HW Process Technologies, Inc.

EMS® Solutions for Acid and Alkaline Mine Drainage

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CTO
HW Process Technologies, Inc.

Membrane Technology: A Superior Solution for the Mining Industry for Acid & Alkaline Drainage

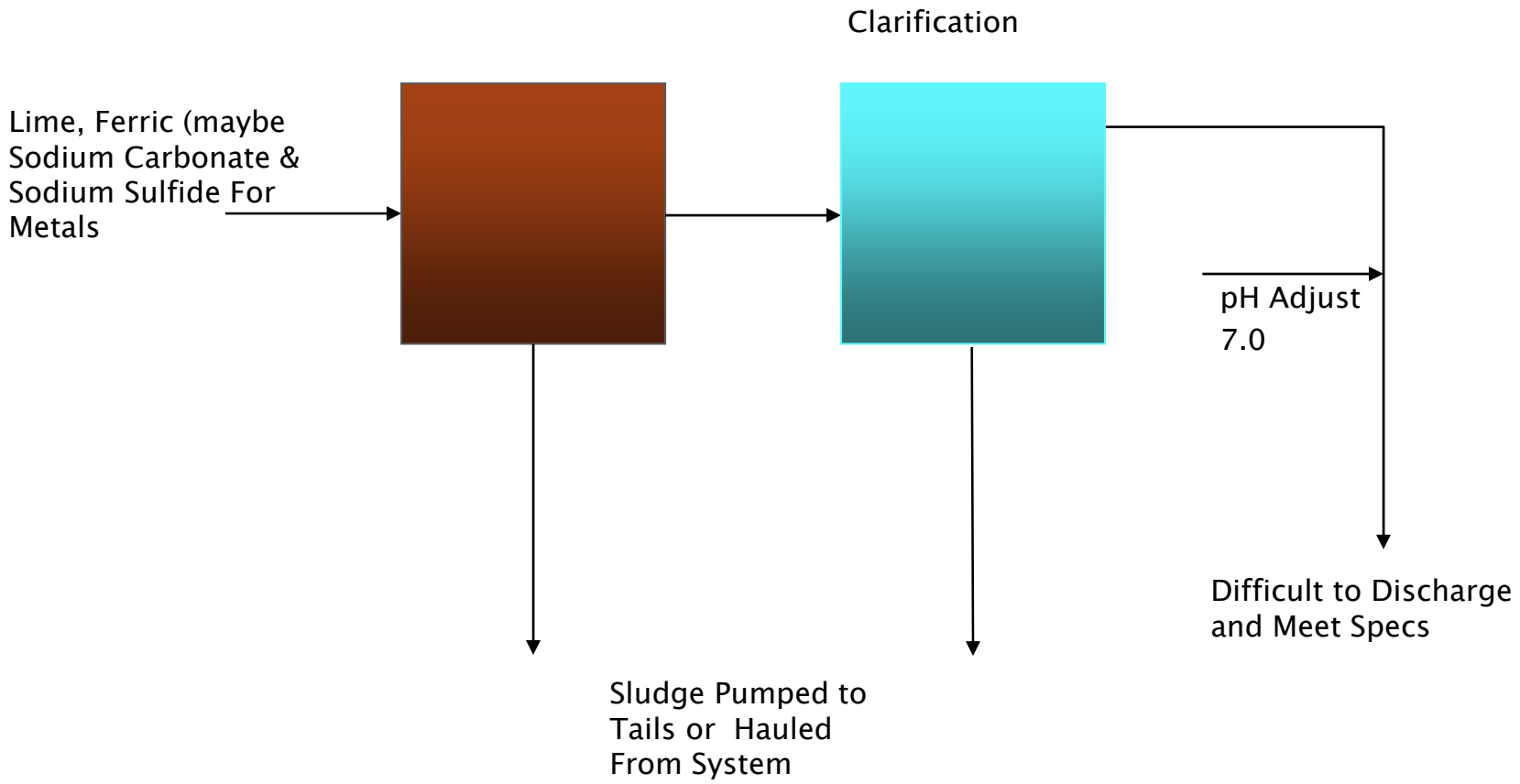
- **Membrane Technology Offers**
  - Recovery of metals–Highest Value
  - Recovery of acids or caustic for re-use–Next Highest Value
  - Reduction of disposal costs (ARD resides here in the lowest value process)

  - *But some ARD Streams at Current Metals Prices May Prove Profitable*
  - *Does allow a mining company to socially responsible*

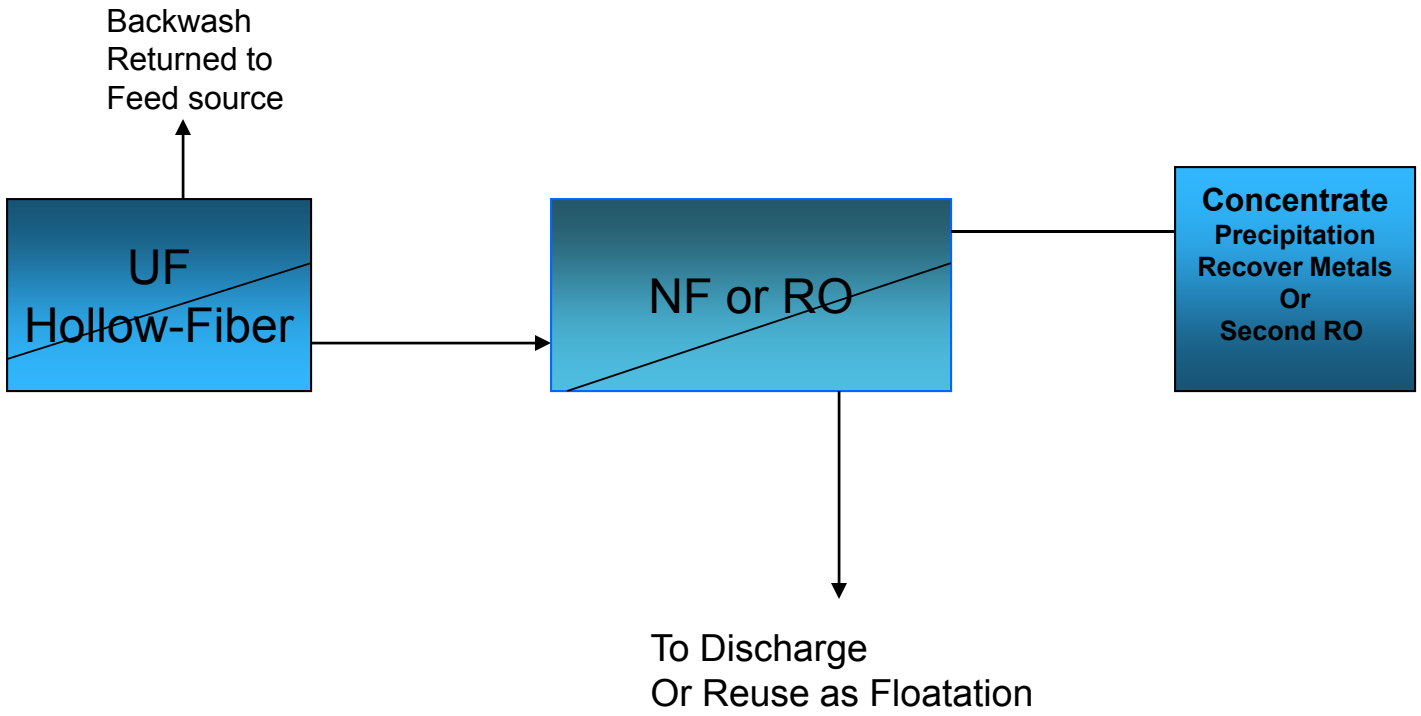
Membrane Filtration use for A & A Mine Drainage

	.	
Ultrafiltration (UF)	**0.01-0.05 Microns**	**All suspended solids** **Bacteria and Colloids**
Nanofiltration (NF)	**No Acid Rejection** **Ammonium Sulfate sepaarted from Sodium Chloride**	**Divalent salts rejected 99% but transmits monovalent salts or acids**
Reverse Osmosis (RO) **Hyperfiltration (HF)**	**Concentrate Acids and Salts up to 10-20%**	**Rejects all salts and acids 99+%**

Present 99% of ARD Acid Streams use Traditional Precipitation is Use for ARD



If Possible HWPT Designs: Direct Membrane Treatment Acid or Alkaline Mine Drainage Prior to Chemical Treattment

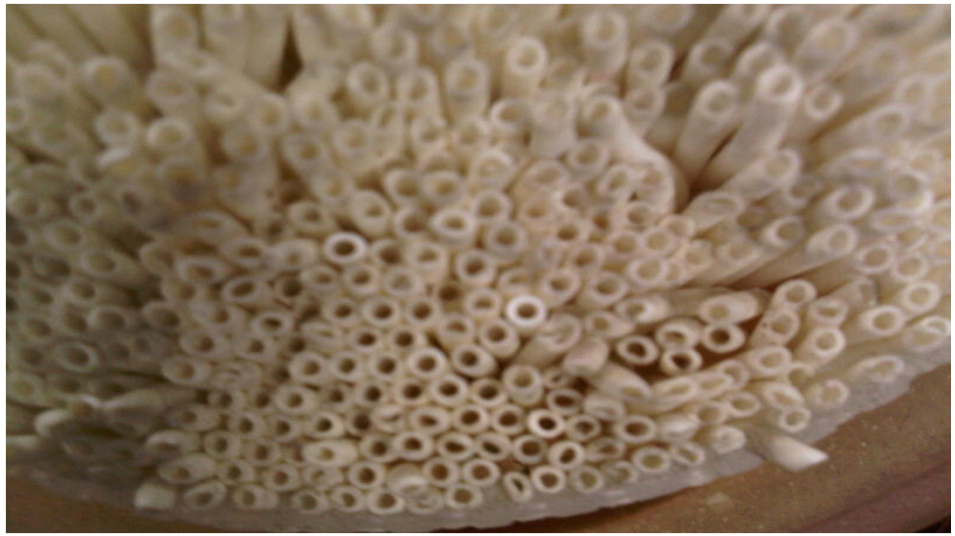


All Skids have Integral Automatic

Hi Temperature Clean-In Place

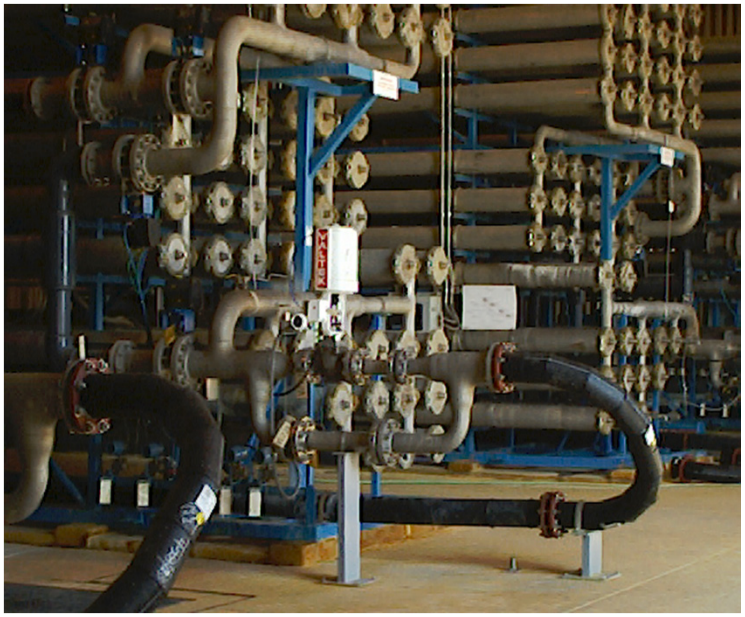
UF Membranes are Hollow Fiber

- Depending upon the application
- HWPT deploys either spiral wound UF or Hollow Fiber UF membranes
  - PCV, PAN, PVDF, PS
  - Use either Inside Out or Outside In depending upon the applications



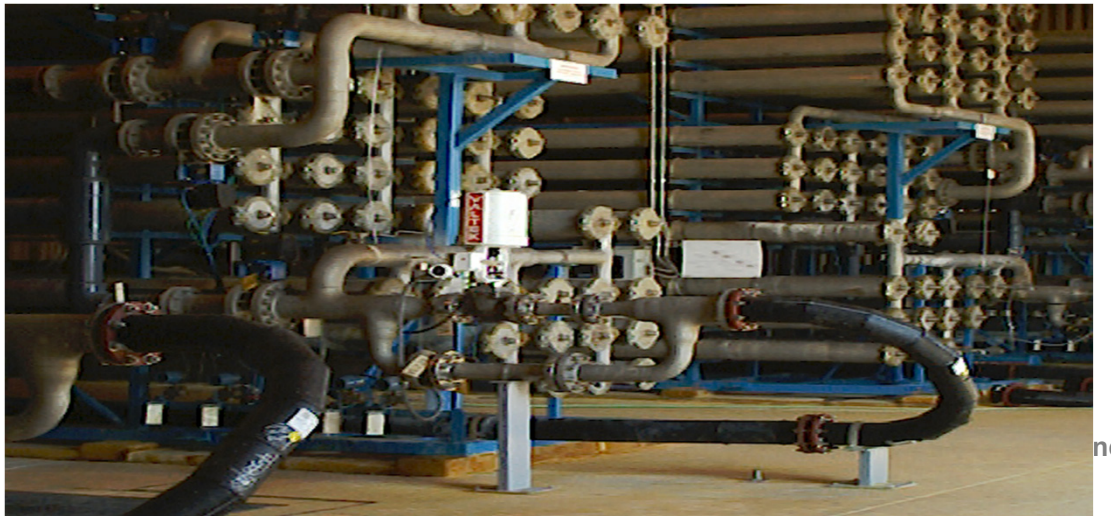
RO or NF Membranes are Spiral Wound

- 20 cm X 100 cm each module contains 30-35 m^2
- Special construction to mitigate calcium sulfate and carbonate precipitation
- Use different Membrane Polymers for specific applications : Polyamides, Sulfonated Polysulfone and even Cellulose Materials



HWPT Designs and Builds Systems to Operate in Difficult Mining Environments

- Hi pH-14
- Low pH – 0
- High Temperture – up to 90° C.
- Ultra-high pressures – 200 Bar
- Most ARD applications making our own stainless vessels we were able to operate on both high and low pH simply by changing membranes. We are doing this at gold mine that had both high and low pH ARD



Acid Mine Drainage Applications

- Coal Mining Acid AMD Pennsylvania 500 m3/h USA
- Ammonium Sulfate from ground water 250 m3/h West Australia
- Chromic Acid from Ground Water 25 m3/h USA
- Copper and Sulfuric Acid from Ground Water 20 m3/h PD in USA
- Heavy Metals Asarco Ground Water at Refinery 5 m3/h USA
- Heavy Metals Sun Metals Ground Water at Refinery 100 m3/h Korea
- Copper & Acid AMD Cananea Mexico 1000 m3/h

Phelps Dodge Acid Waste Stream
Neutralized and Land Farmed Clarifier Supernatant

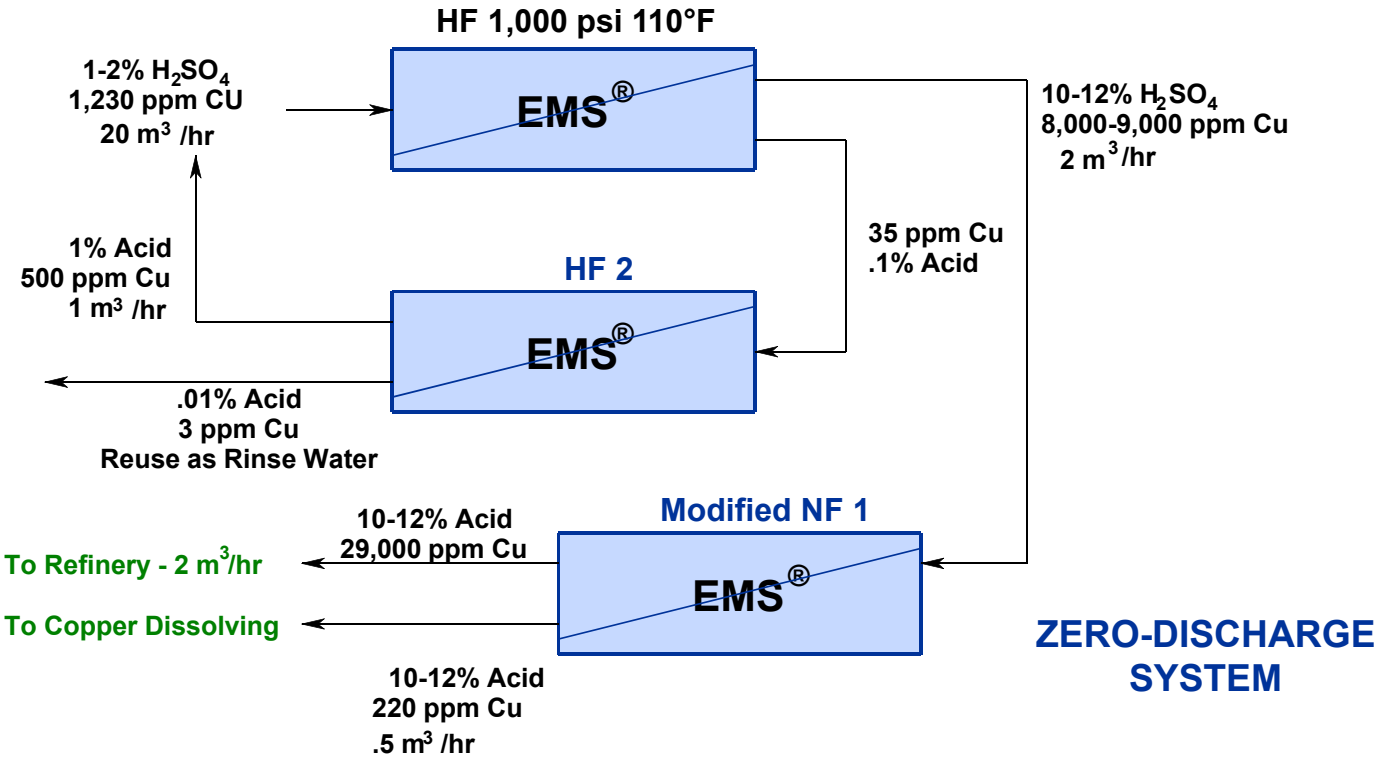
Problem

- PD Rod Mill had a 20 m3/h pH 1 sulfuric acid waste stream with 1200 ppm Cu
- It was neutralized with lime and supernatant with 2-3 ppm Cu land farmed on their property raise alfalfa
- Pressure from City because the copper could enter water table

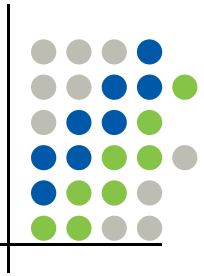
Zero Liquid Discharge Solution

- Installed 3 pass membrane plant that recovered copper
- Recovered Water
- Produced no sludge

17 years' operation of Acid HF and NF systems at Phelps-Dodge



Acid Purification using Modified NF P_2O_5 at 60°C



Component	Feed (ppm)	% Rejection
P_2O_5	256,000	.5%
Sulfate	15,300	99.4%
Aluminum	3,300	99.94%
Iron	2,800	99.2%
Magnesium	2,800	98.75%
Vanadium	600	99.99%
Cadmium	68	93.5%
Organic Carbon	245	60%

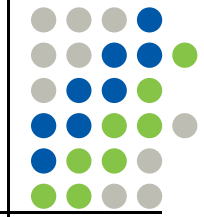
Ammonium Sulfate Concentration–Sodium Chloride Transmission with NF

- Ground Water Contaminated
- 2% Ammonium Sulfate Waste Water and 300 ppm NaCL pH 4
- Two Stage Membrane Approach
- First Stage Concentrates Ammonium Sulfate to 8% at Modest Pressure--30 Bar
- Second Stage Concentrates Ammonium Sulfate to 15% at 80 Bar
- Permeate from NF goes to RO for Sodium Chloride Removal and used as boiler feed make-up

Applied Membrane NF Technology

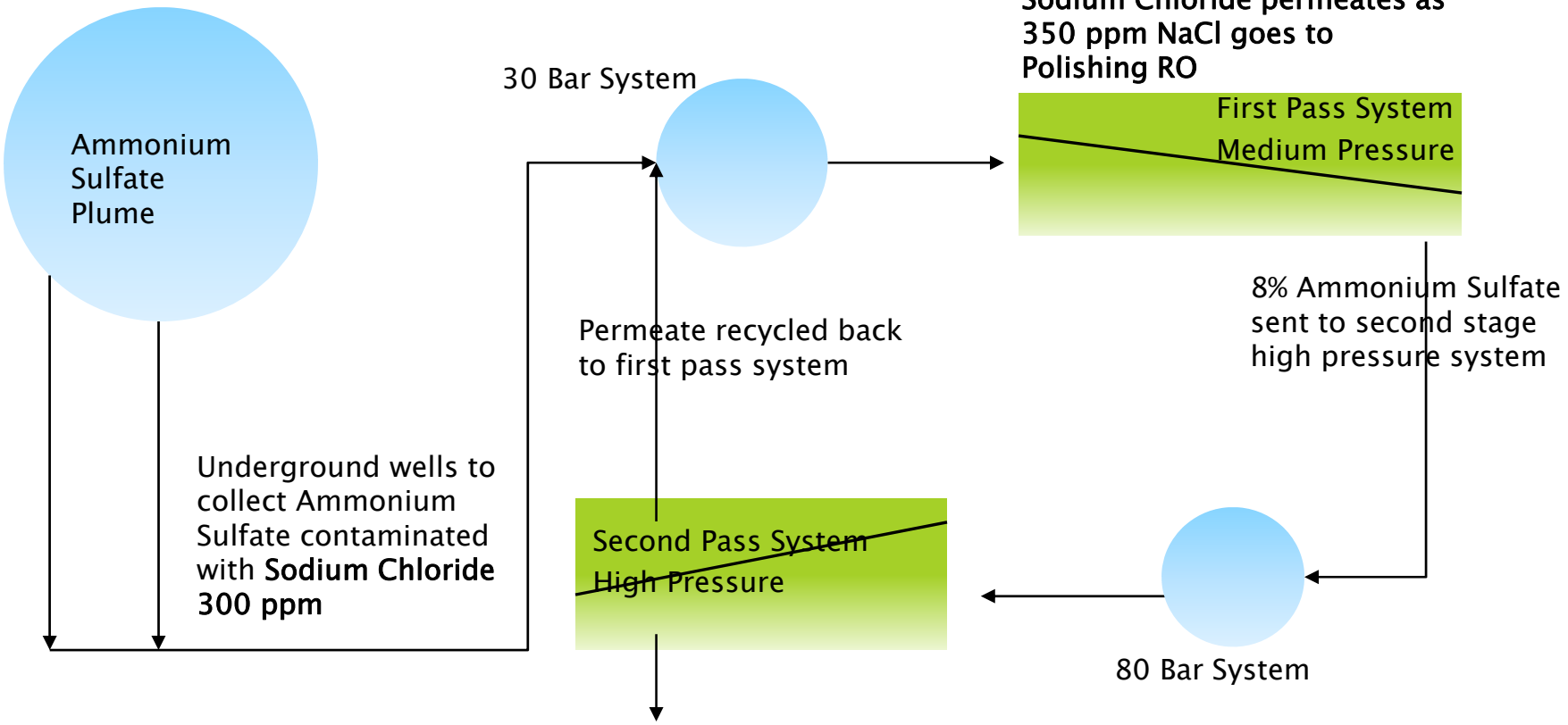
- 2% Ammonium Sulfate Waste Water
- Two Stage Membrane Approach
- First Stage Concentrates Ammonium Sulfate to 8% at Modest Pressure--30 Bar
- Second Stage Concentrates Ammonium Sulfate to 15% at 80 Bar
- Second Stage Permeate is recycled back to First Stage

Final NF Membrane Concentrate goes to Crystallizer and is sold as Fertilizer



- Concentrated Ammonium Sulfate is now at 15%
- Ammonium Sulfate is further Concentrated by Crystallization
- Finally, Ammonium Sulfate is Sold As Fertilizer
- An Excellent Example of Membrane Technology converting a mining drainage problem into a Profitable Product

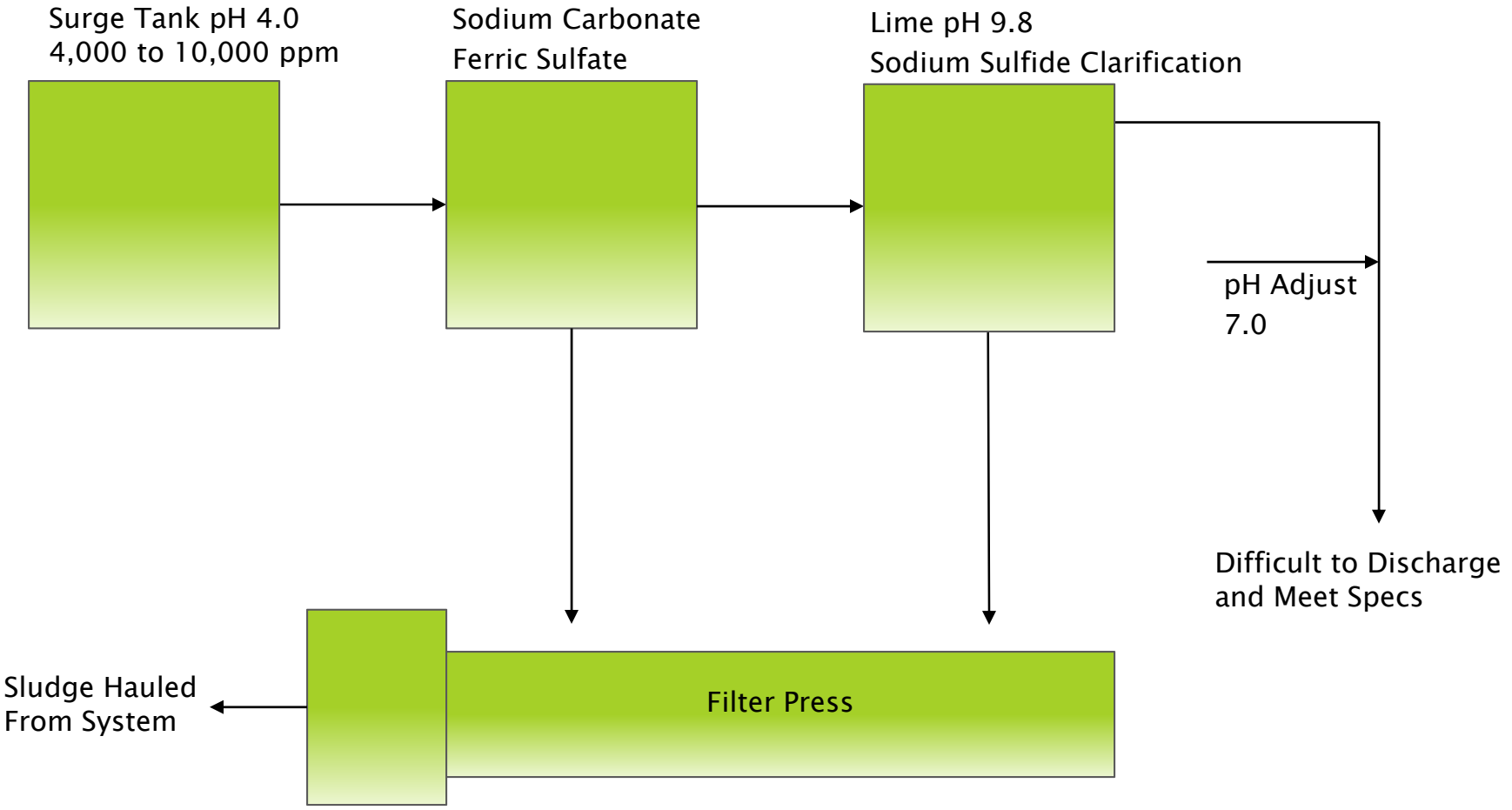
Process Overview: 2 Pass Concentrate Staged



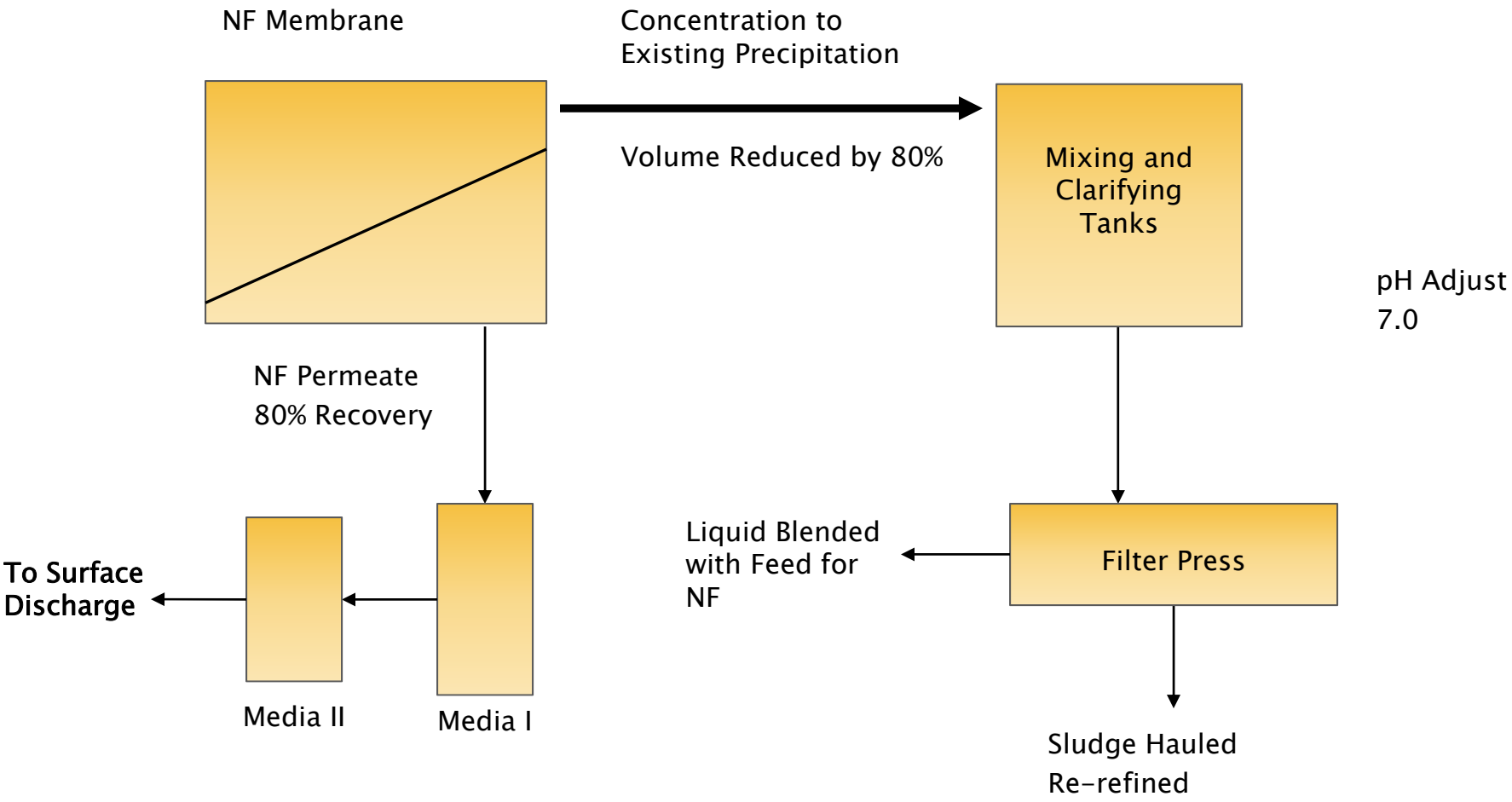
Asarco Refinery Wastewater Reclamation Project

- Legacy refinery with ground water pollution issues after 100 years of operation
- Precipitation system installed in 1985 – $1M capital and huge operating costs
- Membrane system installed in 1993 prior to precipitation – reduced volume to precipitation system from 6 m^3/hr to 1 m^3/hr

Copper Refinery Precipitation Process Prior to Addition of Membrane System



Copper Refinery Layout with Membrane System in Front of Exiting Precipitation System



Capital and Operating Costs
Precipitation vs. Membrane Media

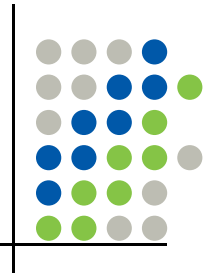
Chemical Precipitation

Cap Cost	$1M
Chemicals	$2.61 per m^3
Sludge Disposal per m^3	$26.53
Total Sludge Generated per m^3	19.24 Kg
Total Op Cost per m^3 treated	$29.15

Membrane Process

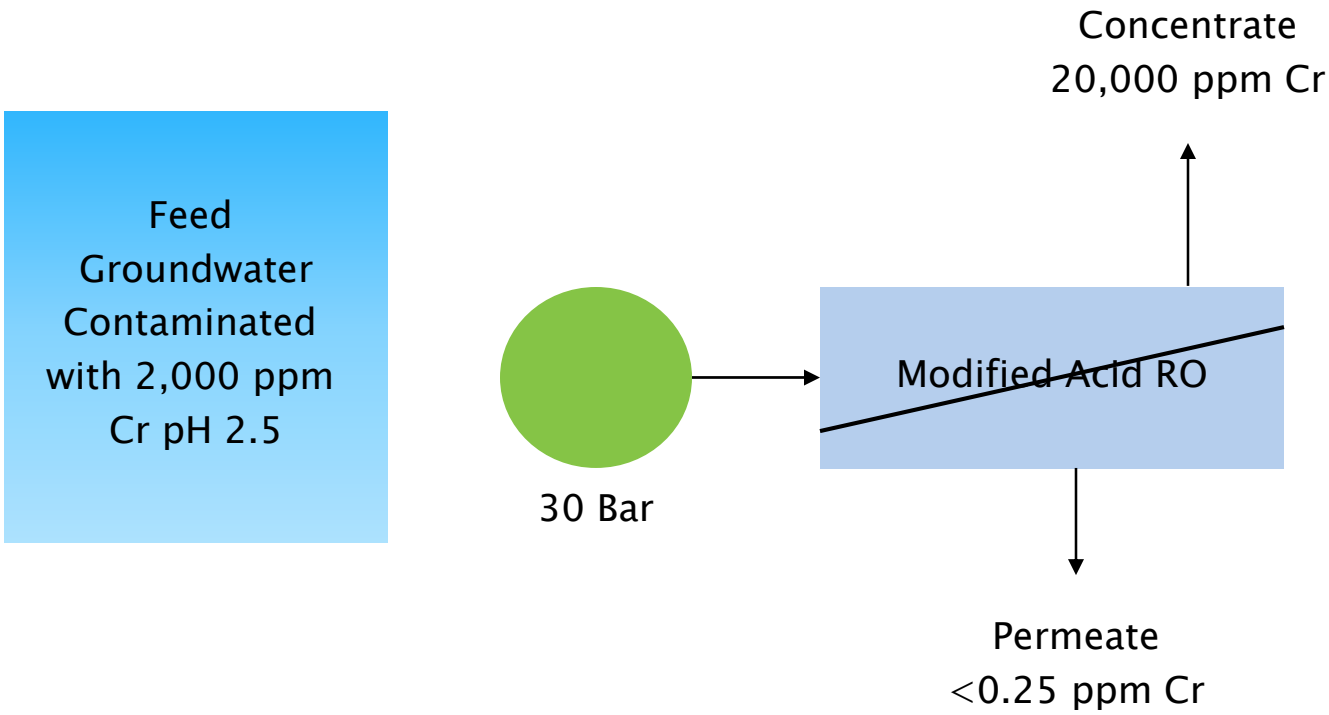
Cap Cost	$300k
Chemicals – membrane cleaning and media regeneration	$.15
Sludge Disposal per m^3	$1.35
Total Sludge Generated per m^3	2.88 Kg
Total Op Cost per m^3 treated	$1.82

Final Permeate Water Analysis

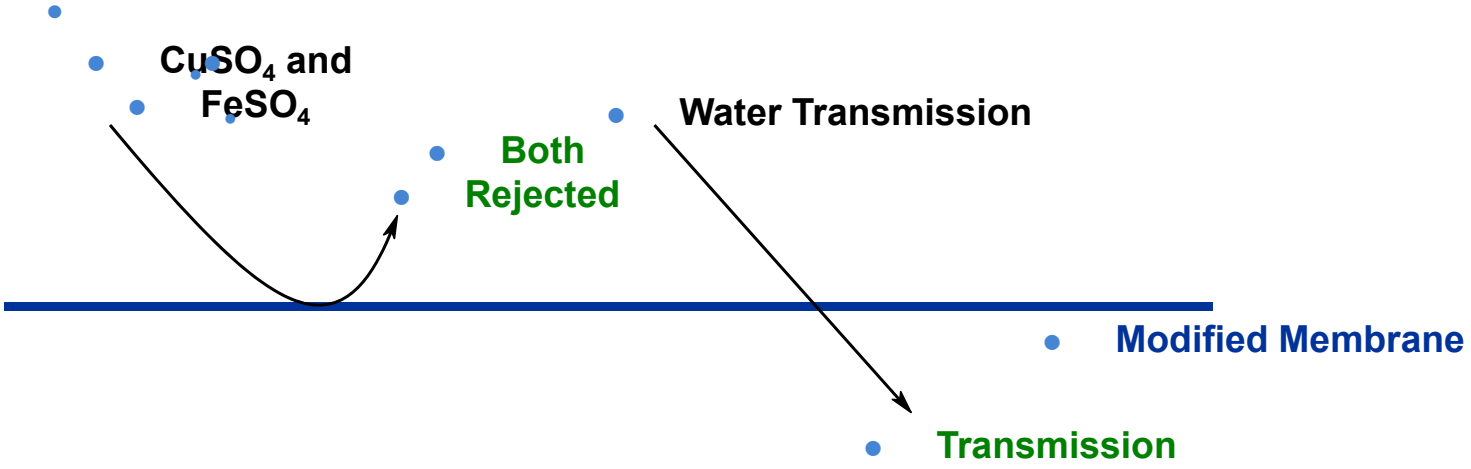


	Feed mg/l	Permeate mg/l
As	10.1	.081
Cd	14.5	.05
Zn	33.5	.01
Pb	3.07	.05
Cu	.073	.01
Fe	.986	.10
Mn	3.33	.5
Total Metals	67.9	.583
		99.14% Extraction

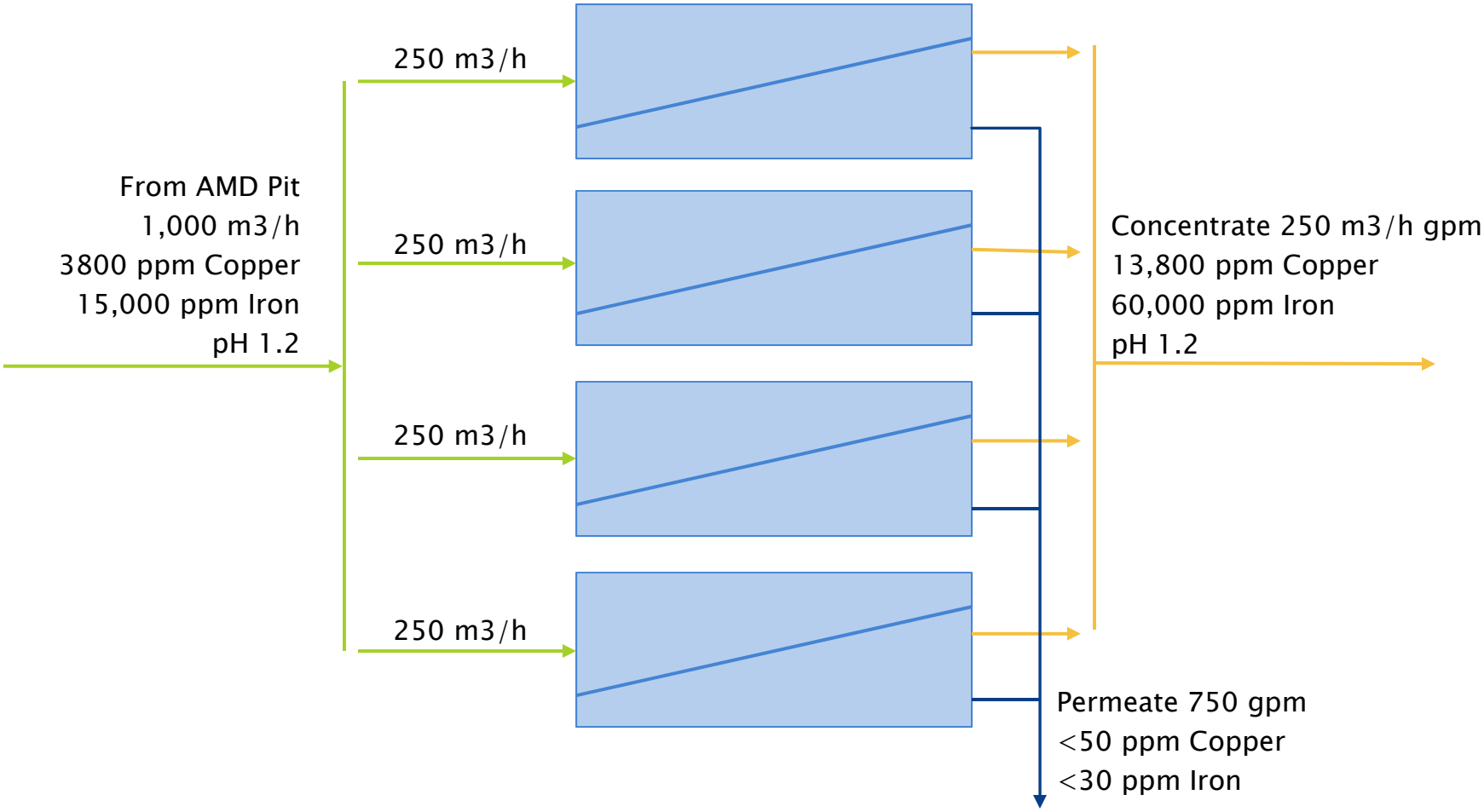
Chromic Acid Contaminated Ground Water



Copper and Iron Rejection with Special Modified HF Membrane-Elements



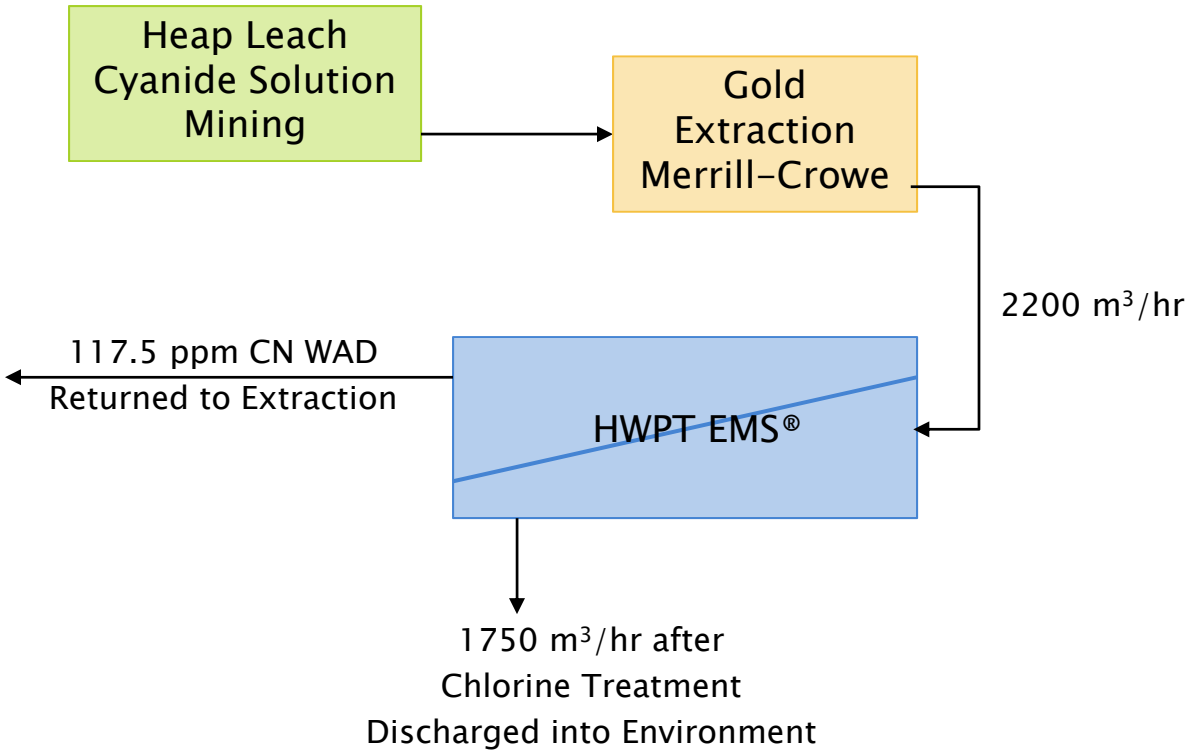
AMD Copper Recovery Process 75% Recovery



Alkaline AMD Applications

- Yanacocha Peru 3000 m3/h
- Cobre Las Cruces Spain 750 m3/h
- Waihi New Zealand 100 m3/h
- Sun Metals Australia 100 m3/h

Yanacocha Process Overview



Water Quality at Yanacocha

Ion mg/L	Feed mg/L	Permeate mg/L	Concentrate mg/L	Discharge Limit mg/L
pH	10.1	8.0	9.7	6.0–9.0
CN WAD	46.7	<.05	117.5	0.2
Arsenic	0.4	<.01	1.5	0.5–1.0
Mercury	0.0025	<.0005	0.0076	0.002
Nitrite	5.19	0.09	17.11	
Gold	0.15	0.0015	0.5	
Copper	3.1	0.1	11.6	0.3
Zinc	17.2	0.3	65.1	1

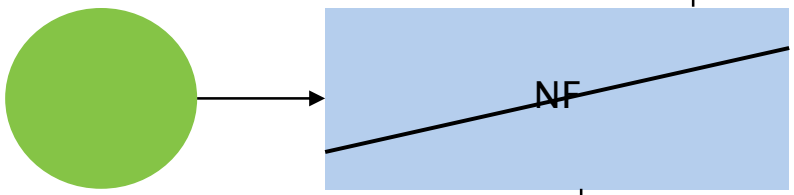
Comments from Newmont's Operators

- Meets water quality discharge standards
  (including nitrites and nitrates not regulated)
- Allows for future safe operation and expansion
- Increased Gold and Silver in membrane concentrates is recovered by CIC system just on concentrate
  (Au and Ag rejected at 96.5% rate by the membranes especially important during upset conditions)
- Cyanide in concentrate is recovered for re-use
- Chlorine consumption reduced by 75% and overall operating cost 70% less than that of a conventional precipitation plant
- EASY TO OPERATE

Ananomical Etchant

- Etchant Process

Feed
250 g/l NH_4Cl
135 g/l NH_4OH
Contaminated
With As 50 mg/l
And SO_4 7.2 g/l



60 Bar

Concentrate
150 g/l $(NH_4)_2 SO_4$
350 ppm As

Permeate
Clean NH_4Cl and NH_4OH

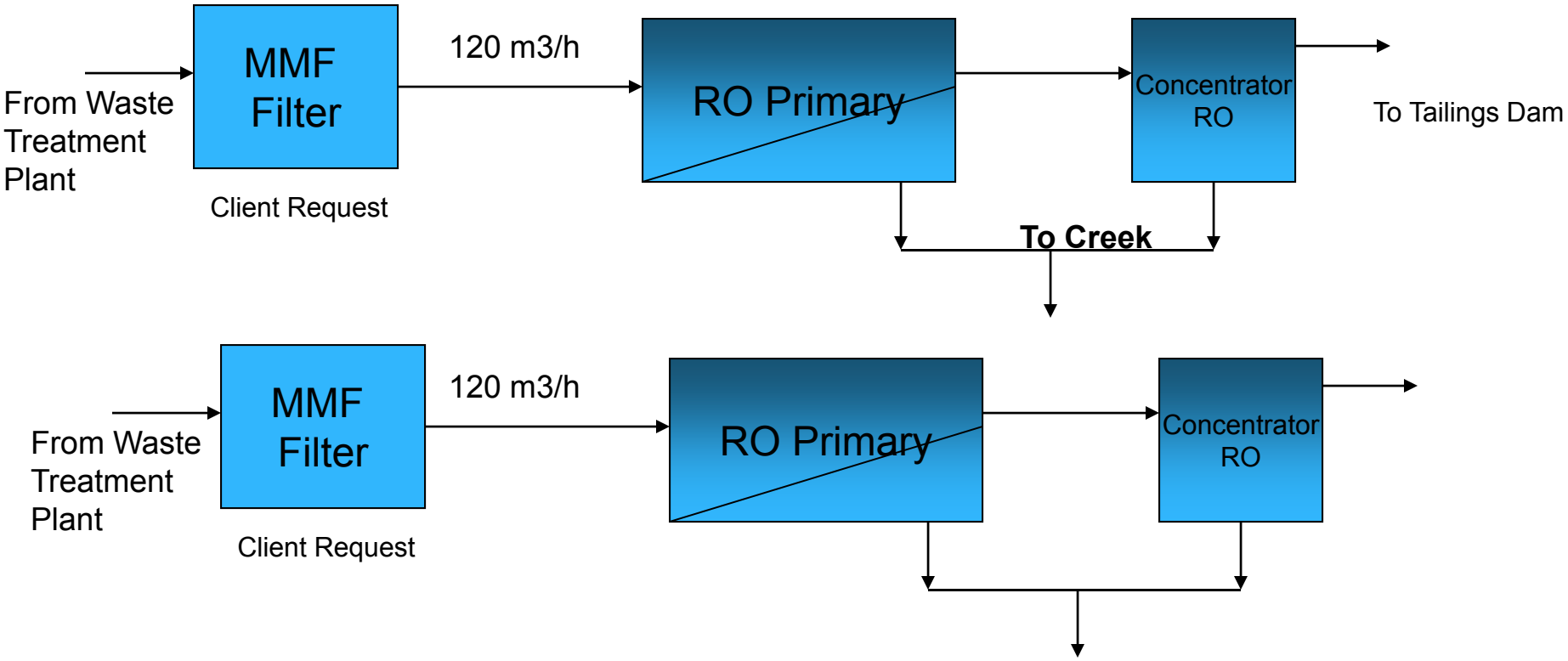
Waihi Gold New Zealand Hi pH Clarifier Effluent

- Water balance issue need to discharge water 200 mm/y rain fall
- Antimony, Arsenic and Selenium not being removed to < 5 ppb levels mandated by government with conventional water treatment system- Acid + Peroxide then Lime followed by clarification
- Membrane system takes feed off Clarifier process
- High Recovery 85%
- Process problem was Calcium Sulfate Precipitation at high recoveries

Waihi Analytical Data Discharge Limits < 5 ppb

- Feed 1550 ppm — Permeate at 85% recovery < 20 ppm
- Antimony Feed 450 ppb — Permeate < 2 ppb
- Selenium Feed 250 ppb — Permeate < 0.2 ppb
- Arsenic 10 ppb — Permeate <0.01 ppb
- Permeate Discharged directly into a Trout Stream

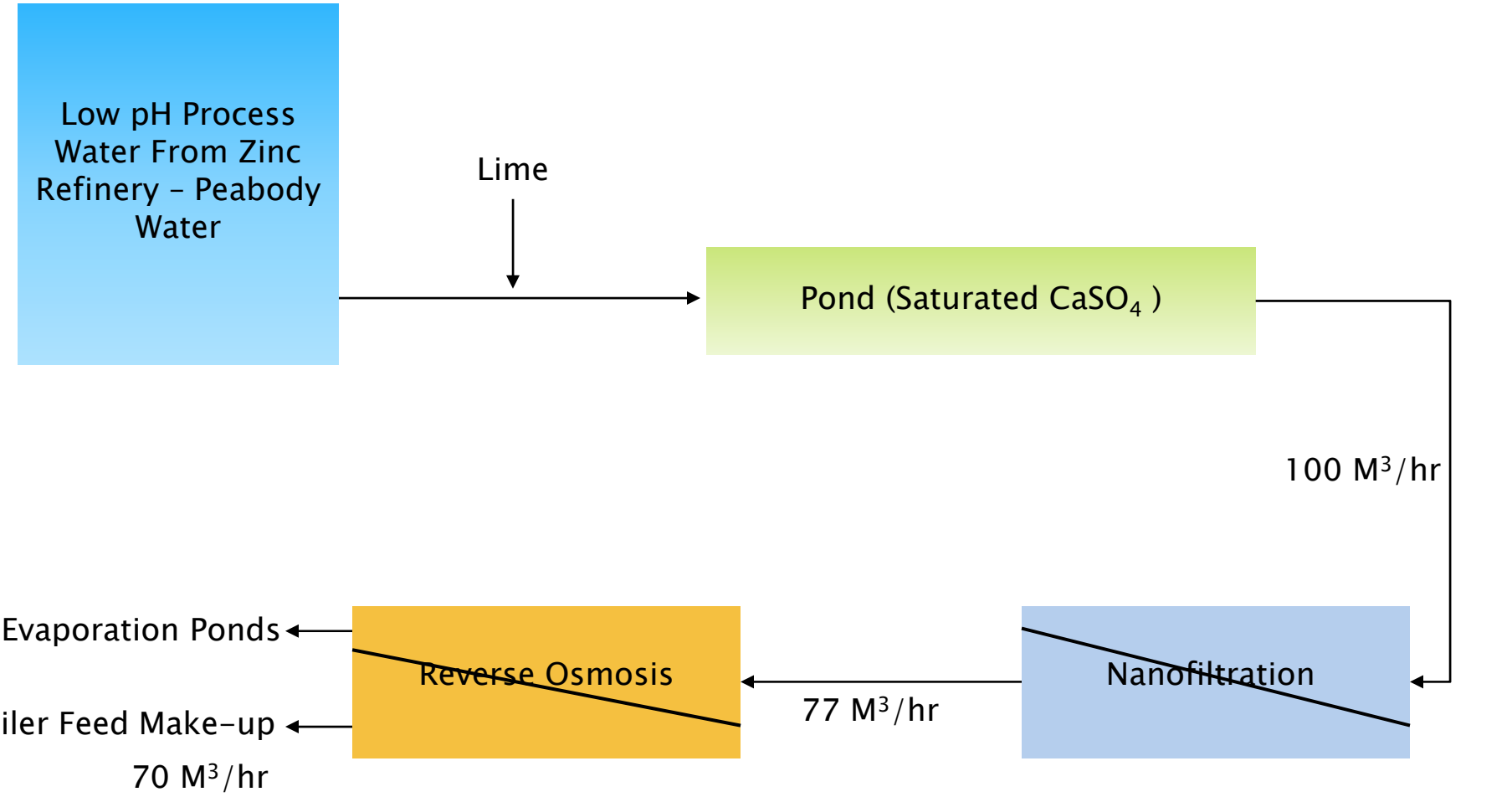
Duplex Design each Train capable of 120 m3/h



Sun Metals Zero Discharge Project

- New Zinc Refinery in Townsville, Australia
- $A 0.5 Billion Investment
- Zero Discharge Permitting Because Townsville is on Great Barrier Reef
- After Construction Commenced Sun Discovered Their Plant Effluent Could contain up to 30 ppm of Boron
- Conventional Precipitation Could Not Remove Boron
- NF (hardness removal) followed by feed adjusted up to pH 10 RO <1 ppm boron in permeate

Sun Metals Zero Discharge Zinc Refinery

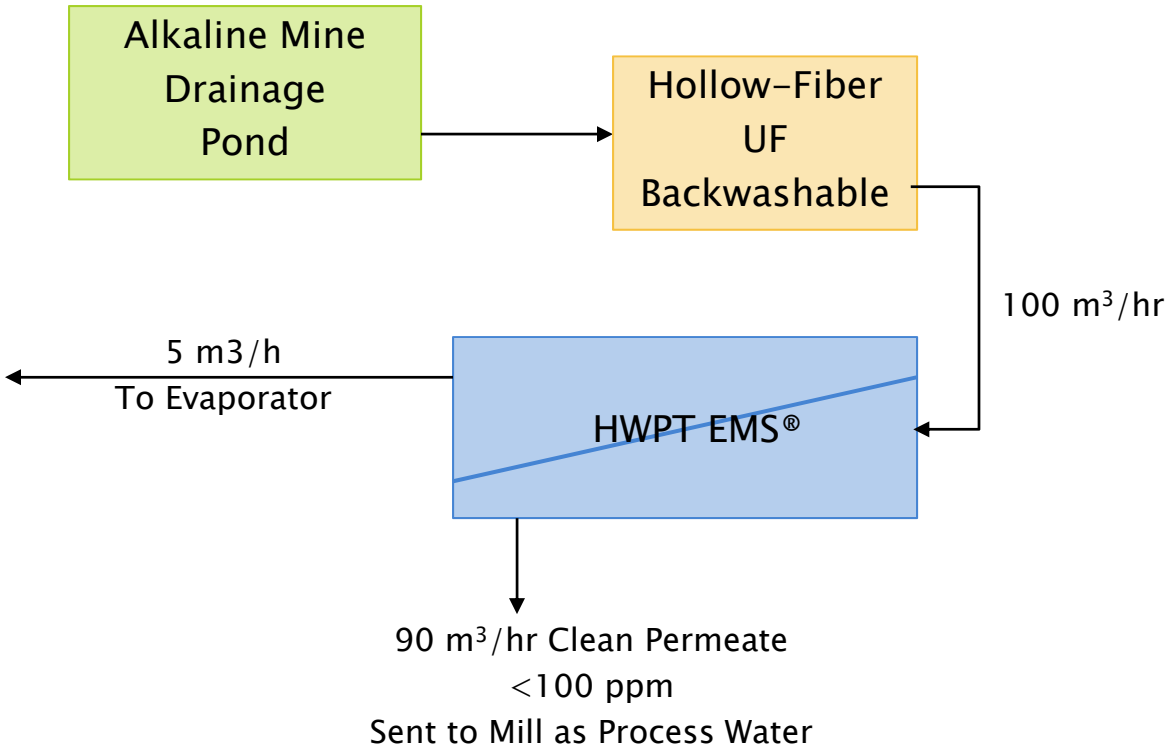


Cobre Los Crucas
Seville, Spain

- Application 1
  - New Mine Copper Open Pit Mine
  - Alkaline Mine Drainage from Rainy Season
  - Contaminated with Arsenic, Fluoride and Boron
  - Zero Liquid Discharge Facility
- Application 2
  - To Maintain Static Hydraulic Pressure on Open Pit Ground Water is Pumped from Wells around the Perimeter of the Pit
  - These “Water Wells” once they reach the surface must be treated for high levels of Arsenic, Fluoride and Boron
  - Clean Permeate Re-injected into Ground Water
  - Membrane Plants Operate at 95-97% Recovery and the Concentrate is Evaporated

Application 1
CLC
Alkaline Mine Drainage

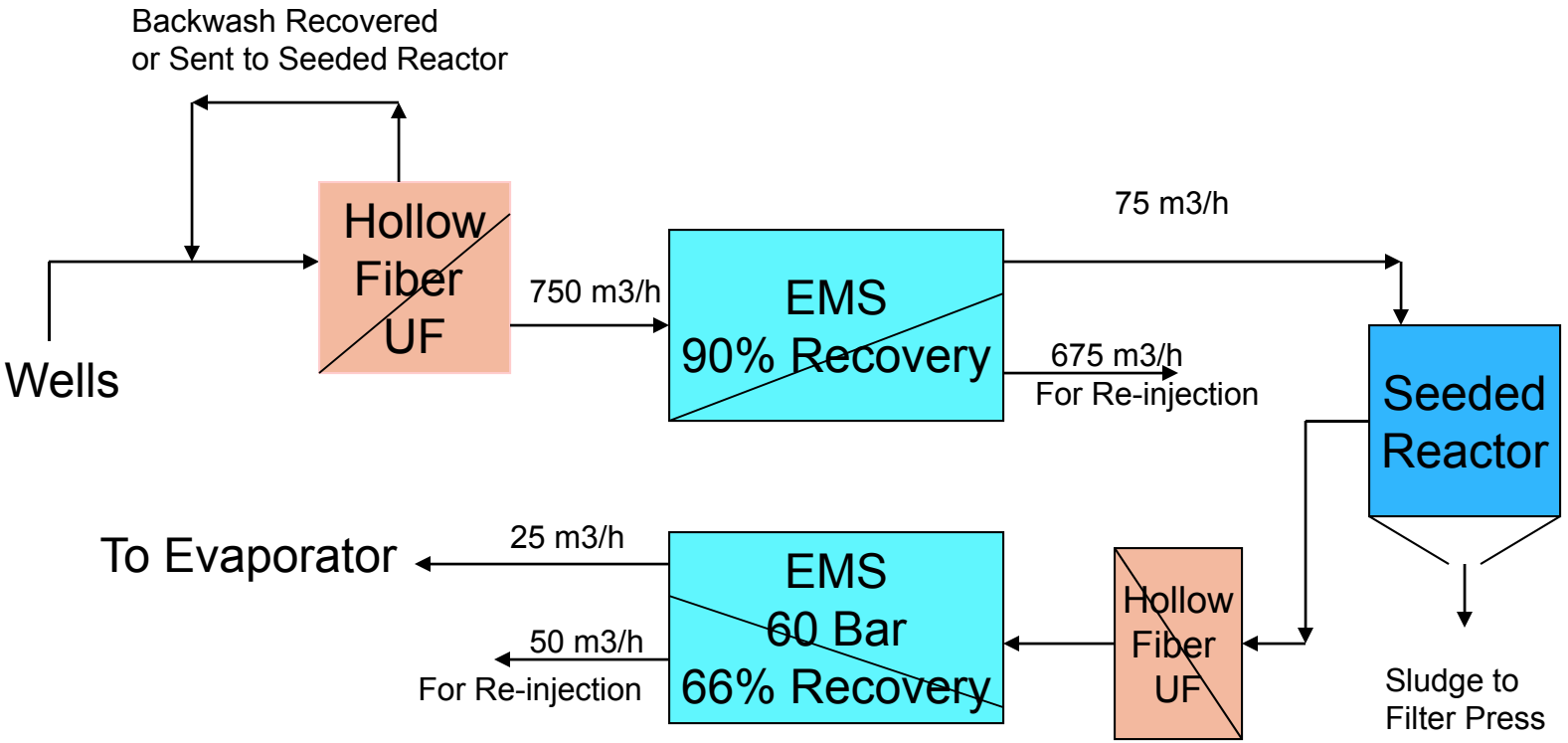
Application 1
Cobre Los Crucas Copper Mine
Alkaline Mine Drainage



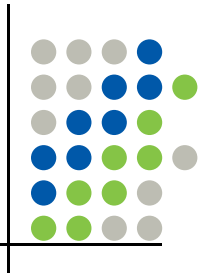
Application 2
CLC
Well Water Treatment and Re-injection

- Perimeter Wells Drilled around Open Pit Pump Ground Water that must be Treated before Re-injection

Application 2
Cobre Los Crucas
ZLD Process Flow Diagram EMS Plant Recovery 95-97.5%



What EMS does it cost?



- Depending upon complexity and pressure large systems >100 m3/h
- $500-$750/m3 includes design, engineering, E-house, Data Collection
- Smaller Systems $600-$1000/m3
- Installation +/-25% of capital depending upon location
- Typical Element life 3 to 7 years

What Makes EMS® Plants Unique?

- Special membranes and element construction
- Special system design
- Special operating procedures based on intimate knowledge of the client's process
- Special cleaning procedures
- 25 years of process membrane systems experience