THE MIDDLE EAST DESALINATION RESEARCH CENTER

Cost Estimating of SWRO Desalination Plants

Day 1: Plant Cost Fundamentals

June 25, 2013

15:45-16:30

1.5 Construction Costs for Post-treatment, Concentrate Management, and Other Facilities

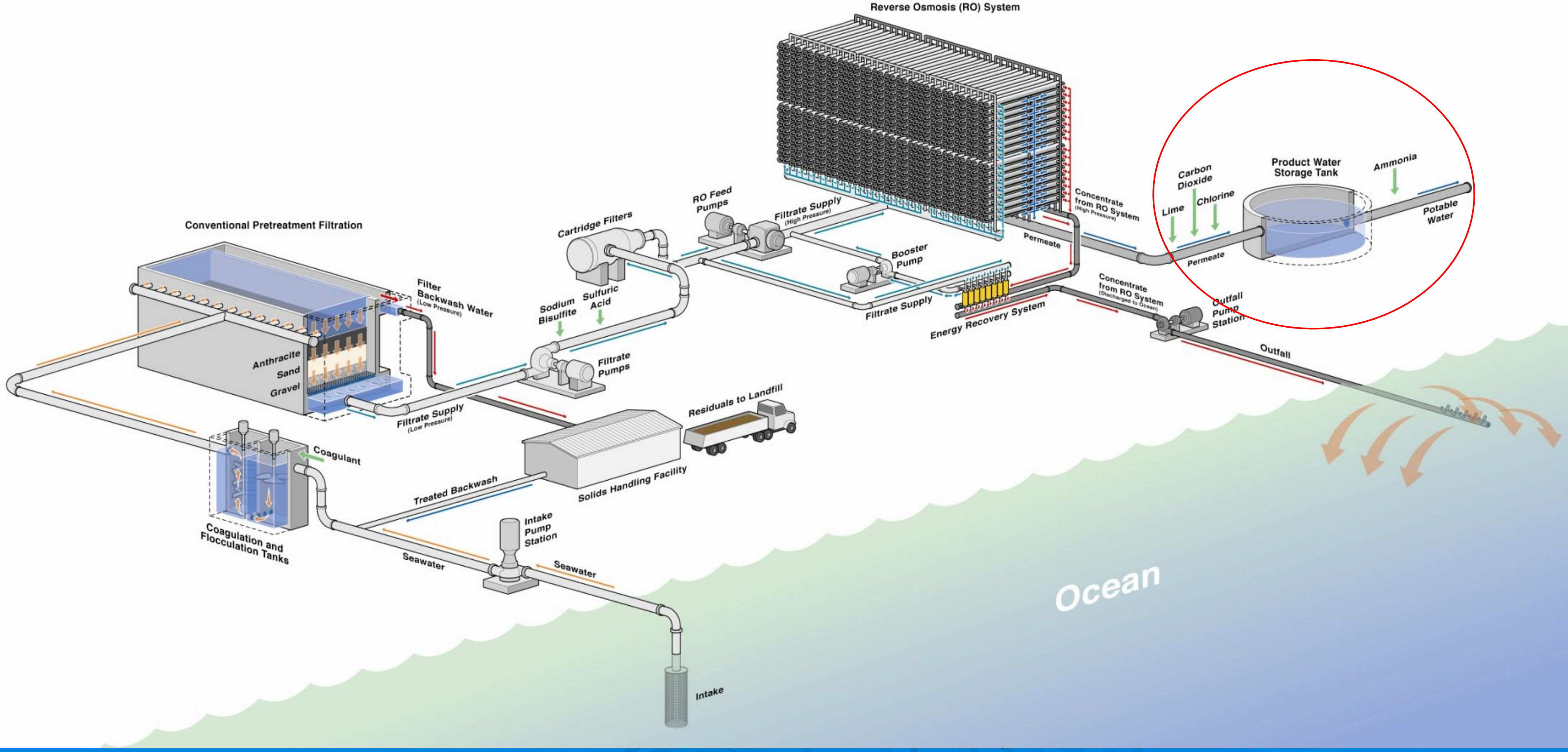
Water Globe Consulting

Nikolay Voutchkov, PE, BCEE

Construction Costs for Other Facilities - Outline

- Post-treatment Costs
- Concentrate Disposal Costs
- Waste and Solids Handling Costs
- Costs of Electrical and Instrumentation System
- Costs of Auxiliary and Service Equipment and Facilities
- Building Costs
- Startup, Commissioning and Acceptance Testing Costs

Permeate Post-treatment



Post-Treatment

- Corrosion Control Goals:
  - Alkalinity > 40 mg/L (as $CaCO_3$);
  - Calcium Carbonate Precipitation Potential (CCPP) – 4 to 10 mg/L as $CaCO_3$;
  - Larson Ratio < 5;
  - Hardness > 50 mg/L as $CaCO_3$;
  - pH – 8.3 to 8.8.

- **Disinfection and Finished Water Quality:**
  - Chlorination;
  - Choramination;
  - Chlorine Residual Stability – Effect of Bromide.

Addition of Alkalinity

- Carbonate & Bicarbonate Alkalinity:

  Provide Buffering Capacity to Prevent pH Variation in the Distribution System.

- Alkalinity Addition:
  - Addition of NaOH or Ca(OH)2 to Permeate Which Contains Carbonic Acid;
  - Addition of Carbonic Acid + Lime;
  - Addition of Sodium Carbonate or bicarbonate;
  - Calcium Carbonate (Calcite) Contact Filters.

Post Treatment – Lime Addition

Key System Elements:

1. Lime Silos and Feed System
2. Lime Contactors
3. CO_2 Feed System
4. Acid Addition System
5. NaOH Addition System

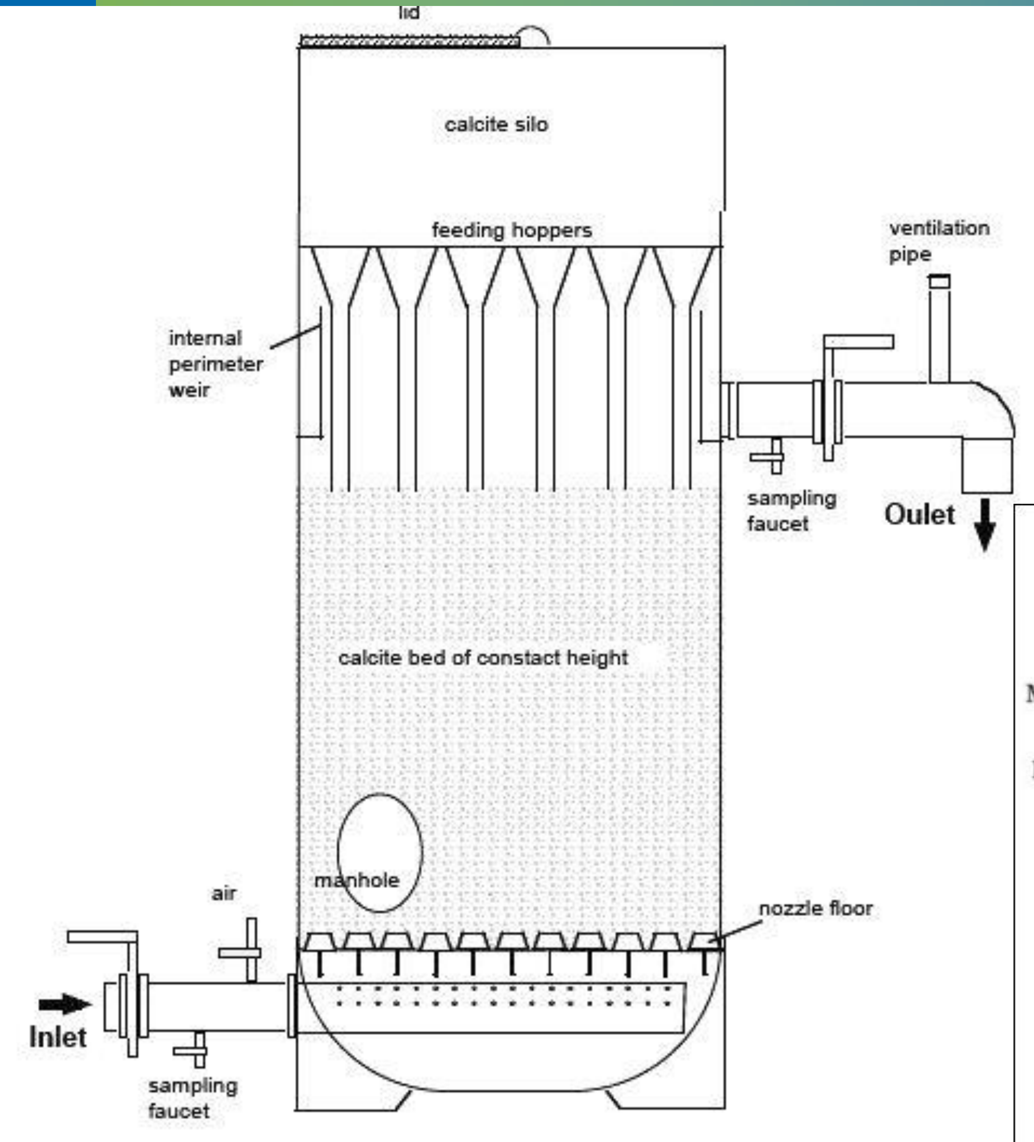
Post-treatment – Calcite Filters

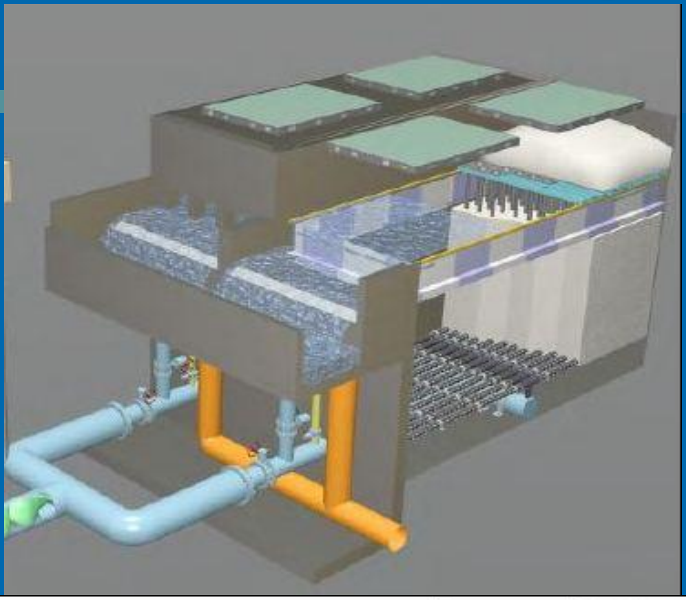
- Check Permeate Quality for Conductivity;
- Compare Water Quality of Individual RO Trains;
- Check Chemical Feed and Mixing Systems – Lime/Calcite Quality & Quantity;
- Check Turbidity of Conditioned Water –

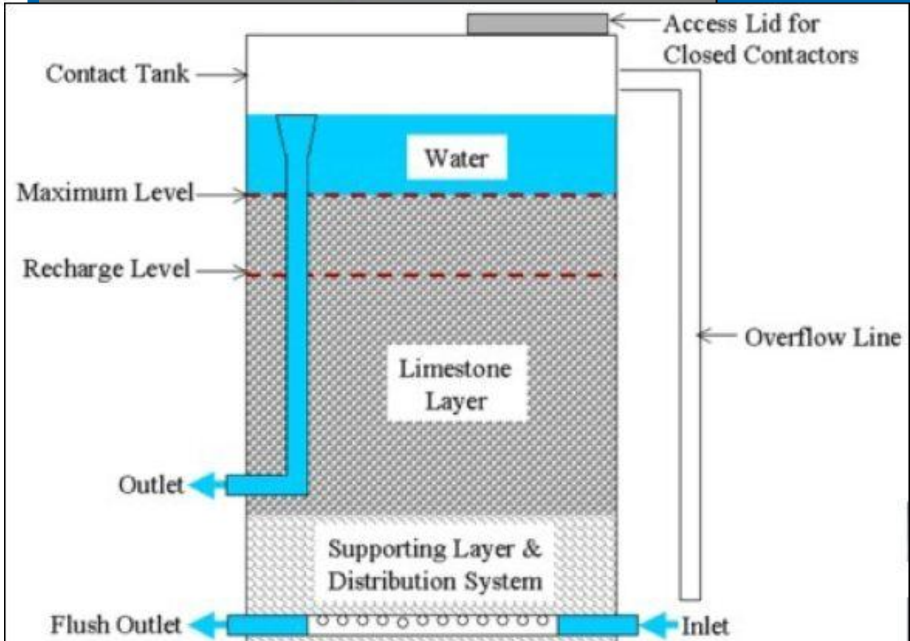
  Lime May Add Turbidity.

Calcite Contact Filters – Larnaka, Cyprus

Barcelona SWRO Plant has Once of the Most Advanced Calcite Filtration Technologies



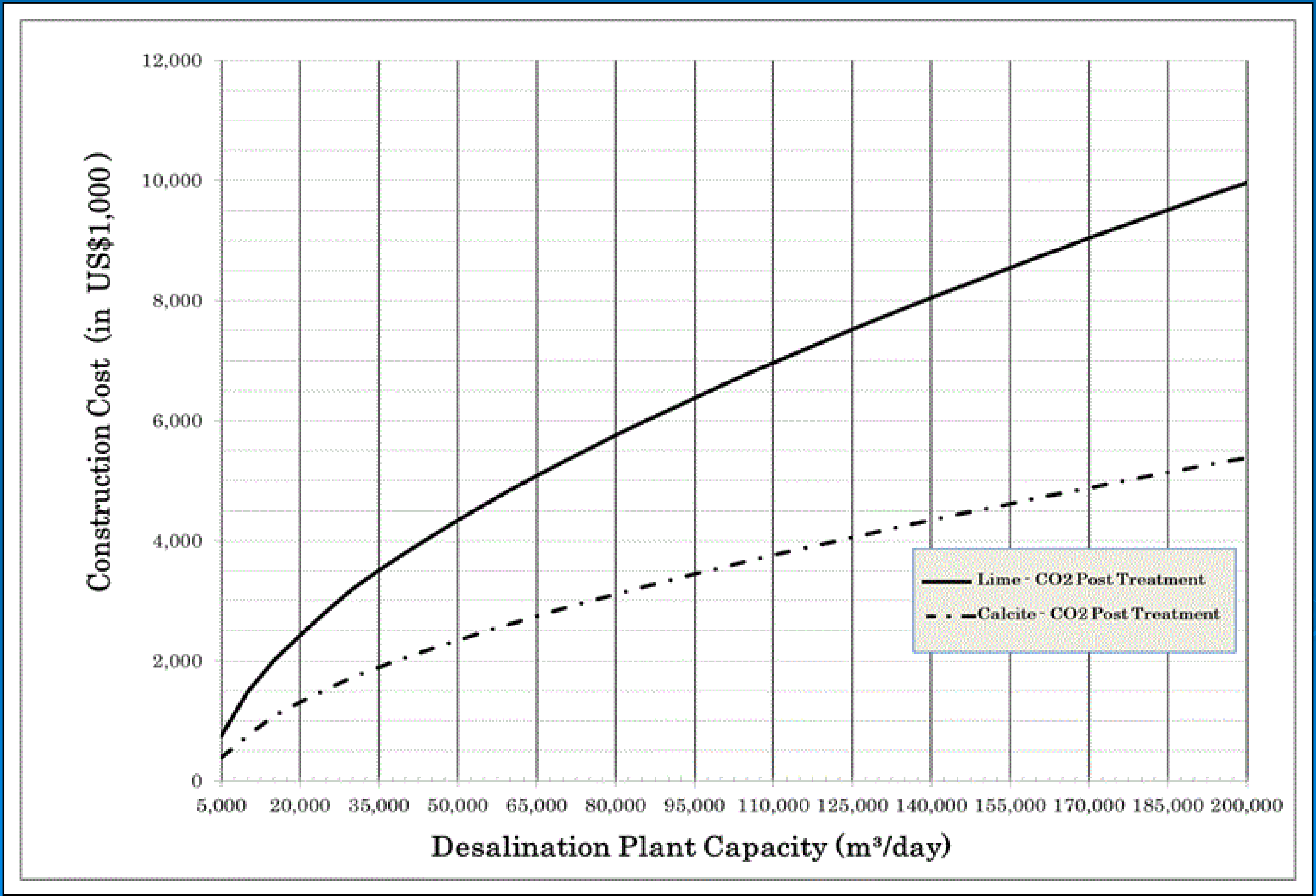




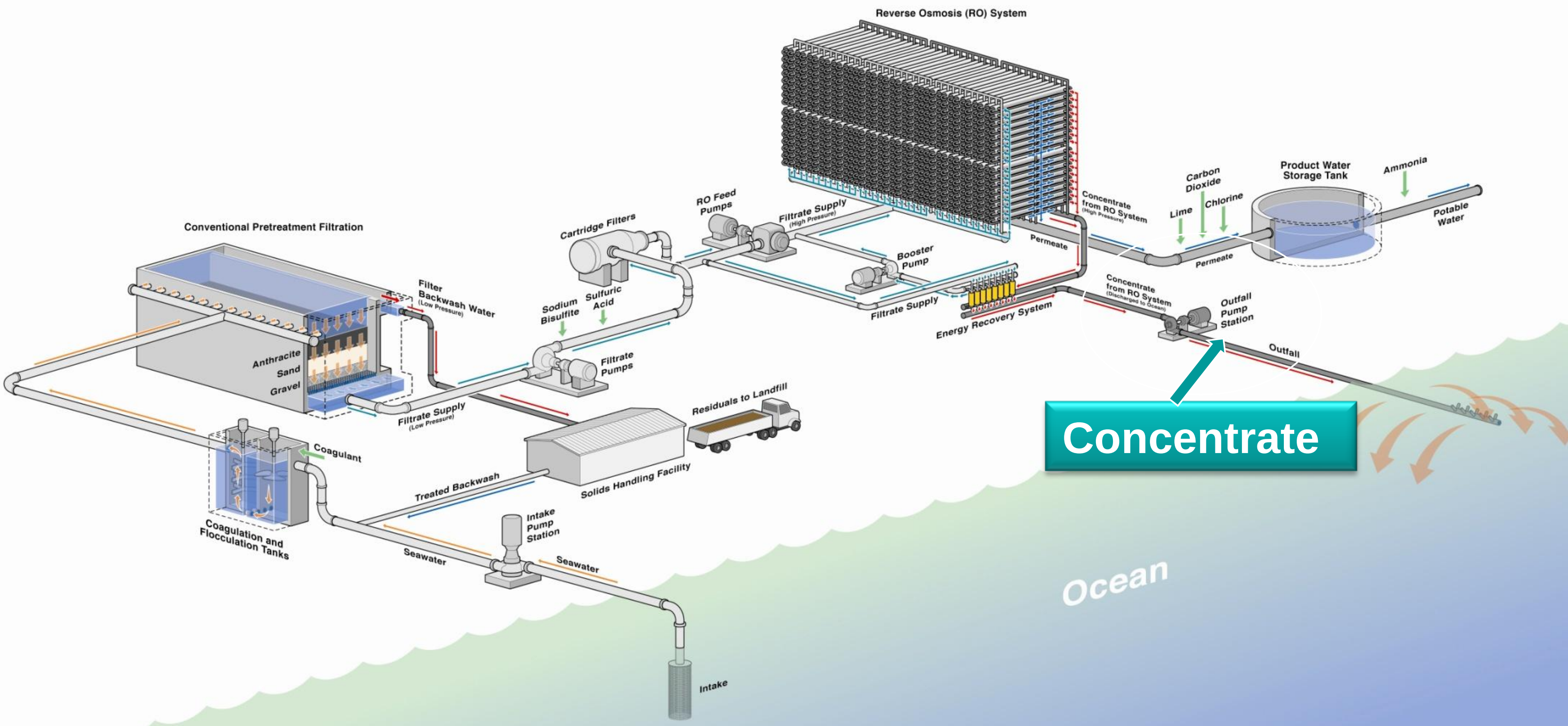
Post-treatment Construction Costs

- Dependent on Target Water Quality:
  - Hardness
  - Alkalinity
  - pH
  - Need for Addition of Corrosion Inhibitors
  - Type of Disinfection
  - Need for Addition of Fluoride & Magnesium in the Drinking Water
- Usually Between US\$80 and 275/m^3/day

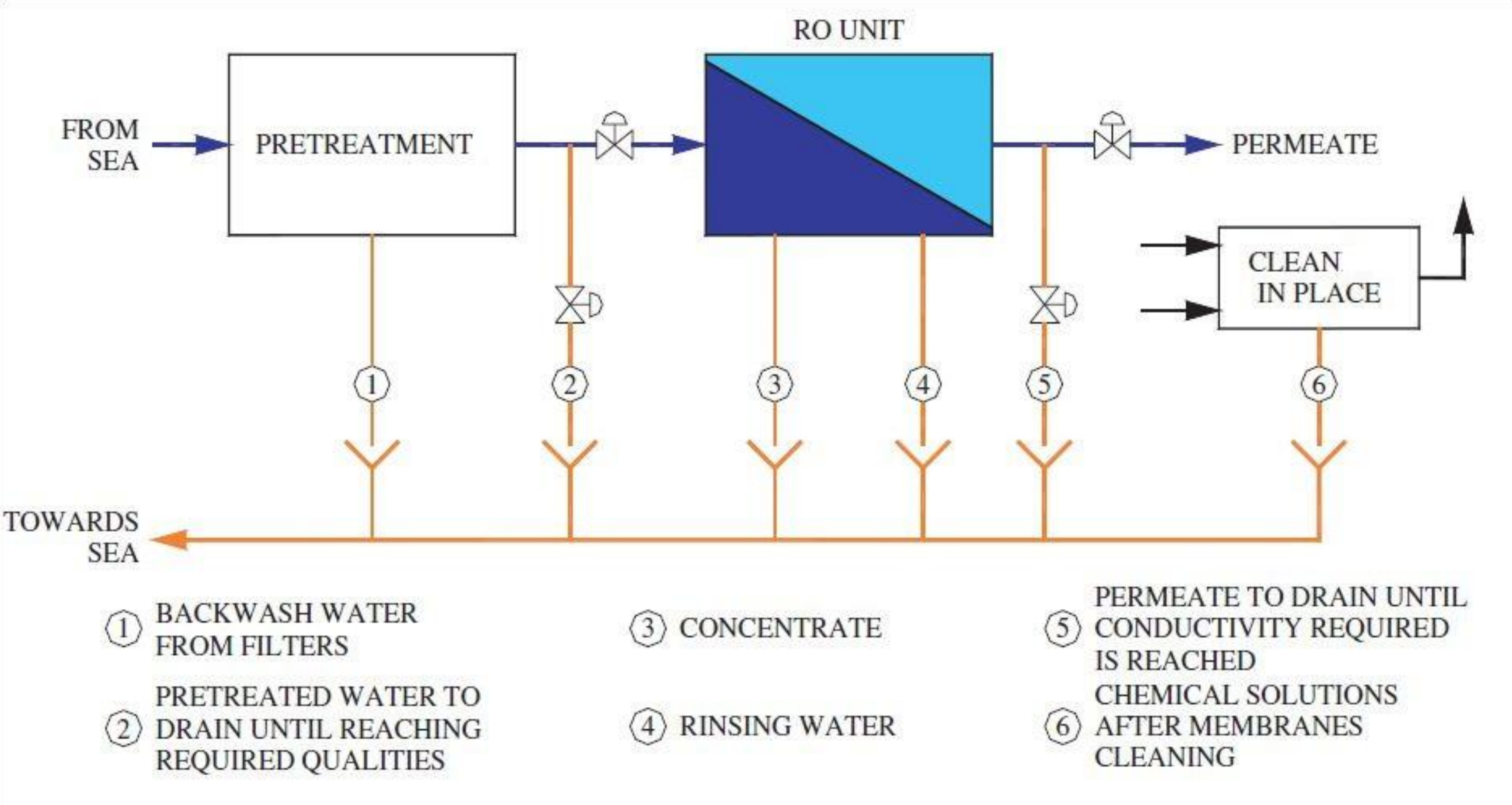
Lime & Calcite/CO2 System Construction Costs



SWRO Plant – Concentrate



Desalination Plant Waste Streams



Concentrate Salinity & Flow

$$TDS_{concentrate} = TDS_{feed}\left(\frac{1}{1-Y}\right) - \frac{Y \times TDS_{permeate}}{100(1-Y)}$$

$$Y = \frac{\text{Permeate flow rate}}{\text{Feed flow rate}}$$

$$Q_{concentrate} = Q_{permeate}\,(1/Y - 1)$$

Y- Plant Recovery Rate (%)

Example:

Plant Production Capacity, $Q_{permeate}$ = 2.0 Ml/d;

Plant Recovery, Y = 45 % (i.e., 0.45);

$Q_{concentrate}$ = 2.0 ML/d (1/0.45 – 1) = **2.4 ML/d**

Concentrate – Most Widely Used Disposal Alternatives

- Direct Ocean Outfall Discharge
- Discharge to Sanitary Sewer
- Co-Discharge with Power Plant Cooling Water

Direct Ocean Outfall Discharge

- <u>Used in Large Plants </u>– All Australian SWRO Plants; Ashkelon, Israel; Point Lisas, Trinidad; Desalination Plants in Cyprus and Most Plants in Spain.
- Key Issues – Suitable Location for Adequate Blending and Dilution
- Difficult to Obtain Environmental License
- Costly for Large Plants – Usually Requires the Construction of Long Outfall and Elaborate Diffuser Structure

Alternatives for Dispersal of Saline Discharge

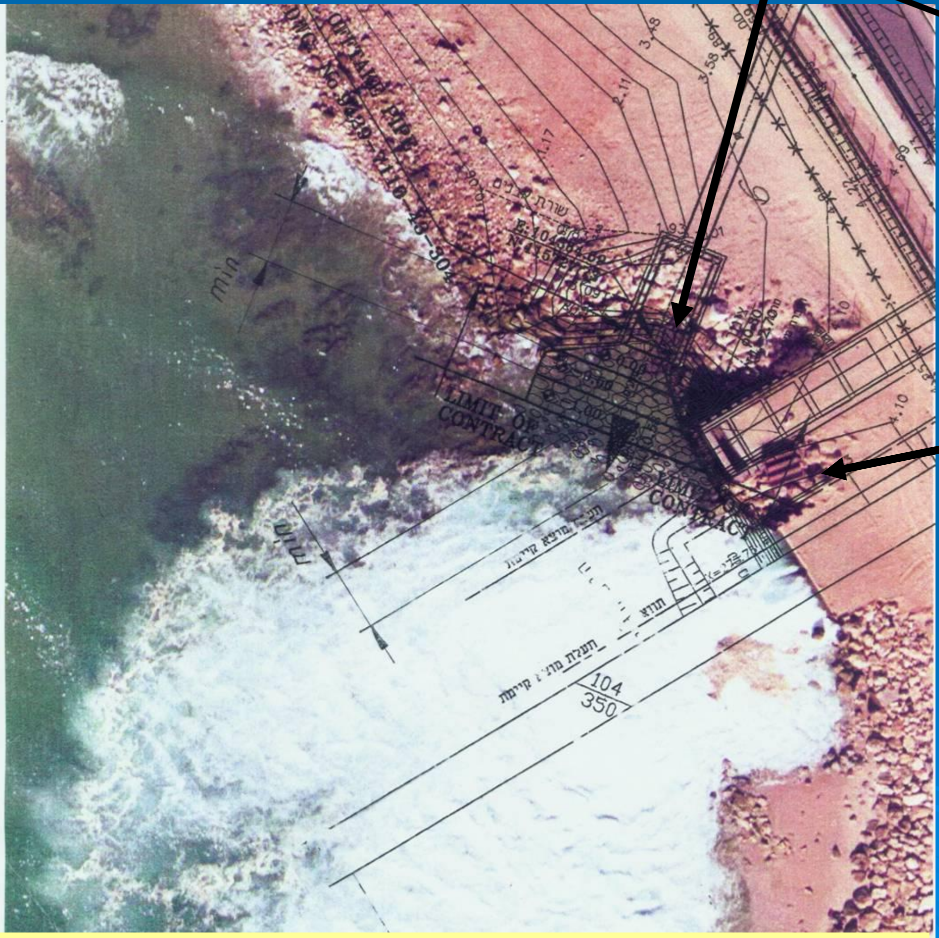
- Use of Mixing Energy & Transport Capacity of Tidal Zone – Near-shore Discharge;
- Use of the Buoyancy of Existing Fresh Water Discharge (Existing WWTP Outfall);
- Use the Buoyancy of Existing Thermal Discharge (Power Plant Cooling Water Outfall);
- Build New Diffuser System Directing Discharge Up Inclined @ 45 to 60°.

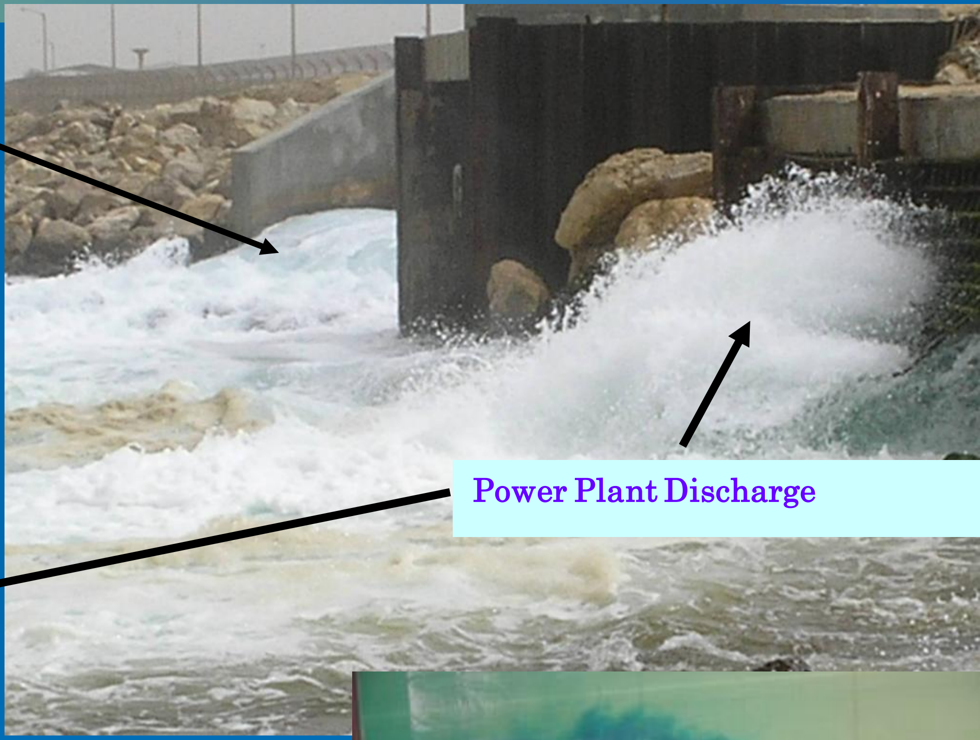
Near-Shore Discharge – Common Low-Cost Option

- Near Shore Discharge Structures Are Usually Easier to Build and Operate than Long Outfalls

Near-Shore vs. Diffuser Discharge

Desalination Plant Discharge



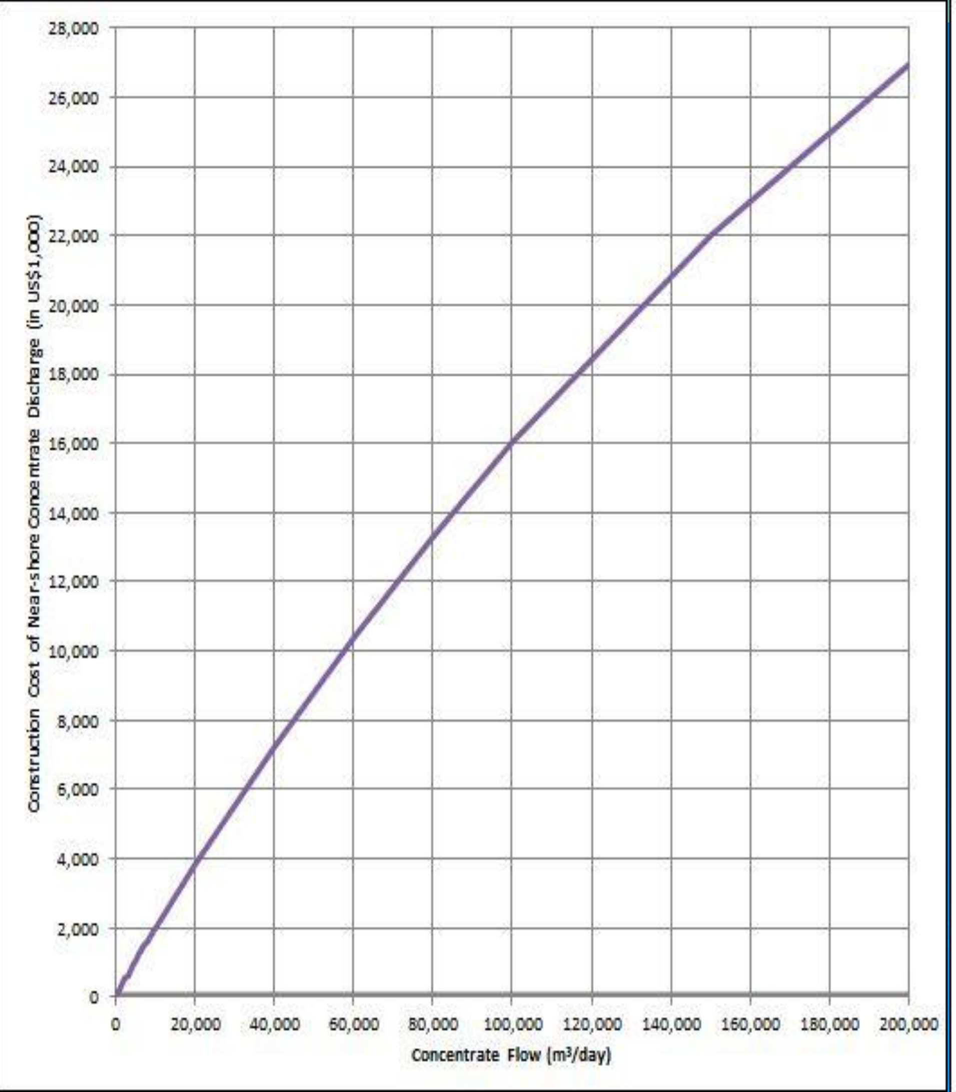


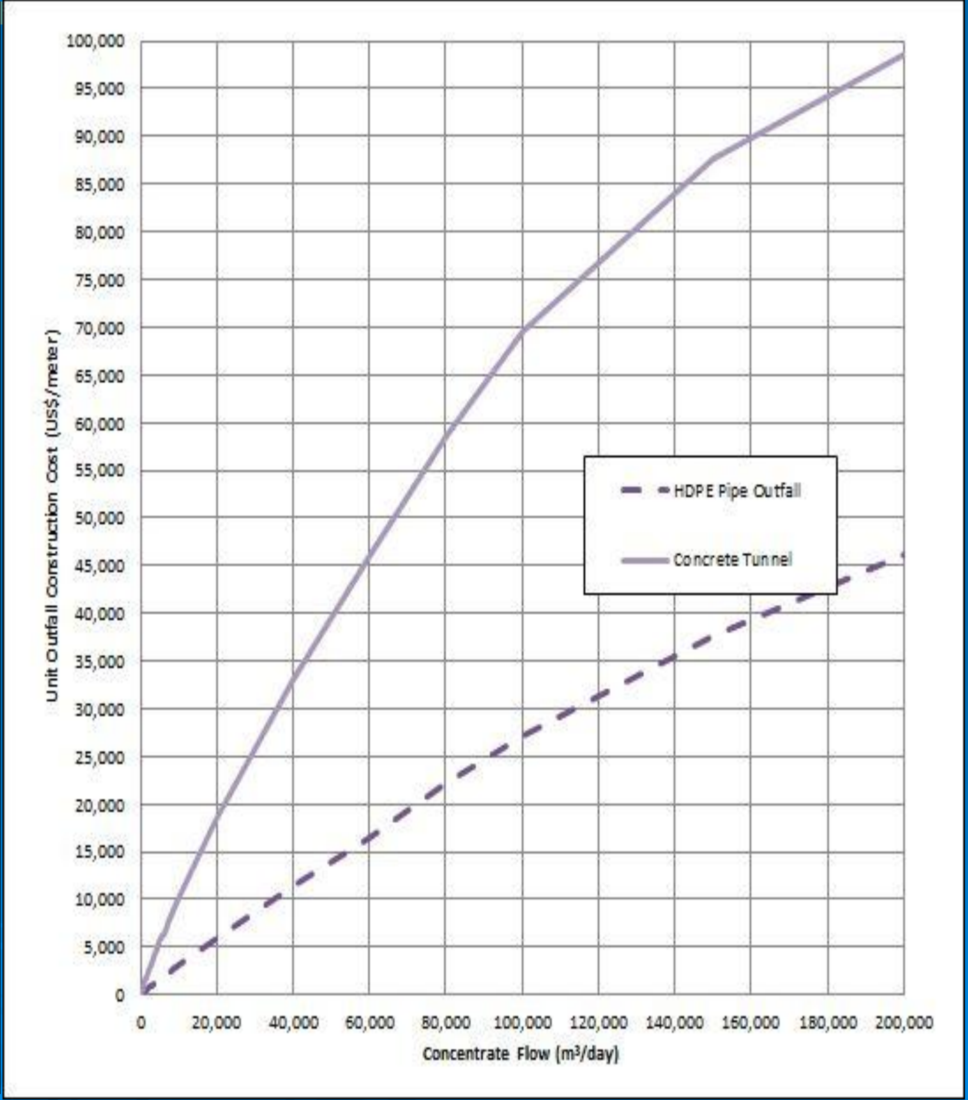
Power Plant Discharge

ASHKELON DESALINATION PLANT

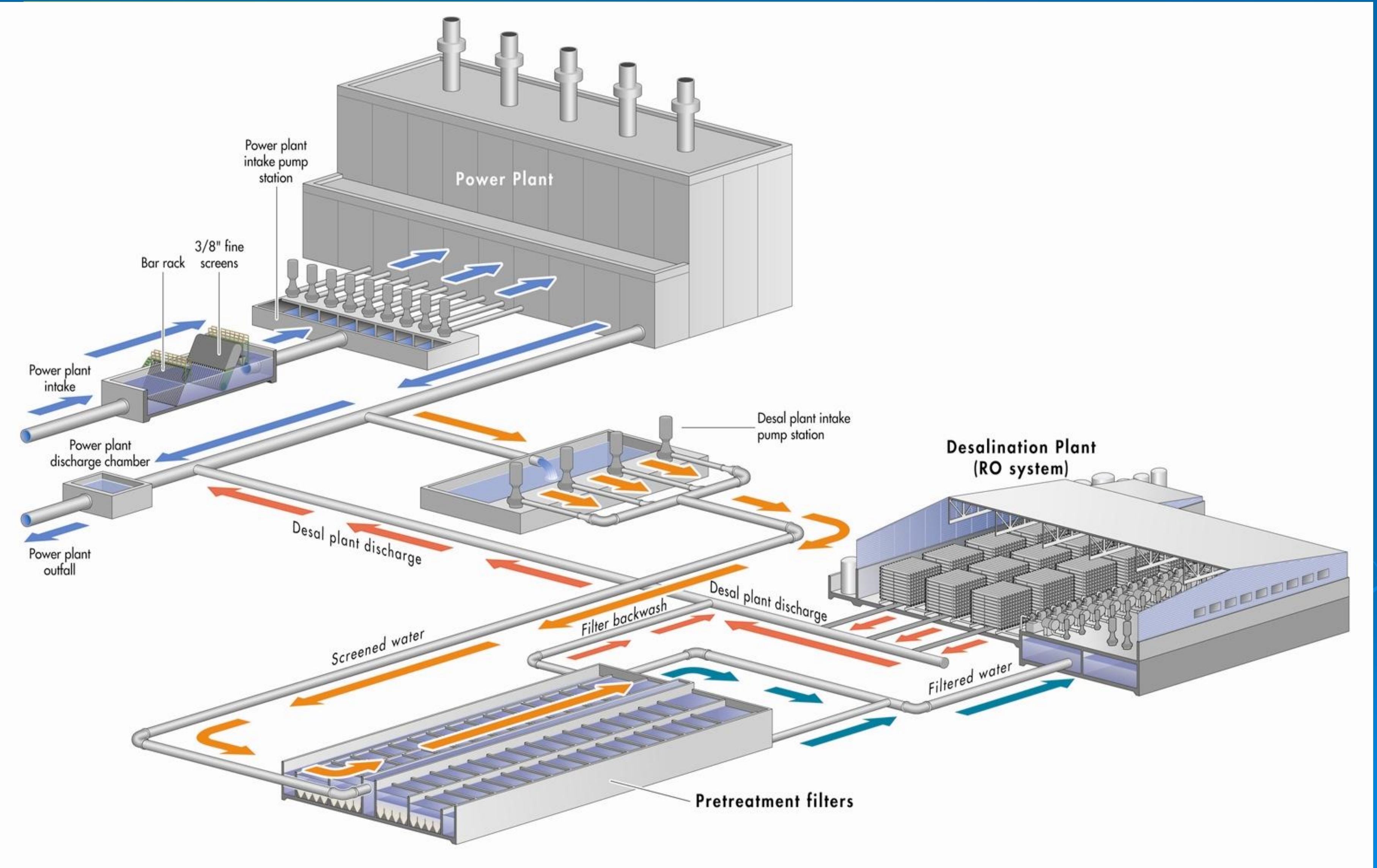
Diffuser Discharge

Near vs. Offshore Discharge - Costs





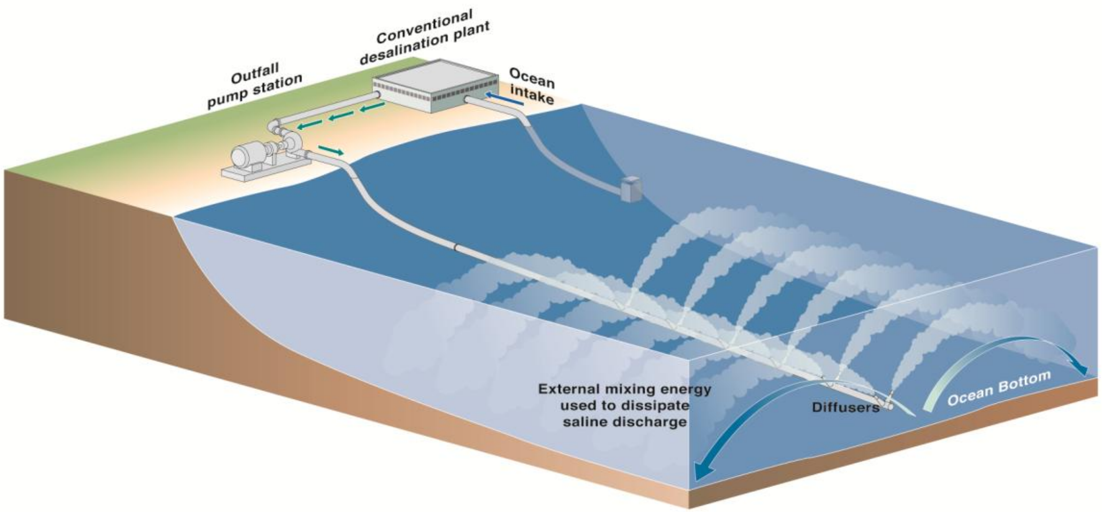
Power Plant Collocation Concept

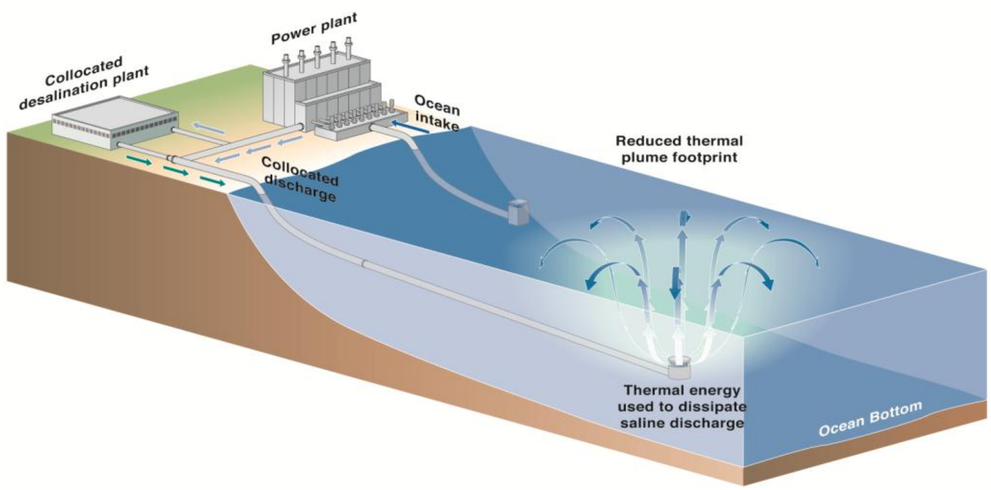


Key Benefits of Collocation With Power Plant

- Mutually Accelerated Dissipation of Salinity and Thermal Plumes.
- No Need for Construction of Separate Outfall – 10 to 30 % Construction Cost Savings.
- Minimal Environmental Impact:
  - No Beach or Ocean Floor Habitat Disturbance;
  - No New Ocean Source Water Collected – Minimized Entrainment.
- Power Cost Savings.

Comparison of Diffuser-based & Collocated Discharges





Construction Costs of Key Concentrate Disposal Methods

Concentrate Disposal Method	Disposal Construction Cost (US$/m³.day)
New Surface Water Discharge (New Outfall with Diffusers)	50 – 750
Collocation of Desalination Plant and Power Plant Discharge	10 - 30
Co-Disposal With Wastewater Treatment Plant Discharge	30 - 150
Sanitary Sewer Discharge	5 – 150
Deep/Beach Well Injection	200 – 625
Evaporation Ponds	300 – 4,500
Spray Irrigation	200 – 1,000
Zero Liquid Discharge	1,500 – 5,000

Note: US$1/m³.day = US$3,785/MGD

Waste & Solids Handling Costs

- Dependent on:
  - Source Water TSS Concentration
  - Acceptability of Solids Disposal to the Ocean by the Environmental Regulatory Body

- Usually Between US$15 and 75/m³.day for construction of solids retention and equalization basin &

  US$20 – 180/m³.day for solids handling system with mechanical dewatering

Costs of Electrical & Instrumentation System

- Dependent on:
  - Salinity
  - Temperature
  - Number of RO Stages & Passes
  - Level of Plant Automation
  - Distance of Plant to High-voltage Power Supply Source
- Usually Between US$100 and 250/$m^3$/day

Construction Costs of Auxiliary and Service Equipment and Facilities

- Dependent on:
  - Source Water Quality
  - Staff Size
  - Plant Capacity

- Usually Between US$30 and 150/$m^3$/day

Building Construction Costs

- Dependent on:
  - Source Water Quality
  - Staff Size
  - Plant Capacity
- Usually Between US$50 and 100/$m^3$/day

Construction Costs Associated with Startup, Commissioning and Acceptance Testing

- Dependent on:
  - Source Water Quality
  - Plant Capacity
  - Plant Complexity
  - Regulatory Requirements
- Usually Between US$40 and 80/$m^3$/day

Summary of Construction (Direct) Capital Costs

Cost Item	Percentage of Total Capital Cost (%)	
	Low-Complexity Project	High-Complexity Project
Direct Capital (Construction) Costs		
12. Site Preparation, Roads and Parking	1.5 – 2.0	0.6 – 1.0
13. Intake	4.5 – 6.0	3.0 – 5.0
14. Pretreatment	8.5 – 9.5	6.0 – 8.0
15. RO System Equipment	38.0 – 44.0	30.5 – 36.0
16. Post-Treatment	1.5 – 2.5	1.0 – 2.0
17. Concentrate Disposal	3.0 – 4.0	1.5 – 3.0
18. Waste and Solids Handling	2.0 – 2.5	1.0 – 1.5
19. Electrical & Instrumentation Systems	2.5 – 3.5	1.5 – 2.5
20. Auxiliary and Equipment and Utilities	2.5 – 3.0	1.0 – 2.0
21. Buildings	4.5 – 5.5	3.0 – 5.0
22. Start Up, Commissioning and Acceptance Testing	1.5 – 2.5	1.0 – 2.0
Subtotal Direct (Construction) Costs (% of Total Capital Costs)	**70.0 – 85.0**	**50.0 – 68.0**

Questions and Discussions