POISON!!!
In OU r Water

Courtesy Arsenic Information Page

http://www.enn.com/news/enn-stories/2001/09/09142001/arsenichands.jpg

Arsenic Removal from the University of Oklahoma Water Supply

Paul Gerber

Collin Martin

John Siska

April 2004

Background

- OU has high arsenic levels (48 ppb) in wells that need to be treated
- EPA says limit needs to be 10 ppb by January 2006
- Current limit is 50 ppb

Our Purpose

- Evaluate effectiveness of alternative technologies
- Determine which technology is best suited
- Perform cost evaluation of the best technologies

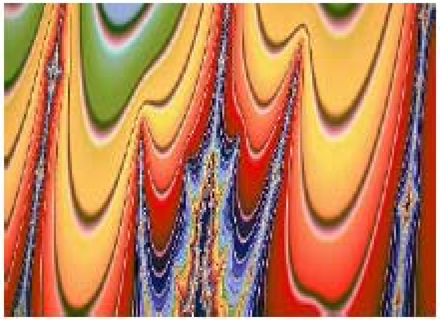
The History of Arsenic

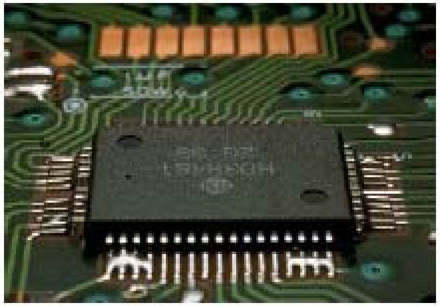
Occurs naturally in rocks and soil, water, air, and plants and animals.

It can be further released into the environment through natural activities such as volcanic action, erosion of rocks, and forest fires

http://www.webelements.com/webelements/elements/text/As/key.html

Uses of Arsenic



PAST

Insecticides

Herbicides

Paints

Dyes

CURRENT

Wood preservative

Production of glass

Electronics

Medicine

Effects of Arsenic

How Arsenic Enters the Body

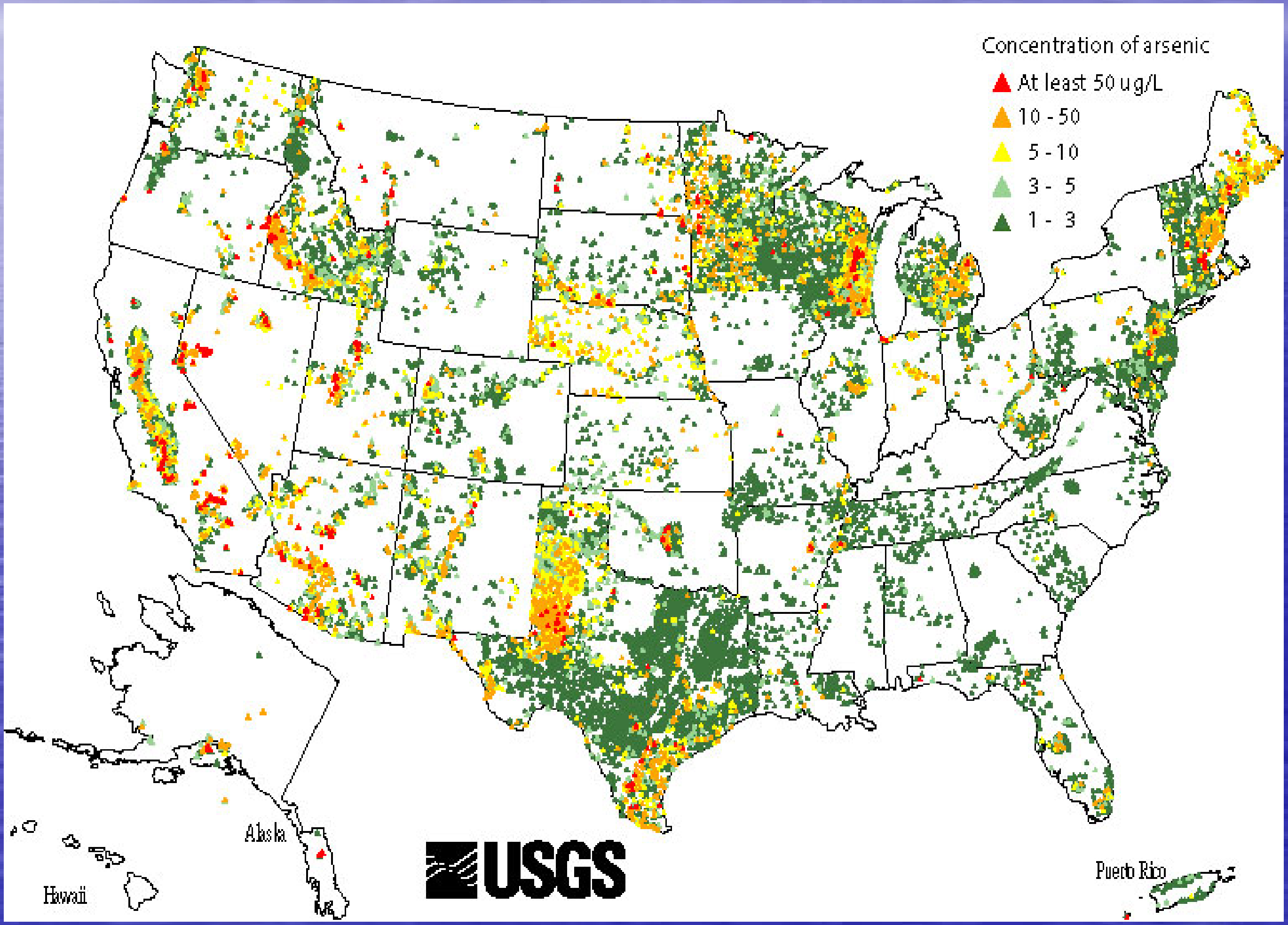
- From the food we eat every day
- By drinking water containing arsenic or eating food cooked in this water
- By breathing air containing it
- Arsenic is quickly absorbed into the bloodstream

Known Health Effects

- Thickening and discoloration of the skin
- Stomach pain
- Nausea, vomiting, and diarrhea (300 to 30,000 ppb)
- Numbness in the hands and feet
- Direct skin contact may cause redness and swelling

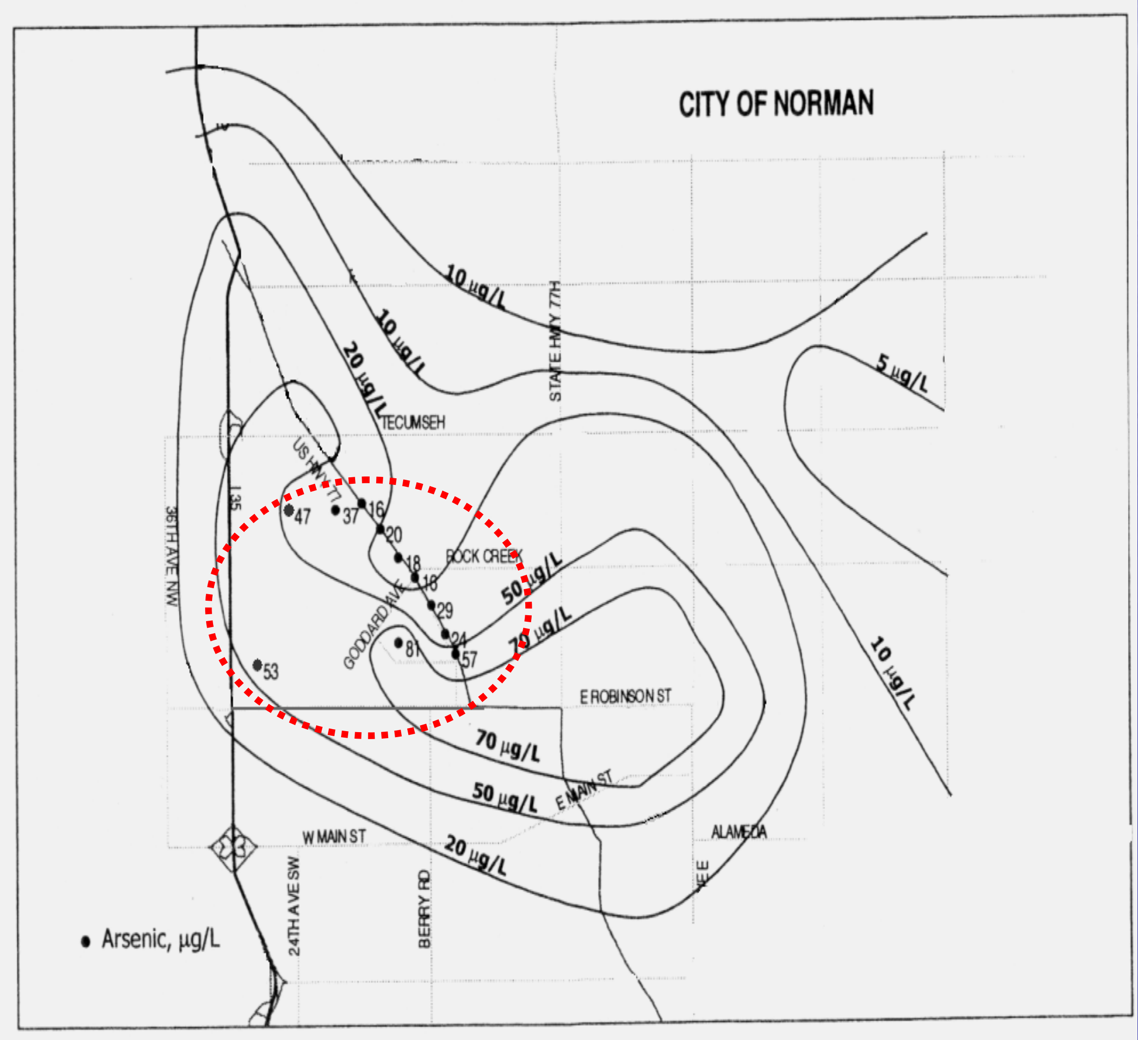
Large oral doses (above 60,000 ppb in food or water) can cause death

Where is it?



Ryker, S.J., Nov. 2001, *Mapping arsenic in groundwater*: Geotimes v.46 no.11, p.34-36.

OU's Wells with Arsenic



Average Arsenic Content

48 ppb

CH2M Hill Group Results

Assumed City of Norman and OU were one entitiy

- CH2M Hill recommendation does not apply strictly to the University of Oklahoma
- New Wells and Blending
  - Capital Investment: $9.2
  - NPC: $35,000,000

POE & Associates 2002 Results

- Purchase all potable water from the City of Norman
- Cost: $100,000 + Water Purchase Cost
  - Based on $4.00/1000 Gallons
  - Changing water connections
    - Potable wells
    - City of Norman

Past Engineering Group Results

Civil Engineering Group 2001

- 3 MGPD Ion Exchange
- Capital Investment: $2,179,000
  - NPC: $17,079,000

Chemical Engineering Group 2003

- 1.6 MGPD Ion Exchange
- Capital Investment: $2,000,000
  - NPC: $3,100,000
  - Based on $1.14/1000 Gallons

Sources of Water

- Westheimer Airport (North Campus) Wells
  - High in Arsenic (30-50 ppb)
  - Must be Treated
  - Very Soft (30 mg/L) Water
- OKC (Purchased) Water
  - Low in Arsenic, but Expensive
  - Soft (60 mg/L) Water
- South Campus Wells
  - Currently Used for Irrigation
  - 2 ppb Arsenic
  - Very Cheap, but Very Hard (340 mg/L) Water

Water Treatment Processes

- Water Purchase
- Nanofiltration
- Microfiltration
- Polyelectrolyte Enhanced Ultrafiltration
- Reverse Osmosis
- Ion Exchange

Water Purchase

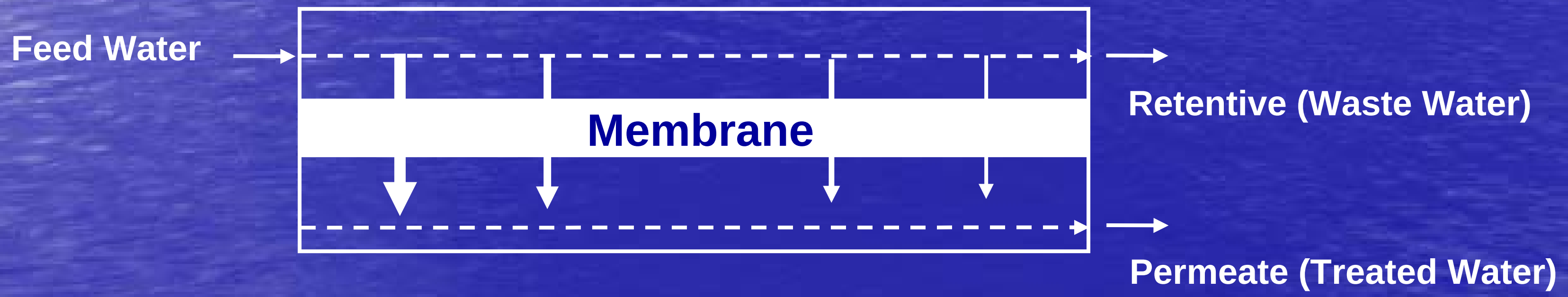
- Buy potable water directly from OKC at $0.98 per thousand gallons.
- Pay $0.05 per thousand gallons to transmit this water to OU from OKC through Norman.

Water Purchase

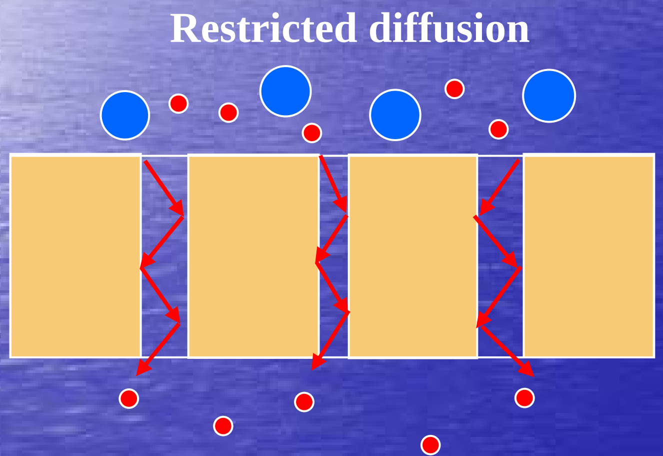
- Pros
  - No Initial Investment
  - No Significant Construction Needed
- Cons
  - Dependence on OKC and Norman for Water
  - High Water Cost

Membrane Separation

- A mixture is separated
- Allows one component to move through faster than others
- Separated into a retentive and a permeate stream



Nanofiltration, Microfiltration and Ultrafiltration

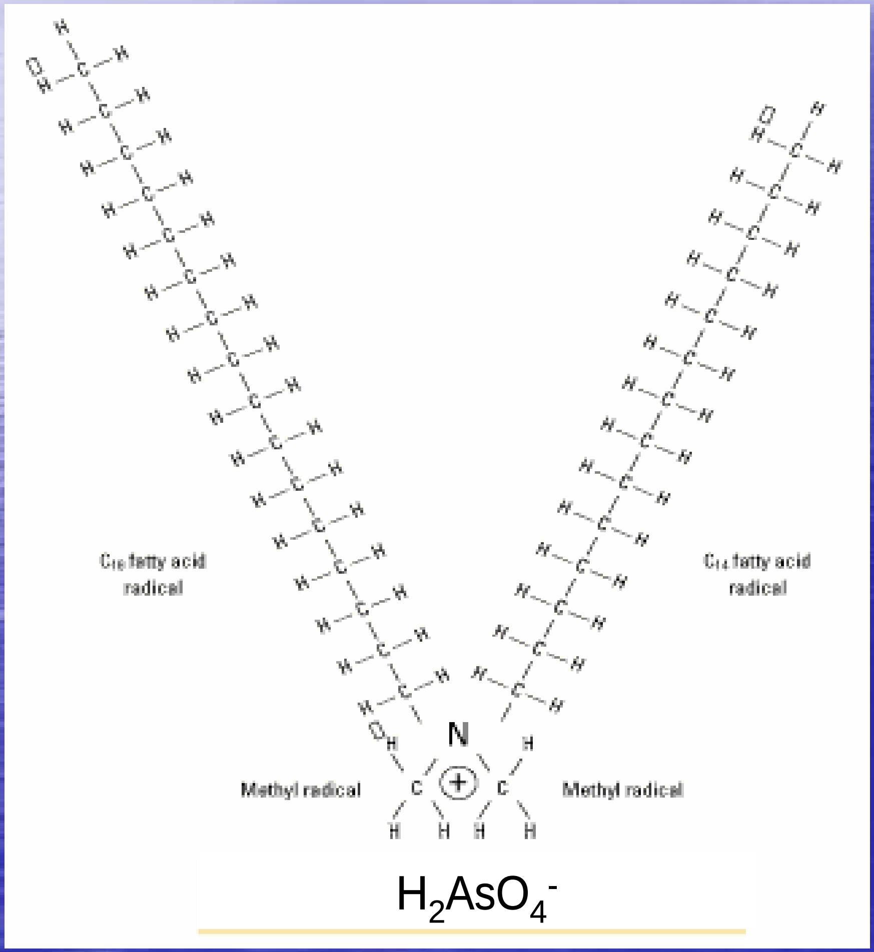


- Nanofiltration membranes are capable of removing arsenate because of their small pore size.
- Microfiltration's pore size is too large to remove arsenate.
- Ultrafiltration's membrane pore sizes are small enough to block the polymer that is bounded to the arsenate.

Polyelectrolyte Enhanced Ultrafiltration

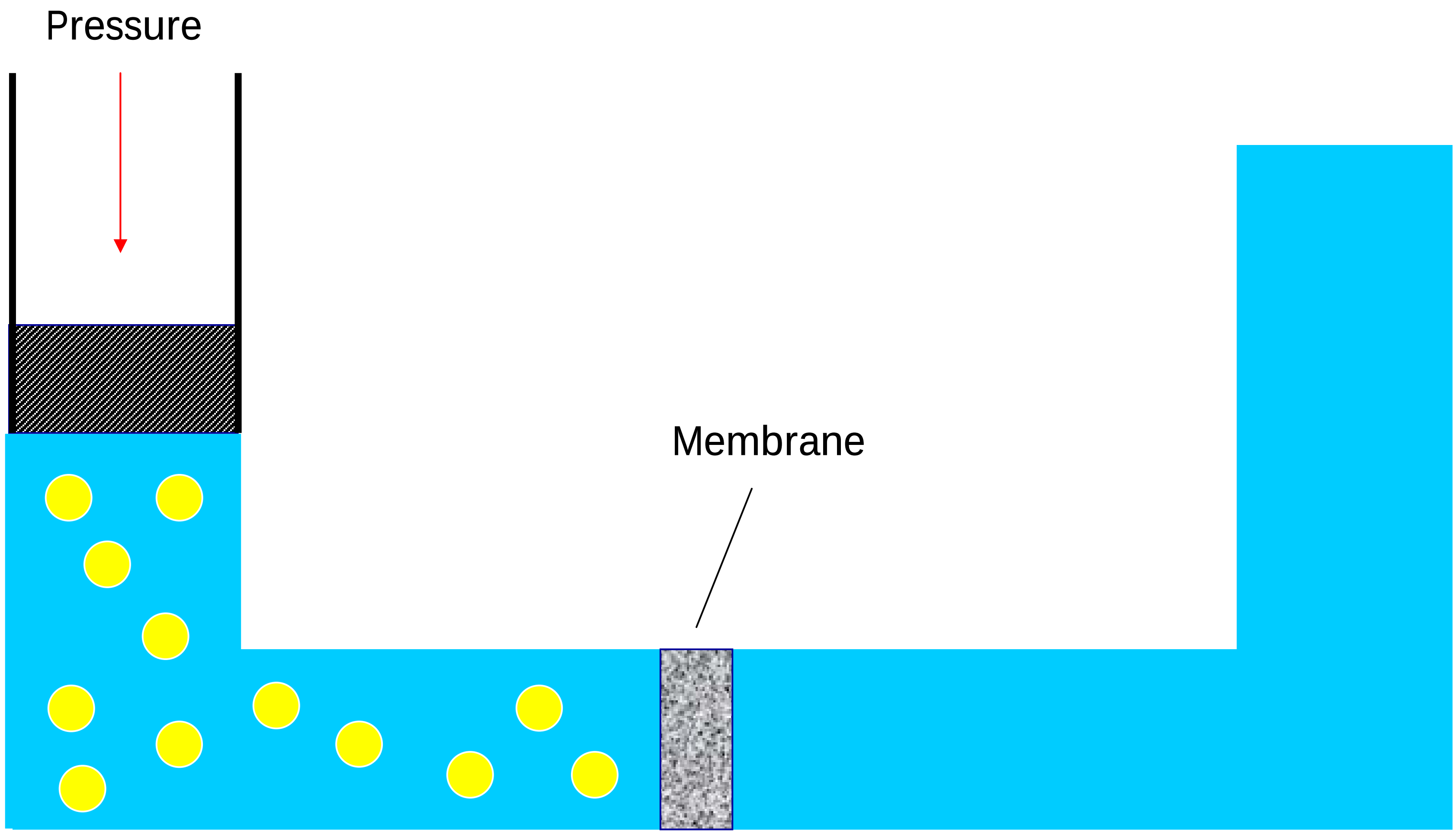
- Polymers (long-chain molecules) with a cationic (positive charge) head group
- Water soluble
- Biodegrade easily

Polyelectrolyte Enhanced Ultrafiltration

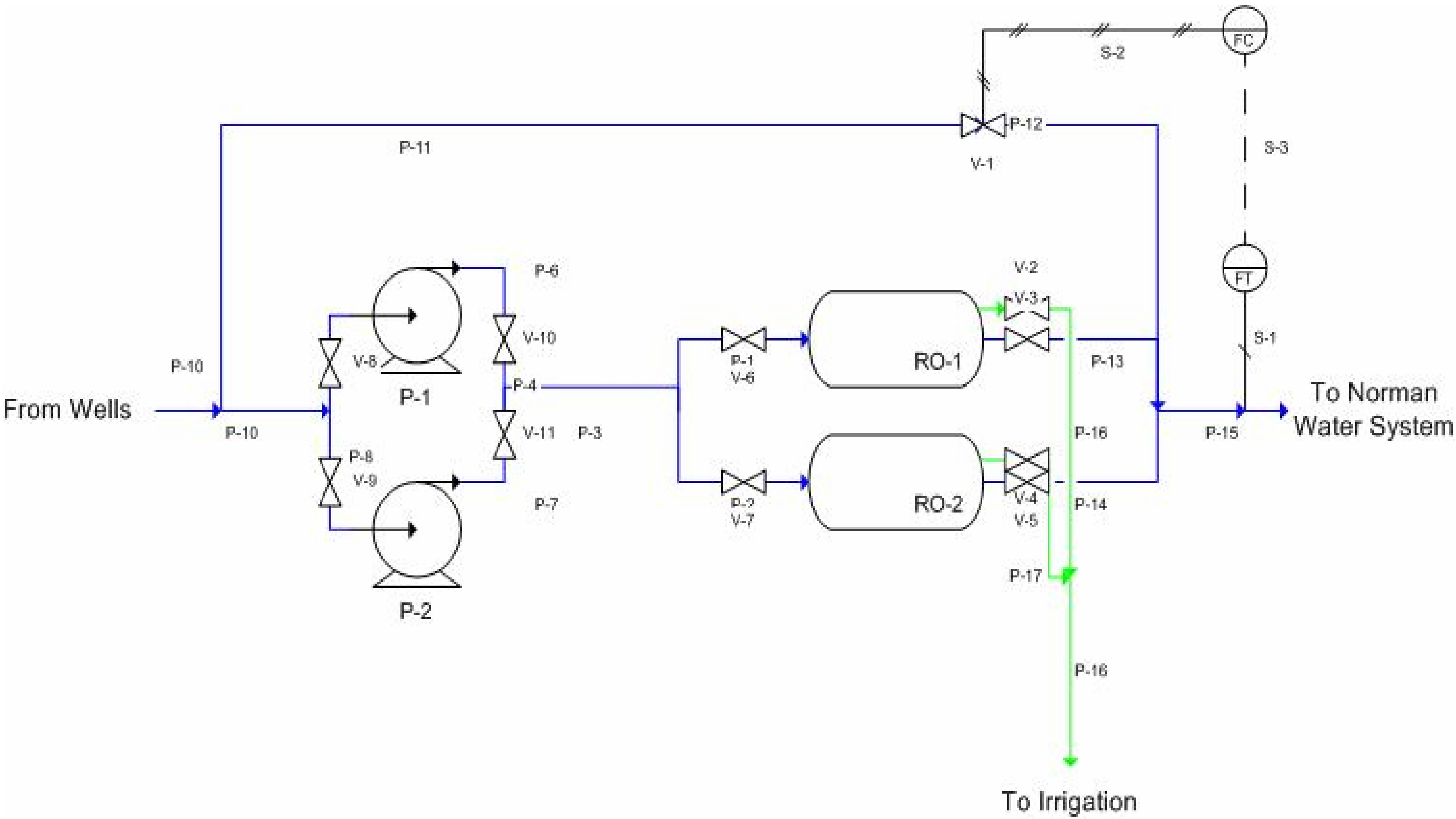


- The polymer used is a polyelectrolyte of opposite charge to the target ion (Arsenate).
- Pollutant ions bind to the polymer
  - Electrostatic attraction
- Polymer complexes are retained by the membrane in the waste stream.
- Uncomplexed ions (water molecules) pass through the membrane to the treated stream.
- But polymer is expensive…

Reverse Osmosis



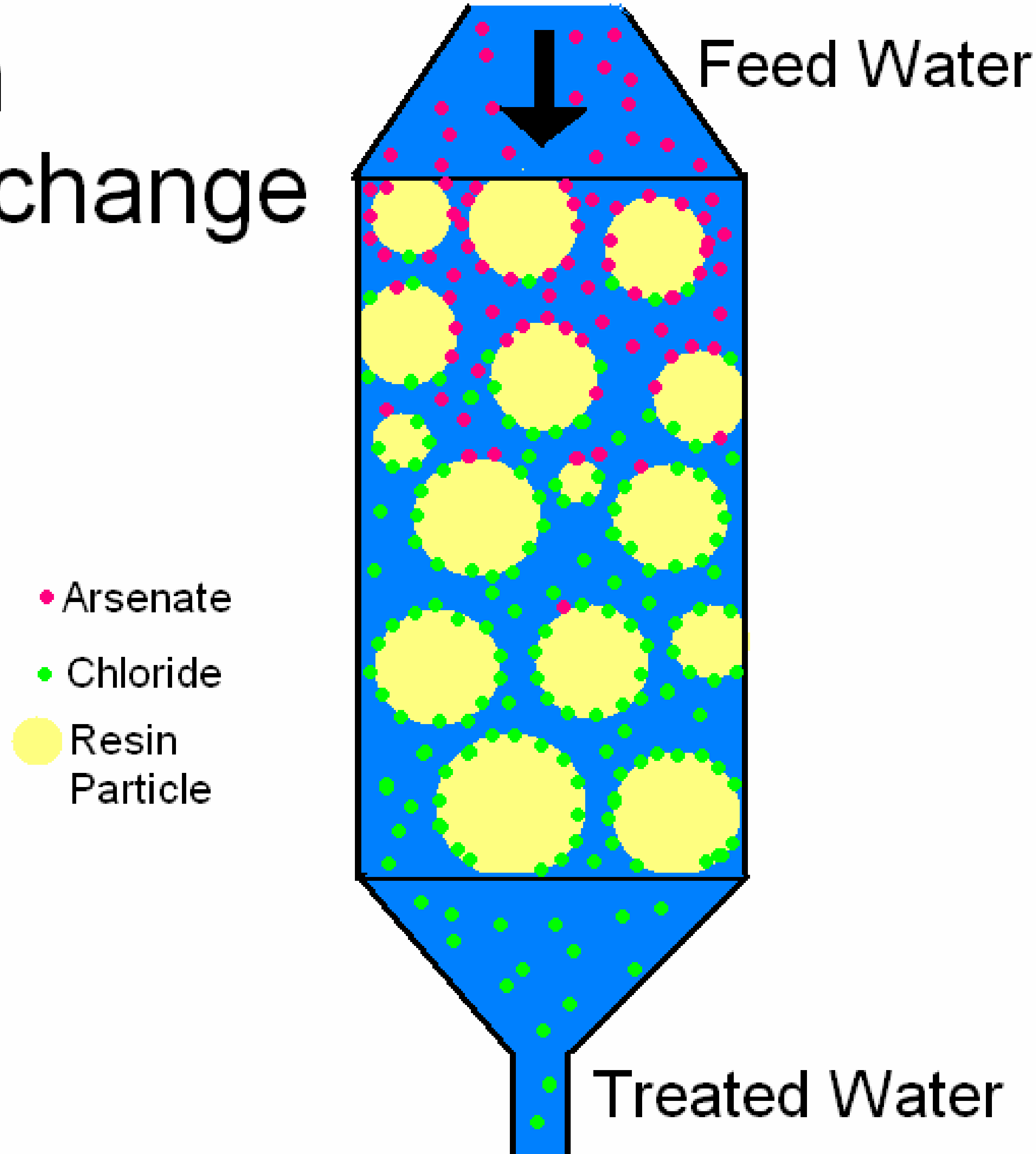
Reverse Osmosis



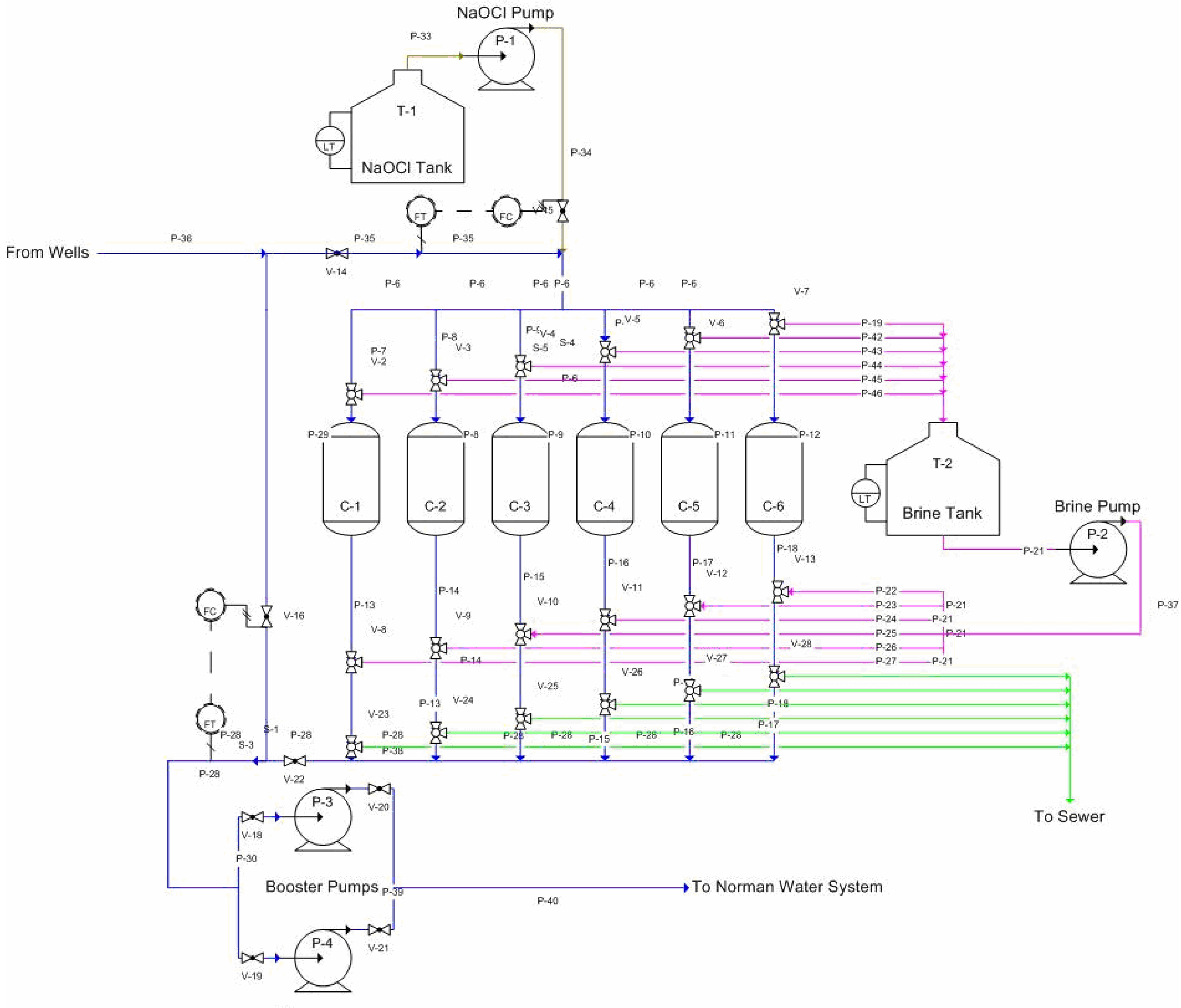
Reverse Osmosis

- Pros
  - No Chemicals Needed for Normal Operation
  - Low Maintenance, Easy to Operate
- Cons
  - Very Expensive (Membrane)
  - High Pumping Costs
  - Creates a lot of Waste (Reject Water)

Ion Exchange



Ion Exchange



Ion Exchange

- Pros
  - Inexpensive to Start-Up and Operate
  - Removes Virtually All Arsenic from the Water
- Cons
  - Resin must be Regenerated/Replaced
  - Risk of Arsenic Breakthrough
  - Produces a lot of Waste (but much less than RO)

Detailed Calculations

- Water Systems Integration
- Economic Analysis of Treatment Options
- Basis of Calculations (unless otherwise specified):
  - 0.75 MGPD (520 gpm) Potable Demand Today
  - 1% Annual Growth in Water Demand
  - 1% Inflation
  - 5% Discounting for Net Present Cost Calculations

Water Systems Integration

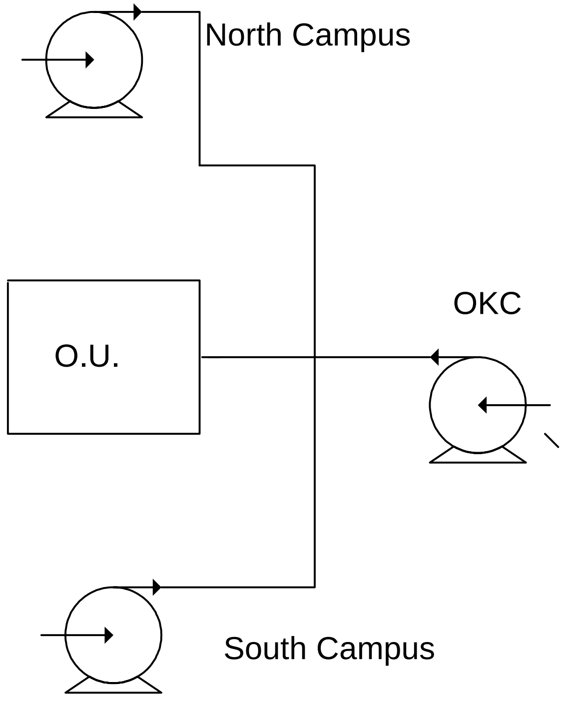
- North Campus Treatment Facility Integration
- South Campus Well Integration

Options

1. Buying all water from OKC (WP)
2. Treating all north campus water (IX)
3. Blending treated water with south campus water (IX + SC)
4. Blending purchased water with south campus water (WP + SC)
5. Treating South Campus Water Directly for Hardness

Water Sources and Costs per 1000 gallons

- $1.030 OKC
- $0.791 Ion Exchange
- $0.085 South Campus



North Campus

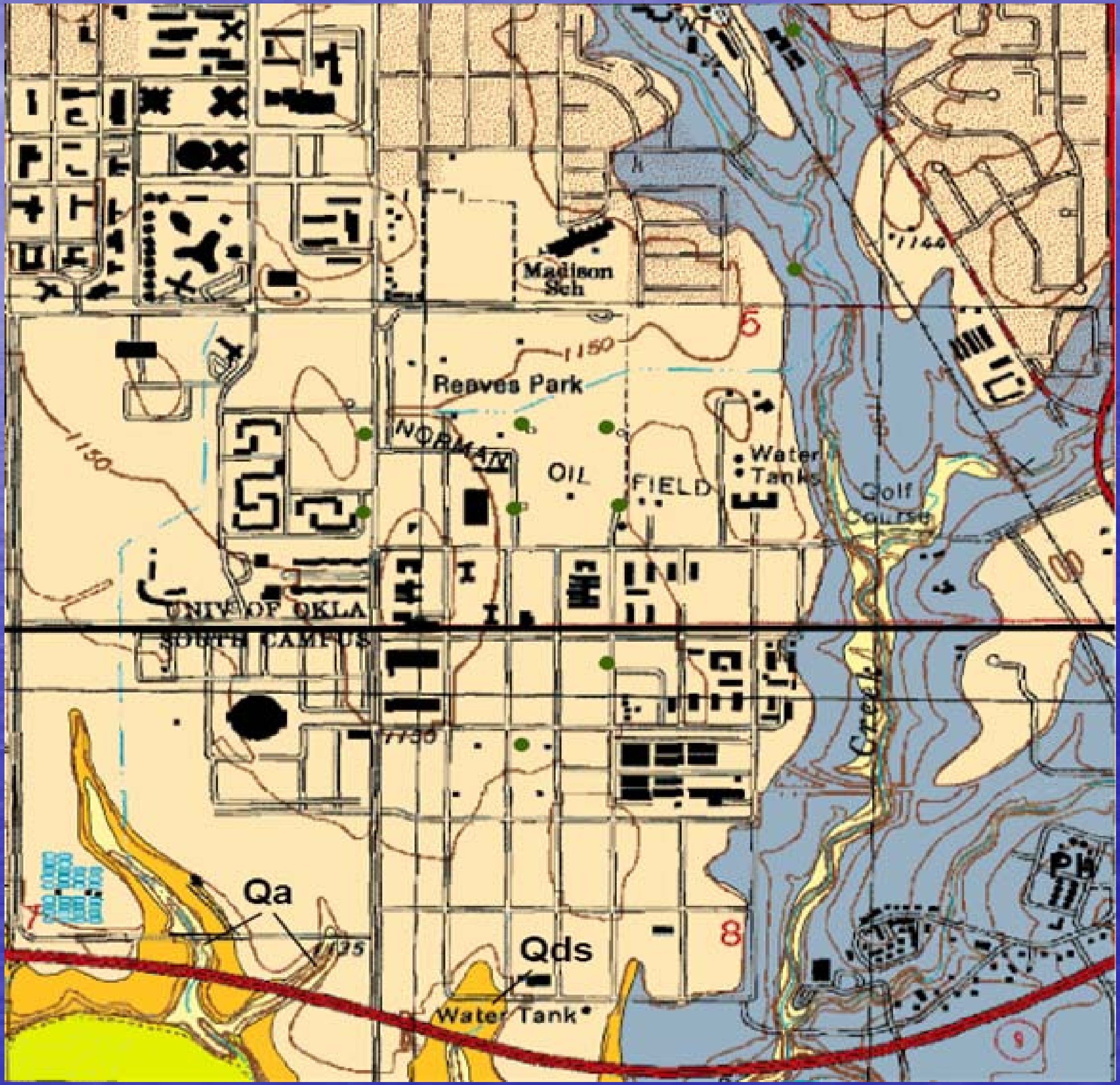
13

North Campus

	# Parts	Cost/Part	Total Cost
Facility	1	$300,000	$300,000
Pumps	2	$15,200	$30,400
Gate valves	5	$2,700	$13,500
Relief valve	1	$525	$525
Check valves	3	$1,650	$4,950
Meters	2	$5,100	$10,200
Meter vault	1	$3,200	$3,200
Elbows 90	7	$315	$2,205
T connectors	4	$475	$1,900
Pipe SCD 80 (1 foot) 8"	400	$36	$14,400
Variable Drives	2	$7,500	$15,000
Controllers	2	$2,000	$4,000
		Total	**$400,280**

Operating Expenses		Cost ($/yr)
Pump Power		$23,389
Utilities		$1,700
	Total:	**$25,089**

South Campus Wells 2, 10 and 11



South Campus Wells

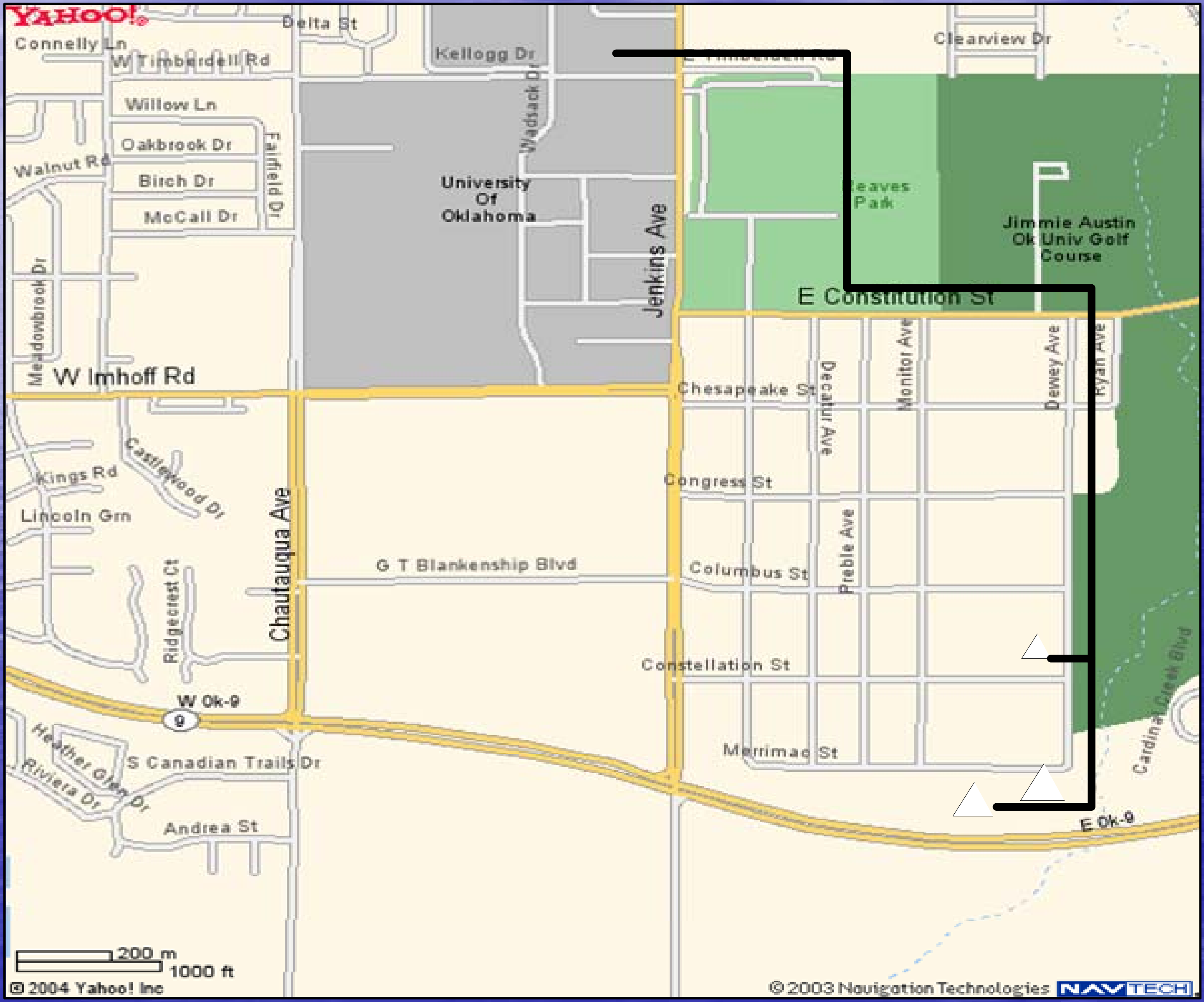
- 11 Wells Total, with Flowrates of 12 – 282 gpm

Well	1	**2**	3	4	5	6	7	8	9	**10**	**11**
GPM	16	**160**	25	50	55	16	50	35	12	**218**	**282**

DEQ Test Results S.C. Well 10

Test Ran	Total Alkalinity g/L	TDS mg/L	Nitrates mg/L	Hardness mg/L	Chloride mg/L	Sulfite mg/L	Conductance UMHOS/cm	Ph	Arsenic ppb
Test Results	337	418	1.44	**342**	10	25.1	743	7.28	**2**
Limits	None	500	10	None	250	150	None	6.5 - 8.5	**10**

South Campus Wells: 2, 10, & 11



Cost of Integrating South campus

C 901 8" PVC PIPE in feet	10032	$19.10	191611.2
Tee	2	$340.00	680
90 Elbow	5	$209.00	1045
Pipe and Fittings			
Trenching in feet	10032	$0.85	8527.2
Meter	1	$5,075.00	5075
Vault	1	$3,700.00	3700
Re-classifying wells	3	$500.00	1500
Up-grading wells	3	$1,000.00	3000
		Total	**$215,138**
Operating Expenses		**Cost ($/yr)**	
Maintenance		$4,500.00	
Pump Power Wells		$21,204.00	
	Total	**$25,704.00**	

However, Using the South Campus Wells Increases Irrigation Costs

- Due to deeper wells and royalties
- Increases cost by $0.31/1000 gal
- Maximum cost per year $46,872
- Minimum cost per year $33,480
- Average Value per year $40,176

Augmenting with South Campus

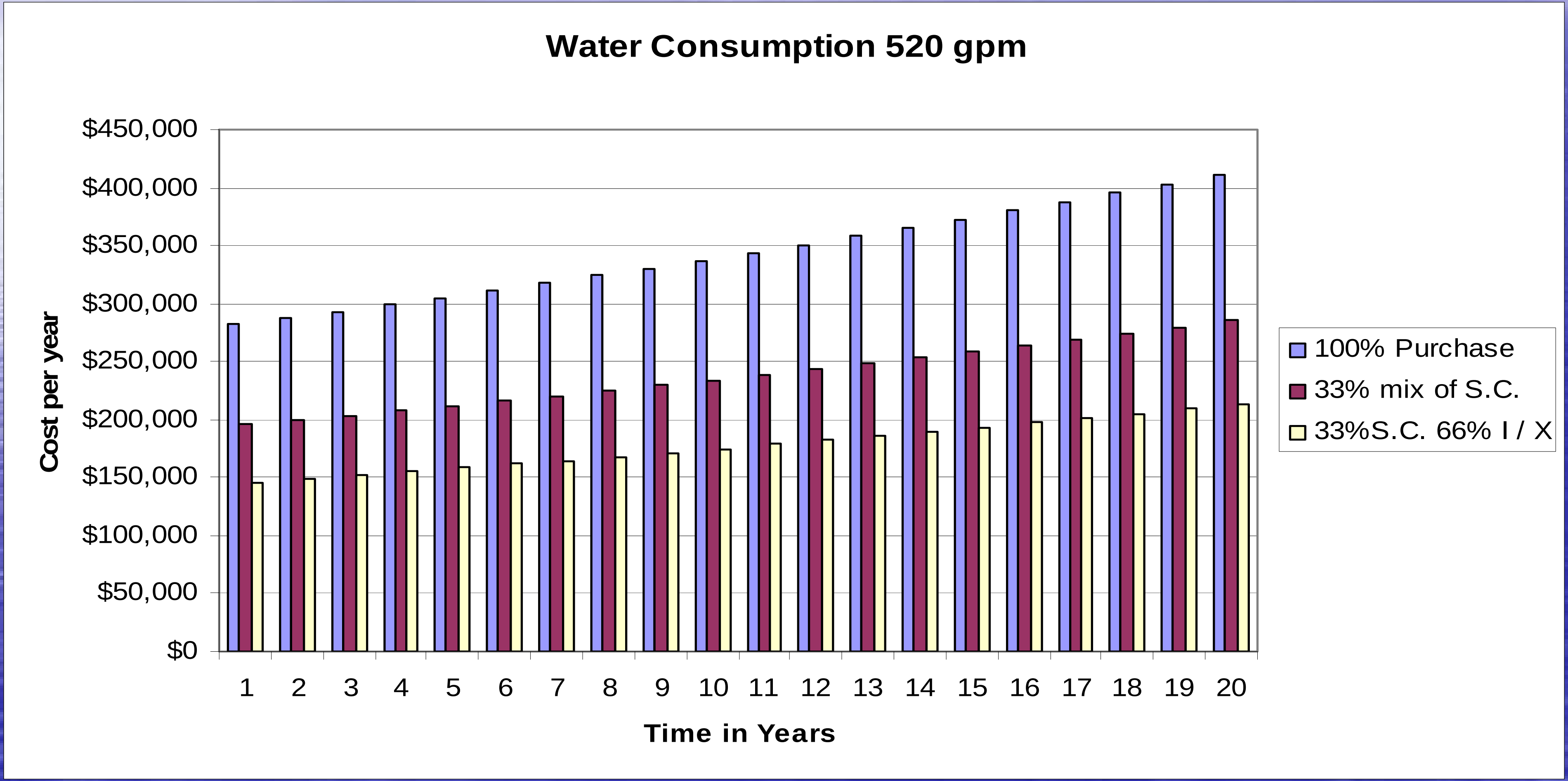
Source	Cost/1000 gallon	Average Cost 50-50%	Average Cost 66-33%
Oklahoma city	$1.030	$0.558	$0.715
Ion Exchange	$0.791	$0.438	$0.556
South Campus Wells 2,10,11	$0.085		

University Water Cost
150 mg/L Hardness

Year	500 gpm purchase Cost	Purchase / S.C 66/33%	Savings per Year	IX / S.C. 66/33%	Savings with IX & S.C.
1	$281,944	$195,523	**$86,421**	$146,300	**$135,644**
5	$305,305	$211,723	**$93,582**	$158,422	**$146,883**
10	$337,247	$233,874	**$103,373**	$174,997	**$162,250**
15	$372,530	$258,342	**$114,188**	$193,305	**$179,225**
20	$411,505	$285,371	**$126,134**	$213,529	**$197,976**

Year	1000 gpm purchase Cost	Purchase / S.C 66/33%	Savings per Year	IX / S.C. 66/33%	Savings with IX & S.C.
1	$541,368	$375,428	**$165,940**	$280,915	**$260,453**
5	$586,224	$406,535	**$179,689**	$348,598	**$323,207**
10	$647,556	$449,067	**$198,488**	$456,577	**$423,320**
15	$715,305	$496,050	**$219,255**	$598,001	**$554,443**
20	$790,141	$547,948	**$242,194**	$783,232	**$726,182**

Water Cost Mixing 33% of South Campus Wells

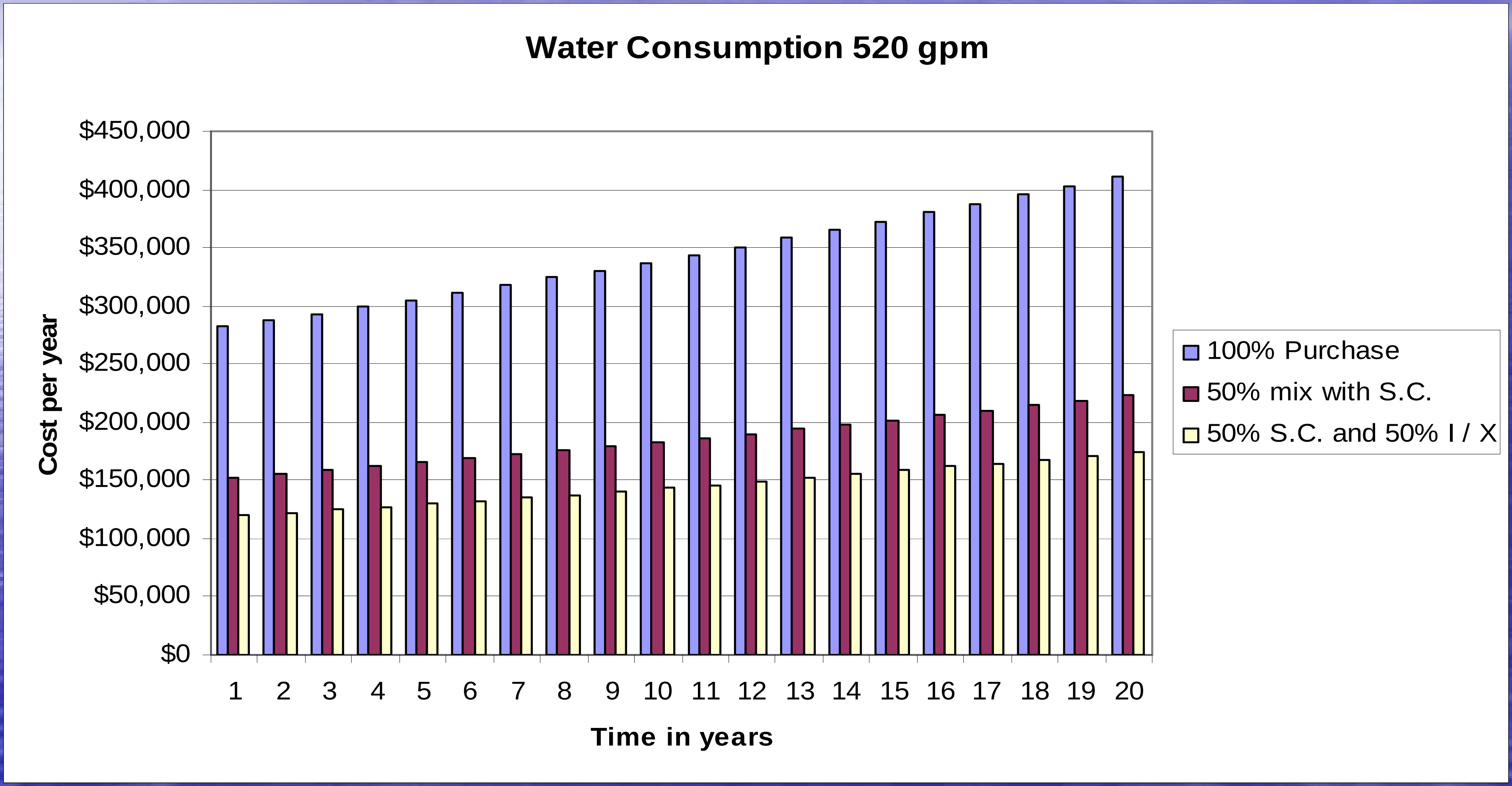


University Water Cost
200 mg/L Hardness

Year	500 gpm purchase Cost	Purchase/ S.C. 50/50%	Savings per Year	IX / S.C. 50/50%	Savings IX / S.C.
1	$281,944	$152,606	**$129,338**	$119,895	**$162,049**
5	$305,305	$165,250	**$140,055**	$129,829	**$175,476**
10	$372,530	$182,539	**$154,708**	$143,412	**$193,835**
15	$372,530	$201,636	**$170,894**	$158,416	**$214,114**
20	$411,505	$222,732	**$188,773**	$174,989	**$236,515**

Year	1000 gpm purchase Cost	Purchase/ S.C. 50/50%	Savings per Year	IX / S.C. 50/50%	Savings IX / S.C.
1	$541,368	$293,022	**$248,346**	$230,213	**$311,155**
5	$586,224	$317,301	**$268,923**	$285,680	**$386,125**
10	$715,305	$350,498	**$297,058**	$374,170	**$505,727**
15	$715,305	$387,167	**$328,137**	$490,068	**$662,376**
20	$790,141	$428,803	**$361,338**	$641,867	**$867,546**

Water Cost Mixing 50% of South Campus Wells



North/South Campus Time Line

Time in Months	**Steps in Process**
3	Initiating Proposal
3	Prepare and Present to Regents
3	Selection for Bid Process
3	Re-Submission to Regents
18	Construction Complete after Regents Approval
30	Total Time

Treating South Campus Water Hardness Directly

- Use Ion Exchange
  - Most widely used method of hardness correction
  - Much cheaper than membrane processes
  - Cationic Exchange Resin
  - Will attract ions such as calcium and magnesium
  - Use of NaCl or KCl for treatment

Treating Water Hardness

- 342 mg/L of hardness
  - 160 mg/L of sodium
  - For every liter (0.26 gallon) of water intake, there would be 160 mg of sodium intake
  - 1 cup of skim milk has about 125 mg sodium
  - Concerns about diet

Options for Water Hardness

Potassium chloride as an alternative

Does not damage vegetation, it is good for human consumption in the treated water

Waste does not have to go to the waste treatment plant.

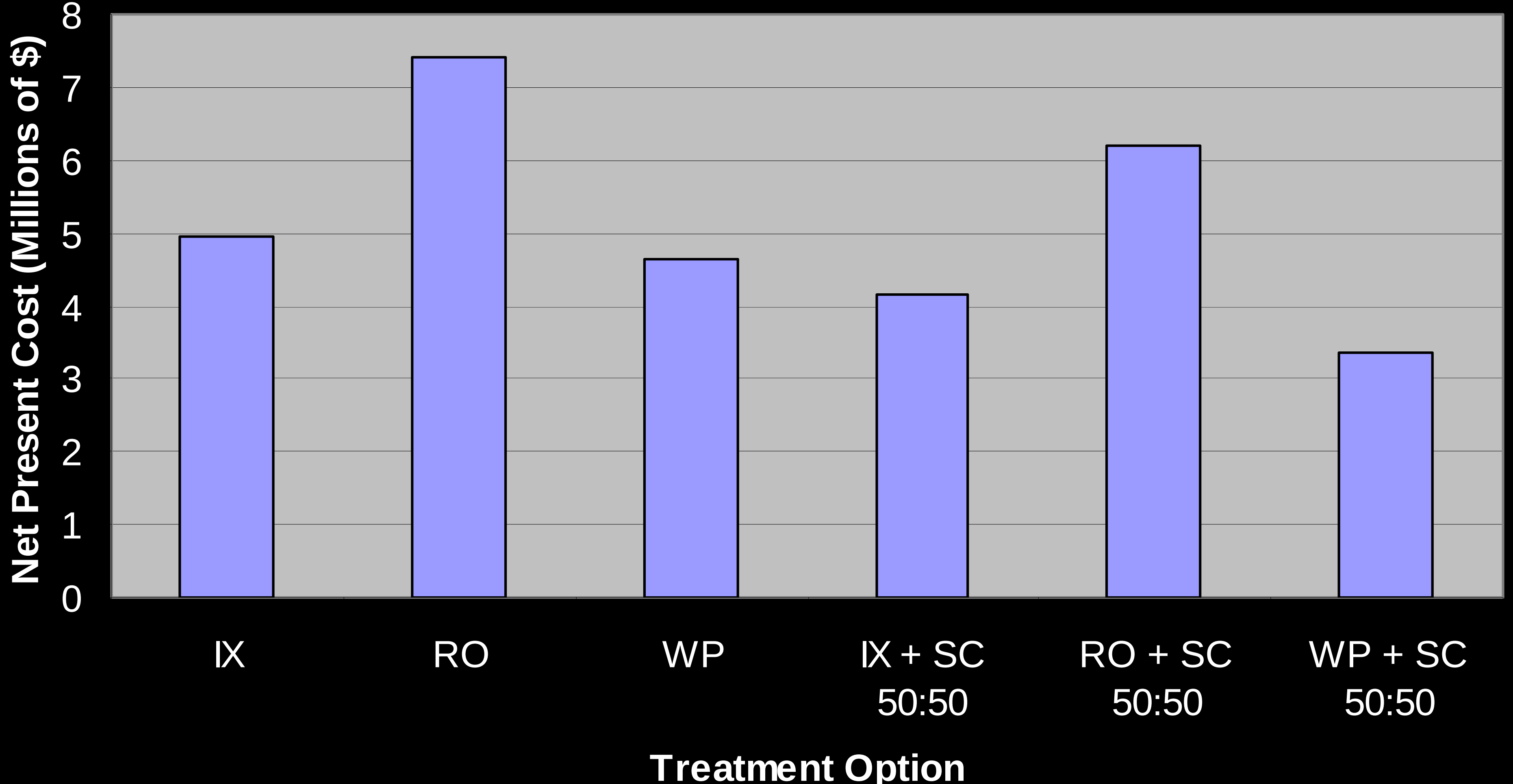
Treating Water Hardness Directly

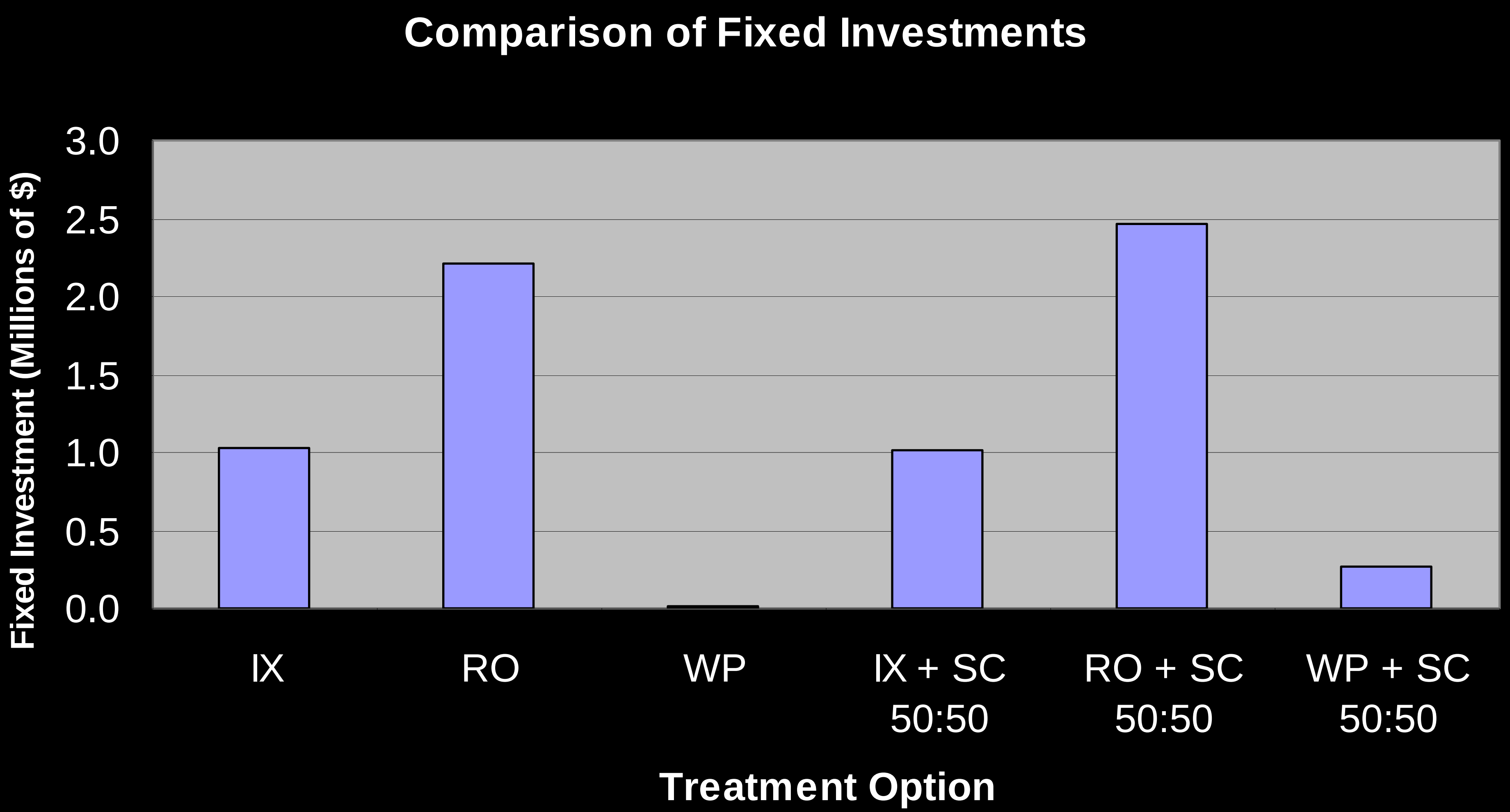
- $11.7M Net Present Cost
- Economically Unattractive

Economics of Water Treatment

- Net Present Worth Treatment Process Comparison
- Fixed Investment Comparison
- Operating Cost Comparison
- Uncertainty Analysis
- Conclusions

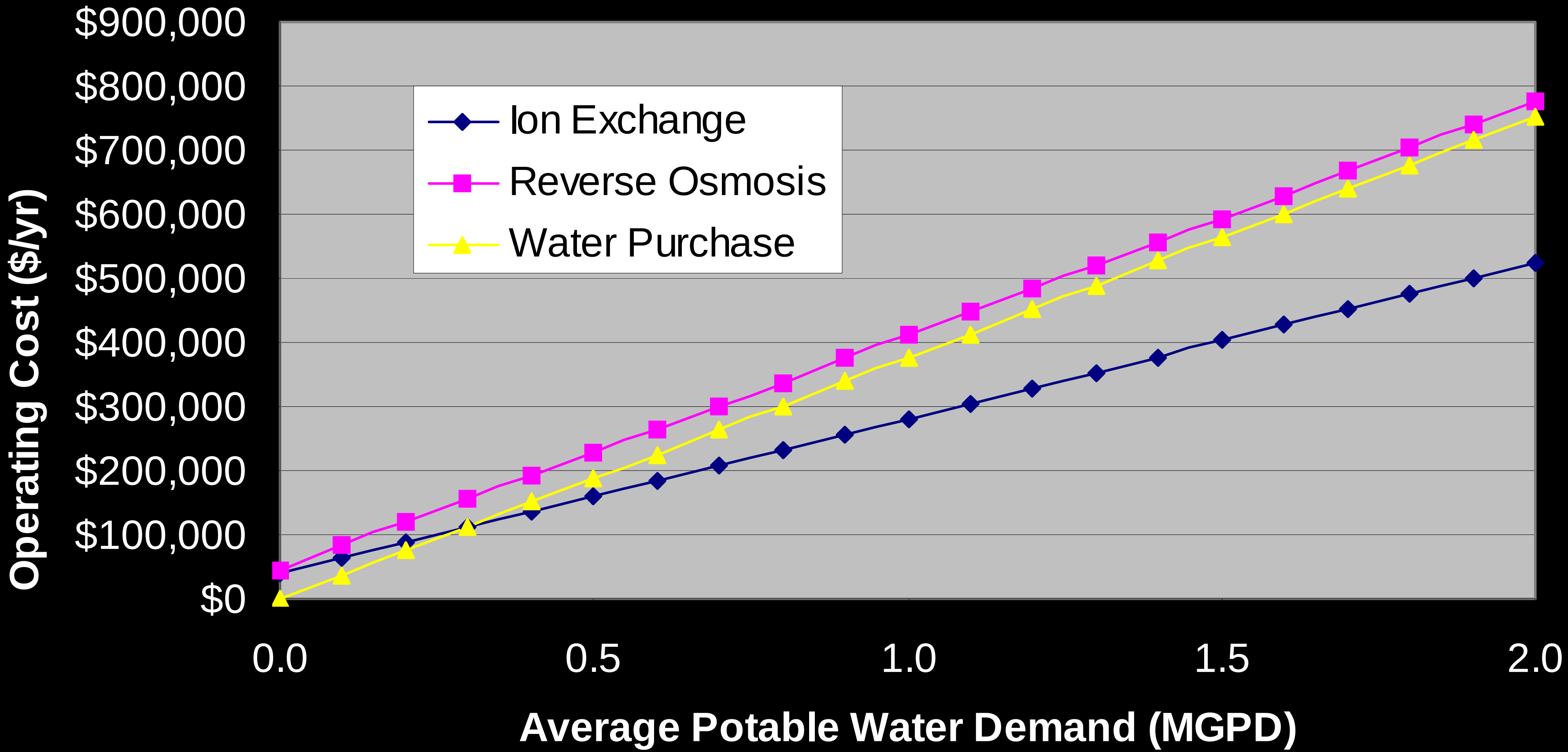
Net Present Costs of Different Treatment Options



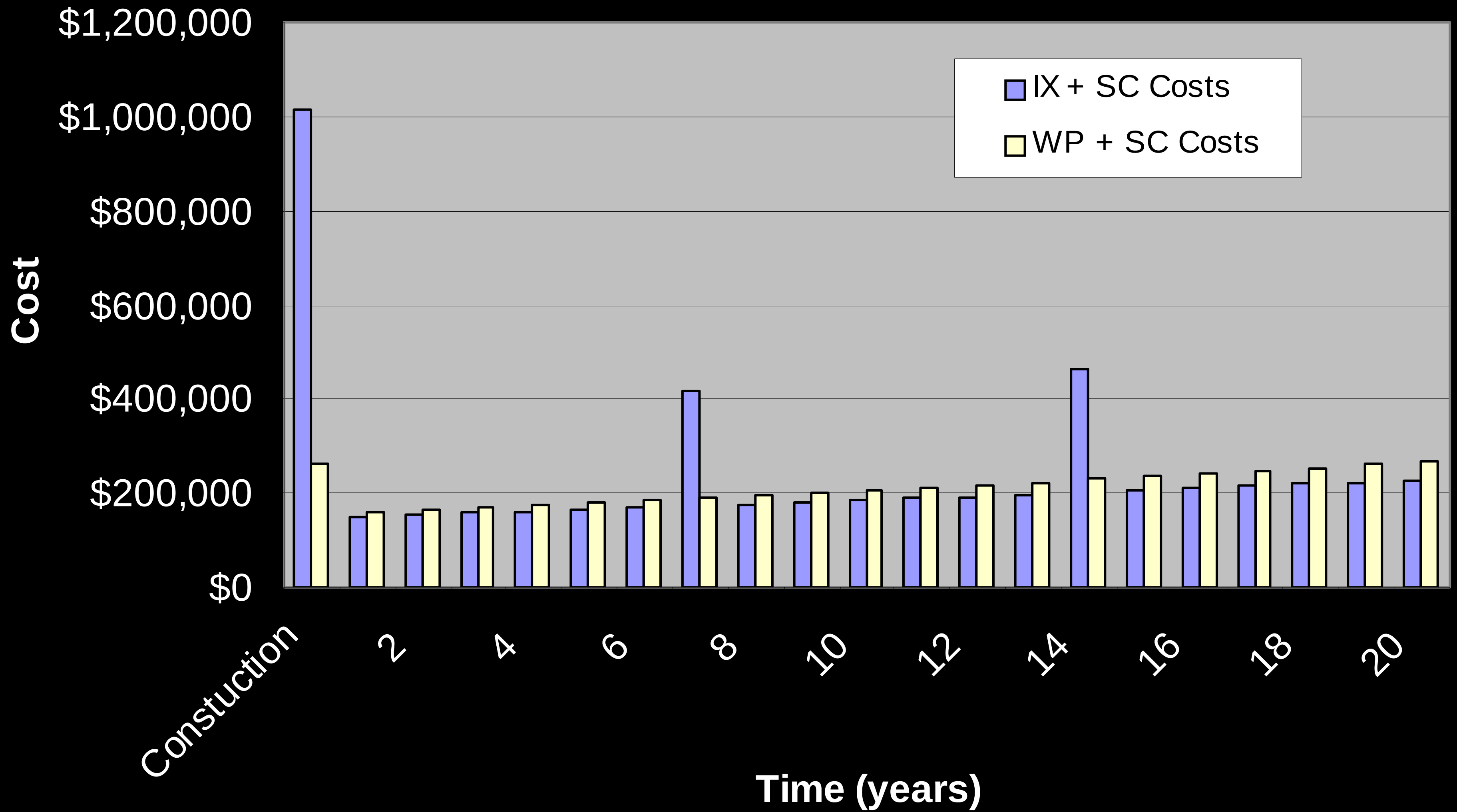


Comparison of Fixed Investments
Fixed Investment (Millions of $)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
IX
RO
WP
IX + SC 50:50
RO + SC 50:50
WP + SC 50:50
Treatment Option

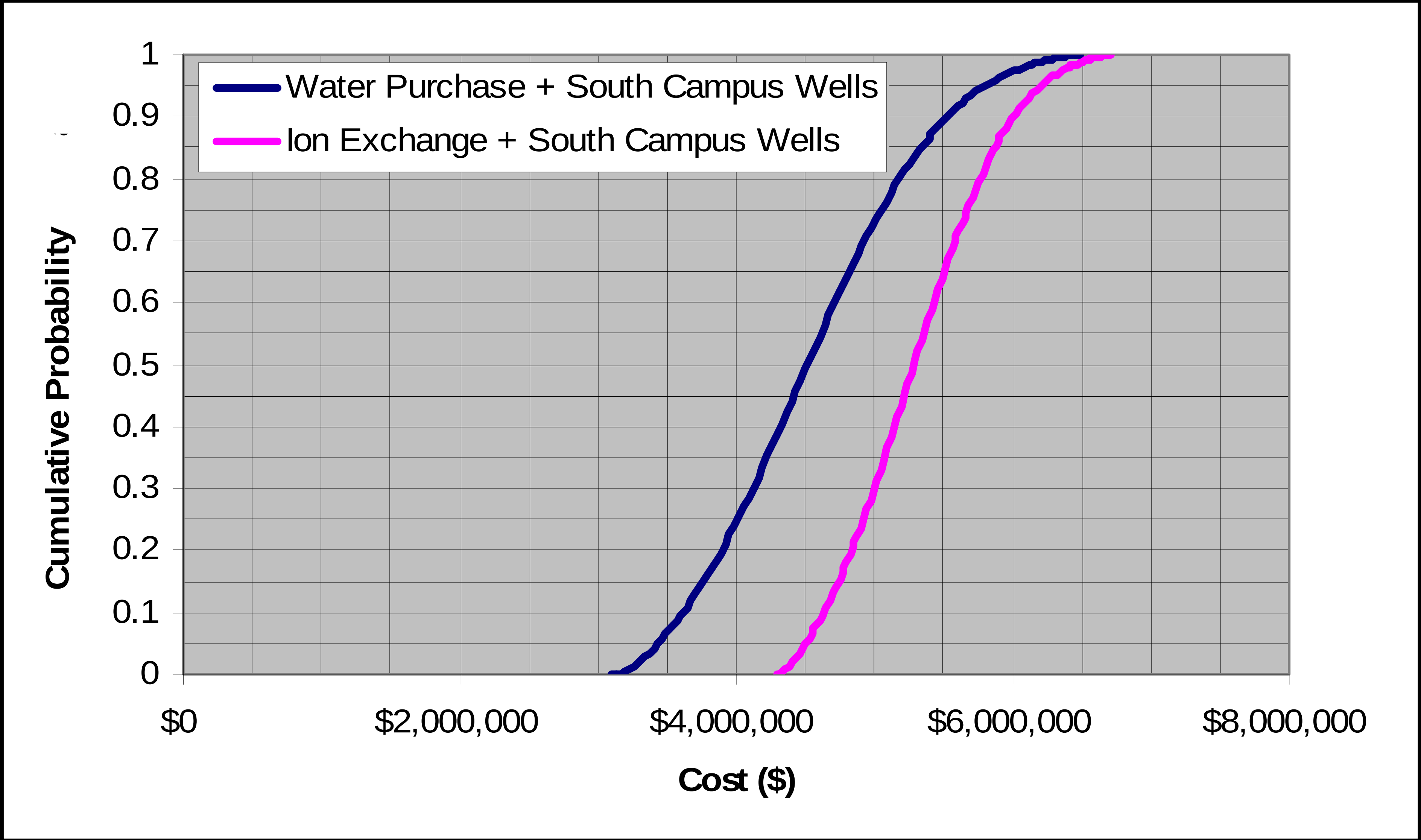
Operating Cost vs. Operating Flow Rate



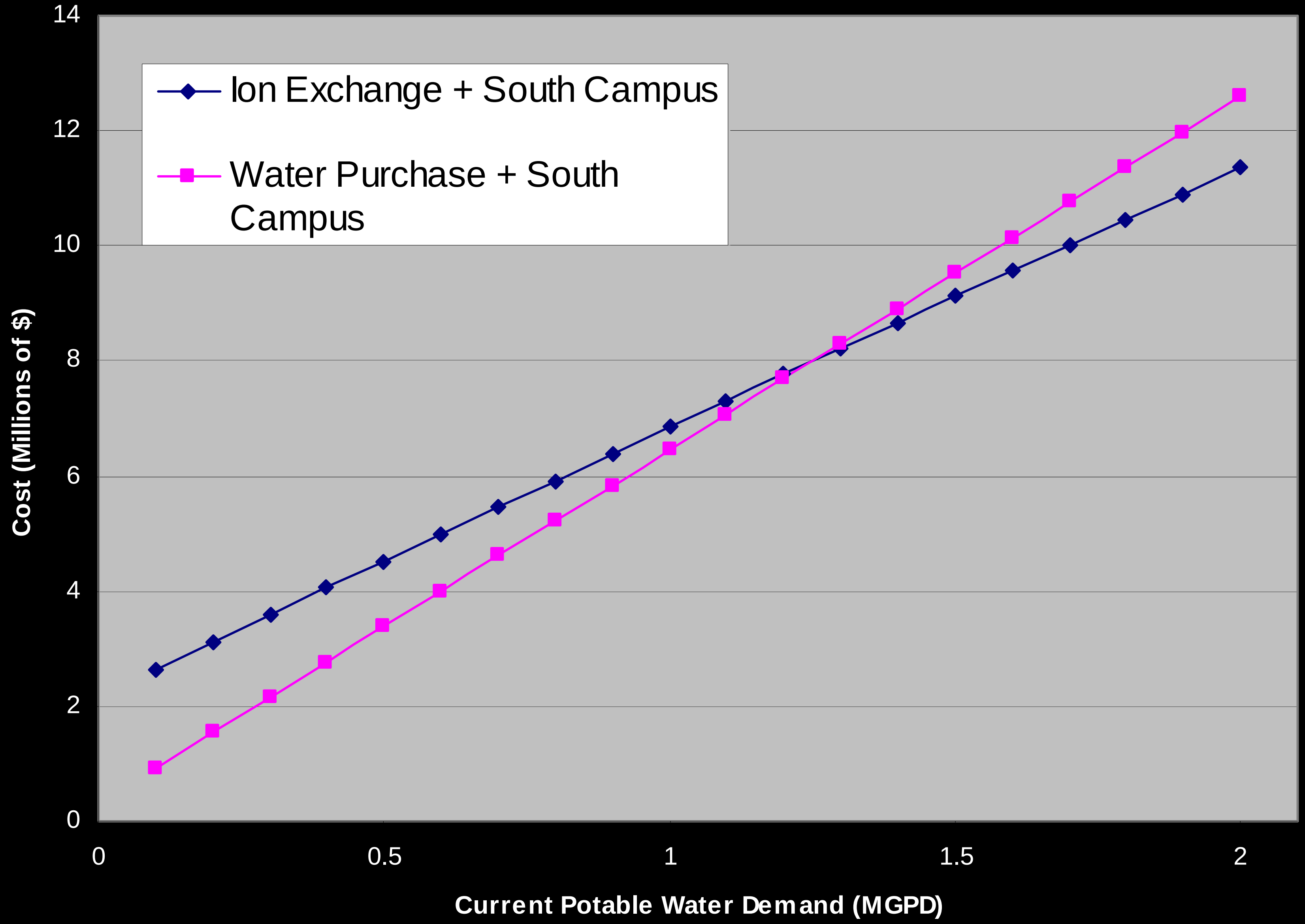
Project Cost Timeline



Uncertainty Analysis



Conclusion Depends on Recommendation, However...

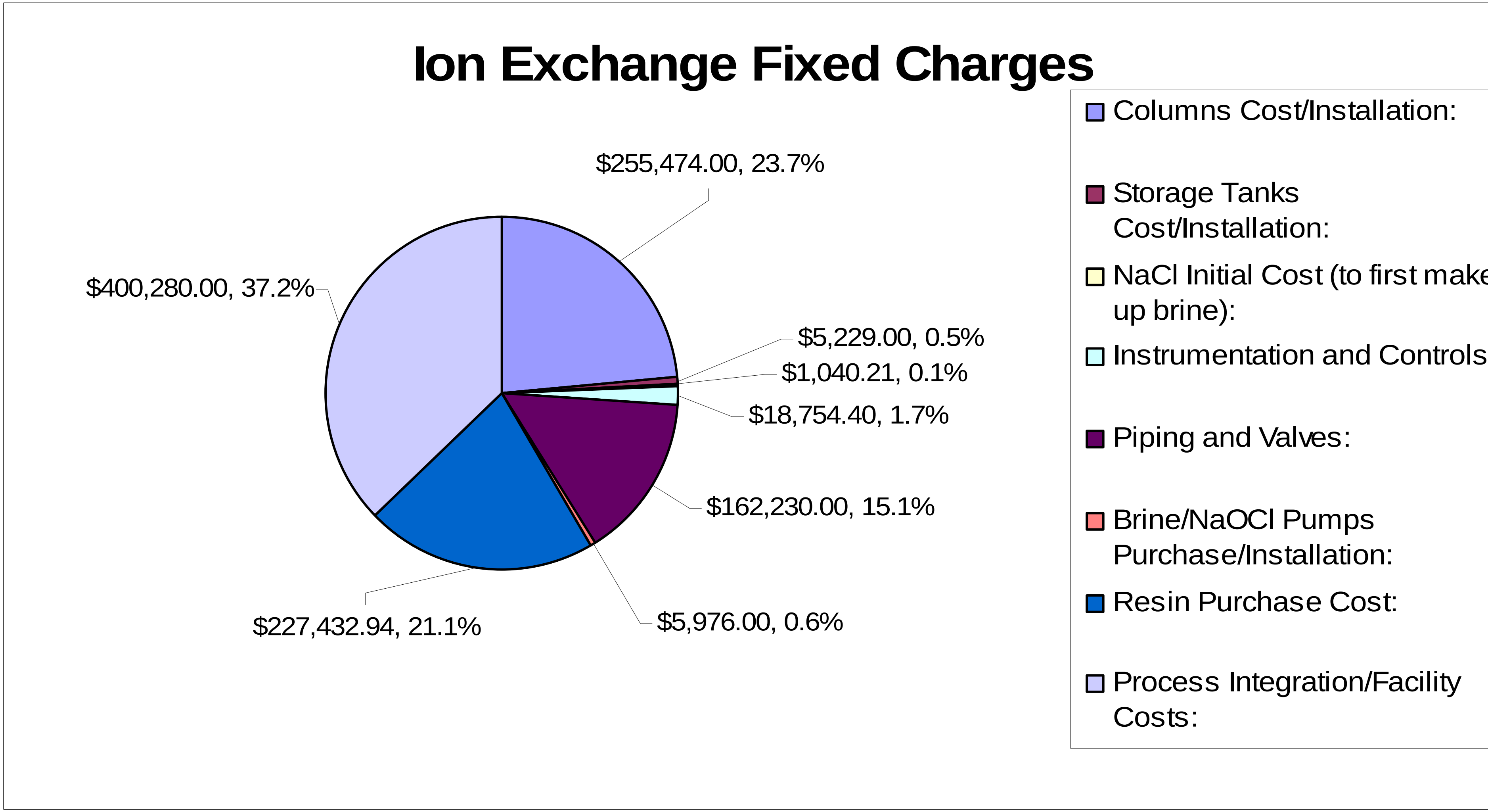


Conclusions

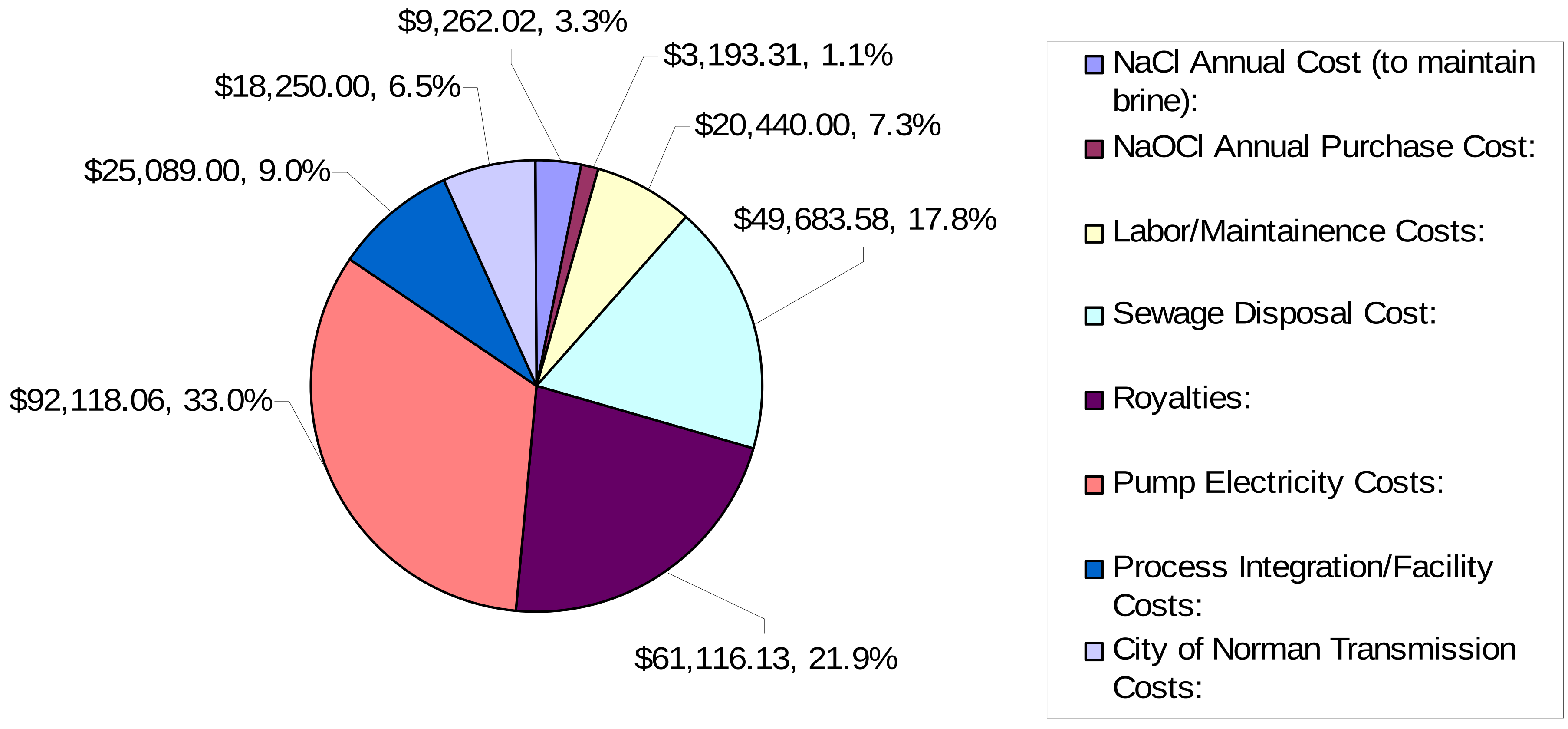
- Blend South Campus Water with Purchased Water at low (<1.25 MGPD) Current Water Demands
- Using Ion Exchange with South Campus Water for higher (>1.25 MGPD) Current Water Demands
- Use 50:50 Blending Ratio to Achieve 200 mg/L Hardness (Moderately Hard)
- Resulting Water will be 5 ppb in Arsenic

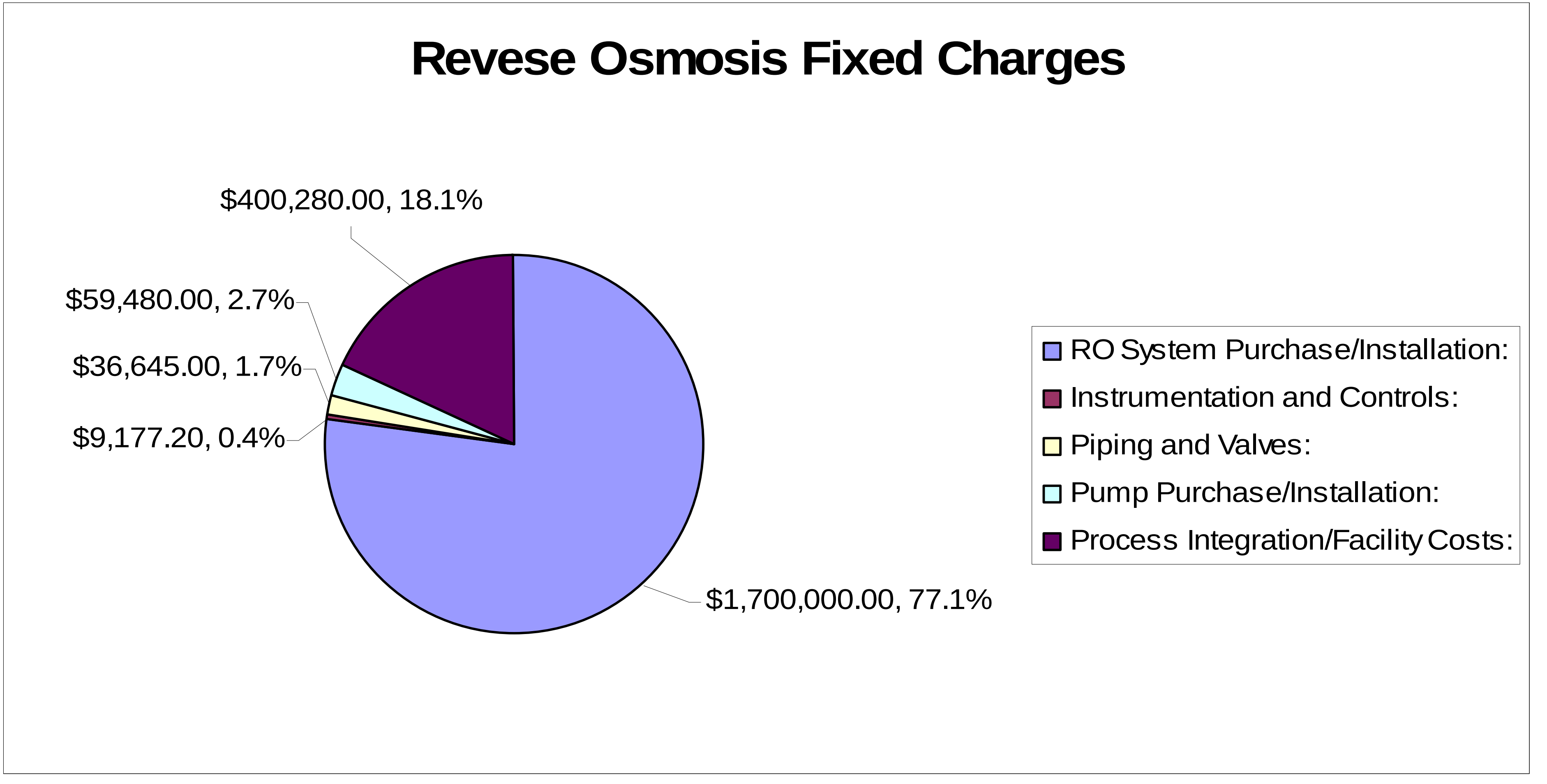
Questions?

Appendix Slides

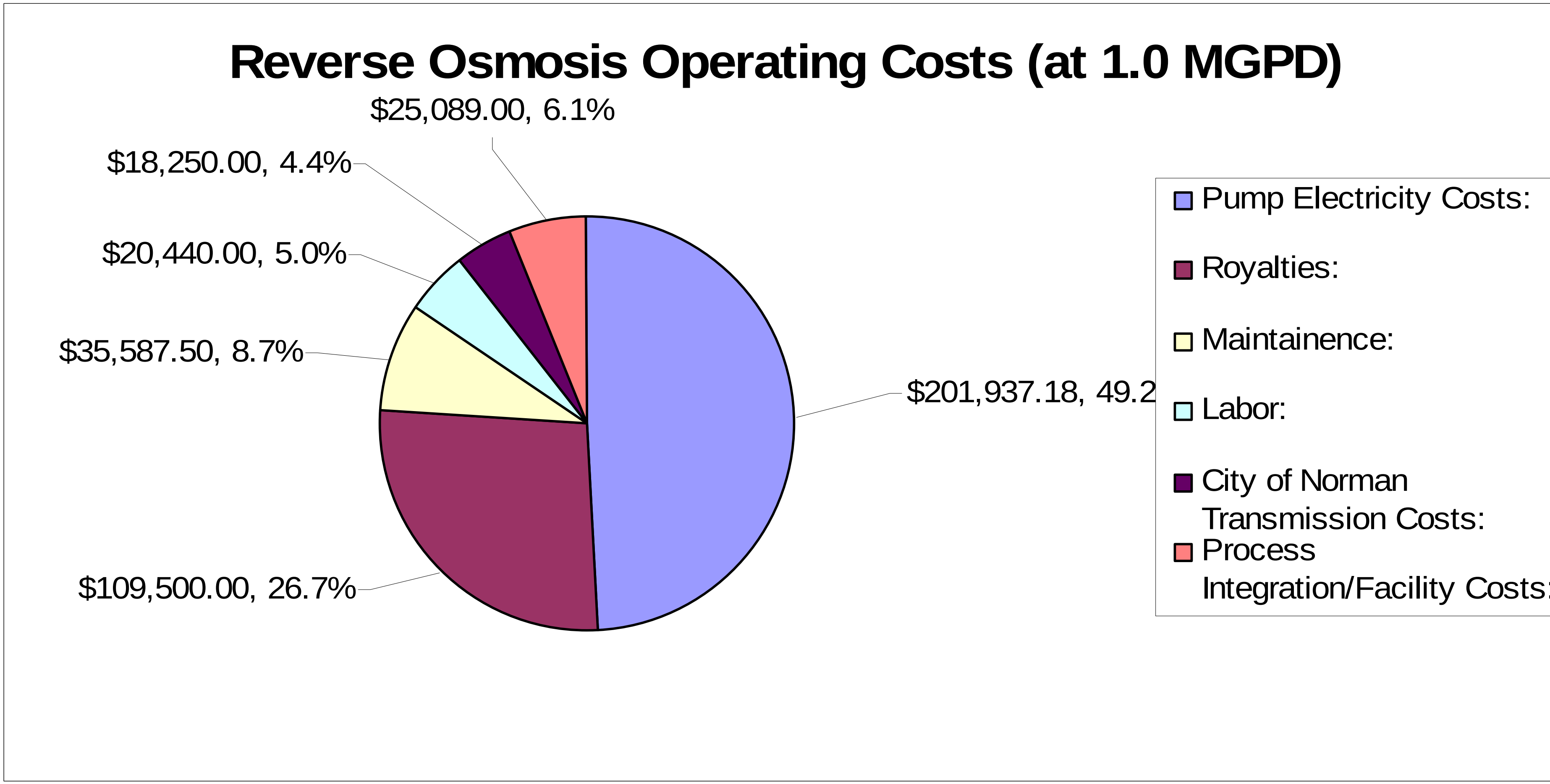

Ion Exchange Fixed Charges
$255,474.00, 23.7%
$400,280.00, 37.2%
$5,229.00, 0.5%
$1,040.21, 0.1%
$18,754.40, 1.7%
$162,230.00, 15.1%
$227,432.94, 21.1%
$5,976.00, 0.6%
Columns Cost/Installation:
Storage Tanks Cost/Installation:
NaCl Initial Cost (to first make up brine):
Instrumentation and Controls:
Piping and Valves:
Brine/NaOCl Pumps Purchase/Installation:
Resin Purchase Cost:
Process Integration/Facility Costs:

Ion Exchange Operating Costs (at 1.0 MGPD)

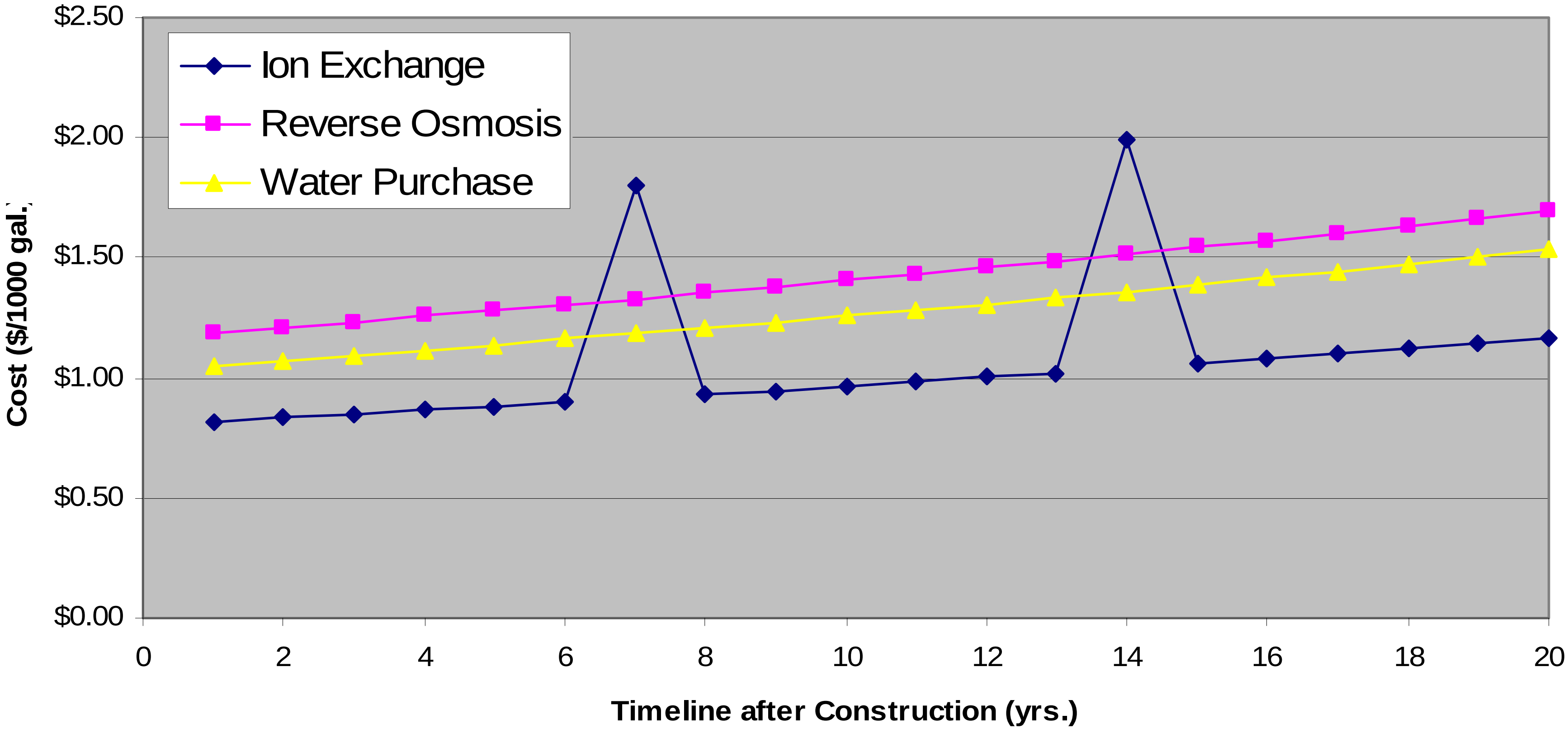




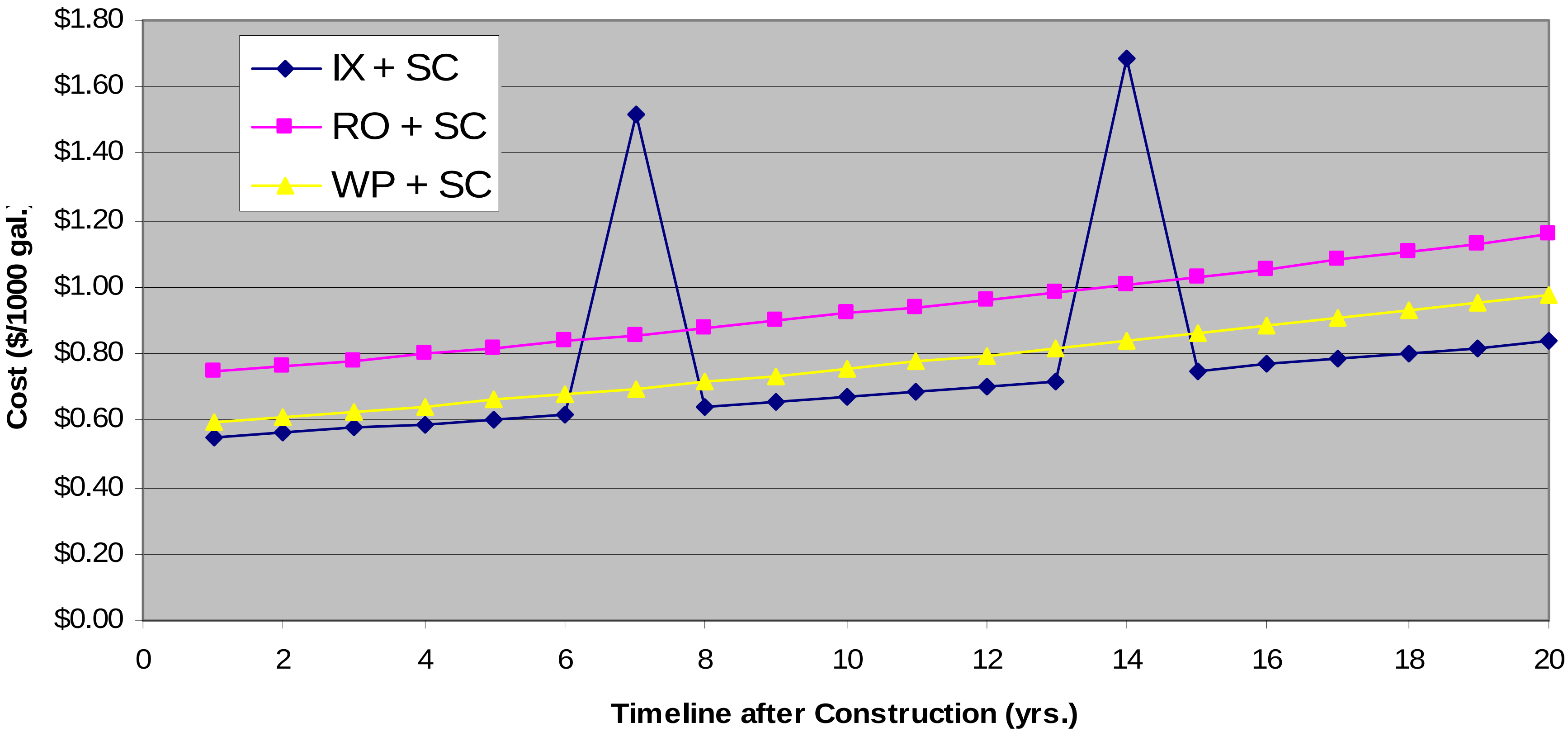
Revese Osmosis Fixed Charges
$400,280.00, 18.1%
$59,480.00, 2.7%
$36,645.00, 1.7%
$9,177.20, 0.4%
$1,700,000.00, 77.1%
RO System Purchase/Installation:
Instrumentation and Controls:
Piping and Valves:
Pump Purchase/Installation:
Process Integration/Facility Costs:


Reverse Osmosis Operating Costs (at 1.0 MGPD)
$25,089.00, 6.1%
$18,250.00, 4.4%
$20,440.00, 5.0%
$35,587.50, 8.7%
$201,937.18, 49.2
$109,500.00, 26.7%
Pump Electricity Costs:
Royalties:
Maintainence:
Labor:
City of Norman Transmission Costs:
Process Integration/Facility Costs:

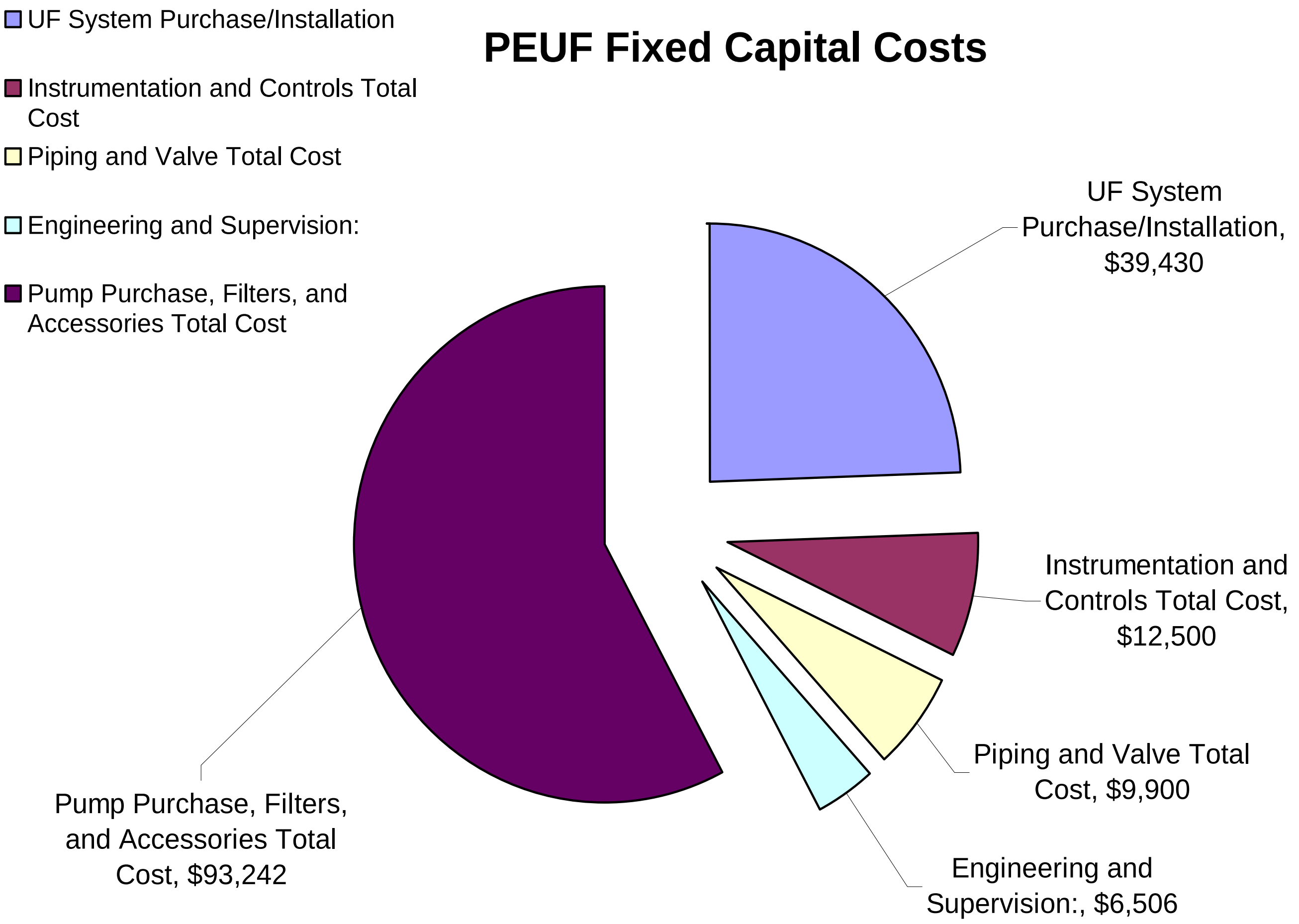
After Investment Water Costs

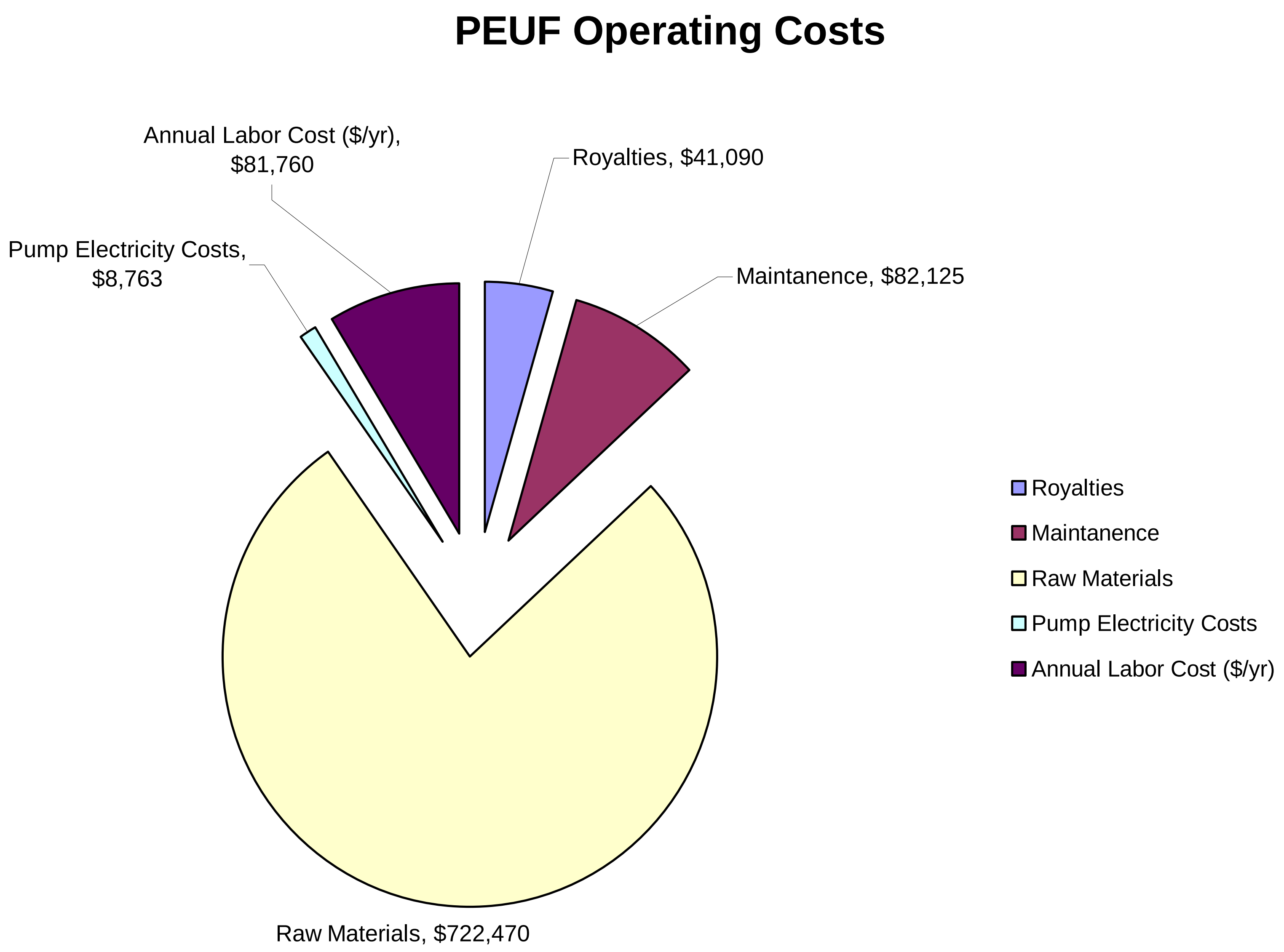


After Investment Water Costs



PEUF Fixed Capital Costs




PEUF Operating Costs
Annual Labor Cost ($/yr), $81,760
Royalties, $41,090
Pump Electricity Costs, $8,763
Maintanence, $82,125
Raw Materials, $722,470
Royalties
Maintanence
Raw Materials
Pump Electricity Costs
Annual Labor Cost ($/yr)