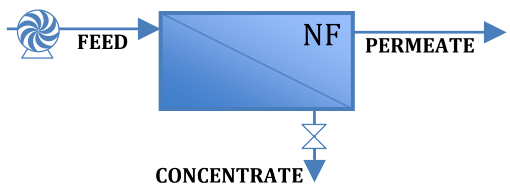
Nanofiltration

Nanofiltration (NF) 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 NF membrane. The residual feed stream (referred to as retentate, concentrate, or reject) is concentrated by the process, and depending on water quality, may be suitable for further water recovery in additional downstream unit processes; otherwise, the residual stream requires disposal. NF is designed to achieve high removal of divalent and multivalent ions (e.g., calcium, magnesium, sulfate, iron, arsenic, etc.), and is occasionally referred to as membrane softening. NF may achieve moderate to low removal of monovalent ions (e.g., sodium, potassium, chloride). NF is commonly employed to remove hardness from brackish groundwater to produce potable water. Water characterized by high concentrations of calcium or magnesium and monovalent salts may be treated with NF prior to a reverse osmosis. An illustration of the process is shown below.



Summary of technical assessment of NF

Criteria	Description/Rationale
Status of technology	Mature and robust technology for water softening and metals removal in various sectors of the industrial and municipal water treatment sectors. Has been employed for produced water treatment.
Feed water quality bins	Feed water total dissolved solids concentration applicability depends on feed solution composition and may range from 500 to 12,000 mg/L. Most useful for treatment of water with high concentrations of divalent ions (e.g., magnesium, calcium, barium, sulfate), multivalent metals ions (e.g., iron, manganese), and radionuclides. Also applicable for specific classes of organic compounds.
Product water quality	NF permeate quality depends on feed water composition and operating conditions. High rejection (>99%) of larger divalent ions and metals with moderate rejection (<90%) of monovalent salts is expected.
Recovery	Product water recovery is between 75% and 90%.
Energy use	NF requires less energy than equivalent reverse osmosis based systems for a similar feed water quality. Approximately 2 kWh/kgal (0.08 kWh/bbl) of energy is required 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 frequency depends 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_2O_2.
Expected lifetime of critical components	Depending on operating conditions, NF membranes will require replacement within 3 to 7 years.

Summary of technical assessment of NF

Criteria	Description/Rationale
Infrastructure considerations	NF requires an equivalent footprint when compared to brackish water reverse osmosis, and a minimal operational footprint compared to thermal desalination technologies. As with other pressure driven membrane processes, NF can be easily automated, and have excellent mobility.
O&M considerations	Monitoring and control required for feed pH, flow rates, and pressures. System automation lessens demands on 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: NF systems operate semi-continuously with automated, short duration chemical cleaning or osmotic backwashing cycles. Types of energy required: electrical.
Capital and O&M costs	Capital costs vary from \$0.8 to \$4/gpd (or \$35 to \$170/bpd), depending on various factors including size, materials of construction, and site location. Operating costs are assumed similar to brackish water reverse osmosis, approximately \$0.70/kgal (or \$0.03/bbl). Moderate 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 harmful constituents from the feed water that will otherwise foul or scale the membrane. Particular attention should be given to hydrophobic organic compounds and sparingly soluble salts.
Post-treatment of product water	Product water may require remineralization to restore sodium adsorption ratio (SAR) values. This may be achieved by lime bed contacting and/or by blending small amounts of filtered and sterilized feed water with permeate.
Concentrate management or waste disposal	No special concentrate treatment is required. Relatively high recovery rates of 75% to 90% generate small volume of concentrated brine.
Applicability for produced water treatment	Moderate – NF is inappropriate as a standalone technology. NF processes will remove >99% of hardness, and will have substantially lower removal of sodium and chloride ions, thus sodium adsorption ratio is maximized in the product stream; however, NF may provide an excellent pretreatment prior to reverse osmosis.
Note: 1 barrel = 42 US gallon	