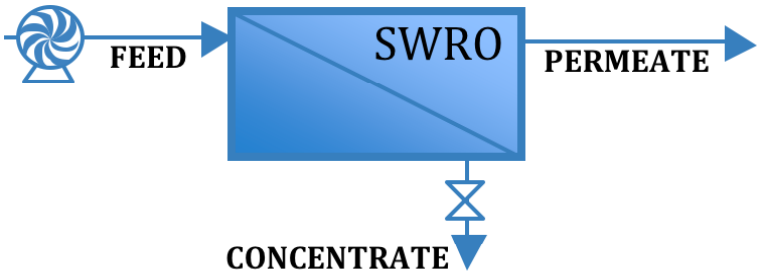
Seawater Reverse Osmosis

Reverse osmosis (RO) is a pressure-driven membrane process. Hydraulic pressure is used to overcome the feed solution's osmotic pressure and to induce diffusion of pure water (referred to as permeate) through a semi-permeable RO membrane. The solutes in the feed stream are concentrated during the process and leave the system as concentrated brine (referred to as retentate, or concentrate, or reject). Depending on feed water quality, more water can be recovered from the brine in downstream unit processes; otherwise, large volumes process residuals might requires disposal. Seawater RO (SWRO), compared to brackish water RO or nanofiltration processes, is capable of more selective separation of water from other constituents in the feed stream. Membrane properties make SWRO suitable for removing monovalent ions (e.g., sodium, potassium, chloride), multivalent ions (e.g., calcium, magnesium, sulfate, iron, arsenic), and many organic compounds from various feed streams. SWRO is commonly used for seawater desalination, boiler makeup water treatment, and for some brackish water desalination scenarios where a high removal of monovalent ions is required.



Summary of technical assessment of SWRO

Criteria	**Description/Rationale**
Status of technology	Mature and robust technology for seawater desalination. Has been employed for produced water treatment. Reports from various producers in the CBM produced water field indicate that many RO pilot studies failed, but this is largely the result of insufficient process integration and poor pretreatment.
Feed water quality bins	Most applicable for total dissolved solids ranging from 20,000 to 40,000 mg/L, and water containing monovalent (sodium, chloride), divalent (magnesium, calcium, barium, sulfate), multi-valent (iron, manganese) electrolytes, and radionuclides. Also applicable for specific classes of organic compounds.
Product water quality	The quality of SWRO permeate depends on feed water salinity and operating conditions. Typically, product water total dissolved solids ranges from 100 to 400 mg/L (>99.4% rejection), ammonia rejection is approximately 80%, boron rejection is typically less than 50% when operating at neutral pH.
Recovery	Product water recovery is between 30% and 60%.
Energy use	With energy recovery device, SWRO requires 11-16 kWh/kgal (0.46-0.67 kWh/bbl) of energy to power the system's high-pressure pumps.
Chemical use	Scale inhibitor and caustic may be required for process control to prevent scaling or fouling. Chemical cleaning rates depend on feed water quality. Membrane cleaning is triggered when certain operating conditions are exceeded, and may require the use of NaOH, Na_4EDTA, HCl, $Na_2S_2O_4$, or H_3PO_4.

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Expected lifetime of critical components	Depending on operating conditions, SWRO membranes will require replacement within 3 to 7 years.
Infrastructure considerations	SWRO requires minimal operational footprints compared to thermal desalination technologies, and can be highly automated. SWRO skids can be mobile.
O&M considerations	Monitoring and control required for feed pH, flow rates, total dissolved solids, turbidity, as well as pressures. System automation lessens the demands for skilled labor; however, a skilled technician is required to perform routine system maintenance. Level of flexibility: high sensitivity to organic and inorganic constituents in the feed water. Level of robustness: thin film composite membranes have high pH tolerance, but cannot be exposed to feed temperatures in excess of 113˚F (45˚C). Level of reliability: SWRO systems operate semi-continuously with automated, short duration chemical rinse or osmotic backwashing cycles. Types of energy required: electrical.
Capital and O&M costs	Capital costs vary from $3 to $7/gpd (or $125 to $295/bpd), depending on various factors including size, materials of construction, and site location. Operating costs depend on energy price and feed water total dissolved solids, and it is approximately $2/kgal (or $0.08/bbl). Substantial reductions in energy costs can be obtained by implementing energy recovery subsystems.
Pretreatment of feed water	All high-pressure membrane technologies require extensive pretreatment to remove constituents that will otherwise foul or scale the membrane. Particular attention should be given to hydrophobic organic compounds and sparingly soluble salts. The silt density index of the feed stream should not exceed 3-5.
Post-treatment of product water	Product water may require pH stabilization or remineralization. This may be achieved by lime bed contacting or by blending small amounts of filtered and sterilized feed water with permeate.
Concentrate management or waste disposal	No special concentrate treatment is required, unless radionuclides are highly concentrated in the reject stream. Due to the relatively low recovery rates of 30% to 60%, large volume of concentrated brine is generated. SWRO operations are commonly located near oceans, which allows them to dispose of the brine by pumping it back into the ocean through diffusers.
Applicability for produced water treatment	Excellent - with appropriate pretreatment processes
Note: 1 barrel = 42 US gallon (*): Assuming that ion is in a reduced (unoxidized) state	