC/ DOC	27 November 2020
17.	Receipt of revised analysis results for TOC/ DOC	26 February 2021
M/s. NEERI, Chennai		
18.	Release of Work order for TOC/DOC analysis	09 February 2021
19.	Receipt of analysis results for TOC/ DOC	22 February 2021

4. LABORATORY RESULTS AND DISCUSSION

The seawater analysis results from two laboratories viz., M/s Indomer and IIT, Madras for 4 sampling locations and the DPR design parameters are presented below in Table 3.

The laboratory analysis data presented in the table below are the final results after incorporation of the PMC comments on the seawater analysis reports followed by revision of the chemical analysis for seawater samples. Due to gross inconsistency in the analysed test results produced by both the laboratories i.e., Indomer and IIT Madras, PMC conducted several meetings with them and advised them to revise the analysis and recheck the seawater constituents' values. Major inconsistency in the test results was found in the values for TDS, salinity, TSS, TOC, metal ions etc which were again tested by the laboratories, and the values were changed and/or reconfirmed.

The average values of the seawater parameters at the four sampling locations are presented in the table for both the laboratories. A comparison of these average values from two laboratories has been presented in percent difference. As expected, the major difference (more than 100%) in the analysed values received from two laboratories is due to the parameters involving organic matter such as TOC, DOC, BOD and oil & grease. The values of these parameters provided by IIT(M) are found several folds higher than that of the values supplied by M/s Indomer. The method of TOC/ DOC analysis carried out by M/s. Indomer is Chemical titration method, whereas the analysis method followed by IIT Madras is APHA 5310B – High temperature Thermal Combustion method. It is to be noted that the method of analysis recommended by PMC is the high temperature thermal combustion method.

Even after repeated analysis after PMC's comments, the laboratories reported the same difference in values of the TOC/DOC parameters and therefore, PMC considered the values of these parameters as non-conclusive. Nevertheless, these values have serious implication on the selection and design of the seawater pre-treatment processes for the RO feed.

Having the above situation, PMC decided to send the samples for TOC/DOC analysis outside India to the countries like Singapore, Australia or Germany. An Australian reputed laboratory was earmarked, and samples were dispatched to that Australian laboratory. But unfortunately, the samples were held back at Indian Customs and even after persuasion, the samples were not allowed to go outside India. Following this, the samples were given to a laboratory in Bangalore named Eurofins, a branch of Germany laboratory for conducting test in Germany. Eurofins sent the samples to Germany for the test of TOC/DOC. Overall seawater analysis results from Indomer and IIT Madras have been provided in Table-3 while the results of TOC and DOC from all agencies including Eurofins are presented in Table-4.

Table 3: Comparison of Analysis Results from Two Different Laboratories

Sl. No.	Parameters	Unit	Indomer Analysis Data					IIT Madras Analysis Data					% Diff - Indomer & IIT	DPR Data	Remarks
			SP1	SP2	SP3	SP4	Avg	SP1	SP2	SP3	SP4	Avg			
1	Temperature	°C	27	26.5	26.5	26	**26.5**					**-**	-	27.9	
2	pH		8.01	8.22	8.23	8.2	**8.2**	8.05	8.28	8.31	8.27	**8.2**	-1%	8.2	
3	Colour (Before filtration-0.45µm	Hazen	4.6	3.91	4.01	2.95	**3.9**	Pale yellow	Slight yellow	Slight yellow	Slight yellow	**-**	-	-	
	Colour (After filtration-0.45 µm	Hazen	1.37	1.29	1.56	0.58	**1.2**					**-**	-	-	
4	Conductivity	µS/cm	55200	55100	55200	55700	**55300**	58675	59550	58705	57775	**58676**	-6%	-	
5	Total Dissolved Solids (TDS)	mg/l	36940	36930	36950	37340	**37040**	34720	35130	35720	35520	**35273**	5%	-	OK TDS is within design limit
6	Salinity	PSU	34.9	34.9	35	35.1	**35.0**	35.8	35.45	35.55	35.55	**35.6**	-2%	-	
7	Turbidity	NTU	8.3	8.4	7.8	8.4	**8.2**	8.76	1.82	1.65	4.49	**4.2**	49%	10	
8	Total Suspended Solids	mg/l	12.1	12.4	11.2	12	**11.9**	27.33	6.14	5.52	15.8	**13.7**	-15%	75	
9	Calcium as Ca	mg/l	455	444	455	455	**452.3**	488.3	489.6	520.2	511.5	**502.4**	-11%	467	
10	Magnesium as Mg	mg/l	1399	1405	1386	1399	**1397.3**	1117	1037	1038	1006	**1049.3**	25%	1258	

Sl. No.	Parameters	Unit	Indomer Analysis Data					IIT Madras Analysis Data					% Diff - Indomer & IIT	DPR Data	Remarks
			SP1	SP2	SP3	SP4	Avg	SP1	SP2	SP3	SP4	Avg			
11	Total Hardness as $CaCO_3$	mg/l	6885	6885	6831	6885	**6871.5**	5650	5950	5400	5500	**5625.0**	18%	-	
12	Sodium as Na	mg/l	12310	12308	12328	12396	**12335.5**	11431	11553	11786	11542	**11578**	6%	10789	
13	Potassium as K	mg/l	442	448	452	446	**447.0**	447.2	446.5	451.3	452.5	**449.4**	-1%	391	
14	Bicarbonate as HCO_3	mg/l	125	127	124	127	**125.8**	127.6	114.1	123.3	130.2	**123.8**	2%	126.3	
15	Total Alkalinity as $CaCO_3$	mg/l	125	127	124	127	**125.8**	140.8	149.9	167.5	151	**152.3**	-21%	-	
16	Sulphate as SO_4	mg/l	2944	2833	2879	2742	**2849.5**	2266.2	2317.9	2336	1765.5	**2171.3**	24%	2878	
17	Phosphate as PO_4	mg/l	0.25	0.21	0.19	0.18	**0.2**	0.02	0.02	0.02	0.02	**0.0**	90%	-	
18	Total Phosphorus as P	mg/l	2.83	2.22	2.45	3.65	**2.8**					**-**	-	-	
19	Chloride as Cl-	mg/l	19001	19001	19072	19143	**19054.3**	19651	20060	22084	21651	**20862**	-9%	19247	OK
20	Fluoride as F-	mg/l	1.61	1.55	1.58	1.58	**1.6**	1.08	1.12	1.36	1.05	**1.2**	27%	1.63	
21	Ammoniacal Nitrogen as NH_4-N	µmol/l	4.43	3.49	3.77	2.99	**3.7**	0.66	0.28	0.33	0.14	**0.4**	90%	0.2	
22	Nitrate as NO_3	µmol/l	7.47	5.44	4.79	4.58	**5.6**	0.18	0.19	0.17	0.19	**0.2**	97%	4	
23	Nitrite as NO_2	µmol/l	0.26	0.17	0.13	0.11	**0.2**	0.06	0.06	0.06	0.05	**0.1**	66%	-	

Sl. No.	Parameters	Unit	Indomer Analysis Data					IIT Madras Analysis Data					% Diff - Indomer & IIT	DPR Data	Remarks
			SP1	SP2	SP3	SP4	Avg	SP1	SP2	SP3	SP4	Avg			
24	Total Nitrogen as N	µmol/l	12.2	9.15	8.74	7.72	**9.5**	0.72	0.6	0.31	0.28	**0.5**	95%	-	
25	Total Organic Carbon (TOC)	mg/l	2.9	4.5	5.1	4.2	**4.2**	41.73	30.85	39.38	36.41	**37.1**	**-788%**	-	Non- Conclusive - Requires further Investigation
26	Dissolved Organic Carbon (DOC)	mg/l	1.6	2.2	3.2	2.2	**2.3**	19.19	9.15	13.06	16.55	**14.5**	**-530%**	-	Non- Conclusive - Requires further Investigation
27	Silica as SiO_2	mg/l	0.18	0.11	0.11	0.1	**0.1**	4.53	5.073	5.065	4.79	**4.9**	**-3792%**	1.38	High difference – No design issue
28	Dissolved Oxygen	mg/l	5.6	6.3	6.1	6	**6.0**	7.09	7.16	7.08	6.86	**7.0**	-17%	-	
29	BOD5	mg/l	1.6	1.7	1.8	1.8	**1.7**	16.3	8.8	13.8	12.5	**12.9**	**-645%**	-	Non- Conclusive - Requires further Investigation
30	COD	mg/l	18.7	22.5	21.3	20.7	**20.8**					**-**	**-**	-	
31	Silt Density Index	SDI	1	1.2	1	1.6	**1.2**	5.8	5.2	5.1	5.3	**5.4**	-346%	-	Within design limit
32	Oil and Grease	mg/l	<0.1	<0.1	<0.1	<0.1	**0.1**	8.2	4.6	0.8	6.2	**5.0**	**-4850%**	-	Non- Conclusive - Requires further Investigation
33	Phenolic compounds	mg/l	<0.01	<0.01	<0.01	<0.01	**<0.01**	BDL	BDL	BDL	BDL	**<0.01**	-	-	
34	Boron as B	mg/l	3.83	3.61	3.63	3.62	**3.7**	-	-	-	-	**-**	-	3.17	Within design limit
35	Barium as Ba	µg/l	13.7	13.2	13.8	11.95	**13.2**	103.5	136	342.5	123.5	**176.4**	-1240%	-	

Sl. No.	Parameters	Unit	Indomer Analysis Data					IIT Madras Analysis Data					% Diff - Indomer & IIT	DPR Data	Remarks
			SP1	SP2	SP3	SP4	Avg	SP1	SP2	SP3	SP4	Avg			
36	Strontium as Sr	mg/l	5.83	5.56	5.58	5.54	**5.6**	4.5	5.1	5.2	5.1	**5.0**	12%	-	
37	Cadmium as Cd	µg/l	6.4	6.5	6.43	5.85	**6.3**	1.5	1	92	1.5	**24.0**	-281%	-	
38	Lead as Pb	µg/l	<0.1	<0.1	<0.1		**<0.1**	192.5	223.5	253	139.5	**202.1**	#VALUE!	-	
39	Iron as Fe	µg/l	<0.1	<0.1	<0.1	<0.1	**<0.1**	<0.1	<0.1	<0.1	<0.1	**<0.1**	0	-	
40	Manganese as Mn	µg/l	11.86	<0.1	<0.1	<0.1	**11.9**	32.5	66	140	39	**69.4**	-485%	-	
41	Copper as Cu	µg/l	<0.1	<0.1	<0.1	<0.1	**<0.1**	238.5	363	372	237.5	**302.8**	-	-	
42	Total Arsenic as As	µg/l	12.5	13.8	12.3	14.8	**13.4**	2.5	21	127	7	**39.4**	-195%	-	
43	Zinc as Zn	µg/l	20.1	19.8	20.3	20.1	**20.1**	10.8	11.2	11.3	11.2	**11.1**	45%	-	
44	Algal count	Species /ml	145	132	155	161	**148.3**	-	-	-	-	**-**	-	-	
45	Chlorophyll	mg/m^3	0.93	0.89	1.06	1.22	**1.0**	2.6	2.1	1.9	2.3	2.2	-1.17		
46	Total Viable Colony Count	CFU/ml	2.08×10^3	1.94×10^3	2.10×10^3	2.12×10^3	**2.06×10^3**	-	-	-	-	**-**	-	-	

The analysis results for TOC/DOC in seawater from SP2 and SP4 sampling locations conducted by three laboratories are given below in Table-4.

Table 4: TOC/ DOC Results from Three Different Laboratories

Sl. No.	Parameters	Unit	Indomer Pvt. Ltd., Chennai		IIT Madras		Eurofins, Germany	
			SP2	SP4	SP2	SP4	SP2	SP4
1	Total Organic Carbon (TOC)	mg/l	4.5	4.2	30.85	36.41	1.2	1.2
2	Dissolved Organic Carbon (DOC)	mg/l	2.2	2.2	9.15	16.55	1.2	1.1

The results in the above table indicate that the TOC/DOC values are very close for Indomer and Eurofins while the values from IIT Madras are quite high. It is to be noted that the Indomer has used non-conventional method for TOC/DOC determination while IIT Madras and Eurofins have used the high temperature combustion method which is the most appropriate and recommended method for the TOC/DOC analysis. However, the IIT results for TOC/DOC are too high to perceive as the correct value. Usually, the TOC is found to remain within 5 mg/l in the seawater. NIOT has also reported the TOC concentration in seawater within the range of 8 mg/l.

The results in the above tables reveal that the quality of seawater in terms of TOC/DOC and TSS is not improving with increase in the distance of the intake location offshore. As per IIT Madras, the DOC concentration is much less at SP2 (about 1000m from seashore) compared to SP4 (about 2000m from seashore). This indicates that there will be no quality improvement for seawater by selecting intake point far from the shore inside sea.

To confirm the results of Eurofins for TOC and DOC, a sample from the intake well of Nemmeli plant (sample location – SP1) was again collected on 9th of February 2021 and sent to Eurofins and NEERI laboratories for the test of TOC and DOC contents in the seawater. The results obtained are given below in Table 5. The results from Eurofins were found consistent within 2 mg/l of TOC. While results of NEERI indicate TOC slightly above 4 mg/l.

Table 5: TOC/ DOC Results from Two Laboratories using HTC Method

Sl. No.	Parameters	Unit	Sample Location	NEERI	Eurofins, Germany
1	Total Organic Carbon (TOC)	mg/l	SP1	4.164	2.0
2	Dissolved Organic Carbon (DOC)	mg/l	SP1	3.274	1.9

5. CONCLUSIONS AND RECOMMENDATIONS

Seawater has been analysed by four different laboratories and the results have been discussed above. The conclusions and recommendations are given as follows:

1. The major seawater quality parameters such as salinity, TDS, TSS, turbidity, boron, other metal ions are within the proposed design limits (as per DPR) for 400 MLD Chennai Seawater Desalination Plant.

2. The seawater quality in terms of TDS, TSS, Turbidity, SDI and metal ions are not varying much with the distance from the seashore inside the sea. So, there is no seawater quality gain by extending intake point far inside the sea.

3. TOC values and other organic matters reported by the laboratories are varying. Three laboratories reported TOC values within the average limit of 5 mg/l as in Concept Design Report while one laboratory (IIT Madras) has indicated much higher value up to 36.4 mg/l. Further investigation was conducted to confirm the range of TOC values in seawater. The results reveal the TOC value below the assumed concept mean design value of 5 mg/L.

4. With respect to the Concept Design Report finalization, PMC recommends keeping the proposed TOC value of max 8 mg/l in raw seawater. For RFP document, the design raw seawater quality will be presented as INDICATIVE and that the contractor shall be given responsibility to verify the raw seawater quality including the content of TOC before initiating the design of the pre-treatment processes.

5. The recommended raw water quality for the Concept Design Report remains the same as presented below in Table 5.

Table 5: Raw Seawater Quality for Process Design

Parameters	Raw seawater design Parameter values		
	Minimum value	Mean value	Maximum value
TDS	32000	36000	39000
pH	8.00	8.13	8.20
Temperature	26.0	28.3	31.5
Boron	3.2	3.53	3.80
Turbidity	1.0	12	150
TSS	10	75	300
Total Organic Carbon (TOC)	3.0	5	8
Algae count (cells per ml)	100	500	30000
Jellyfish attacks	N.A	N.A	Yearly Occurrences

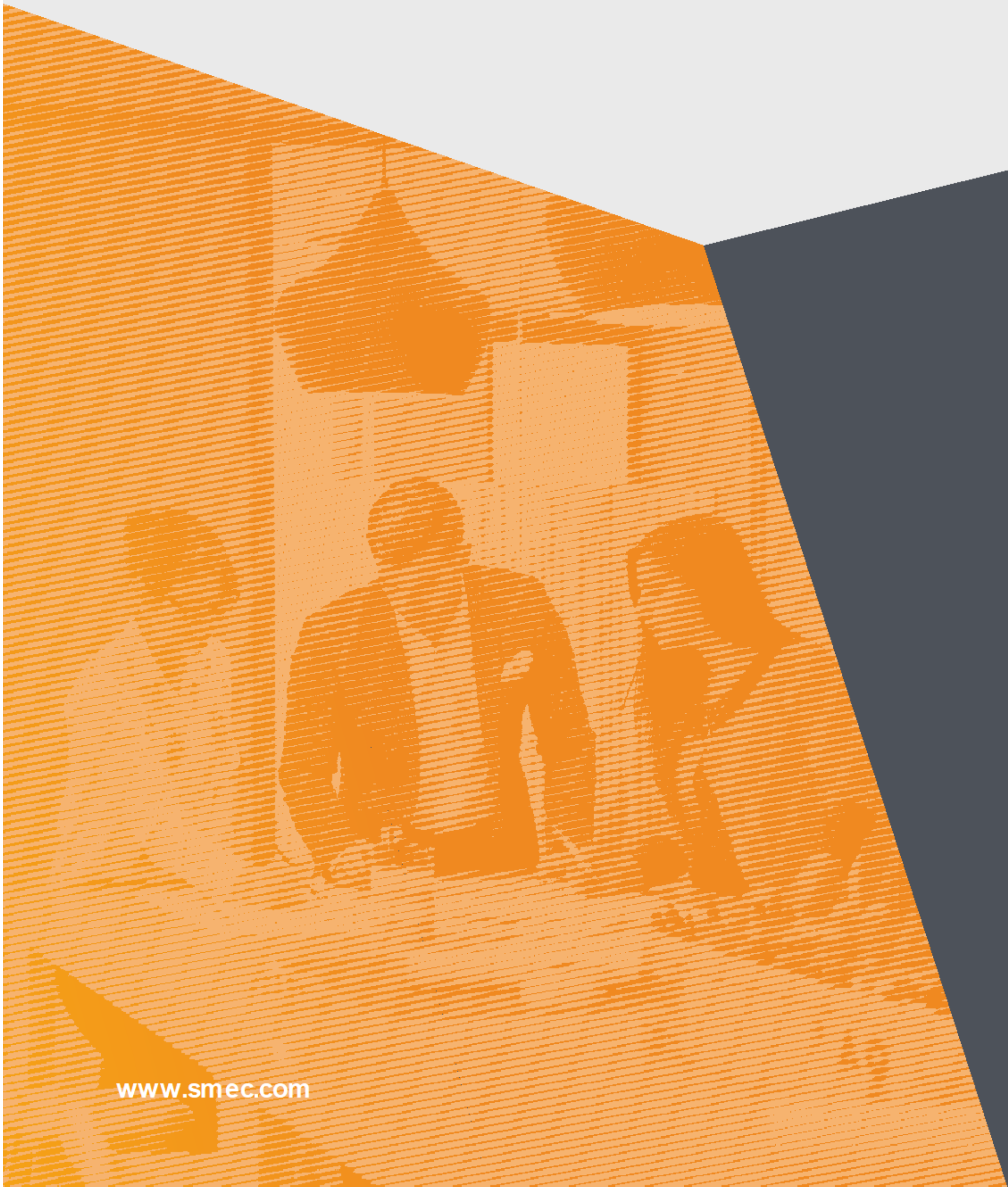
6. ANNEXURES

The following annexures are included with this Report:

- Annexure 1: M/s. Indomer Coastal Hydraulics (P) Ltd. - Seawater Analysis Report
- Annexure 2: IIT Madras - Seawater Analysis Report
- Annexure 3: M/s. Eurofins Unwelt west GmbH - TOC/DOC analysis
- Annexure 4: M/s. Eurofins Unwelt west GmbH - TOC/DOC analysis (2nd time)
- Annexure 5: NEERI, Chennai - TOC/DOC analysis

The CHENNAI 400 MLD DESALINATION PLANT is a Project being delivered by the Chennai Metropolitan Water Supply & Sewerage Board (CMWSSB) with the assistance of an Official Development Assistance (ODA) loan from the Japan International Cooperation Agency (JICA).

The Project Management Consultant (PMC) for the Chennai 400 MLD Desalination Plant project is a consortium led by SMEC International Pty Ltd in partnership with TATA Consulting Engineers Limited (TCE), NJS Engineers India Pvt Ltd (NJSEI) and SMEC India Pvt Ltd.



Annexure 1

M/s. Indomer Coastal Hydraulics (P) Ltd. - Seawater Analysis Report

SEAWATER ANALYSIS FOR 400 MLD DESALINATION PLANT AT PERUR, CHENNAI, TAMIL NADU

SEAWATER ANALYSIS REPORT

PROJECT CODE: 696082021

For

SMEC India Pvt. Ltd.
Gurugram

SEPTEMBER 2020

INDOMER COASTAL HYDRAULICS (P) LTD.

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Client	SMEC India Pvt. Ltd., Gurugram, Haryana
Project Title	Seawater analysis for 400 MLD desalination plant at Perur, Chennai, Tamil Nadu.
Project	696082021
Abstract	CMWSSB has planned to set up a 400 MLD desalination plant at Perur. CMWSSB has nominated SMEC India Pvt Ltd., Gurugram as Project Consultant. SMEC has in turn asked to Indomer Coastal Hydraulics (P) Ltd., Chennai, to collect seawater samples at selected four locations and do the analysis for specified parameters. Indomer has done the sample collection in August 2020. This report presents the details of the methodology adopted for analysis and the results.
Foreword	The materials presented in this Measurement report carry the copyright of SMEC and INDOMER. The data presented in the report should not be altered or distorted or copied or presented in different manner by anyone without the written consent from SMEC or INDOMER.
Document	Controlled
References	SMEC India Pvt Ltd.- SCA4 Rev00 10051/dt.19th August, 2020

Date	Report Type	Originator	Checked by	Approved by	Approver's
16.09.2020	Final	J. Jaganmohan	J.Guru Prasath	Dr. P. Chandramohan	
1	Project Code	696082021		Text pages	20
2	File Location	F:/2020 Projects/Aug -20/Perur			

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1. INTRODUCTION

Chennai Metropolitan Water Supply & Sewerage Board (CMWSSB) has appointed SMEC India Pvt. Ltd., Gurugram for the Consultancy work related to the proposed 400 MLD desalination plant Perur, Chennai.

SMEC has in turn asked to Indomer Coastal Hydraulics (P) Ltd., Chennai, to collect seawater samples at selected four locations and do the analysis for specified parameters. Indomer has done the sample collection in August 2020. This report presents the details of the methodology adopted for analysis and the results. The location map is shown below

All calendar dates are referred in Indian style as dd.mm.yy. (eg. 28.08.20 for 28th August 2020) and the time is referred to Indian Standard Time in 24-hour clock, eg. 3 PM is written as 1500 hrs. SI units are followed for all fundamental and derived units. The depths are referred with respect to Chart Datum. The UTM coordinates are indicated in WGS 84 spheroid - Zone 44N.

Fig. 1.1. Location map

Team members

Sl. No.	Name of the Expert/s	Qualification	Project Role
1	Dr. P. Chandramohan	Ph.D. (Ocean Engineering)	Project Coordinator
2	Mr. J. Guru Prasath	B.E. (Marine Engineering)	Team Leader
3	Dr. K. Venkataraman	Ph.D. (Zoology/Animal Biology)	QA & QC
4	Dr. A. Kannathasan	Ph.D. (Marine Biology)	Field data collection
5	Mr. J. Vinoth Kumar	B.E. (Civil Engineering)	Field data collection
6	Mr. S. Vijay	B.E. (Civil Engineering)	Field data collection
7	Mr. M. Sharath	B.E. (Electronic and Instrumentation Engineering)	Field data collection
8	Mr. J. Jaganmohan	M.Sc. Chemistry	Laboratory analysis
9	Dr. G. Idhayachandran	Ph.D. (Marine Biology)	Laboratory analysis
10	Ms. S. Kasthuri	M.Sc. Chemistry	Laboratory analysis

2. SCOPE OF WORK

i) To carry out the seawater and biological sample collections, testing and analysis at 4 locations as specified by the client.

ii) To prepare and submit the report.

2.1. Sampling Plan

As per terms of reference planned to collect the seawater and biological samples at 4 locations (SP1, SP2, SP3 and SP4) for proposed desalination plant at Perur, Chennai.

Details of seawater sampling locations

Station No.	UTM Coordinates (WGS 84) Zone 44 N		Distance from Shore (m)	Sampling depth (m)
	X (m)	Y (m)		
SP1	415950	1404525	Existing 100 MLD DSP pumping Station	Existing 100MLD DSP pumping Station
SP2	417536	1405436	1140	3 m above the seabed
SP3	418126	1405211	1800	3 m above the seabed
SP4	418733	1405008	2400	3 m above the seabed

2.2. List of equipments

The following equipments were used for collection of seawater samples and biological samples at field.

Sl. No.	Instruments
1	Thermometer
2	Refractometer
3	pH meter
4	Flow meter
5	Hemisphere DGPS
6	Van dorn Samplers
7	Plankton Nets
8	Sediment grabs
9	Sieve, shovel and quadrant
10	BOD bottles
11	DO bottles
12	Burettes (25 ml)
13	Plastic sampler bottles
14	Ice box
15	Chemicals and reagents

3. SEAWATER QUALITY

3.1. Collection of seawater samples

The seawater and biological samples were collected at 4 locations (Stn. SP1, SP2, SP3 and SP4). Stn. SP1 was collected at the existing Nemmeli desalination plant pumping station. Stn. SP2, SP3 and SP4 were collected at a distance of 1140 m, 1800 m and 2400 m offshore respectively.

Additionally, two samples were collected at 2 locations in the near shore region (Stn. NS1 and NS2) as per the request of the client representatives during sampling.

Seawater samples were collected in 3 sets of each 10 litre capacity. One set of sample was used for analysis by Indomer and another two sets of samples had been handed over to SMEC. From the collected seawater, temperature and pH were measured on board at site. The samples collected for Dissolved oxygen were fixed at site by adding Winkler 'A' and 'B' solution.

The seawater quality parameters were analyzed at Indomer in-house laboratory which has accreditation by National Accreditation Board for Testing and Calibration Laboratories (NABL). The NABL certificate is enclosed in Annexure – I.

The details of the sampling locations are shown in Fig. 3.1 and given in Table 3.1. The water samples were collected at 3 m above the seabed. The seawater - Physico-Chemical parameters quality are given in Table 3.2.

Table 3.1. Details of sampling Locations

Stn. No.	Geographical Coordinates (WGS 84)		UTM Coordinates (WGS 84) Zone 44		Water depth (m)	Sampling depth (m)
	Latitude, N	Longitude, E	X (m)	Y (m)		
SP1	12°42′14″	80°13′33″	415950	1404525	Existing 100 MLD DSP pumping Station	Existing 100 MLD DSP pumping Station
SP2	12°42′44″	80°14′25″	417536	1405436	7	3 m above the seabed
SP3	12°42′36″	80°14′45″	418126	1405211	7	3 m above the seabed
SP4	12°42′31″	80°15′05″	418733	1405008	9	3 m above the seabed
NS1	12°42′31″	80°15′05″	417000	1406000	4	3 m above the seabed
NS2	12°42′31″	80°15′05″	416833	1405399	4	3 m above the seabed

SAMPLING LOCATIONS

Locations	Geographical Coordinates (WGS 84)		UTM Coordinates (Zone 44N)	
	Latitude, N	Longitude, E	Easting (Xm)	Northing (Ym)
Discharge pit	12°42'55"	80°13'50"	416465	1405794
SP1	12°42'14"	80°13'33"	415950	1404525
SP2	12°42'44"	80°14'25"	417536	1405436
SP3	12°42'36"	80°14'45"	418126	1405211
SP4	12°42'31"	80°15'05"	418733	1405008
NS1	12°42'31"	80°15'05"	417000	1406000
NS2	12°42'31"	80°15'05"	416833	1405399

Fig. 3.1. Location map of seawater and biological sampling

Seawater sample collection

3.2. Sampling Protocol

i) Preservation

The samples were collected in cleaned glassed bottles. They were stored in ice box and temperature had been maintained below 5°C. Samples were preserved immediately to avoid any degradation in the quality. These samples were mixed and allowed to reach an ambient temperature before analysis. For the metal analysis, water samples were stored after reducing pH below 2 using nitric acid.

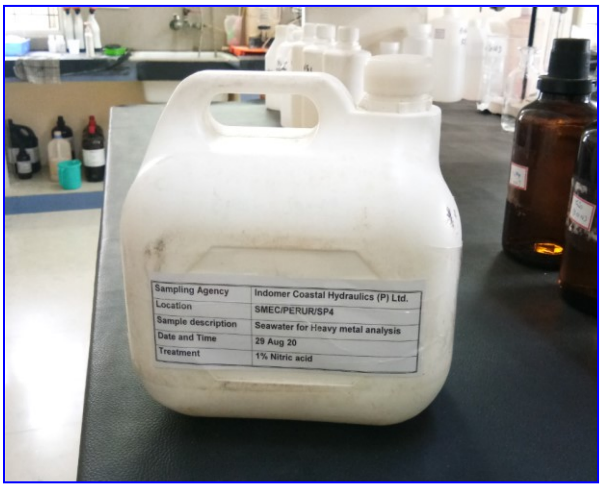
Microbiological samples were preserved with 30 mg of sodium thio-sulphate preservative added for each sterile bottle. Labeled sampling bottles were stored below 5°C.


Seawater samples preservation in cold storage box.

ii) Labelling of samples

The seawater samples were given unique identification code with following tags.

- Sampling Agency
- Sample location,
- Sample description
- Date and time of sample collection
- Treatment type

Labelling of samples

The log sheets for safe transfer of the samples are provided in Annexure – II

Sample Analysis Protocol

Details of Sample Analysis protocol

S. No.	Parameter	Protocol
1	Temperature, °C (During sampling)	APHA 2550 B
2	pH	APHA 4500 H
3	Colour (before and after filtration (0.45 micron)	APHA 2120 C
4	Conductivity, µS/cm	APHA 2510 B
5	Total Dissolved Solids (TDS), mg/L	APHA 2540 C
6	Salinity, PSU	IND/SOP/WQ/13
7	Turbidity, NTU	APHA 2130 B
8	Total Suspended Solids, mg/L	APHA 2540 B
9	Calcium as Ca, mg/L	APHA 3120 B
10	Magnesium as Mg, mg/L	APHA 3120 B
11	Total Hardness as CaCO3 mg/L	APHA 2340 C
12	Sodium as Na, mg/L	APHA 3120 B
13	Potassium as K, mg/L	APHA 3120 B
14	Bicarbonate as HCO3 mg/L	APHA 2320 B
15	Total Alkalinity as CaCO3 mg/L	APHA 2320 B
16	Sulphate as SO4, mg/L	APHA 4500 SO_4^{2} E
17	Phosphate as PO4, mg/L	APHA 4500-P J
18	Total Phosphorus as P, µmol/L	APHA 4500-P J
19	Chloride as Cl-, mg/L	APHA 4500-Cl B or D
20	Fluoride as F-, mg/L	APHA 4500-F D
21	Ammoniacal Nitrogen as NH4, µmol/L	APHA 4500 NH_3
22	Nitrate as NO3, µmol/L	APHA 4500 NO_3^- B
23	Nitrite as NO2, µmol/L	APHA 4500 NO_2
24	Total Nitrogen as N, µmol/L	APHA 4500 N
25	Total Organic Carbon (TOC), mg/L	Titration Method
26	Dissolved Organic Carbon (DOC), mg/L	Titration Method
27	Silica as SiO2, mg/L	APHA 4500-Si D or E
28	DO, mg/L	APHA 4500 O
29	BOD5, mg/L	APHA 5210 B
30	COD, mg/L	APHA 5220 C
31	SDI	ASTM D 4189-07
32	Oil and Grease, mg/L	APHA 5520 C
33	Phenolic compounds, mg/L	APHA 5530 D
34	Boron as B, mg/L	APHA 3120 B
35	Barium as Ba, µg/L	APHA 3120 B
Heavy Metals		
36	Strontium as Sr, mg/L	APHA 3120 B
37	Cadmium as Cd, µg/L	APHA 3120 B

38	Lead as Pb, µg/L	APHA 3120 B
39	Iron as Fe, µg/L	APHA 3120 B
40	Manganese as Mn, µg/L	APHA 3120 B
41	Copper as Cu, µg/L	APHA 3120 B
42	Total Arsenic as As, µg/L	APHA 3120 B
43	Zinc as Zn, µg/L	APHA 3120 B
Biological Parameter		
1	(i) Algal count, Species/ml	APHA 10200 F
	(ii) Chlorophyll, mg/m^3	APHA 10200 H
2	Total Viable Colony Count, CFU/ml	APHA 9215 C

3.3. Methodology for TOC and DOC analysis by chemical titration method

Principle:

$KMnO_4$ is the oxidizing agent that is used to oxidize the organic carbon present in the sample. The unused $KMnO_4$ will then react with KI to liberate an equivalent amount of iodine, which is estimated by titrating against standard sodium-thio-sulphate solution

Apparatus required:

- Burette
- Pipette - 25ml
- Conical Flask - 250ml
- Water bath

Reagent Required:

- Glucose standard
- Potassium permanganate solution: Make 0.01 N solution of $KMnO_4$. Dissolve 1.5803g in 1000ml DM water.
- Standard Sodium-thio-sulphate: Make 0.01 N solution. Dissolve 2.4818g of thio-sulphate in 1000ml DM water
- Potassium Iodide crystals: Approx. 0.25g id weighed and used directly.
- Sodium Hydroxide solution: Make 16% solution by dissolving 16s in 100ml DM water
- Sulphuric acid: Make 4N solution

Procedure:

Take 25 ml of the sample in a 250ml conical flask, add 2.5ml of NaOH solution and 5 ml or more of $KMnO_4$(an exact quantity, which should be consistent in each addition). Close the mouth of the flask with foil paper and heat on water bath for half an hour. Cool the solution to room temperature and then add about 1ml of H_2SO_4 and KI crystals and stir immediately. If the precipitate persists then add more acid till all the precipitate dissolves. Titrate against standard thio-sulphate till the reddish brown coloured solution turns a light yellow then add approximately 2ml of starch indicator and titrate till blue colour disappears or turns colorless. Note the burette reading. The same will be followed for blank sample by taking 25ml of DM water instead of sample.

Note: For DOC analysis – Filter the samples in 0.45 micron filter paper and follow the same procedure.

Calculation:

TOC in mg/l = (TV x N x 8 x 1000)/SV

Where,
TV= Burette reading in ml
N= Normality of sodium-thio-sulphate solution
SV= Sample volume in ml

3.4. Results

The results of seawater quality physic-chemical parameters are given in Table 3.2.

Table 3.2. Seawater - Physico-Chemical parameters

Sl. No.	Parameters	Unit	SP1	SP2	SP3	SP4	NS1	NS2
1	Temperature	°C	27	26.5	26.5	26	27.5	28
2	pH		8.01	8.22	8.23	8.2	8.21	8.19
3	Colour (Before filtration -0.45 micron)	Hazen	4.6	3.91	4.01	2.95	5.33	6.23
	Colour (After filtration -0.45 micron)	Hazen	1.37	1.29	1.56	0.58	0.78	1.29
4	Conductivity	µS/cm	55200	55100	55200	55700	55900	56000
5	Total Dissolved Solids (TDS)	mg/l	36940	36930	36950	37340	37340	37350
6	Salinity	PSU	34.9	34.9	35	35.1	35.1	35.3
7	Turbidity	NTU	8.3	8.4	7.8	8.4	5.8	5.9
8	Total Suspended Solids	mg/l	12.1	12.4	11.2	12	8.3	8.5
9	Calcium as Ca	mg/l	455	444	455	455	455	455
10	Magnesium as Mg	mg/l	1399	1405	1386	1399	1399	1399
11	Total Hardness as CaCO3	mg/l	6885	6885	6831	6885	6885	6885
12	Sodium as Na	mg/l	12310	12308	12328	12396	12402	12450
13	Potassium as K	mg/l	442	448	452	446	450	480
14	Bicarbonate as HCO3	mg/l	125	127	124	127	124	125
15	Total Alkalinity as CaCO3	mg/l	125	127	124	127	124	125
16	Sulphate as SO4	mg/l	2944	2833	2879	2742	2750	2738
17	Phosphate as PO4	mg/l	0.25	0.21	0.19	0.18	0.27	0.25
18	Total Phosphorus as P	mg/l	2.83	2.22	2.45	3.65	3.44	3.12
19	Chloride as Cl-	mg/l	19001	19001	19072	19143	19143	19214
20	Fluoride as F-	mg/l	1.61	1.55	1.58	1.58	1.62	1.59
21	Ammoniacal Nitrogen as NH4-N	µmol/l	4.43	3.49	3.77	2.99	4.49	4.88
22	Nitrate as NO3	µmol/l	7.47	5.44	4.79	4.58	4.81	4.95
23	Nitrite as NO2	µmol/l	0.26	0.17	0.13	0.11	0.17	0.2

Sl. No.	Parameters	Unit	SP1	SP2	SP3	SP4	NS1	NS2
24	Total Nitrogen as N	µmol/l	12.2	9.15	8.74	7.72	9.53	10.1
25	Total Organic Carbon (TOC)	mg/l	2.9	4.5	5.1	4.2	2.2	1.9
26	Dissolved Organic Carbon (DOC)	mg/l	1.6	2.2	3.2	2.2	1.6	1.3
27	Silica as SiO2	mg/l	0.18	0.11	0.11	0.1	0.13	0.1
28	Dissolved Oxygen	mg/l	5.6	6.3	6.1	6	6.2	6.3
29	BOD5	mg/l	1.6	1.7	1.8	1.8	2	1.9
30	COD	mg/l	18.7	22.5	21.3	20.7	23.2	19.4
31	Silt Density Index	SDI	1.0	1.2	1.0	1.6	1.4	1.5
32	Oil and Grease	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
33	Phenolic compounds	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
34	Boron as B	mg/l	3.83	3.61	3.63	3.62	3.35	3.73
35	Barium as Ba	µg/l	13.7	13.2	13.8	11.95	12.9	15
Heavy Metals								
36	Strontium as Sr	mg/l	5.83	5.56	5.58	5.54	5.23	5.74
37	Cadmium as Cd	µg/l	6.4	6.5	6.43	5.85	6.55	7.17
38	Lead as Pb	µg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
39	Iron as Fe	µg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
40	Manganese as Mn	µg/l	11.86	<0.1	<0.1	<0.1	<0.1	<0.1
41	Copper as Cu	µg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
42	Total Arsenic as As	µg/l	12.5	13.8	12.3	14.8	14.3	16.4
43	Zinc as Zn	µg/l	20.1	19.8	20.3	20.1	5.1	5.6

Checking Analyses' correctness as per APHA 1030E, 23rd Edition 2017

Measured TDS	mg/l	36940	36930	36950	37340	37340	37350
Sum of calculated TDS	mg/l	36628	36517	36648	36659	36675	36813
Measured TDS=Calculated TDS, Acceptable ratio is >1.0 to <1.2		1.009	1.011	1.008	1.019	1.018	1.015

3.5. Biological parameters

The biological parameters considered in the present study are chlorophyll '*a*' and bacterial population in coastal waters. The biological parameters - Algal count are presented in Table 3.3

Chlorophyll: Chlorophyll, in various forms, is bound within the living cells of algae and other phytoplankton found in seawater. Chlorophyll-containing organisms are the first step in production in marine food chains, and the health and abundance of these primary producers affect the integrity of the other trophic levels. In the photosynthetic reaction below, carbon dioxide is reduced by water, and chlorophyll assists this transfer. The chlorophyll 'a' concentration varied between 0.89 mg/m^3 (Stn. SP2) and 1.22 mg/m^3 (Stn. SP4) with an average was 1.03 mg/m^3 during the study.

Table 3.3. Biological parameters - Algal count

S. No.	Parameter	Unit	SP1	SP2	SP3	SP4
1	Algal count	Species/ml	145	132	155	161
2	Chlorophyll	mg/m^3	0.93	0.89	1.06	1.22

Microbiology: Microorganism distribution in the marine and brackish environment plays an important role in the decomposition of organic matter and mineralization. Spatial and temporal distribution of the Total fecal coliforms as well as pathogenic bacteria in water is essential to assess the sanitary conditions. Bacterial counts in the waters were analyzed and the results are given in Table 3.4. The microbial population in water ranged from 1.94 $x10^3$ CFU/ml (Stn. SP2) to 2.12 $x10^3$ CFU/ml (Stn. SP4).

Table 3.4. Biological parameter – Total Viable colony count

S. No.	Parameter	Unit	SP1	SP2	SP3	SP4
1	Total Viable Colony Count	CFU/ml	$2.08x10^3$	$1.94x10^3$	$2.10x10^3$	$2.12x10^3$

Annexure - I

National Accreditation Board for Testing and Calibration Laboratories
(A Constituent Board of Quality Council of India)

NABL

QCI

CERTIFICATE OF ACCREDITATION

INDOMER COASTAL HYDRAULICS PRIVATE LIMITED

has been assessed and accredited in accordance with the standard

ISO/IEC 17025:2005

"General Requirements for the Competence of Testing & Calibration Laboratories"

for its facilities at

NO 63, GANDHI ROAD, ALWAR THIRUNAGAR, CHENNAI, TAMIL NADU, INDIA

in the field of

TESTING

Certificate Number:	TC-5232		
Issue Date:	13/01/2019	**Valid Until:**	12/01/2021

In view of the transition deadline for ISO/IEC 17025:2017, the validity of this accreditation certificate will cease on 30.11.2020.

This certificate remains valid for the Scope of Accreditation as specified in the annexure subject to continued satisfactory compliance to the above standard & the relevant requirements of NABL.
(To see the scope of accreditation of this laboratory, you may also visit NABL website www.nabl-india.org)

Signed for and on behalf of NABL

Anil Relia
Chief Executive Officer

Annexure-II

DOCUMENT FOR WATER SAMPLES HANDOVER TO CLIENT				INDOMER Coastal Hydraulics (P) Ltd. इन्डोमर ISO 9001	
				Reference	IND-QMS-REC-033
				Review	Rev. - 1.0
				No. of pages	1
Project: Bathymetry survey, Seawater sample collection and Brine diffusion modeling study for Chennai Perur 400 MLD Desalination plant for CP1. **Client:** SMEC INDIA PRIVATE LIMITED				Project code	696082021
				Date	31.08.2020
Document	Uncontrolled / ~~Controlled~~ / ~~Confidential~~				
Prepared by		Checked by		Approved by	
Name	Mr. J. JAGANMOHAN	Name	Dr. A. KANNATHASAN	Name	Mr. J. GURUPRASATH
Position	Senior Project Officer	Position	Project Officer	Position	Director
Signature with date		Signature with date	A. kannat	Signature with date	J Guruprasath

1. Introduction
SMEC (India) Private Limited, Chennai has approached Indomer Coastal Hydraulics (P) Ltd., Chennai to provide a proposal to conduct an seawater Bathymetry, Seawater sampling and Brine Diffusion Modeling Study at Perur 400 MLD Desalination Plant for CP1. In this regards, Indomer has carried out Bathymetry survey, Seawater and biological samples for the above said project from the 24.08.2020 – 29.08.2020.

The sampling was witnessed by Client representatives Mr. Murali , Mr. Senthil and Mr. Salim.

2. Sample codes for Sea water

Station	Tag Number	No. of samples
SS1	SMEC/PERUR/SP1	2
SS2	SMEC/PERUR/SP2	2
SS3	SMEC/PERUR/SP3	2
SS4	SMEC/PERUR/SP4	2

3. Preservation (IS 3025: Part 1/APHA 22nd Ed. 1360 C)

Sample types	Sample Collection Container	Preservation method
Standard water analysis	Pre-cleaned polyethylene cans (10 Lits.)	Kept the sample at <6°C
Heavy metals	Pre-cleaned polyethylene cans (1 Lit.)	Preserved the samples to acidified 2% HNO_3
Biological samples	Pre-clean and steriled glass bottles (50 ml)	Preserve the sample with Sodium thio-sulphate and Kept the sample at <6°C

I hereby take possession of the water samples and I have checked and confirmed that they have been properly packed and stored on receipt.

Samples received by:

R. Sajid

OBSERVATIONS ON SEAWATER ANALYSIS

A MS Teams meeting was held between M/s. Indomer and M/s. SMEC-TCE-NJS consortium dated 29th September 2020:

The following are the observations on Seawater analysis report:

1) Please include Addition data regarding sampling conditions in the analysis report as indicated below which helps in better understanding of the sea quality parameter.

a. Sea conditions (calm, rough) as it impacts turbidity and TSS readings
Moderate sea status typical end of august 2020

b. Tide conditions (going up or down, still (high or low)
During low tide to high tide

c. Season (monsoon, wind conditions)
Retreating southwest monsoon with normal wind condition

d. Important rain event during the past 5 days before the sampling date
Nothing happened

2) It is observed that the difference between TDS value and associated Calculated TDS (based on Ionic balance) are more than 5%. We request to recheck the TDS, Cations and anions values. Table indicating the analysed TDS values and calculated TDS values and are furnished below:

S.NO.	SAMPLING LOCATION	ANALYSED TDS, mg/L	CALCULATED TDS, mg/L	% DIFFERENCE B/W ANIONS AND CATIONS
1	SP1	37968	34197	12
2	SP2	38044	34442	13
3	SP3	38158	34264	12
4	SP4	38196	35015	15
5	NS1	38190	34435	12
6	NS2	38640	34395	11

We request you to revisit the TDS, Anions and Cations parameter in Seawater analysis report.

Laboratory has reanalyzed the parameters of TDS, Cations, Anions and that calculated Ionic balance values are given the below.

S.NO.	SAMPLING LOCATION	ANALYSED TDS, mg/L	CALCULATED TDS, mg/L	% DIFFERENCE B/W ANIONS AND CATIONS
1	SP1	36940	36628	0.85
2	SP2	36930	36517	1.13
3	SP3	36950	36648	0.82
4	SP4	37340	36659	1.86
5	NS1	37340	36675	1.81
6	NS2	37350	36813	1.46

Conclusion: It is observed that the difference between measured value of TDS and associated calculated value of TDS is less than 5% of acceptable range.

Annexure 2

IIT Madras - Seawater Analysis Report

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Indian Institute of Technology Madras
Chennai – 600 036, India

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Professor

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11 November, 2020

To:

Mr. Senthil.R
Senior Engineering Manager,
SMEC (India) Private Limited
Email: r.senthil@smec.com

Sub:Sea water sample analysis report

Samples by: Indomer Coastal hydraulics (p) limited

Date of sampling: 29-08-2020 (Analyses is done for the sample delivered to IIT Madras)

Table 1 Details of samples

Si. No	Sample ID	Sample location
1	SP1	SMEC/PERUR/SP1
2	SP2	SMEC/PERUR/SP2
3	SP3	SMEC/PERUR/SP3
4	SP4	SMEC/PERUR/SP4

Table 2 Characteristics of sea water samples

Si.No	Parameters	SP1	SP2	SP3	SP4
1	pH	8.05 ± 0.01	8.28 ± 0.01	8.31 ± 0.01	8.27 ± 0.01
2	Turbidity (NTU)	8.76 ± 0.03	1.82 ± 0.04	1.65 ± 0.06	4.49 ± 0.01
3	Electrical conductivity (µS/cm)	58675 ± 35.36	59550 ± 70.71	58705 ± 63.64	57775 ± 35.36
4	Color	Pale yellow	Slight yellow	Slight yellow	Slight yellow
5	Dissolved Oxygen (mg/L)	7.09 ± 0.01	7.16 ± 0.01	7.08 ± 0.01	6.86 ± 0.02
6	Total Suspended Solids (mg/L)	27.33 ± 1.93	6.14 ± 0.09	5.52 ± 0.23	15.80 ± 1.27
7	Total Dissolved Solids (mg/L)	34720 ± 28.28	35130 ± 14.14	35720 ± 28.28	35520 ± 56.57
8	Salinity (PSU)	35.80 ± 0.14	35.45 ± 0.07	35.55 ± 0.07	35.55 ± 0.07
9	Total hardness as $CaCO_3$ (mg/L)	5650 ± 7.71	5950 ± 1.21	5400 ± 1.23	5500 ± 0.50
10	Total alkalinity as $CaCO_3$ (mg/L)	140.80 ± 1.13	149.85 ± 0.21	167.50 ± 3.54	151.00 ± 1.41
11	COD (mg/L)	284 ± 5.09	185 ± 0.79	268.8 ± 1.81	243.2 ± 1.81
12	BOD_5 (mg/L)	16.3 ± 5.3	8.8 ± 1.8	13.8 ± 1.8	12.5 ± 3.5
13	TOC (mg/L)	41.73 ± 0.37	30.85 ± 10.25	39.38 ± 0.12	36.41 ± 0.40
14	DOC (mg/L)	19.19 ± 0.55	9.15 ± 1.22	13.06 ± 0.57	16.55 ± 1.62
15	Total Phosphate (mg/L)	0.03 ± 0.02	0.03 ± 0.01	0.02 ± 0.01	0.03 ± 0.03
16	TN (mg/L)	0.72 ± 0.01	0.60 ± 0.01	0.31 ± 0.03	0.28 ± 0.05
17	Ammoniacal nitrogen (mg/L)	0.66 ± 0.07	0.28 ± 0.07	0.33 ± 0.06	0.14 ± 0.01

18	Nitrate as NO_3^-(mg/L)	0.18 ± 0.03	0.19 ± 0.02	0.17 ± 0.01	0.19 ± 0.01
19	Nitrite as NO_2^- (mg/L)	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.05 ± 0.005
20	Oil & grease (mg/L)	8.20 ± 0.85	4.60 ± 1.41	0.80 ± 0.57	6.20 ± 0.28
21	Silica as SiO_2 (mg/L)	4.53 ± 0.51	5.073 ± 0.84	5.065 ± 0.68	4.79 ± 0.65
22	Silt Density Index (SDI)	5.8 ± 0.2	5.2 ± 0.1	5.1 ± 0.2	5.3 ± 0.1
23	Phenolics (mg/L)	BDL	BDL	BDL	BDL
24	Chlorophyll a (µg/L)	2.6 ± 0.21	2.1 ± 0.55	1.9 ± 0.34	2.3± 0.6
25	Calcium as Ca^{2+} (mg/L)	488.32 ± 7.01	489.62 ± 37.84	520.21 ± 7.68	511.48 ± 15.65
26	Magnesium as Mg^{2+} (mg/L)	1116.60 ± 69.51	1036.52 ± 14.73	1038.36 ± 16.49	1005.68 ± 2.30
27	Ammonium as NH_4^+(mg/L)	0.57 ± 0.14	0.42 ± 0.12	0.45 ± 0.09	0.20 ± 0.04
28	Potassium as K^+ (mg/L)	447.23 ± 3.65	446.51 ± 4.48	451.28 ± 2.51	452.52 ± 4.45
29	Sodium as Na^+ (mg/L)	11430.50 ± 142.92	11552.69 ± 95.81	11785.88 ± 0.38	11542.30 ± 62.54
30	Bicarbonate as HCO_3^- (mg/L)	127.61 ± 2.86	114.11 ± 2.11	123.27 ± 0.53	130.15 ± 0.49
31	Fluoride as F^- (mg/L)	1.08 ± 0.11	1.12 ± 0.05	1.36± 0.09	1.05 ± 0.02
32	Chloride as Cl^- (mg/L)	19651.27 ± 56.98	20059.5 ± 85.36	22083.96 ± 63.2	21651.27 ± 59.6
33	Sulphate as SO_4^{2-} (mg/L)	2266.15 ± 6.38	2317.88 ± 14.23	2335.84 ± 70.13	1765.47 ± 31.91
34	Phosphate as PO_4^{2-} (mg/L)	0.02 ± 0.00	0.02 ± 0.001	0.02 ± 0.00	0.02 ± 0.01
35	Copper as Cu (µg/L)	238.50 ± 0.38	363.00 ± 0.20	372.00 ± 0.65	237.50 ± 0.24
36	Manganese as Mn (µg/L)	32.50 ± 0.29	66 ± 0.35	140 ± 1.33	39 ± 0.16
37	Iron as Fe (µg/L)	BDL	BDL	BDL	BDL
38	Zinc as Zn (µg/L)	10817 ± 4.17	11224 ± 6.26	11327.50 ± 9.44	11215 ± 1.56
39	Cadmium as Cd (µg/L)	1.50 ± 0.03	1.00 ± 0.03	92 ± 0.99	1.50 ± 0.03
40	Arsenic as As (µg/L)	2.50 ± 0.75	21.00 ± 0.16	127.50 ± 2.01	7 ± 0.50
41	Lead as Pb (µg/L)	192.50 ± 0.07	223.50 ± 0.10	253 ± 1.42	139.50 ± 0.09
42	Strontium as Sr (µg/L)	4491 ± 0.44	5084 ± 1.33	5165.50 ± 1.96	5043 ± 0.82

43	Barium as Ba (µg/L)	103.50 ± 0.18	136.00 ± 0.08	342.50 ± 1.46	123.50 ± 0.36

***We are unable to do the Boron analyses**

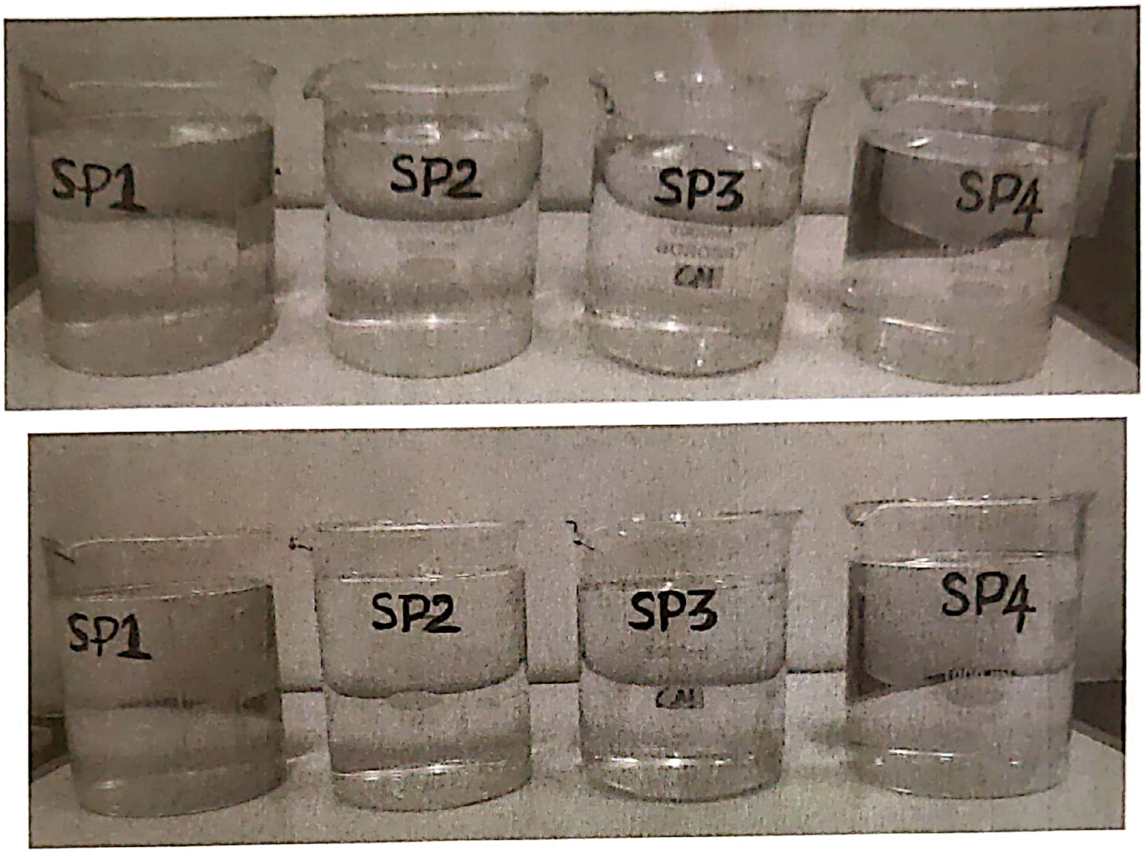


Fig 1 Photographs of given samples

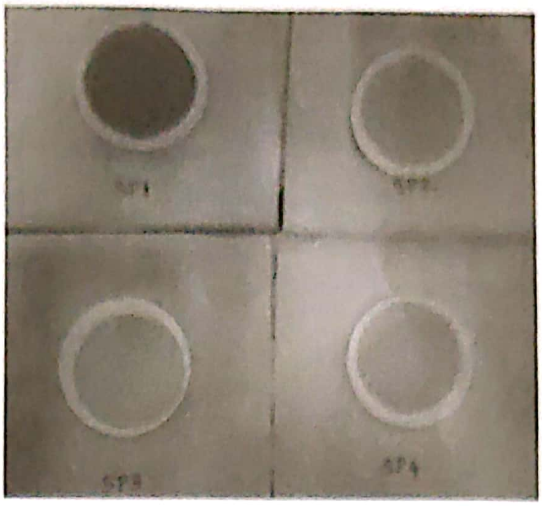
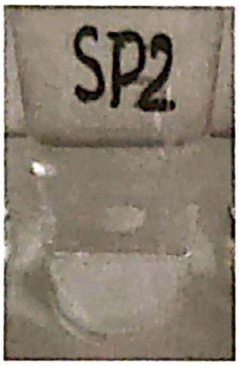
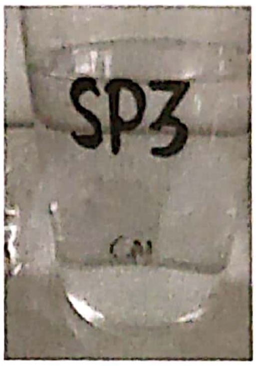


Fig 2 Silt deposited in the filter paper during SDI analysis





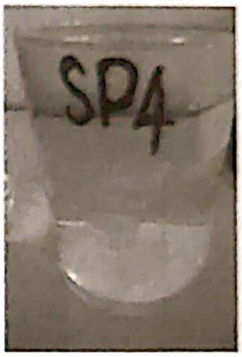


Fig 3 Picture showing closer view of solids deposited

Quality Assurance and Quality Control

Table 3 Charge balance for seawater samples

	Σcations (meq/L)	Σanions (meq/L)
SP1	624.704	602.860
SP2	623.464	615.230
SP3	635.404	672.772
SP4	621.706	648.810

Table 4 Sample calculation Table (For Sample SP1)

	Ion	Conc mg/L	Mol wt	Valency	Equ. Wt	Conc (meq/L)	Total (meq/L)
Cations	Ca2+	488.32	40.1	2	20.05	24.355	
	Mg2+	1116.6	24.3	2	12.15	91.901	
	Na+	11430.5	23	1	23	496.978	624.704
	K+	447.23	39.1	1	39.1	11.438	
	NH4+	0.57	18	1	18	0.032	
Anions	HCO3-	127.61	61	1	61	2.092	
	SO4 2-	2266.15	96.1	2	48.05	47.162	
	Cl-	19651.27	35.5	1	35.5	553.557	
	F-	1.08	18.99	1	18.99	0.044	602.860
	NO3	0.18	62	1	62	0.003	
	NO2	0.06	46	1	46	0.001	
	PO42-	0.02	95	2	47.5	0.000	

(Ligy Philip)

Dr. Ligy Philip
Professor
Environmental & Water Resources Engg.,
Department of Civil Engineering
Indian Institute of Technology Madras
Chennai - 600 036, India

Annexure 3

M/s. Eurofins Unwelt west GmbH - TOC/DOC analysis

eurofins

Batch code: EUINBA-00079684
Report date: 27.11.2020

SMEC India Pvt.Ltd. - CHENNAI
13 A, Puravankara Primus,
No.236 Old Mahabalipuram Road,
Okkiyam-Thuraipakkam
Okkiyyampettai
600 096CHENNAI.
INDIA

Mr R Senthil

ANALYTICAL REPORT

Sample code:	258-2020-11004688	**Report code:**	AR-20-IR-071872-01
Sample name:	Sea Water		
		Received on:	18.11.2020
		Analysed between:	23.11.2020 - 26.11.2020
Sample reference	Customer Provided Details Agency: M/s SMEC India Pvt Ltd Site Sampling Code: SP - 4 Sample Collection Date: 29th Augutst 2020		
Quantity received:	1000 ml		
Sample packing:	Plastic Container	**Condition on receipt:**	Good
Sampling:	NOT SAMPLED BY EUROFINS		

Analysis			*Method*	*Result*	*Unit*	*LOQ*
AN05X	**AN**	DOC (Dissolved Organic Carbon)	DIN EN 1484: 1997-08	1.1	mg/l	1
AN05Y	**AN**	TOC (total organic carbon)	DIN EN 1484: 1997-08	1.2	mg/l	1

The above sample is analysed at Eurofins Umwelt West GmbH (Wesseling) and tested parameters are accredited according to DIN EN ISO/IEC 17025:2005 D-PL-14078-01-00 .

The tests identified by the two letters code AN are subcontracted to our Eurofins Group lab.

Jyoti Sindhu

Ms Jyoti Sindhu

Manager Lab

LOQ = Limit of Quantification

************** END OF REPORT ***************

Eurofins Analytical Services India Private Limited
#540/1, Doddanakundi Industrial Area 2, Hoodi, Whitefield, Bengaluru 560048, Karnataka, India, Tel: +91 80 30982500,
Fax: +91 80 41680405 Email: enquiryeasi@eurofins.com, Website: www.eurofins.in, CIN: U73100KA2009PTC049992

Batch code: EUINBA-00079684
Report date: 27.11.2020

SMEC India Pvt.Ltd. - CHENNAI
13 A, Puravankara Primus,
No.236 Old Mahabalipuram Road,
Okkiyam-Thuraipakkam
Okkiyyampettai
600 096CHENNAI.
INDIA

Mr R Senthil

ANALYTICAL REPORT

Sample code:	258-2020-11004687	**Report code:**	AR-20-IR-071871-01
Sample name:	Sea Water		
		Received on:	18.11.2020
		Analysed between:	23.11.2020 - 26.11.2020
Sample reference	Customer Provided Details Agency: M/s SMEC India Pvt Ltd Site Sampling Code: SP - 2 Sample Collection Date: 29th Augutst 2020		
Quantity received:	1000 ml		
Sample packing:	Plastic Container	**Condition on receipt:**	Good
Sampling:	NOT SAMPLED BY EUROFINS		

Analysis			*Method*	*Result*	*Unit*	*LOQ*
AN05X	**AN**	DOC (Dissolved Organic Carbon)	DIN EN 1484: 1997-08	1.2	mg/l	1
AN05Y	**AN**	TOC (total organic carbon)	DIN EN 1484: 1997-08	1.2	mg/l	1

The above sample is analysed at Eurofins Umwelt West GmbH (Wesseling) and tested parameters are accredited according to DIN EN ISO/IEC 17025:2005 D-PL-14078-01-00 .

The tests identified by the two letters code AN are subcontracted to our Eurofins Group lab.

Jyoti Sindhu

Ms Jyoti Sindhu

Manager Lab

LOQ = Limit of Quantification

************** END OF REPORT ***************

Annexure 4

M/s. Eurofins Unwelt west GmbH - TOC/DOC analysis (2nd time)

Batch code: EUINBA-00085785
Report date: 26.02.2021

SMEC India Pvt.Ltd. - CHENNAI
13 A, Puravankara Primus,
No.236 Old Mahabalipuram Road,
Okkiyam-Thuraipakkam
Okkiyyampettai
600 096CHENNAI.
INDIA

Mr R Senthil

ANALYTICAL REPORT

Sample code:	258-2021-02002791	**Report code:**	AR-21-IR-015718-01
Sample name:	Sea Water		
		Received on:	09.02.2021
		Analysed between:	09.02.2021 - 25.02.2021
Sample reference	Customer Provided Details Sample Identification number : SP - 1 Sample collection location : Existing 100 MLD Desalination Plant at Nemmeli Sample Collection Date: 09.02.2021		
Quantity received:	1000 ml		
Sample packing:	Plastic Container	**Condition on receipt:**	Good
Sampling:	NOT SAMPLED BY EUROFINS		

ANALYSIS			***Method***	***Result***	***Unit***	***LOQ***
AN05X	**AN**	DOC (Dissolved Organic Carbon)	DIN EN 1484: 1997-08	1.9	mg/l	1
AN05Y	**AN**	TOC (total organic carbon)	DIN EN 1484: 1997-08	2.0	mg/l	1

The tests identified by the two letters code AN are subcontracted to our Eurofins Group lab.

Jyoti Sindhu

Ms Jyoti Sindhu

Manager Lab

LOQ = Limit of Quantification

************** END OF REPORT ***************

Annexure 5

NEERI, Chennai - TOC/DOC analysis

Instr.Information

System	TOC VCPH
Detector	Combustion
Catalyst	Regular Sensitivity
Cell Length	long

Sample

Sample Name:	Untitled
Sample ID:	Untitled
Origin:	NPOC Sample Method.met
Status	Completed
Chk. Result	

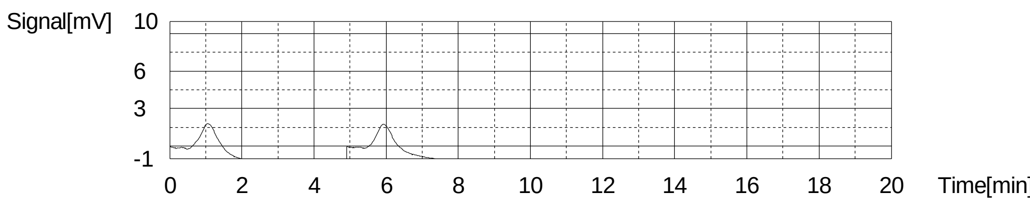
Type	Anal.	Dil.	Result
Unknown	NPOC	1.000	NPOC:1.592ppm

1. Det

Anal.: NPOC

No.	Area	Conc.	Inj. Vol.	Aut. Dil.	Ex.	Cal. Curve	Date / Time
1	5.471	1.511ppm	50uL	1		4 Pt NPOC Calibration.2019_06_04_16_14_57.c	2/22/2021 12:16:35 PM
2	6.057	1.673ppm	50uL	1		4 Pt NPOC Calibration.2019_06_04_16_14_57.c	2/22/2021 12:22:10 PM

Mean Area	5.764
Mean Conc.	1.592ppm
SD Area	0.4144
CV Area	7.19%



Sample

Sample Name:	s1
Sample ID:	Untitled
Origin:	NPOC Sample Method.met
Status	Completed
Chk. Result	

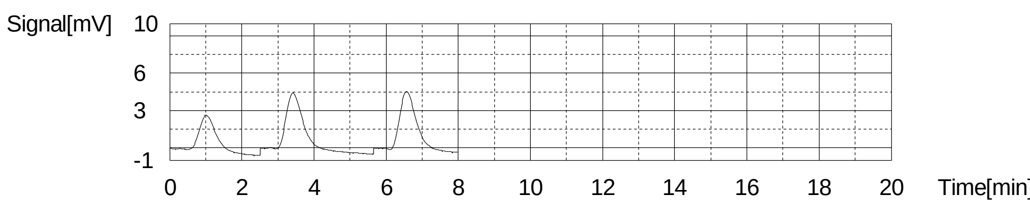
Type	Anal.	Dil.	Result
Unknown	NPOC	1.000	NPOC:4.164ppm

1. Det

Anal.: NPOC

No.	Area	Conc.	Inj. Vol.	Aut. Dil.	Ex.	Cal. Curve	Date / Time
1	9.005	2.487ppm	50uL	1	E	4 Pt NPOC Calibration.2019_06_04_16_14_57.c	2/22/2021 12:30:38 PM
2	15.09	4.167ppm	50uL	1		4 Pt NPOC Calibration.2019_06_04_16_14_57.c	2/22/2021 12:35:56 PM
3	15.07	4.162ppm	50uL	1		4 Pt NPOC Calibration.2019_06_04_16_14_57.c	2/22/2021 12:40:25 PM

Mean Area	15.08
Mean Conc.	4.164ppm
SD Area	0.01414
CV Area	0.09%



Sample

Sample Name:	s1..
Sample ID:	Untitled
Origin:	NPOC Sample Method.met
Status	Completed
Chk. Result	

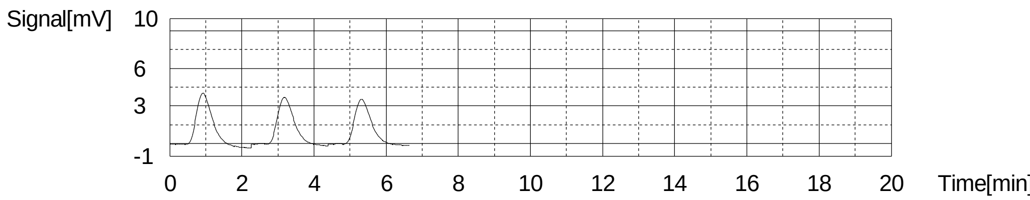
Type	Anal.	Dil.	Result
Unknown	NPOC	1.000	NPOC:3.274ppm

1. Det

Anal.: NPOC

No.	Area	Conc.	Inj. Vol.	Aut. Dil.	Ex.	Cal. Curve	Date / Time
1	13.04	3.601ppm	50uL	1	E	4 Pt NPOC Calibration.2019_06_04_16_14_57.ca	2/22/2021 12:49:45 PM
2	12.02	3.319ppm	50uL	1		4 Pt NPOC Calibration.2019_06_04_16_14_57.ca	2/22/2021 12:54:03 PM
3	11.69	3.228ppm	50uL	1		4 Pt NPOC Calibration.2019_06_04_16_14_57.ca	2/22/2021 12:58:28 PM

Mean Area	11.86
Mean Conc.	3.274ppm
SD Area	0.2333
CV Area	1.97%



Cal. Curve

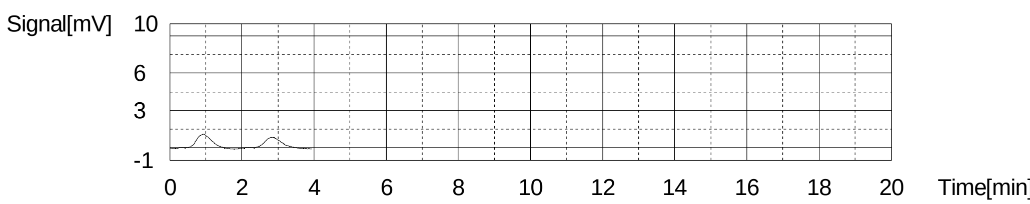
Sample Name:	KHP
Sample ID:	Upto 1000ppm
Cal. Curve:	4 Pt NPOC Calibration.2021_02_22_13_27_59.cal
Status	Completed

Type	Anal.
Standard	NPOC

Conc: 0.000ppm

No.	Area	Inj. Vol.	Aut. Dil.	Rem.	Ex.	Date / Time
1	3.355	20uL	1	*******		2/22/2021 1:32:40 PM
2	2.762	20uL	1	*******		2/22/2021 1:36:41 PM

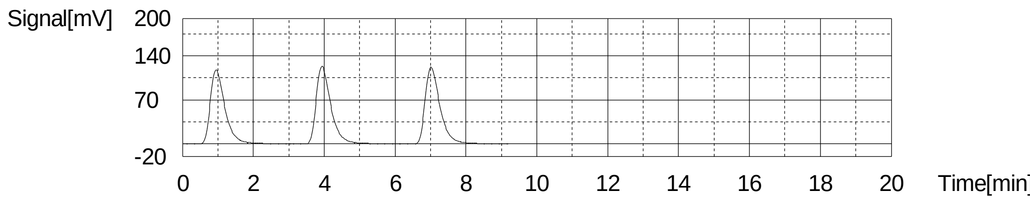
Acid Add.	1.000%
Sp. Time	60.00sec
Mean Area	3.059



Conc: 250.0ppm

No.	Area	Inj. Vol.	Aut. Dil.	Rem.	Ex.	Date / Time
1	342.9	20uL	4	*******	E	2/22/2021 1:44:04 PM
2	360.4	20uL	4	*******		2/22/2021 1:49:19 PM
3	361.4	20uL	4	*******		2/22/2021 1:54:34 PM

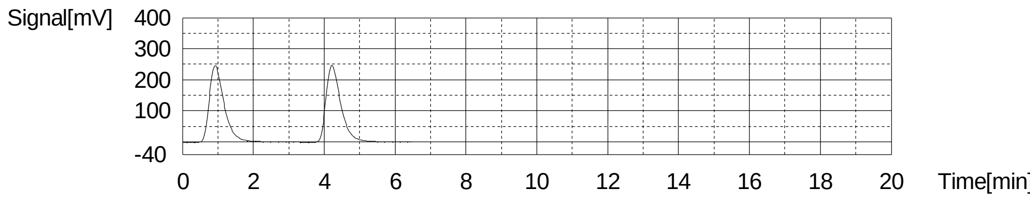
Acid Add.	1.000%
Sp. Time	60.00sec
Mean Area	360.9



Conc: 500.0ppm

No.	Area	Inj. Vol.	Aut. Dil.	Rem.	Ex.	Date / Time
1	729.2	20uL	2	*******		2/22/2021 2:01:56 PM
2	728.6	20uL	2	*******		2/22/2021 2:07:15 PM

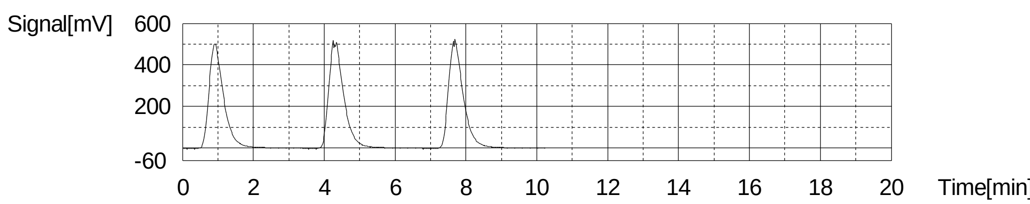
Acid Add.	1.000%
Sp. Time	60.00sec
Mean Area	728.9



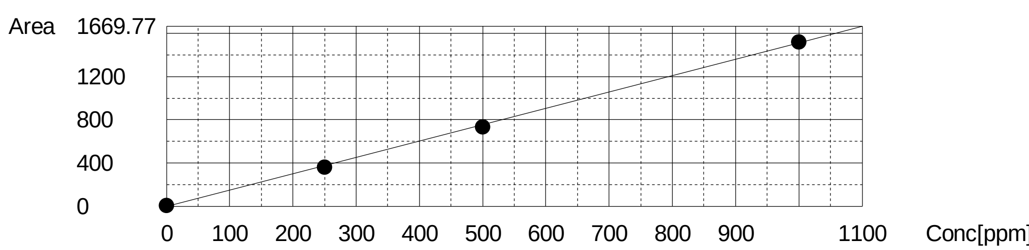
Conc: 1000ppm

No.	Area	Inj. Vol.	Aut. Dil.	Rem.	Ex.	Date / Time
1	1449	20uL	1	*******	E	2/22/2021 2:14:05 PM
2	1521	20uL	1	*******		2/22/2021 2:19:26 PM
3	1514	20uL	1	*******		2/22/2021 2:24:53 PM

Acid Add.	1.000%
Sp. Time	60.00sec
Mean Area	1518



Slope:	1.518
Intercept	0.000
r^2	0.9994
r	0.9997
Zero Shift	Yes

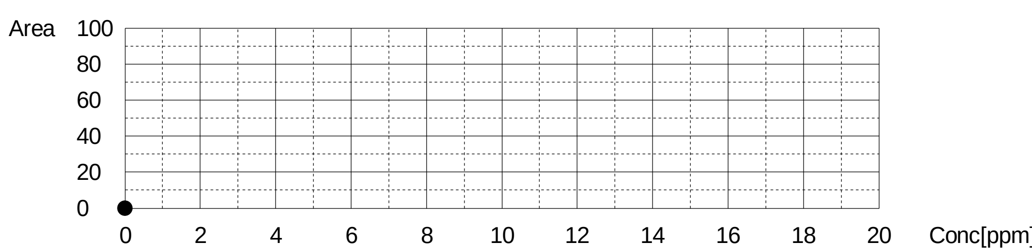


Cal. Curve

Sample Name:	KHP
Sample ID:	Upto 1000ppm
Cal. Curve:	4 Pt NPOC Calibration.2021_02_22_14_24_57.cal
Status	Defined

Type	Anal.
Standard	NPOC

Slope:	-1.#IO
Intercept	0.000
r^2	0.0000
r	0.0000
Zero Shift	Yes



The CHENNAI 400 MLD DESALINATION PLANT is a Project being delivered by the Chennai Metropolitan Water Supply & Sewerage Board (CMWSSB) with the assistance of an Official Development Assistance (ODA) loan from the Japan International Cooperation Agency (JICA).

The Project Management Consultant (PMC) for the Chennai 400 MLD Desalination Plant project is a consortium led by SMEC International Pty Ltd in partnership with Tata Consulting Engineers Limited (TCE), NJS Engineers India Pvt Ltd (NJSEI) and SMEC India Pvt Ltd.

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