Means to Control Salinity without Desalination Processes in Reuse Projects

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2017 Water Reuse Conference (Pacific Northwest)
May 17, 2017

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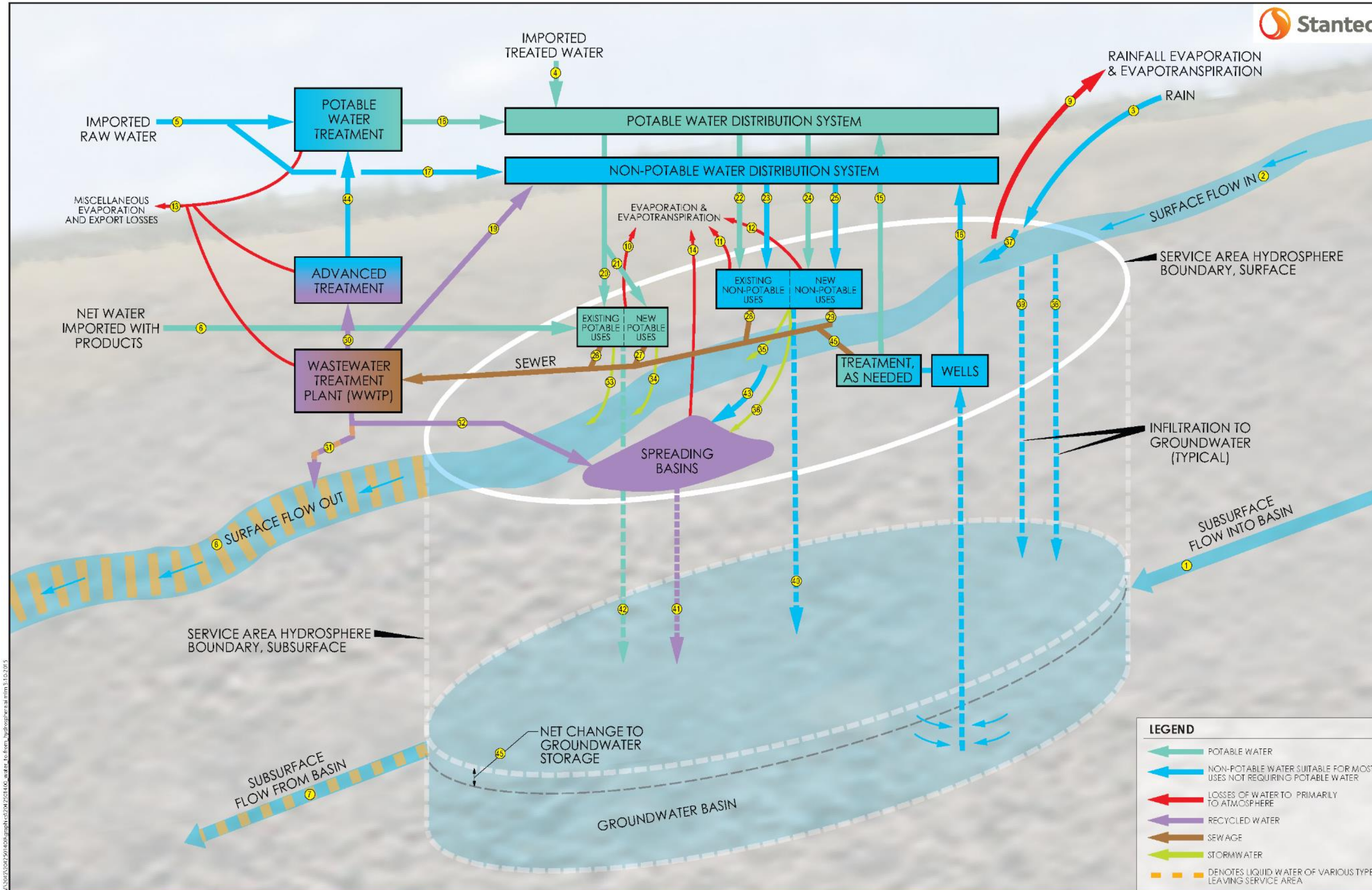
Integrated Water Planning



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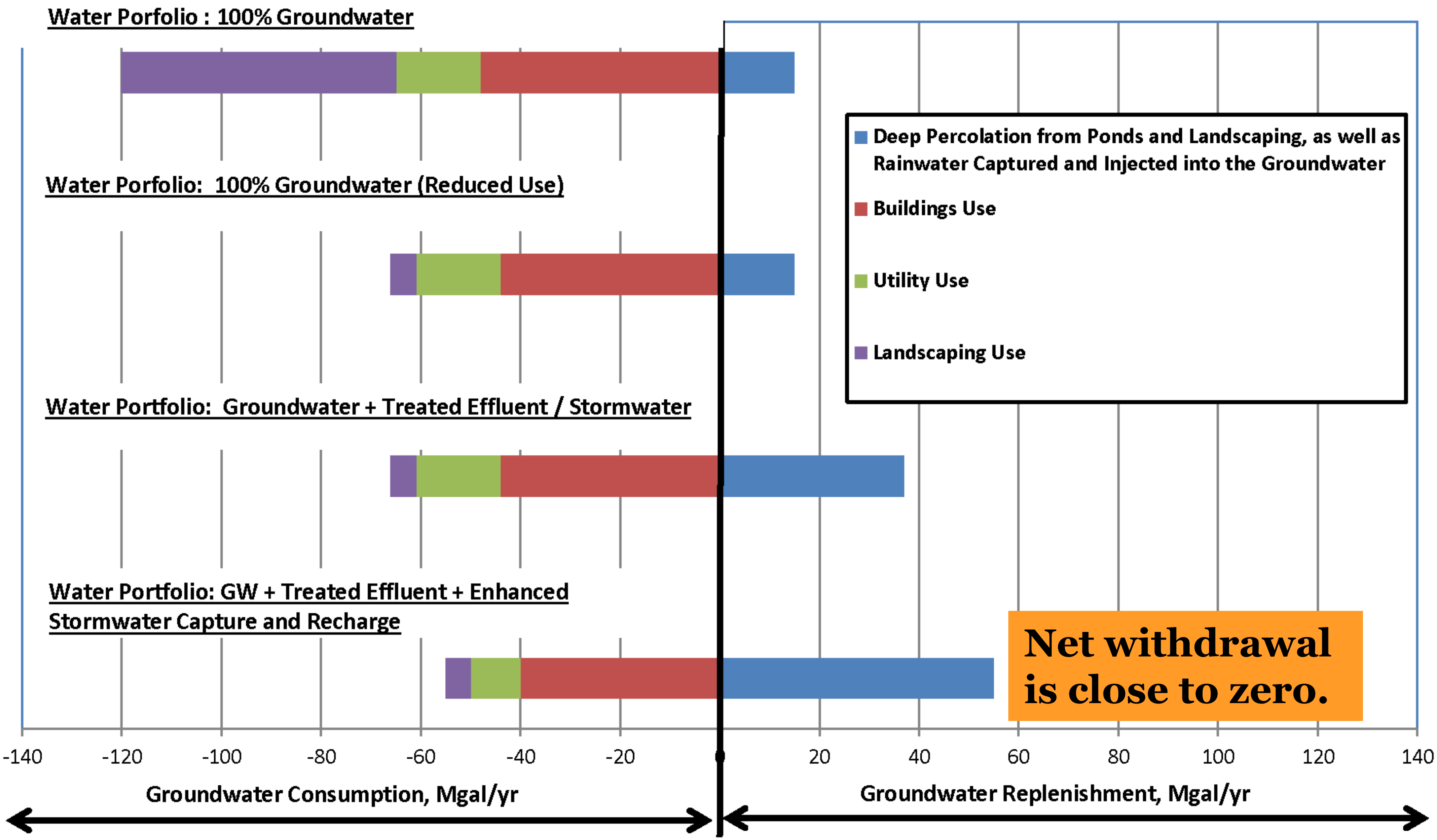
Journey to Water Neutrality / Net-Blue



Water Reuse Projects – Water Quality Concerns

	Pathogens	Chemicals of Emerging Concern (CECs)	Heavy Metals	Salt
Non-potable Reuse (Landscape Irrigation)	Primary concern	No concerns at this time	Site-specific concerns	Site-specific concerns
Potable Reuse	Primary concern	Primary concern	Site-specific concerns	Site-specific concerns

Reuse Projects and Salinity Management

- Most of the inorganic salts are conservative contaminants (e.g., sodium, chloride, boron, etc.)
- Salinity has to be managed in water reuse and efficiency projects

$$\frac{mg}{L}$$

- ➢ Units of mass
- ➢ Liquid volume

- Typically impacts agricultural beneficial use before potable and other uses

Salinity Measurement

	Total Dissolved Solids (TDS)	Electrical Conductivity (EC)	Total Dissolved Fixed Solids (TDFS)	Charge Balance / Electroneutrality
Applicable Scenarios	Natural streams	Online monitoring of natural streams	All matrices	To verify salinity results (QA/QC)
Limitations/ Interferences	Not a good indicator when dissolved organics are present	Not a good indicator when dissolved organic acids are present	Some loss of nitrates and carbonates (typically less than 10%)	More detailed lab work is required
Summary	Need to be verified with TDFS analysis	Need to be verified with TDFS analysis	Recommended for reuse projects	Recommended for QA/QC

Dixon WWTF Project

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ENVISION Certification Silver

QUALITY OF LIFE 13 Credits	LEADERSHIP 10 Credits	RESOURCE ALLOCATION 14 Credits	NATURAL WORLD 15 Credits	CLIMATE AND RISK 8 Credits
Purpose Wellbeing Community	Collaboration Management Planning	Materials Energy Water	Siting Land + Water Biodiversity	Emissions Resilience

Salinity Management

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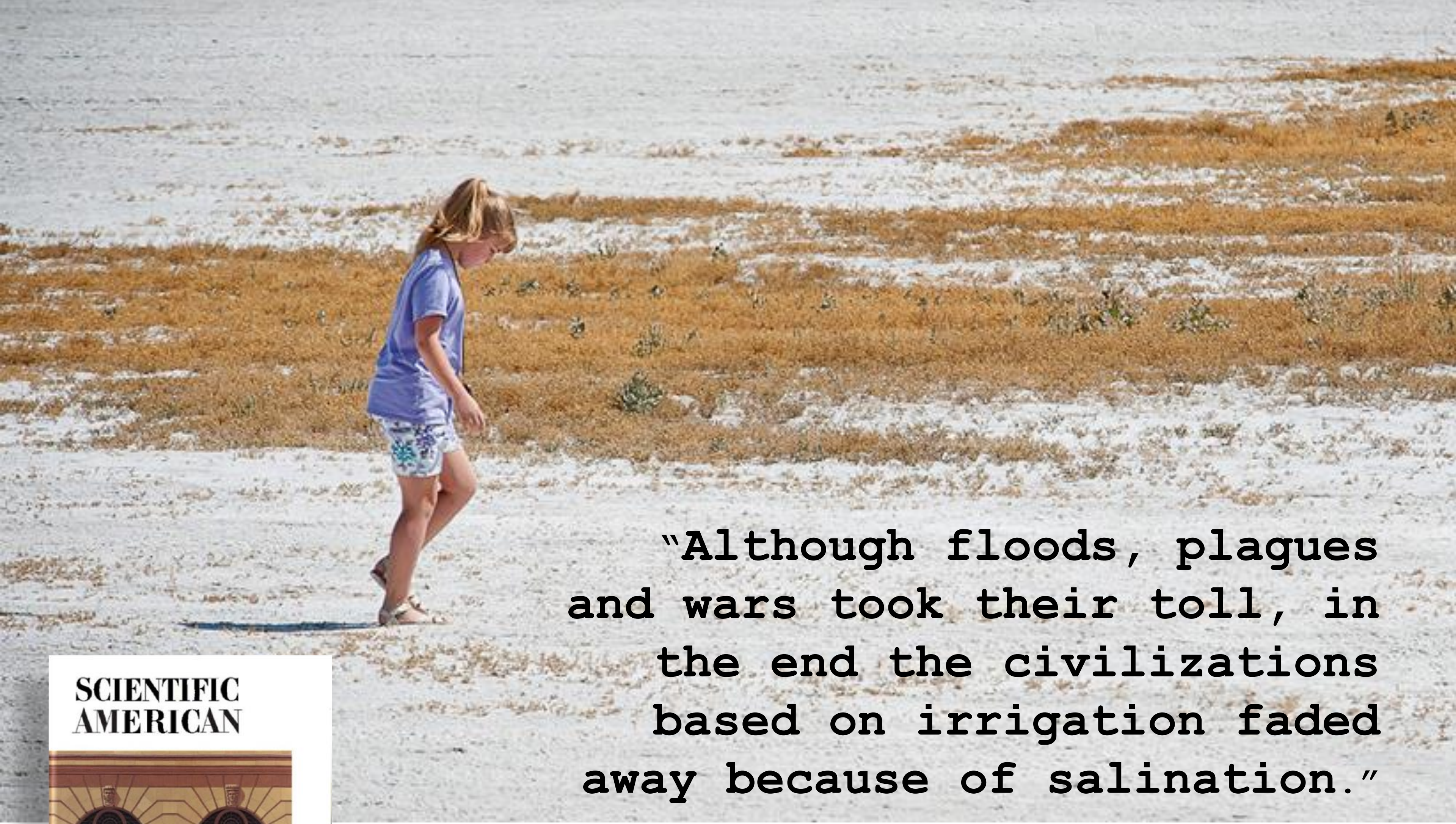
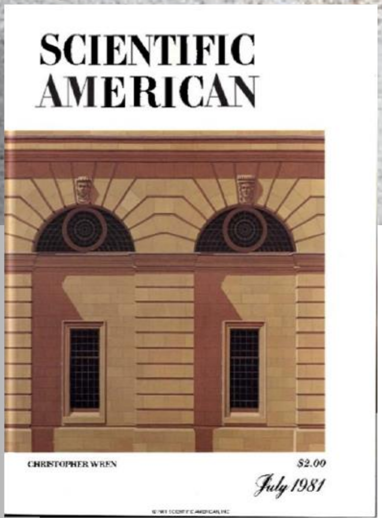
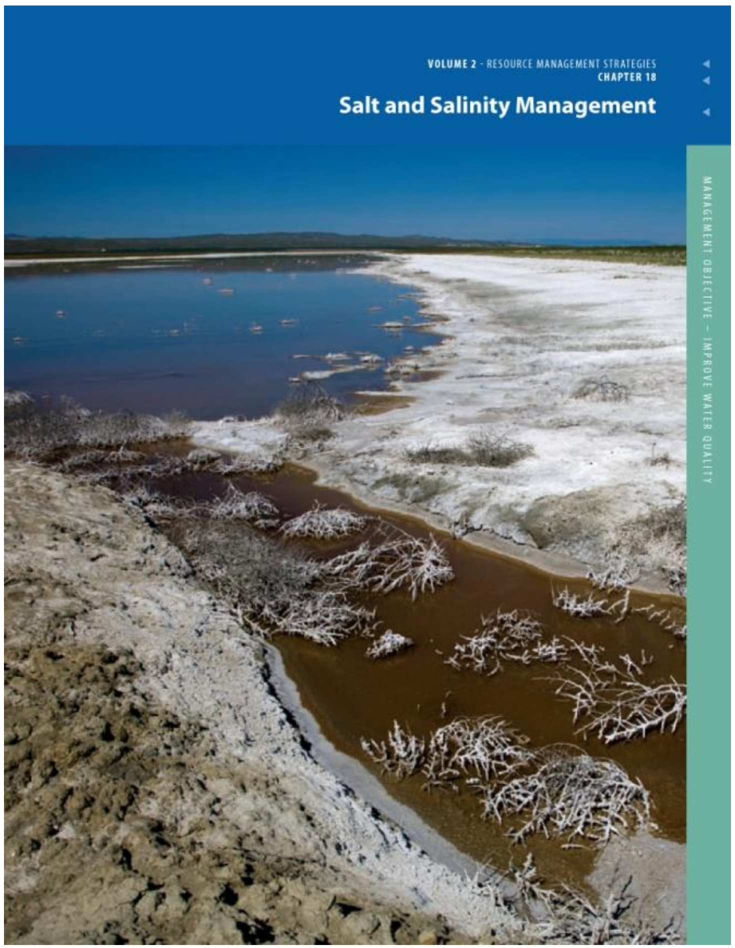


“Although floods, plagues and wars took their toll, in the end the civilizations based on irrigation faded away because of salination.”



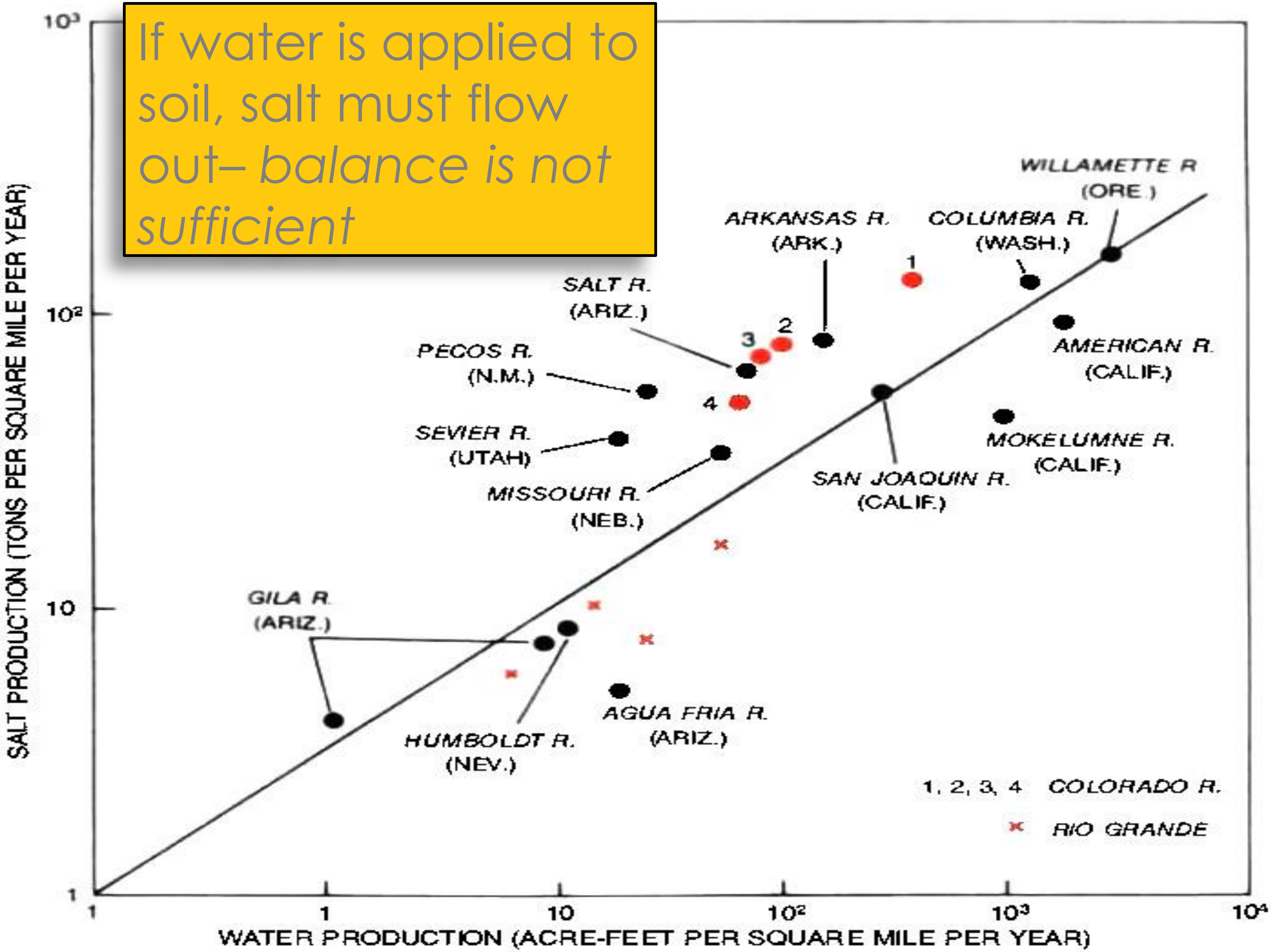
Arthur Pillsbury, 1981,
State Water Project Designer

California Water Plan 2009



"As California uses water more efficiently, supplies will tend to become more saline unless practices and policies are intentionally implemented to maintain salinity at acceptable concentrations."

If water is applied to soil, salt must flow out– *balance is not sufficient*



City of Dixon Salinity Compliance Case Study

Population: ~19,000
(~5,000 Households)
Wastewater Flow: ~1.2 MGD

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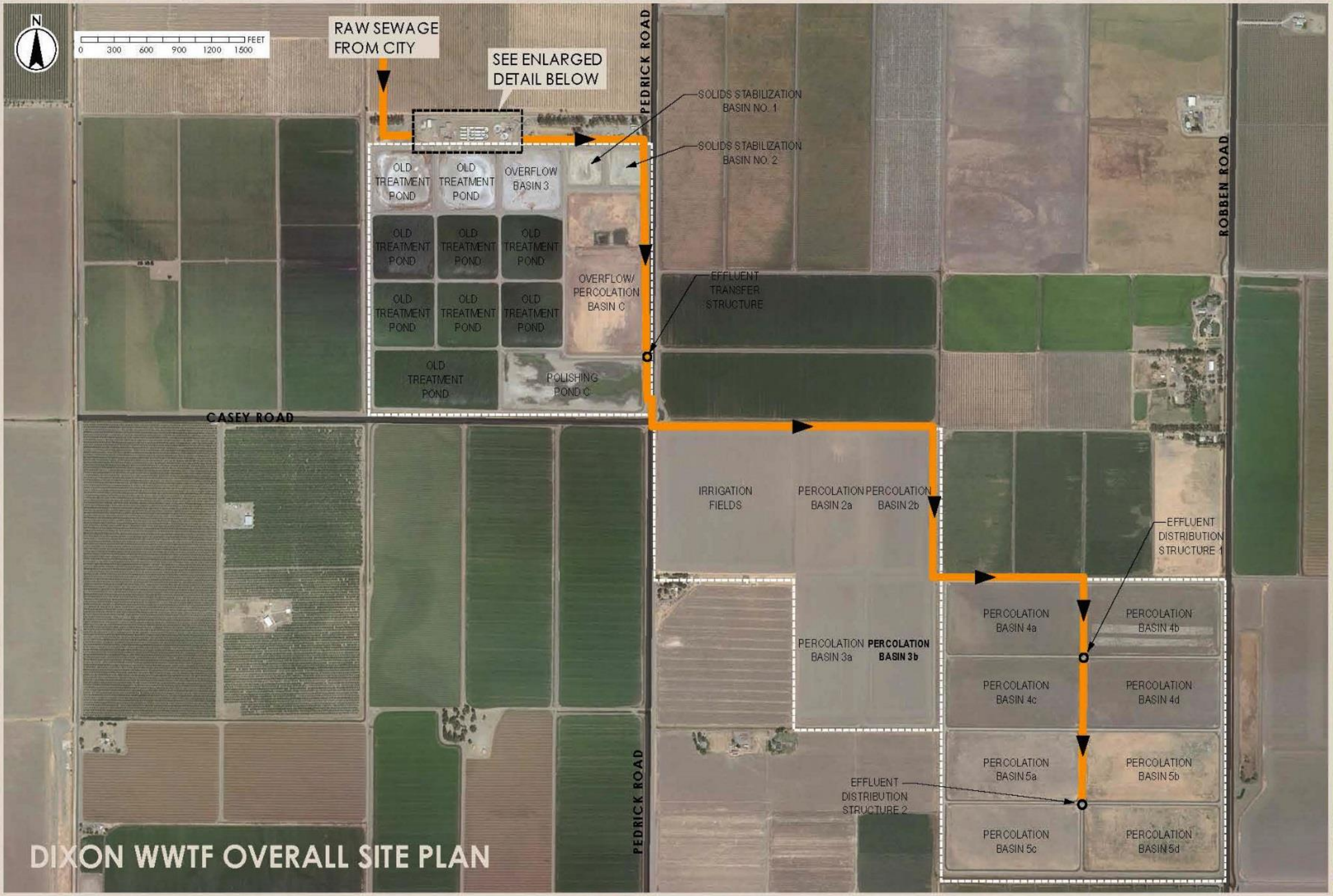

N
0 300 600 900 1200 1500 FEET
RAW SEWAGE FROM CITY
SEE ENLARGED DETAIL BELOW
PEDRICK ROAD
SOLIDS STABILIZATION BASIN NO. 1
SOLIDS STABILIZATION BASIN NO. 2
ROBBEN ROAD
OLD TREATMENT POND
OLD TREATMENT POND
OVERFLOW BASIN 3
OLD TREATMENT POND
OLD TREATMENT POND
OLD TREATMENT POND
OLD TREATMENT POND
OLD TREATMENT POND
OLD TREATMENT POND
OVERFLOW/ PERCOLATION BASIN C
EFFLUENT TRANSFER STRUCTURE
OLD TREATMENT POND
POLISHING POND C
CASEY ROAD
IRRIGATION FIELDS
PERCOLATION BASIN 2a
PERCOLATION BASIN 2b
EFFLUENT DISTRIBUTION STRUCTURE 1
PERCOLATION BASIN 3a
PERCOLATION BASIN 3b
PERCOLATION BASIN 4a
PERCOLATION BASIN 4b
PERCOLATION BASIN 4c
PERCOLATION BASIN 4d
PERCOLATION BASIN 5a
PERCOLATION BASIN 5b
EFFLUENT DISTRIBUTION STRUCTURE 2
PERCOLATION BASIN 5c
PERCOLATION BASIN 5d
PEDRICK ROAD
DIXON WWTF OVERALL SITE PLAN

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Permit requirement - Goal

- **Manage salinity in the local groundwater resource to protect beneficial uses -**
  - Drinking Water
  - Agricultural Use

- **Concentration is what matters –**

$$\frac{mg}{L}$$

- ➢ Units of mass
- ➢ Liquid volume

- **Resolution 68-16, no degradation of high quality waters -**
  - Unless in the interests of the people of California
  - BPTC required

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Permit Compliance Approach

- Source control
  - Industrial BMPs
  - Softener exchange
- Background characterization
- Beneficial use determination
- Site-specific limits development
- Facility planning and alternative analysis
  - Best Practicable Treatment and Control (BPTC)
- Implementation

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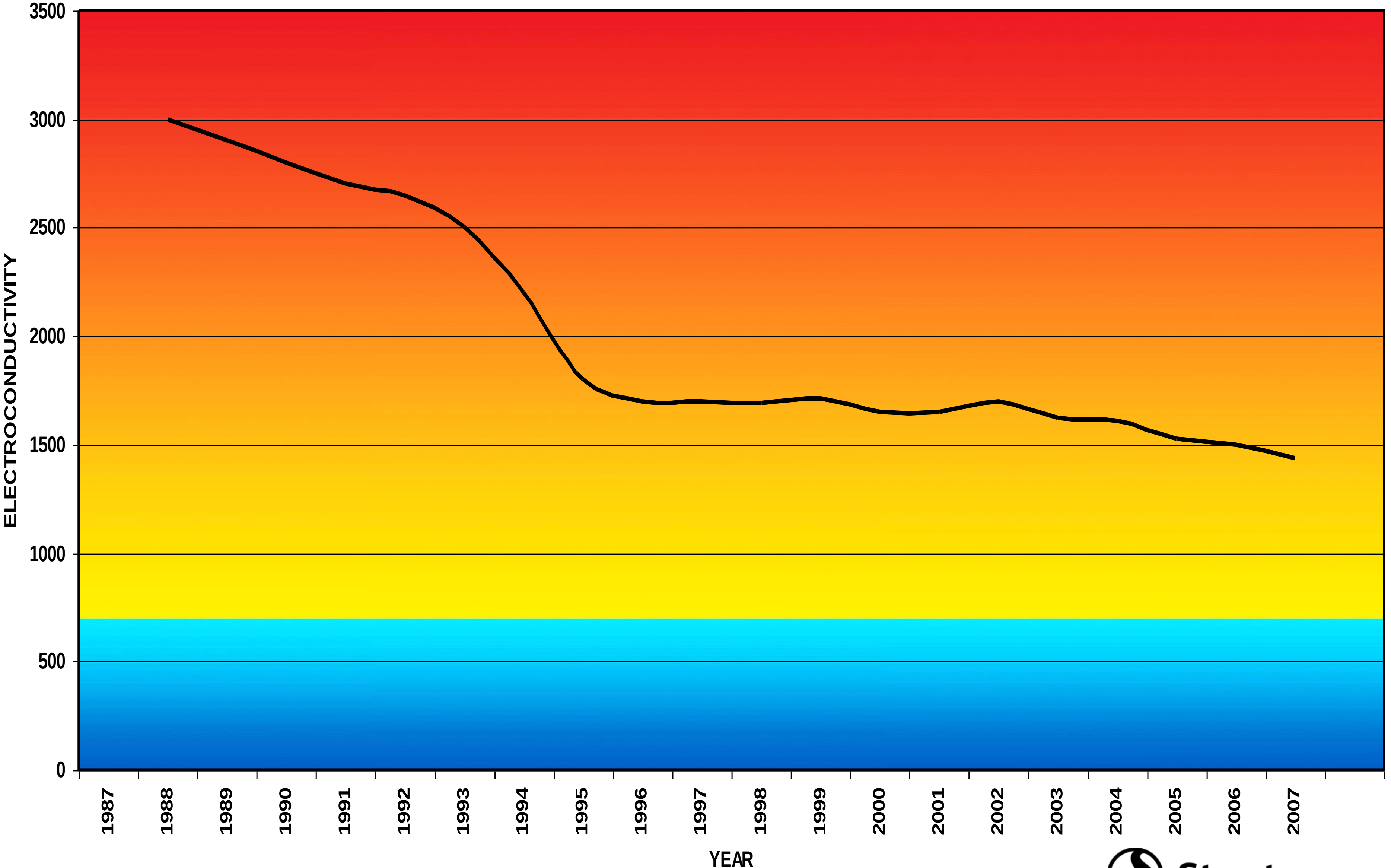
Source Control – Implementation of Industrial BMP



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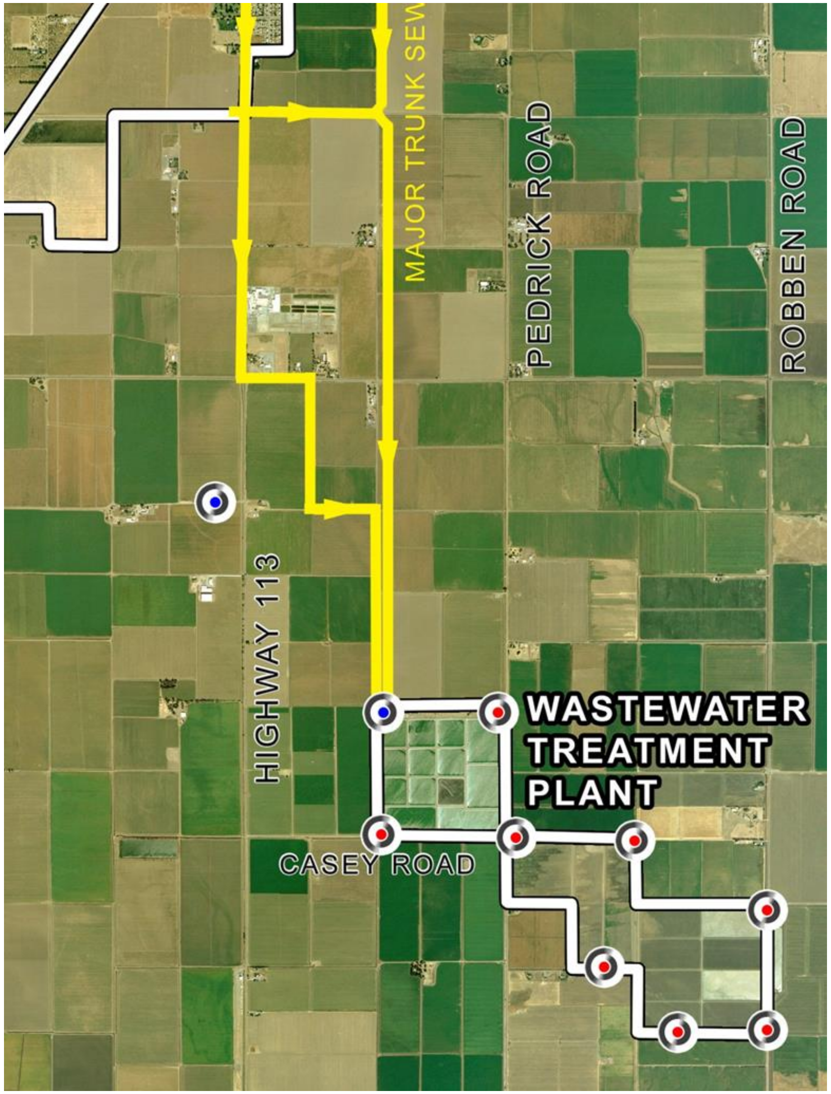
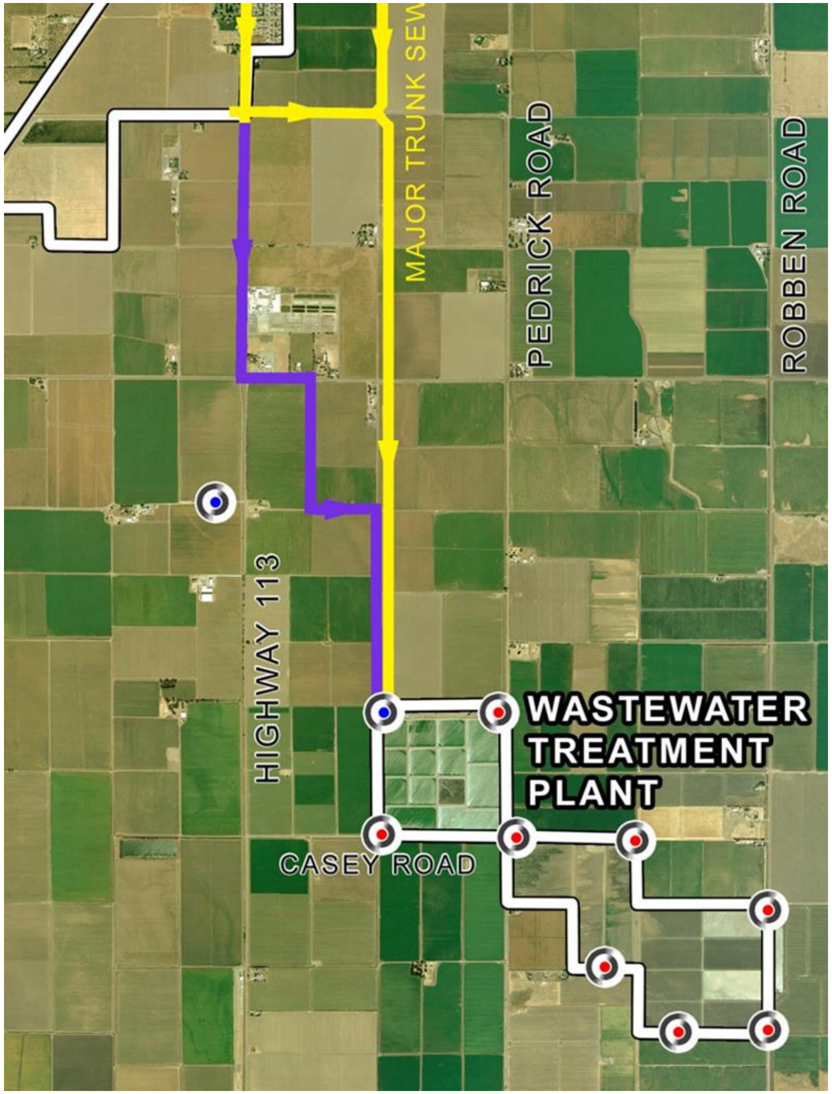
Source Control – Infiltration via Sewer Pipe





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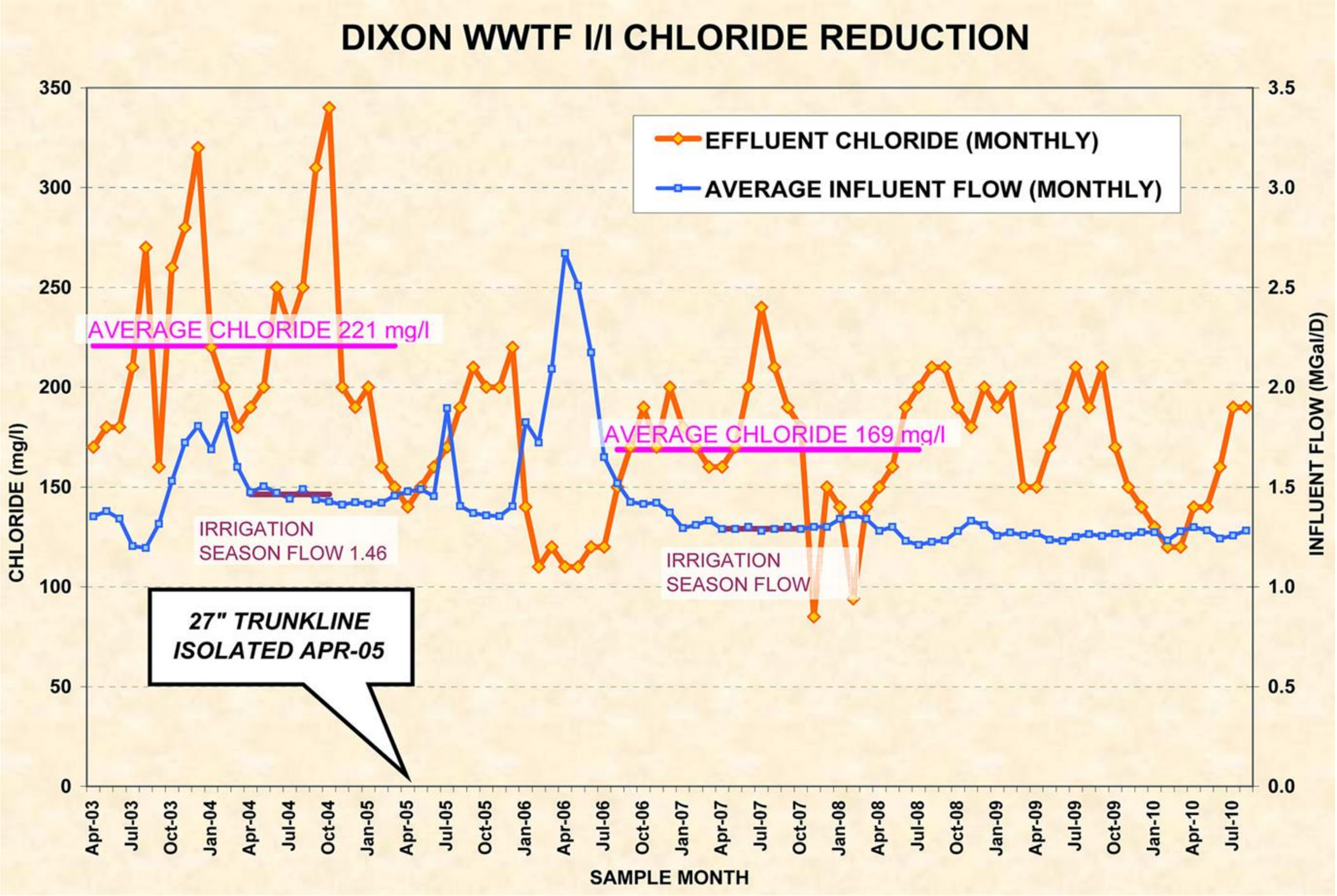
Source Control – Infiltration via Sewer Pipe



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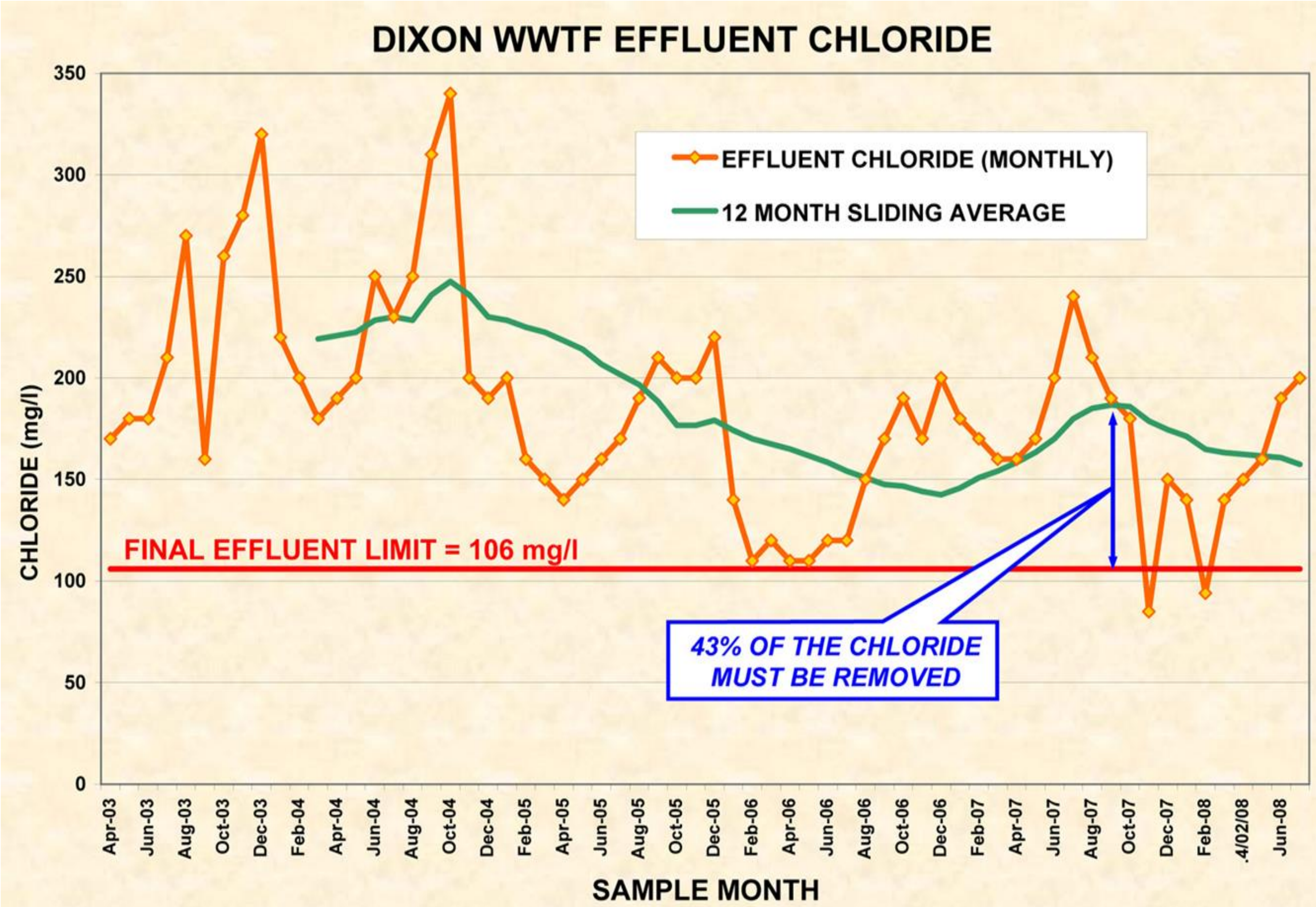
DIXON WWTF EFFLUENT CHLORIDE
EFFLUENT CHLORIDE (MONTHLY)
12 MONTH SLIDING AVERAGE
FINAL EFFLUENT LIMIT = 106 mg/l
43% OF THE CHLORIDE MUST BE REMOVED
CHLORIDE (mg/l)
SAMPLE MONTH
0
50
100
150
200
250
300
350
Apr-03
Jun-03
Aug-03
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
Feb-06
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Aug-06
Oct-06
Dec-06
Feb-07
Apr-07
Jun-07
Aug-07
Oct-07
Dec-07
Feb-08
.4/02/08
Jun-08

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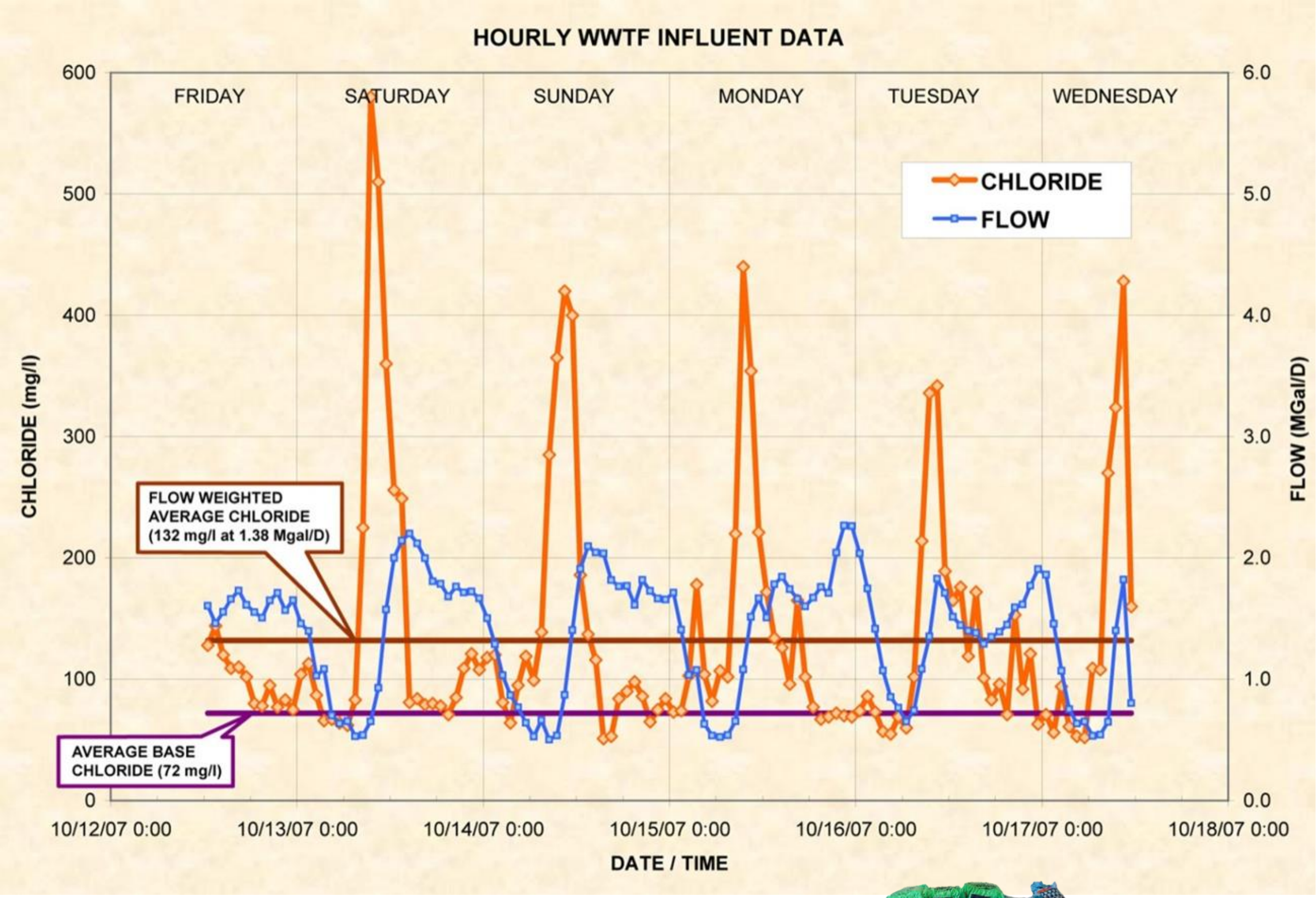
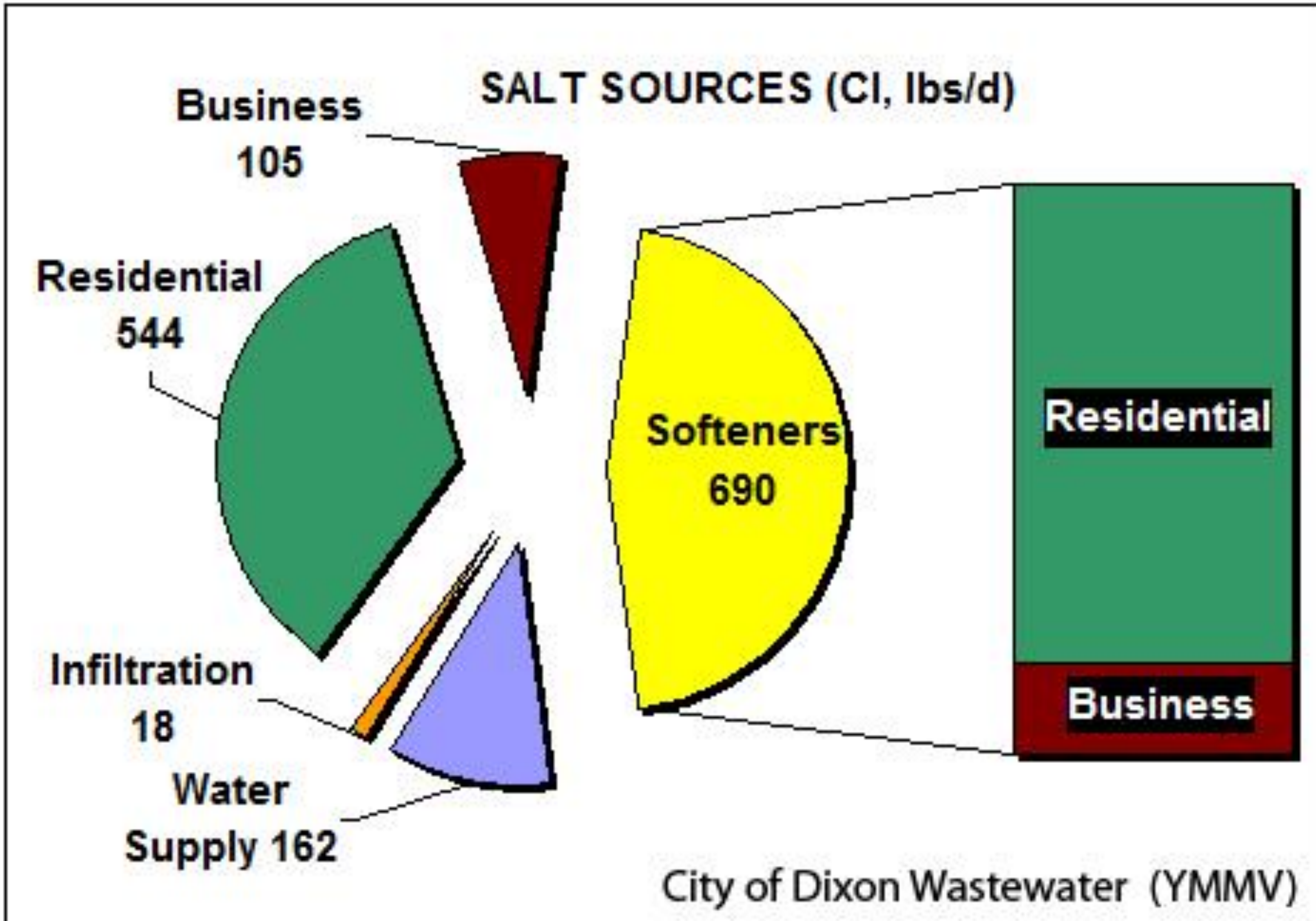
Source Control - How Much SRWS Salt ?



Headworks sampling; 1,140 lbs/day (+/- 190)

Sales Reports; 1,151 lbs/day (+/- 36)

Working Estimate ~ 1,150 lbs/day of SRWS Salt, of which 690 lbs/day is Chloride


SALT SOURCES (Cl, lbs/d)
Business
105
Residential
544
Softeners
690
Residential
Business
Infiltration
18
Water
Supply 162
City of Dixon Wastewater (YMMV)

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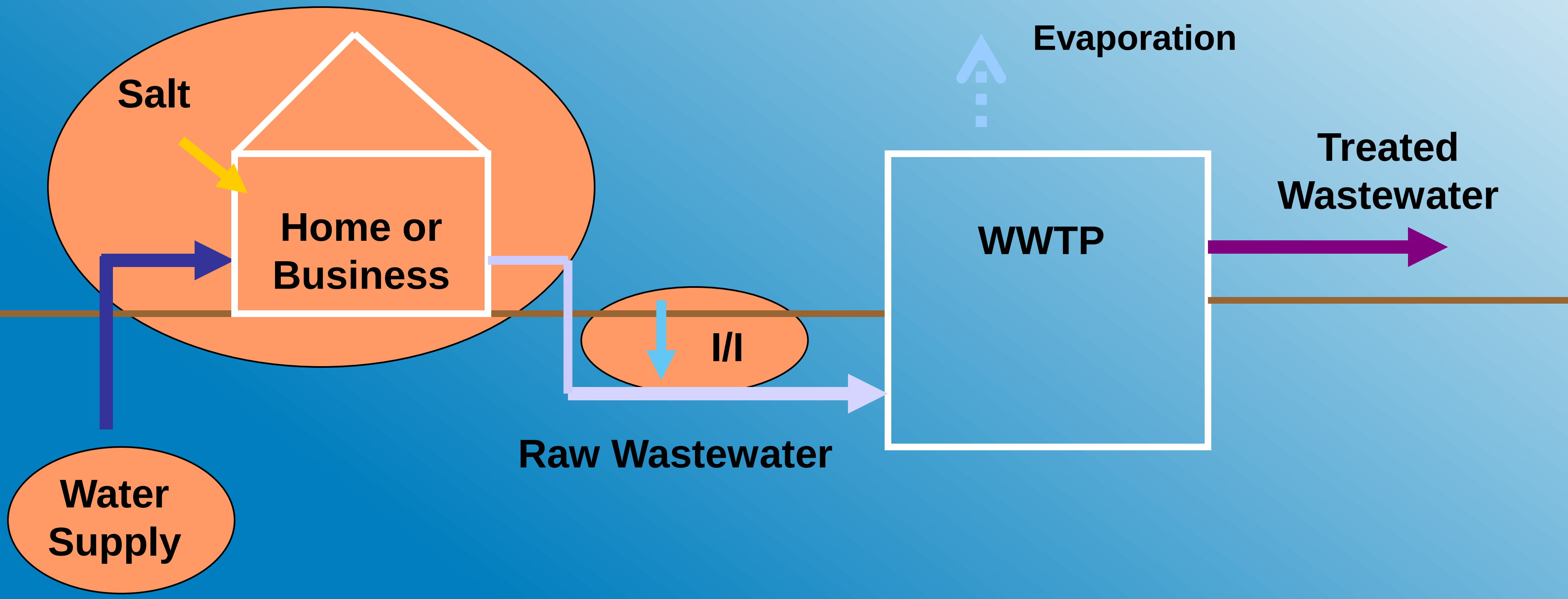
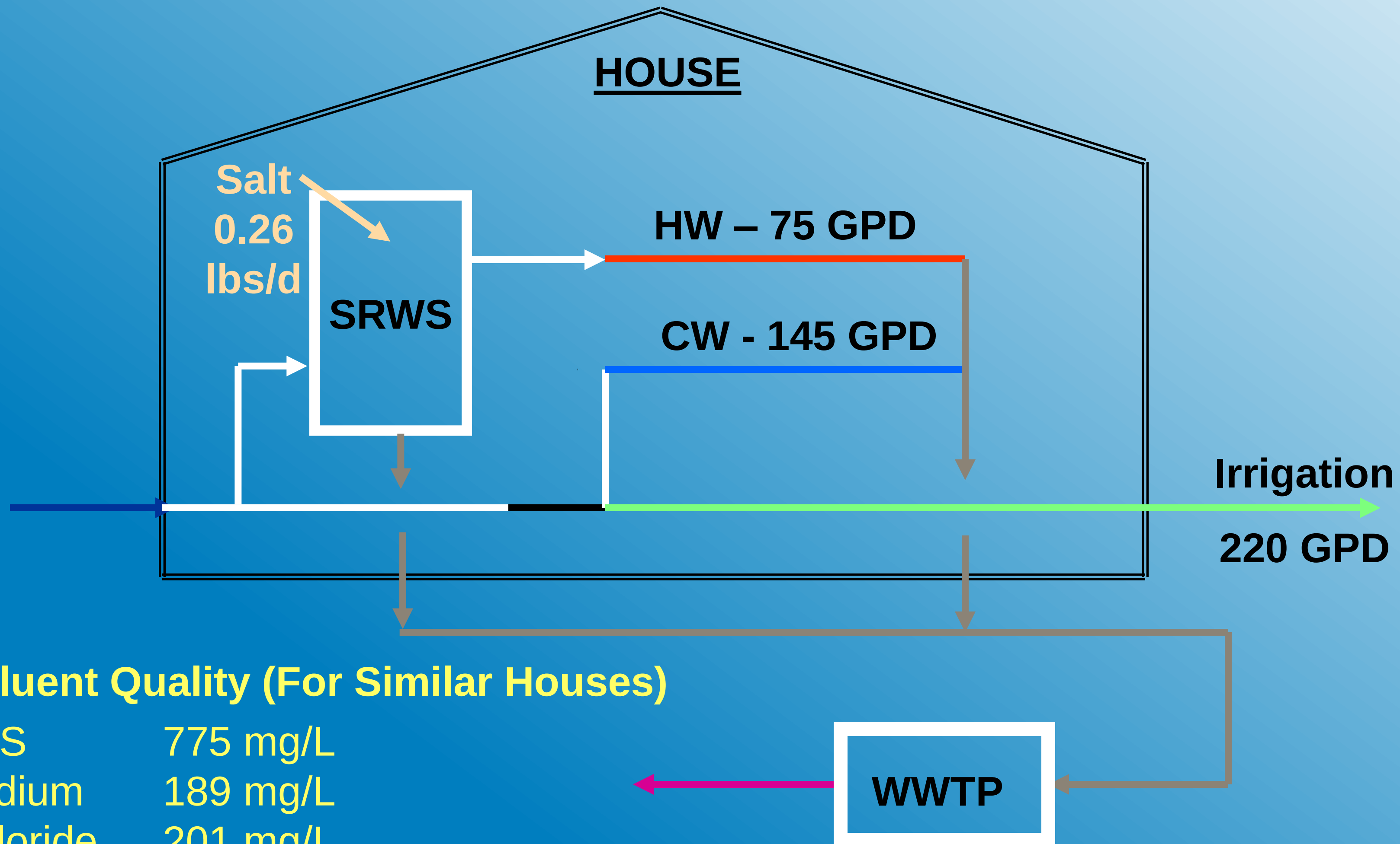
CONCEPTUAL MODEL – RAW WASTEWATER SOURCES



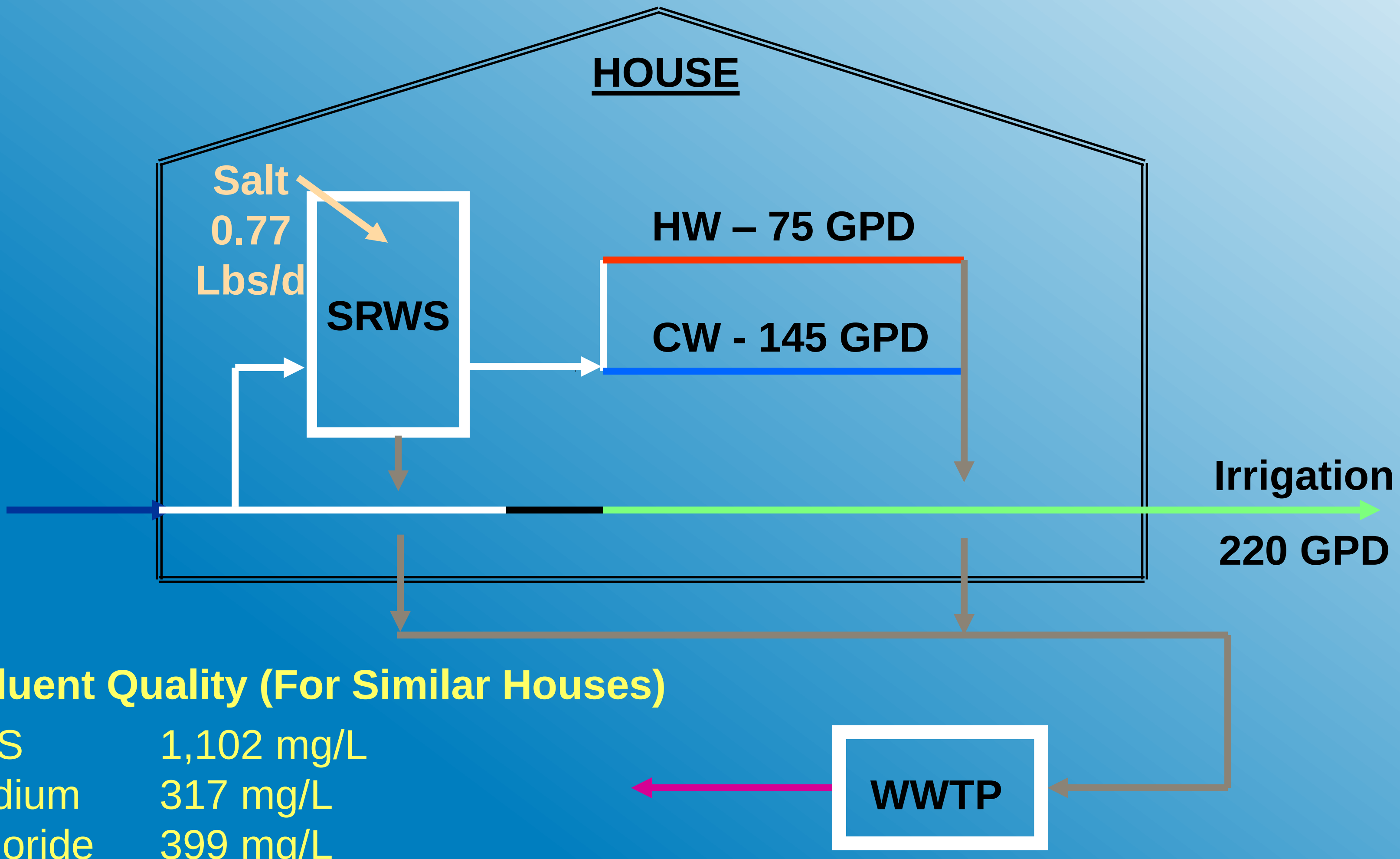
SRWS – HOT WATER ONLY



Effluent Quality (For Similar Houses)

TDS	775 mg/L
Sodium	189 mg/L
Chloride	201 mg/L

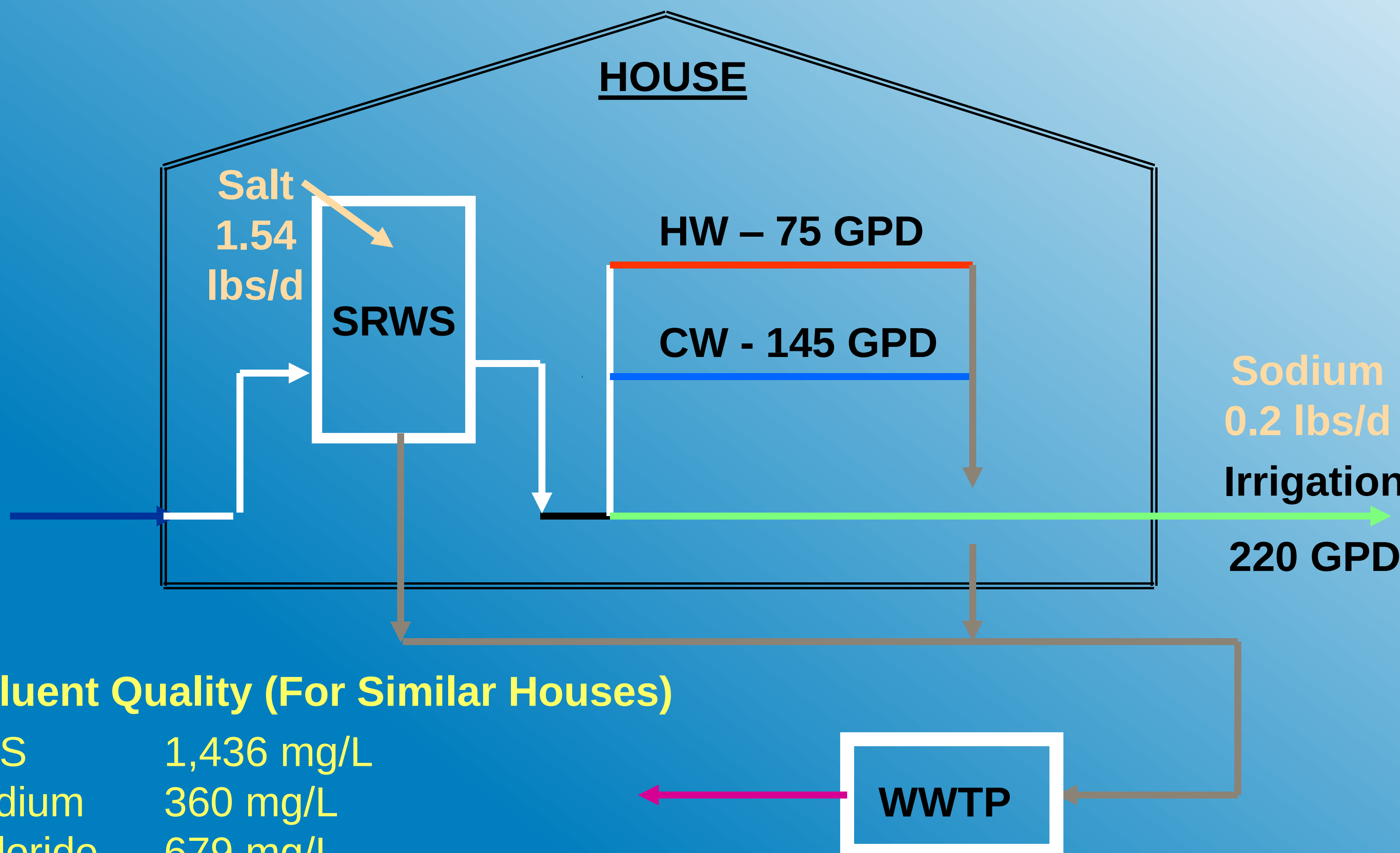
SRWS – INDOOR WATER



Effluent Quality (For Similar Houses)

TDS	1,102 mg/L
Sodium	317 mg/L
Chloride	399 mg/L

SRWS – ALL WATER



Effluent Quality (For Similar Houses)

TDS	1,436 mg/L
Sodium	360 mg/L
Chloride	679 mg/L

Summary Household Wastewater Quality Contributions by Conditioning Choice

Conditioning Choice	TDS (mg/L)	Na (mg/L)	Cl (mg/L)
SRWS – All Water	**1,510**	**400**	**730**
SRWS – Indoor Water	**1,125**	**325**	**415**
SRWS – Hot Water	**810**	**200**	**220**
CEX – All Water	**620**	**265**	**95**
CEX – Indoor Water	**620**	**265**	**95**
CEX – Hot Water	**620**	**180**	**95**
Non-Salt Conditioning	**600**	**120**	**95**
Effluent Limits	**N/A**	**145**	**106**

Estm., City of Dixon (4,000 grains/lb)

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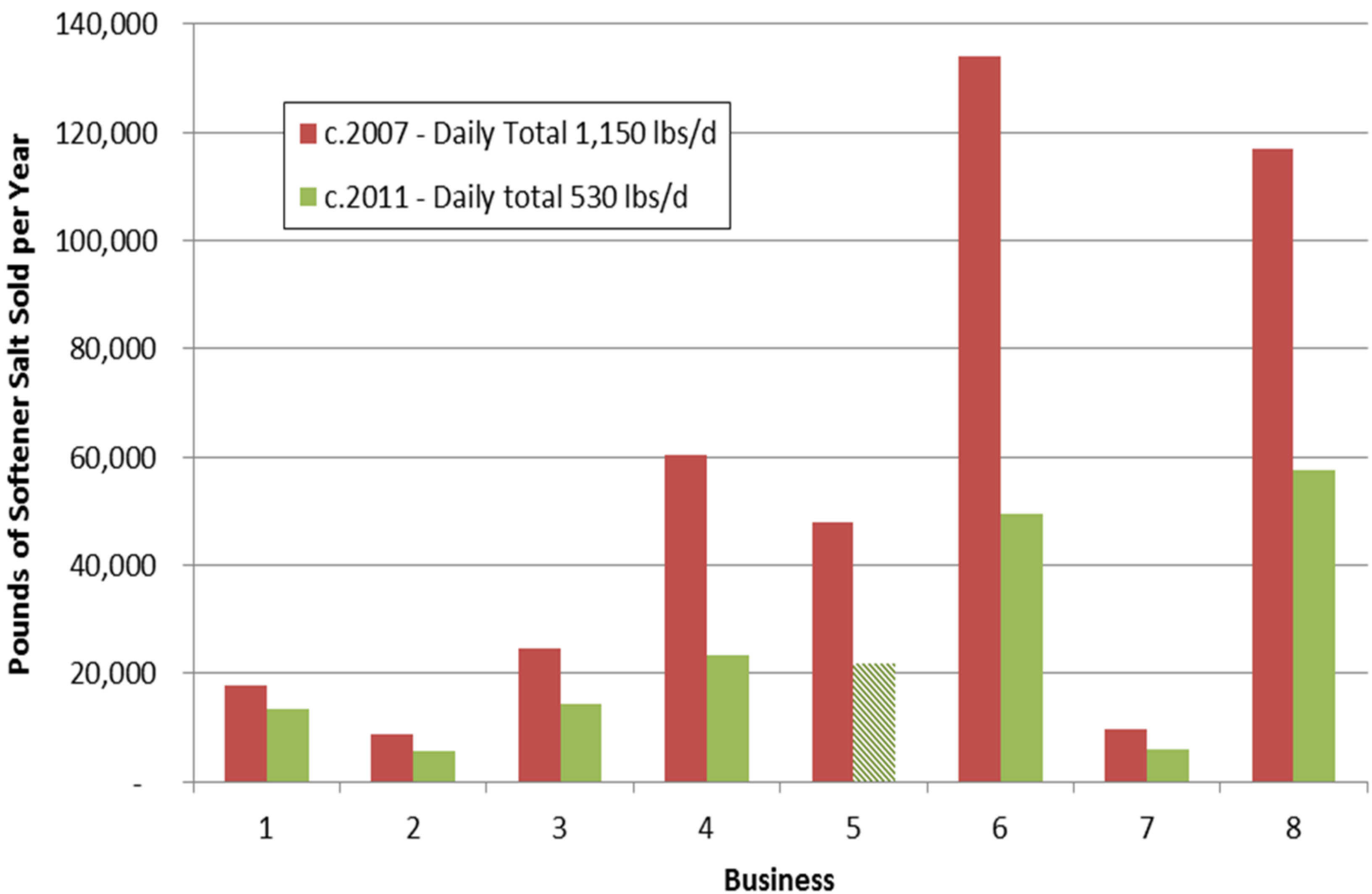
Source Control – Softener Exchange Program

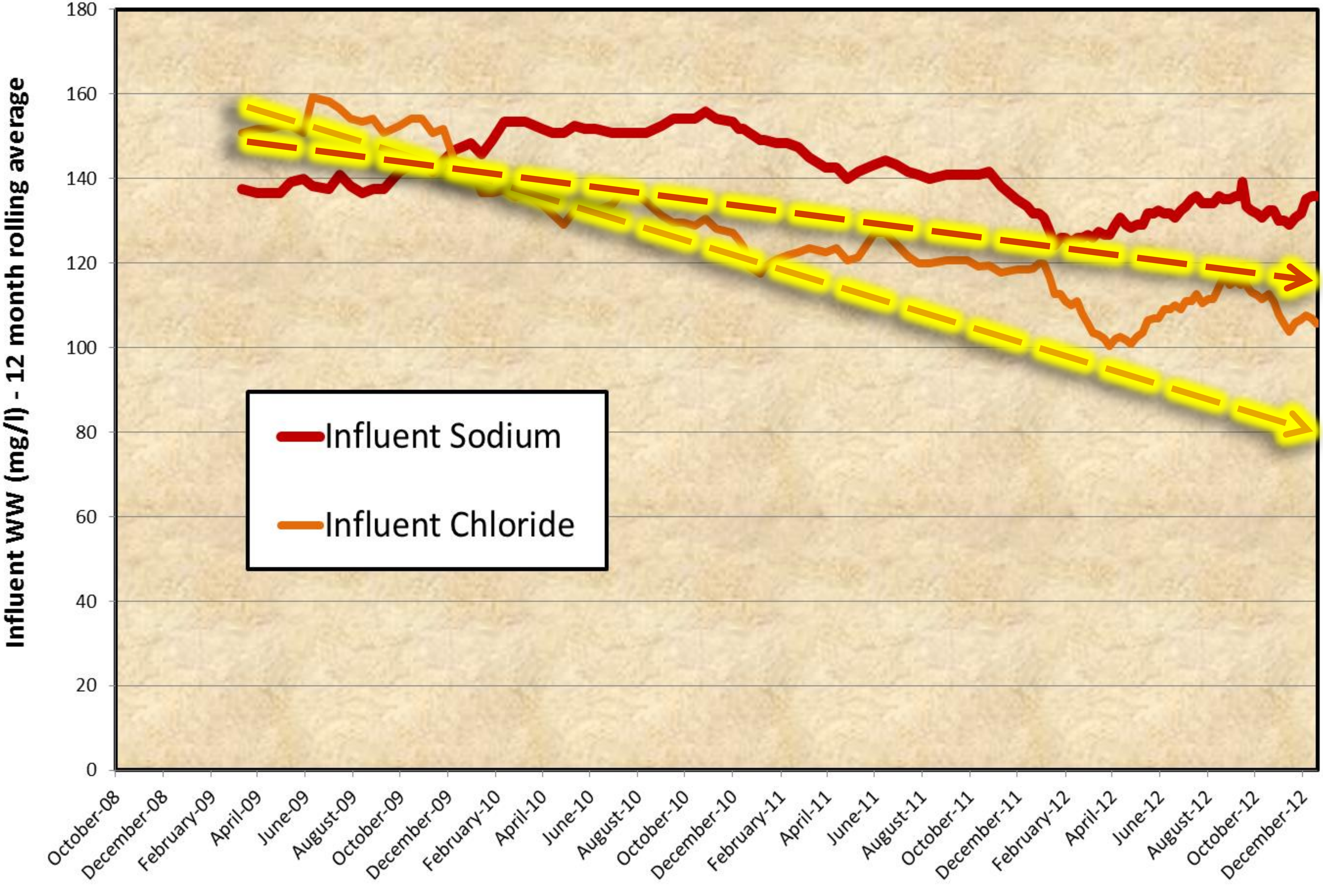
AB1366 PROHIBITION OF ALL SRWS: PASSED
LOCAL INCENTIVE PROGRAM: APPROVED

- Nov 2010: Initial Round, $1,200 cash offer
- Immediate response: 76 units removed, 160 unit waiting list
- April 2011: Second Round, $300 cash plus $300 sewer bill credit
- November 2011: Third Round, $300/$300
- Total Removed to Date: 515
- Incentive and Plumber payments to date: $500K

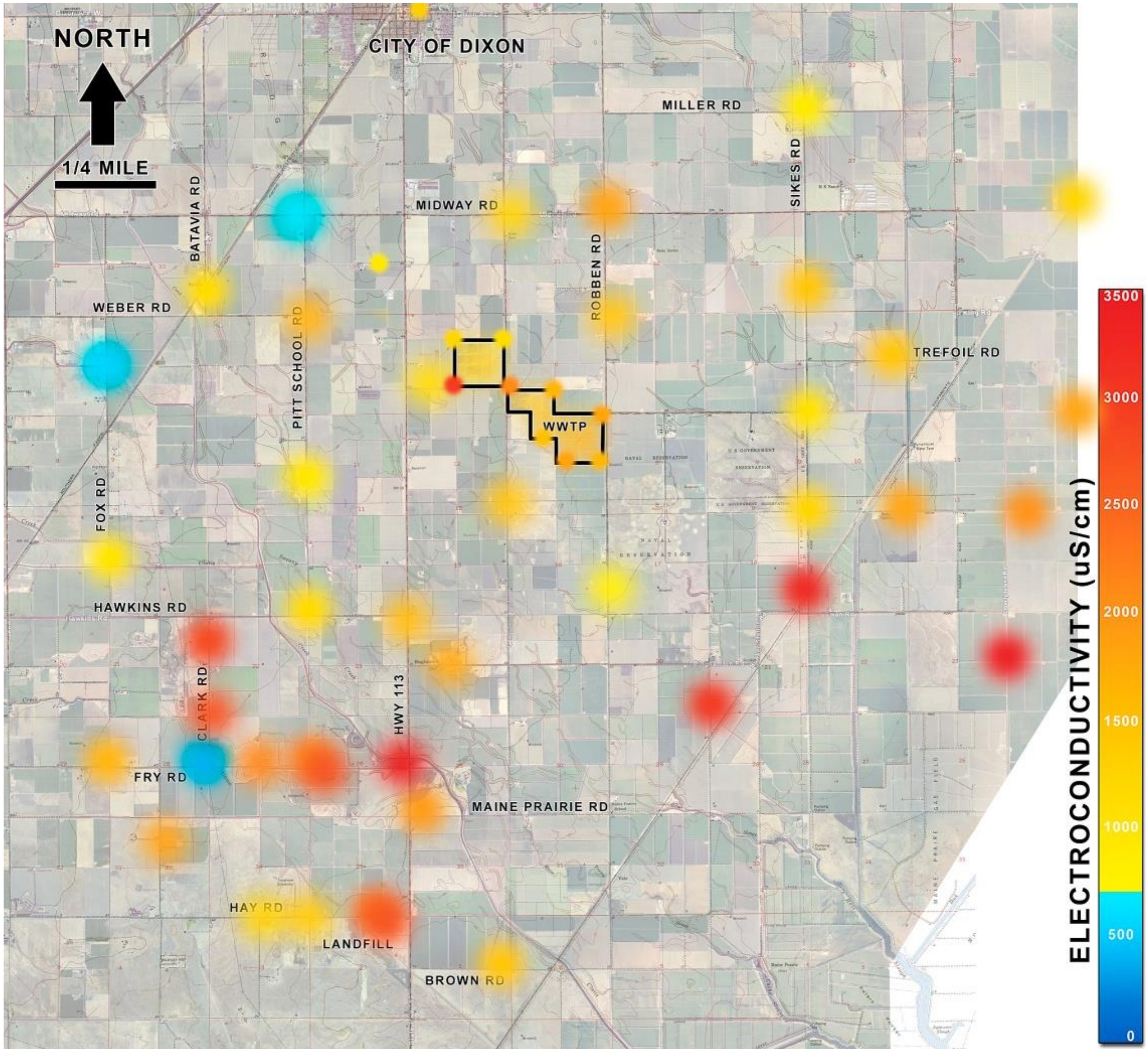
Source Control – Salt Load Reduction from Softener Exchange



Source Control – Softener Exchange Results/Outcomes



Background Characterization



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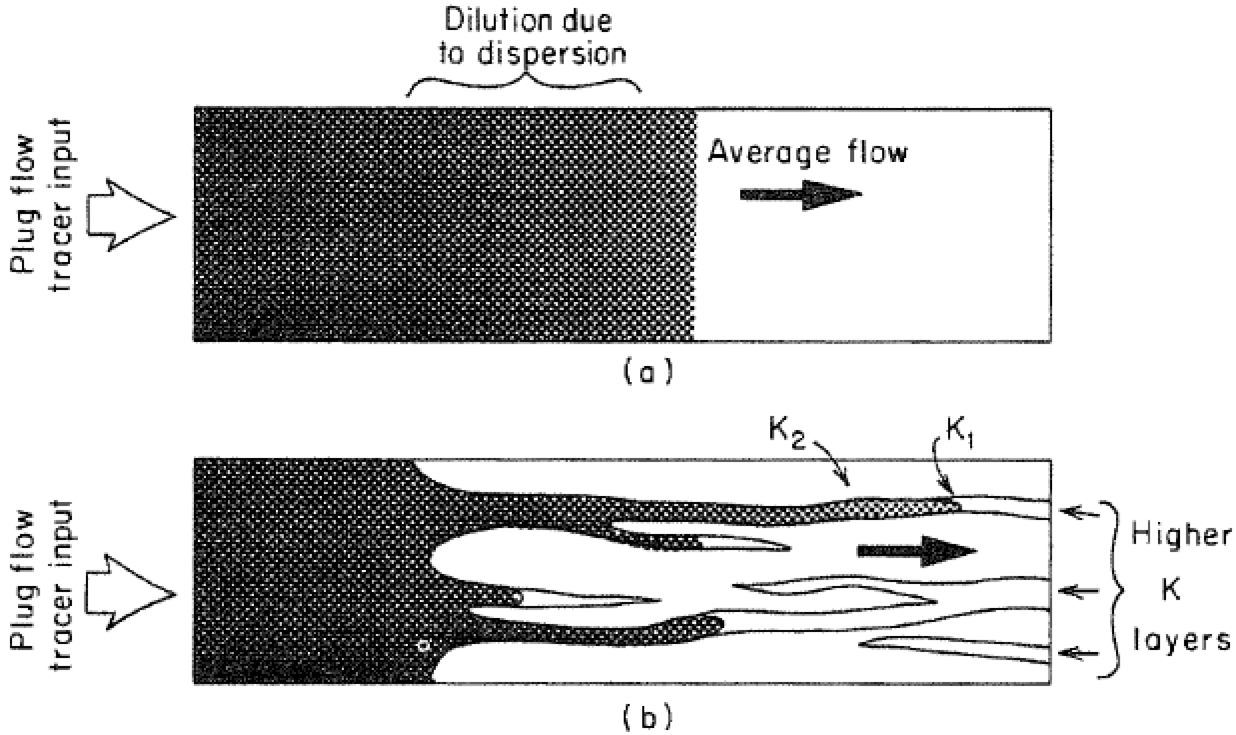
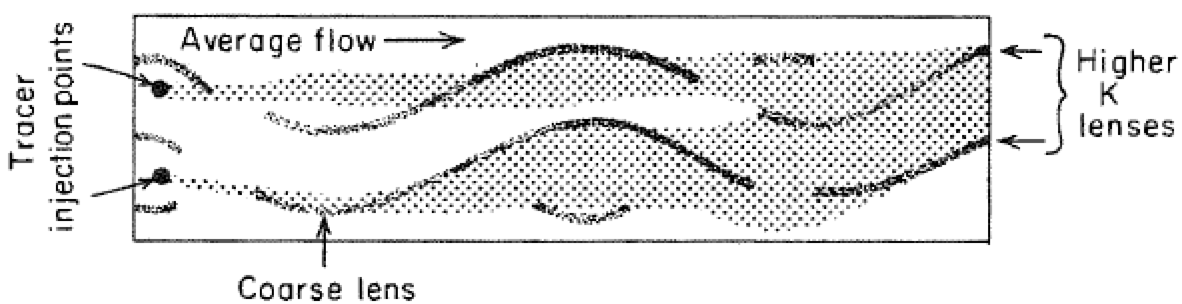
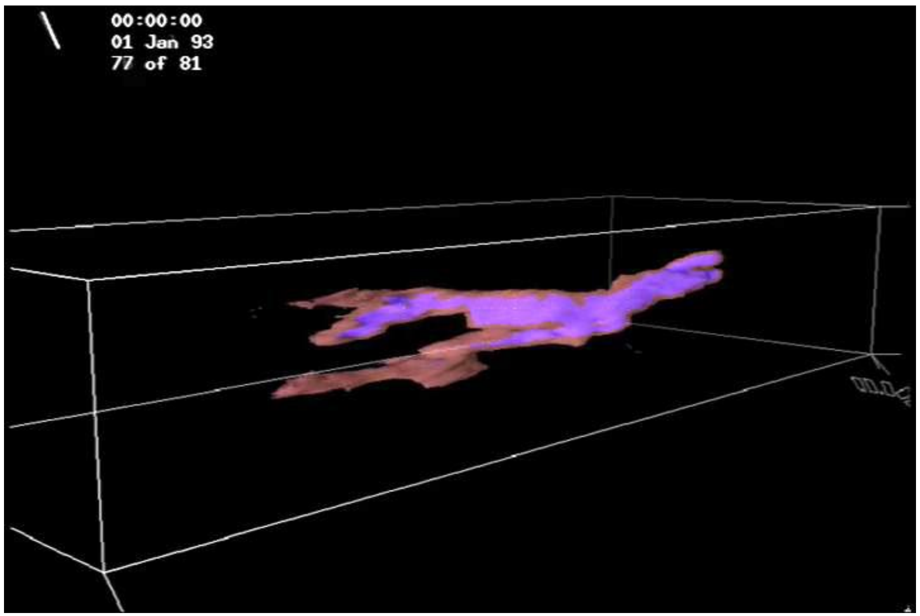
Background Characterization



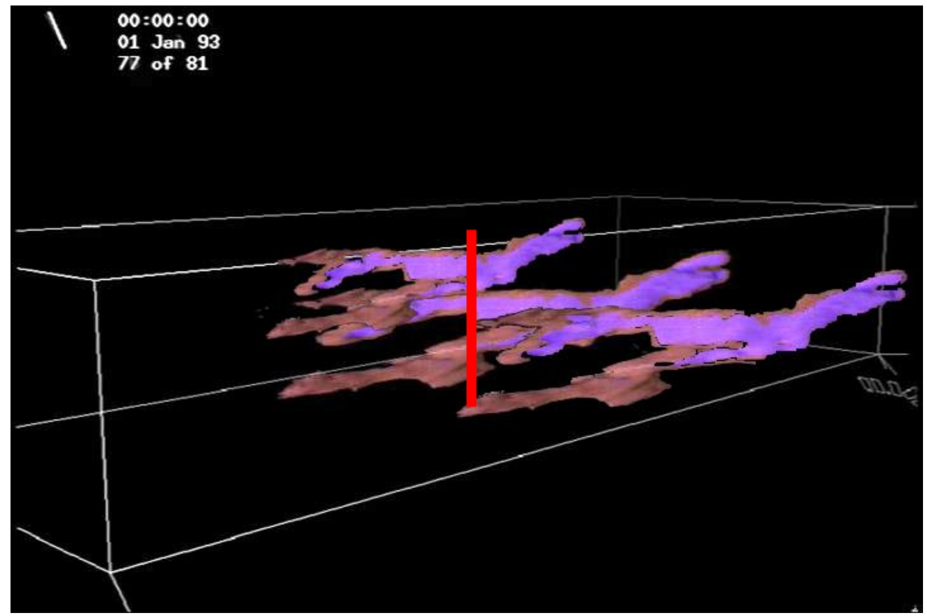


Background Characterization

ISOLATED CONTAMINANT –
HETROGENIOUS BACKGROUND



PERVASIVE CONTAMINANT –
HETROGENIOUS BACKGROUND



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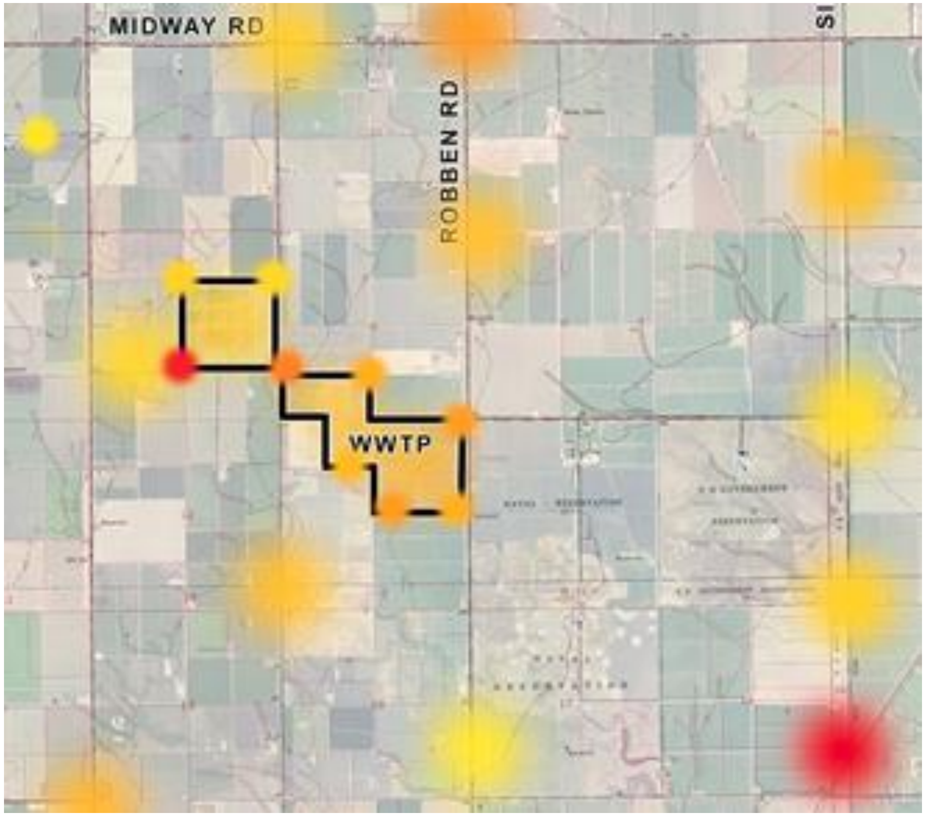
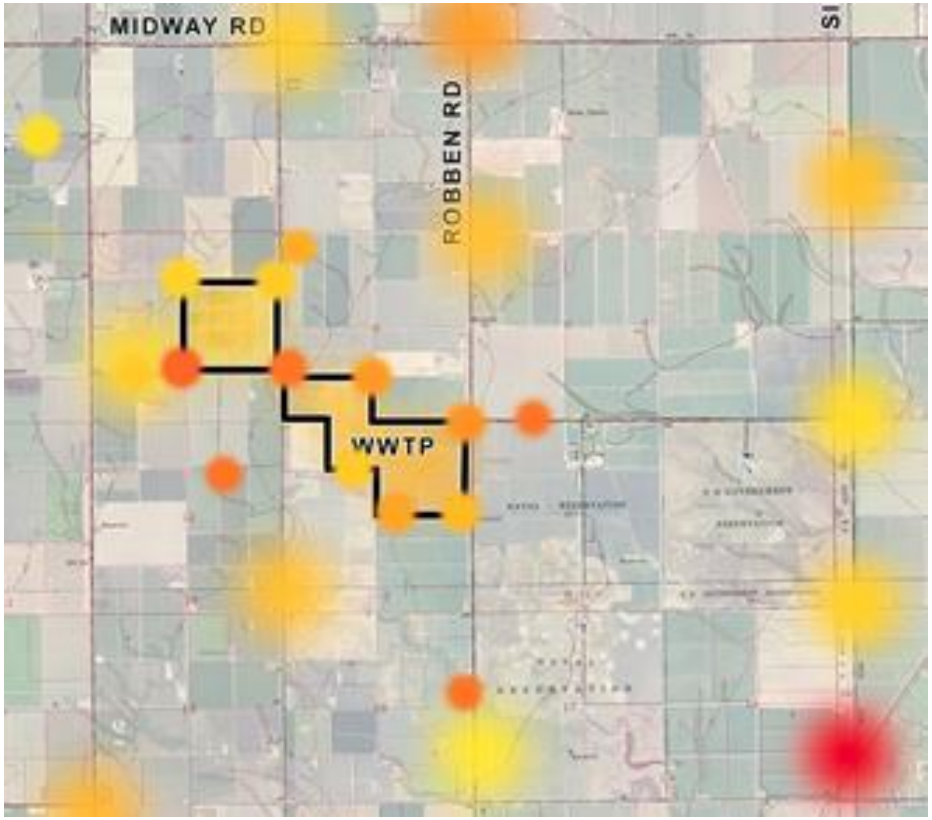
Background Characterization



2008



2012

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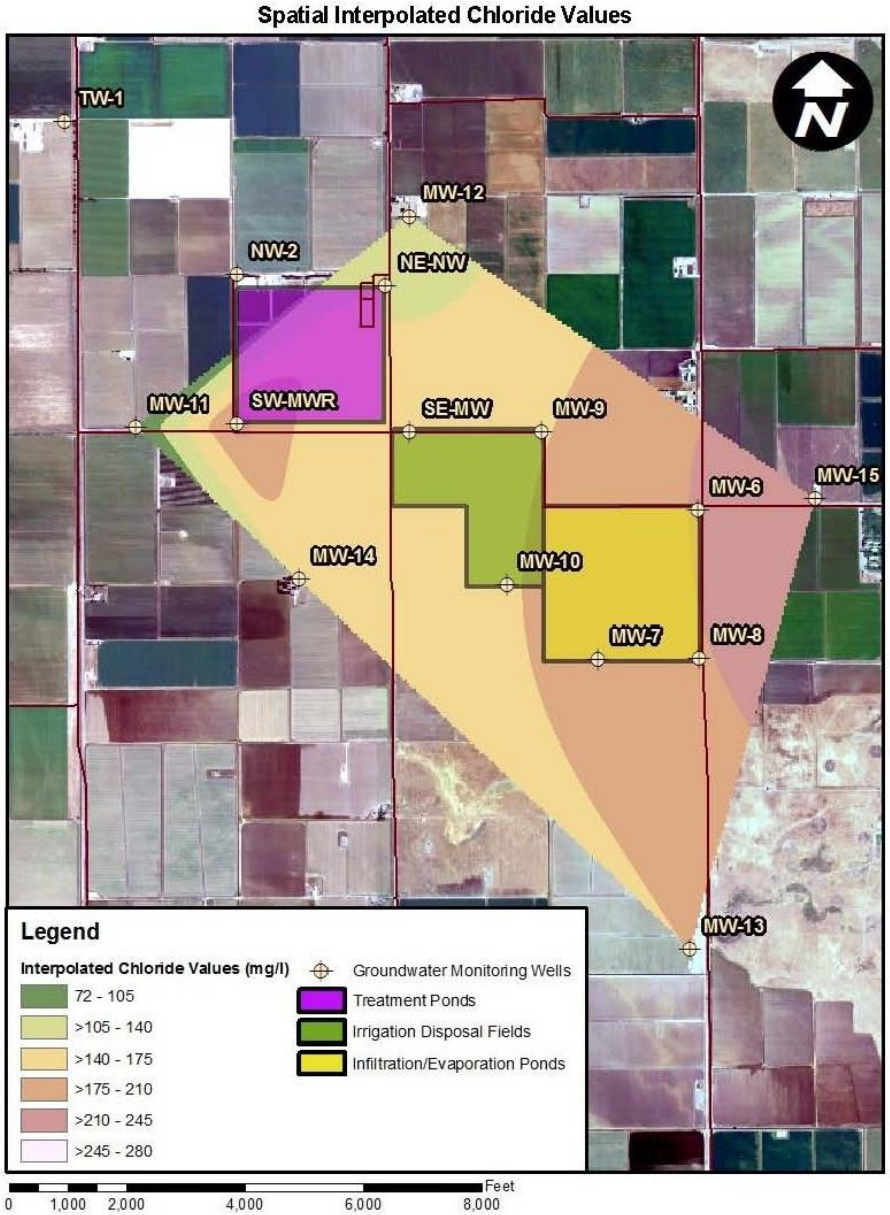
Background Characterization



- Many background wells were considered
- Statistical calculations were utilized for numerical limits
- Compliance wells are being utilized for monitoring trends
- Compliance sampling is being done at WWTF effluent

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Background Characterization

Constituent	SW-MWR	MW-11	MW-12	MW-13	MW-14	MW-15	Background Groundwater Quality
Nitrate-N (mg/L)	24	31	14	11	51	9	61
TDS (mg/L)	1,280	830	960	1,310	1,410	1,430	1,600
Chloride (mg/L)	110	80	115	175	165	250	270
Sodium (mg/L)	235	95	120	215	160	85	280
Boron (mg/L)	0.35	0.25	0.75	0.60	0.35	0.70	0.8
Sulfate (mg/L)	280	100	145	205	130	385	410
Iron (mg/L)	<0.1*	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Manganese (mg/L)	<0.02*	<0.02	<0.02	<0.02	<0.02	<0.02	0.02

* One or more outliers were removed using the Thompson tau technique

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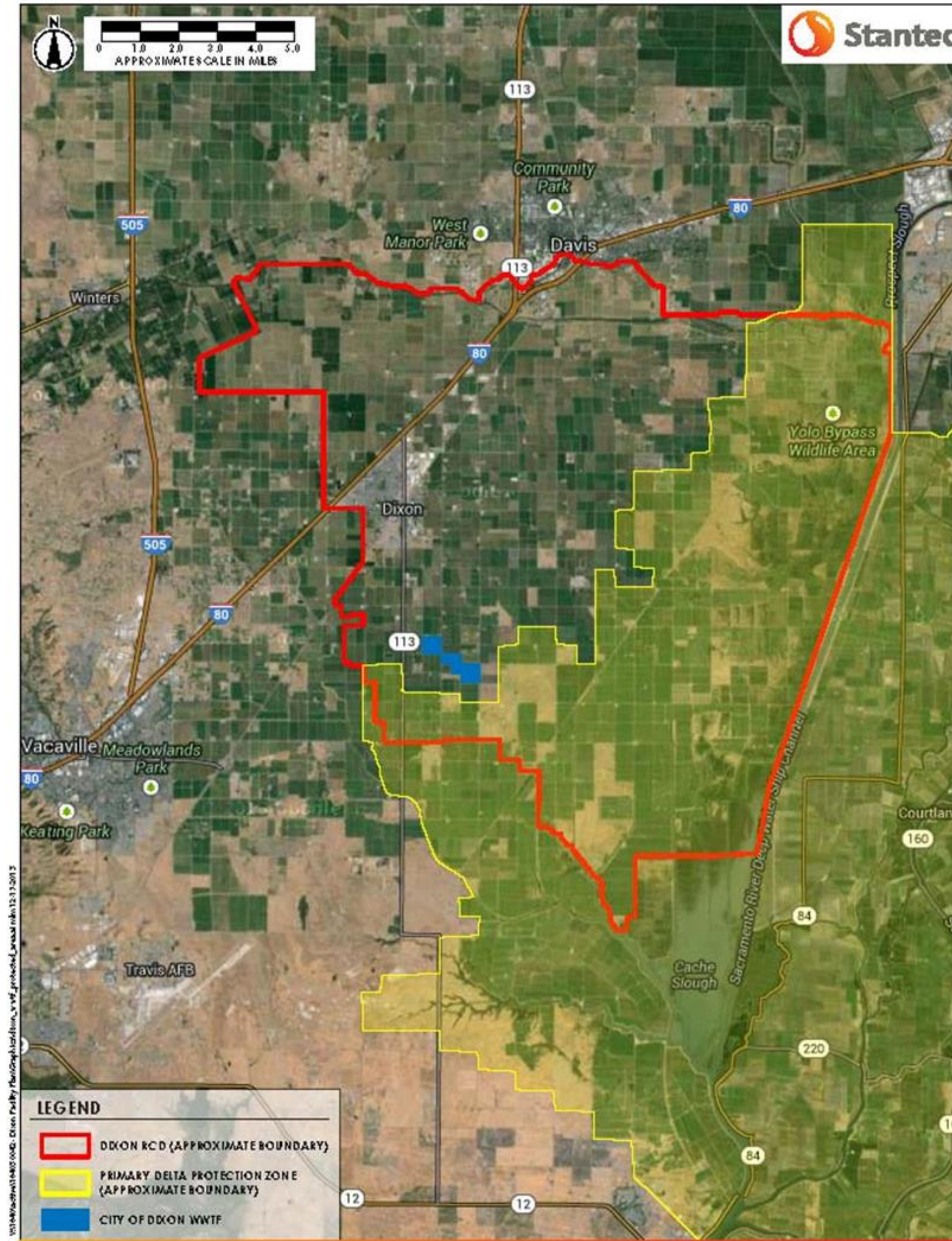
Beneficial Use Determination

Area of Influence (Local)

- 1 mile radius

Area of Influence (Regional)

- Dixon Resource Conservation District
- Delta Protection Zone



City of Dixon WWTF Improvements Project

Map of Protected Areas

Beneficial Use Determination

Most Sensitive Crops
(Grown in area of influence)

- Boron
  - Winter Wheat and Beans
    - Snap Beans response used for Beans (12% decline per 1 mg/l of B)

- TDS
  - Alfalfa
    - Uses EC data and TDS translator (1,000 umhos/cm = 640 mg/L TDS)
    - Sodium and Chloride response derived from EC/TDS data

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Impact of Softener Exchange on Effluent Boron Concentration

Category	Detergents & Softeners	
Group	Peroxide-releasing bleach/oxy bleach/non-chlorine bleach	
Active Ingredient	Sodium perborate/Sodium Borate (Borax); requires higher water temperature or an activator at lower temperature.	
Product Name	**Manufacturer**	**Ingredient**
CLOROX 2® Color Safe Bleach (Dry)	The Clorox Co.	Sodium Perborate (7-13%)
Ultra CLOROX 2® Color Safe Bleach (Dry)	The Clorox Co.	Sodium Perborate (1-5%)
Mrs. Meyer's Laundry Detergents	Mrs. Meyer's Clean Day/Caldera Co.	Sodium Borate (Borax)
20 Mule Team® Borax Laundry Natural Laundry Booster	The Dial Corp.	Sodium Borate (Borax)
Sun Powered Laundry Detergent with Cuddle soft	Sun Corp.	Sodium Perborate (<1%)

Site-Specific Groundwater WQOs

Constituent	Municipal WQO	Agricultural WQO	Site-specific WQO[1]
Nitrate-N (mg/L)	10[2]	--	10
TDS (mg/L)	500 – 1,500[3]	1,500	1,500
Chloride (mg/L)	250 – 600[3]	>880[4]	600
Sodium (mg/L)	NA	>340[4]	>340[4]
Boron (mg/L)	NA	1.65	1.65
Sulfate (mg/L)	250 – 600[3]	--	500[2]
Iron (mg/L)	0.3[3]	--	0.3
Manganese (mg/L)	0.05[3]	--	0.05

1 Municipal or agricultural WQO, whichever is lower.

2 Primary MCL.

3 Secondary MCL range or specified value.

4 Conservative value not recommended as a water quality objective; but can be used to determine protective groundwater limit.

NA = Not applicable

- - = Not proposed

Groundwater WQOs Over Time

Constituent	c. 1980's	c. 1997	c. 2008	c. 2017
TDS	450	450	800	1600
Sodium	Undefined - study	69 mg/L	143 mg/L	600 mg/L
Chloride	Undefined - study	106 mg/L	106 mg/L	340 mg/L
Boron	Undefined - study	Undefined - study	0.7 mg/L	1.65 mg/L
Nitrate	Undefined - study	Undefined - study	Undefined - study	10 mg/L

Effluent Limitations

Constituent	Units	Limit	Basis of Compliance Determination
BOD_5 [1]	mg/L	30	Monthly average
BOD_5	mg/L	50	Monthly maximum
Total nitrogen	mg/L	10	Flow-weighted annual average
Chloride	mg/L	150	Flow-weighted annual average
Boron	mg/L	1.4	Flow-weighted annual average

Facility Planning – Alternative Analysis

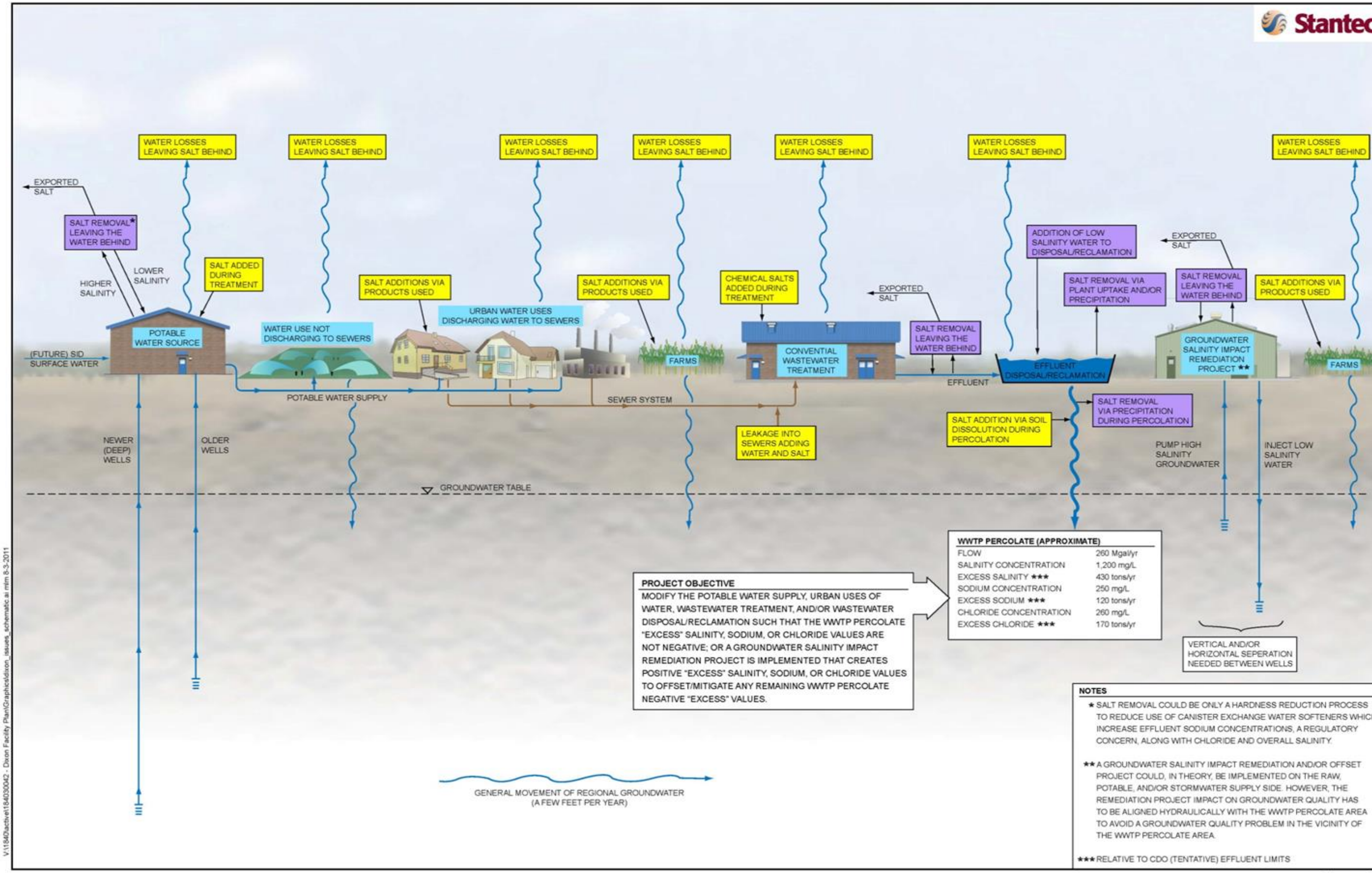
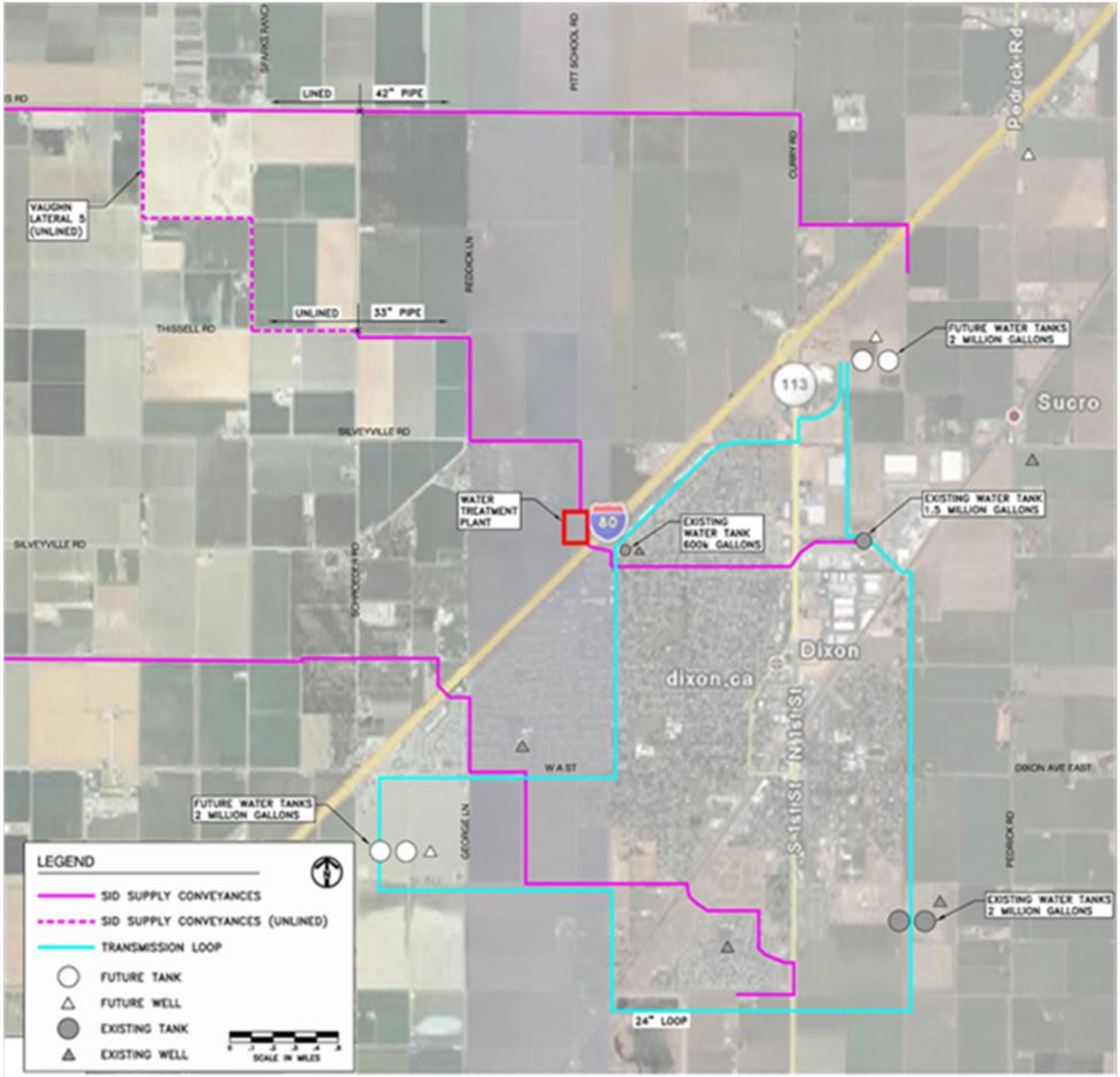


Figure 6-1
Salinity, Sodium, and Chloride Issues Facing the City Schematic

Facility Planning – New Water Supply



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Facility Planning – Well Head Treatment

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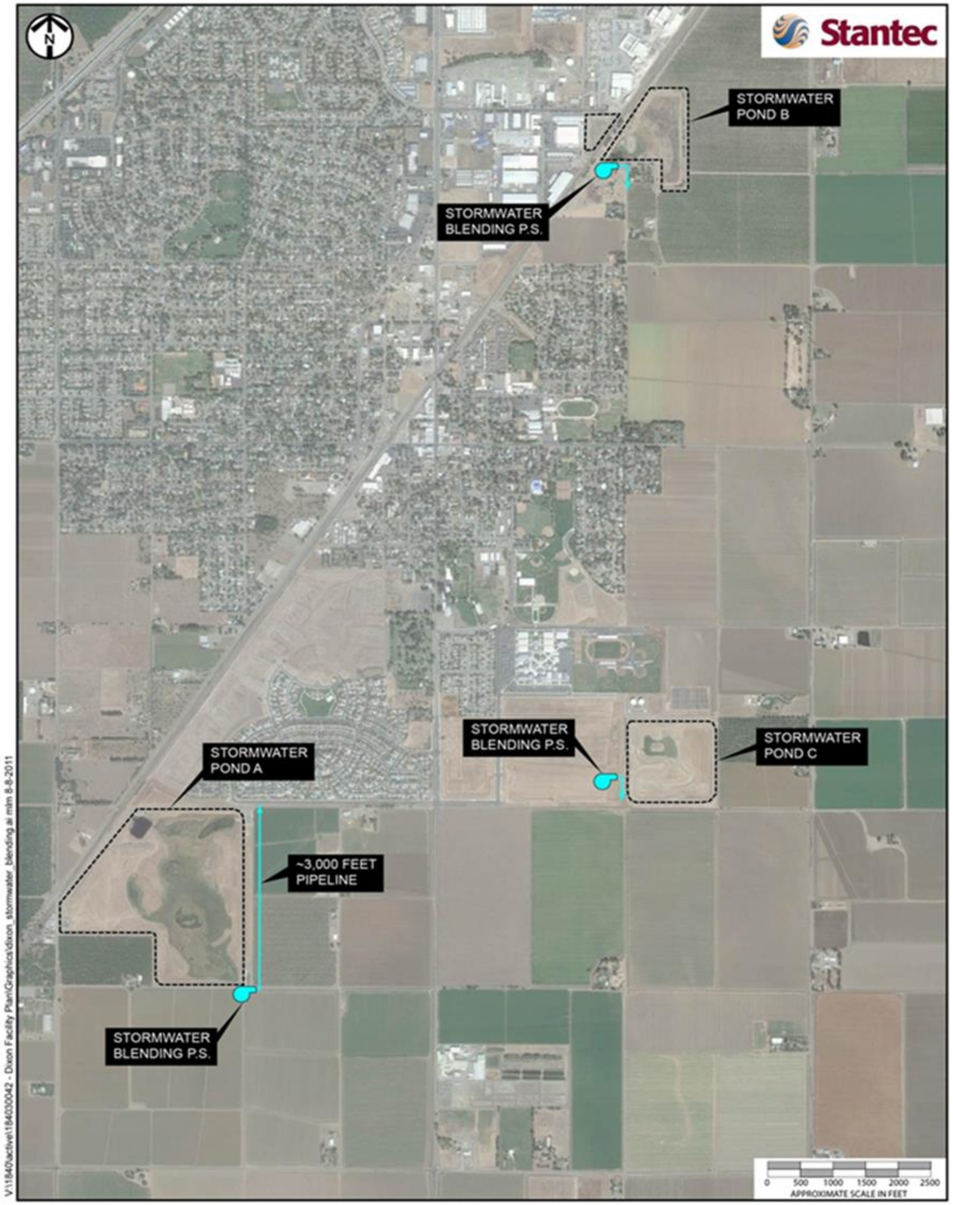
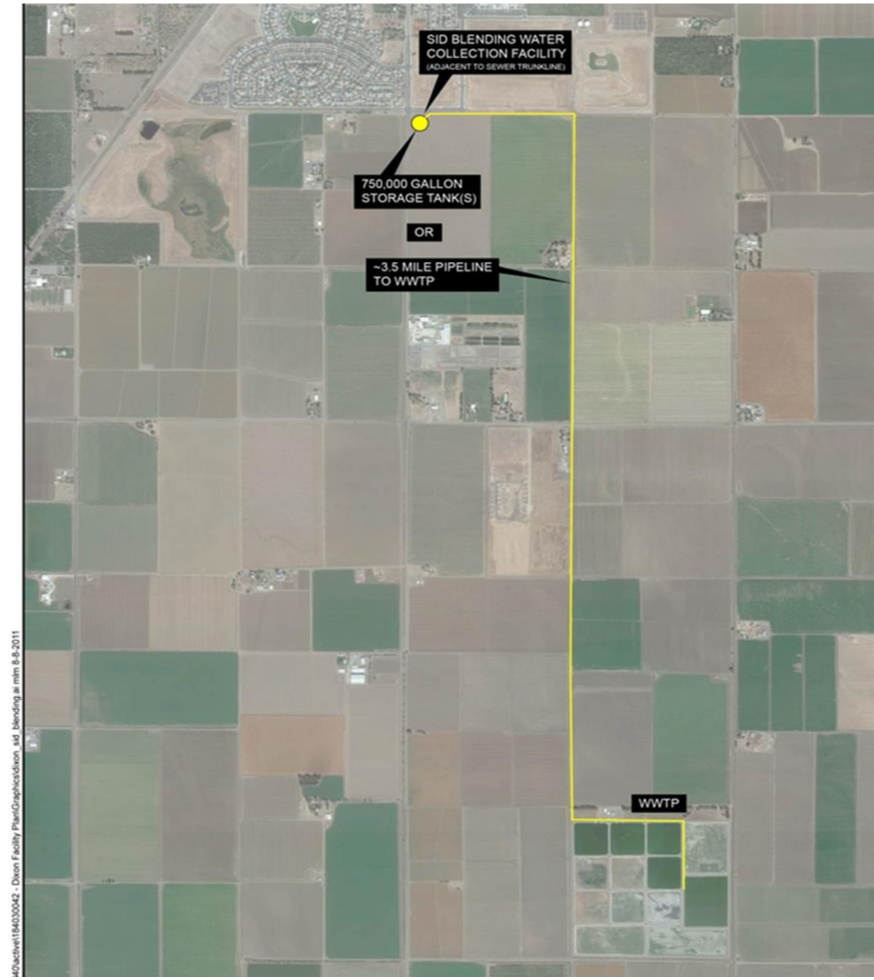
Facility Planning – Blending Water





Stormwater / Freshwater

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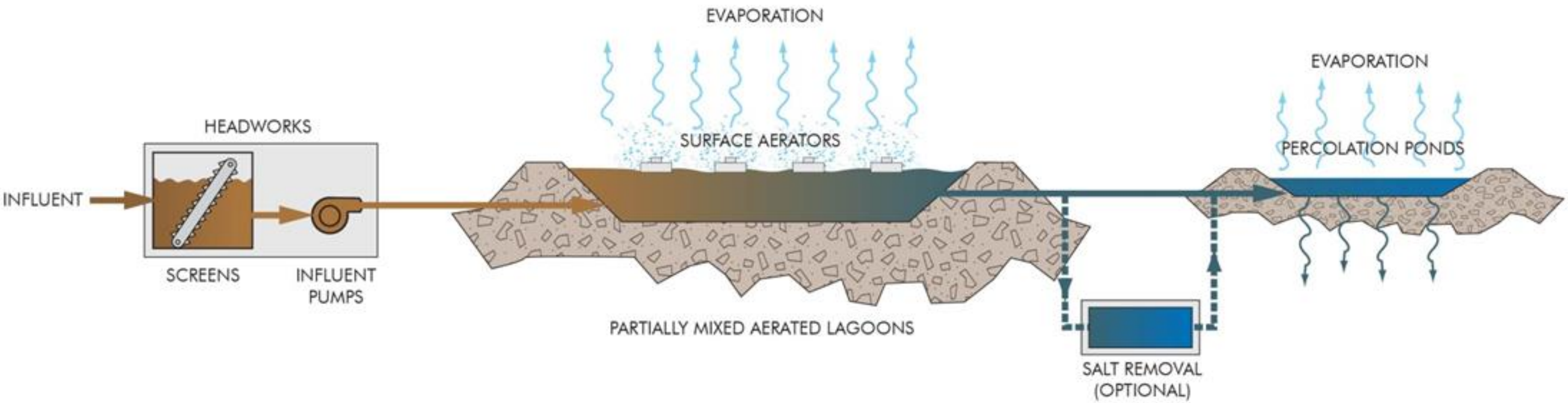
Facility Planning – Salt Removal at WWTF



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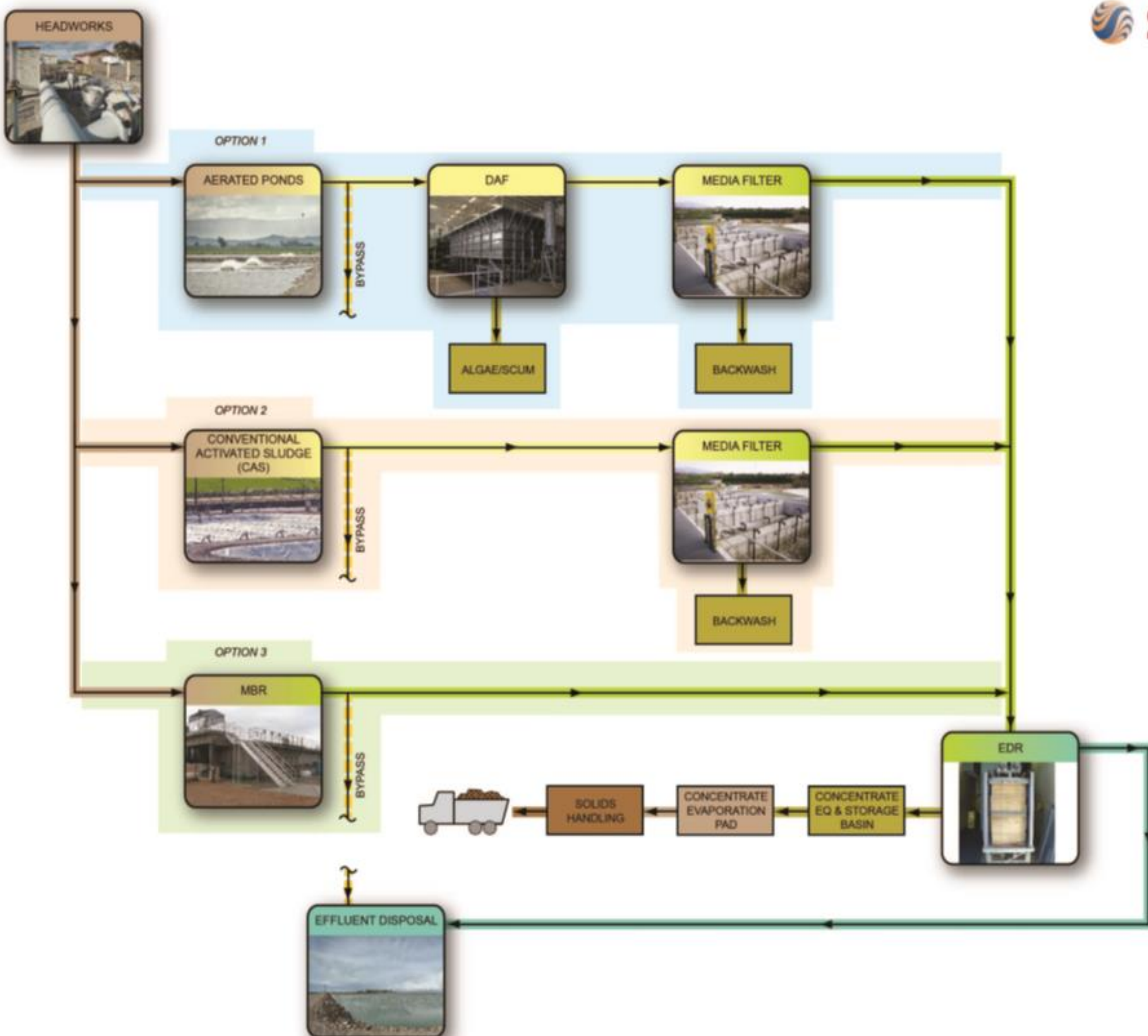
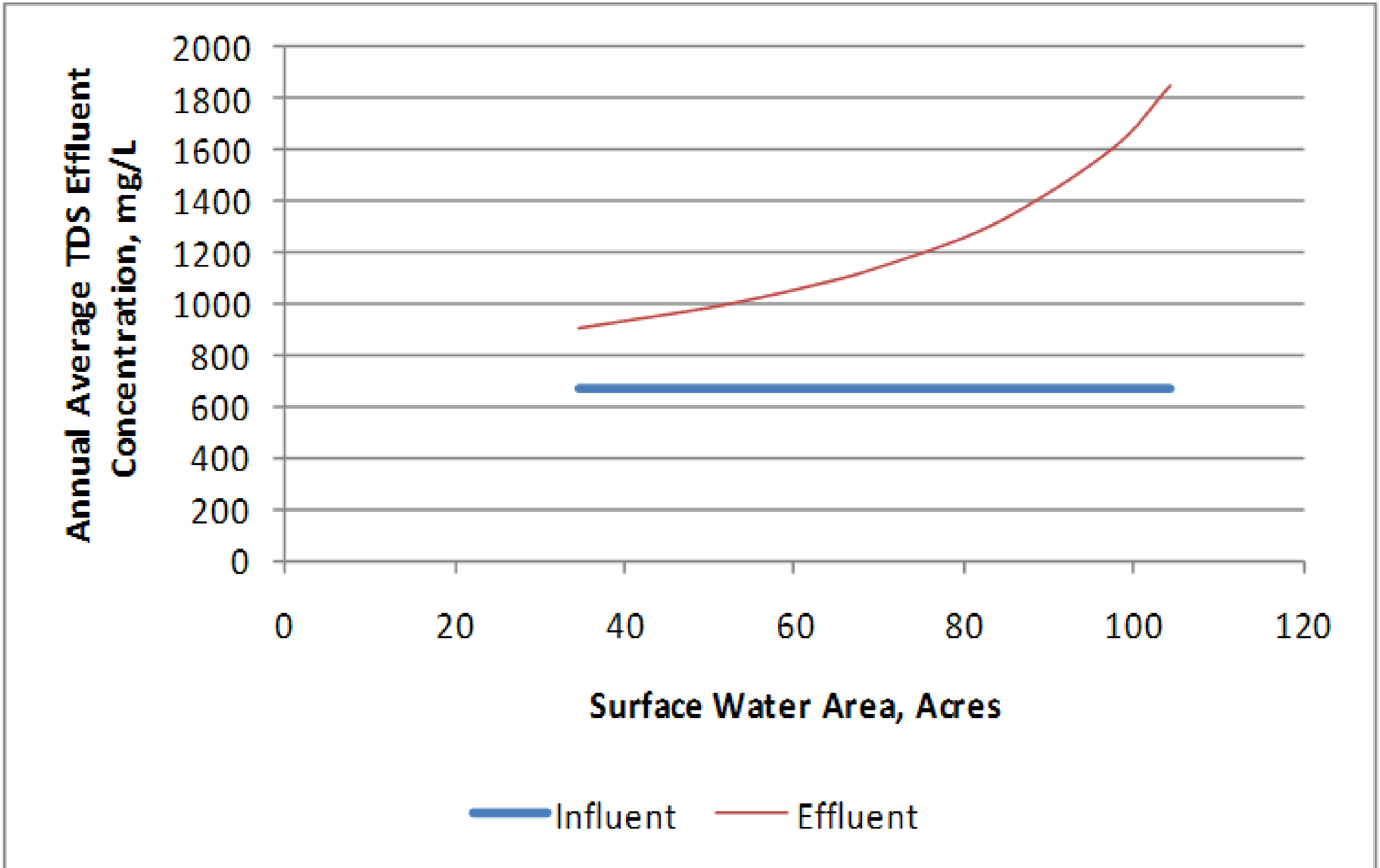

HEADWORKS
OPTION 1
AERATED PONDS
BYPASS
DAF
MEDIA FILTER
ALGAE/SCUM
BACKWASH
OPTION 2
CONVENTIONAL ACTIVATED SLUDGE (CAS)
BYPASS
MEDIA FILTER
BACKWASH
OPTION 3
MBR
BYPASS
EDR
CONCENTRATE EQ & STORAGE BASIN
CONCENTRATE EVAPORATION PAD
SOLIDS HANDLING
EFFLUENT DISPOSAL

Evaporation Loss: Pond Vs. Activated Sludge Process



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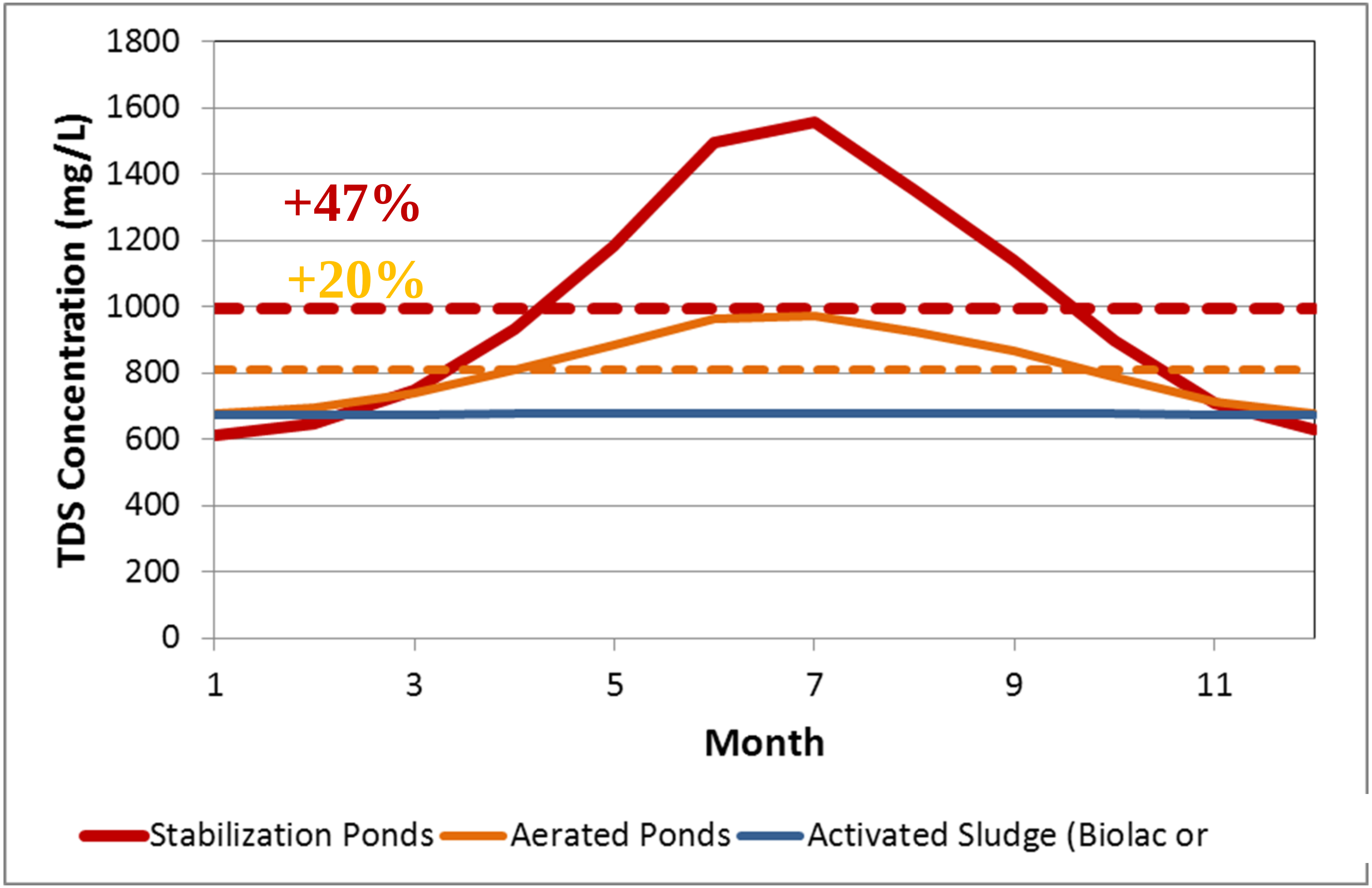
Evaporation Loss: Pond vs. Activated Sludge Process



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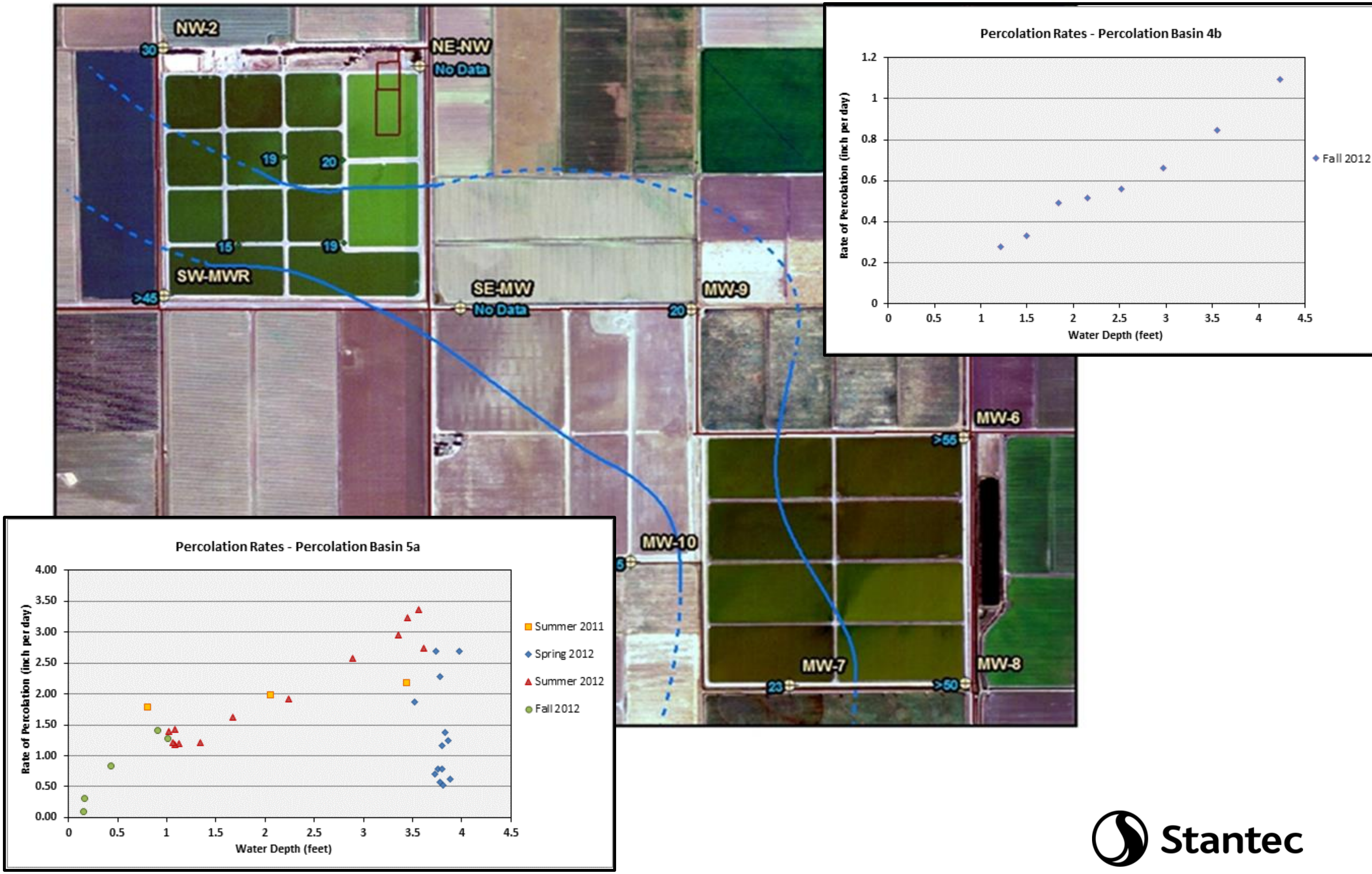
Optimization of Infiltration Basin Operation



Implementation

Incremental Costs to Remove or Mitigate 30% of Dixon's Chloride Load to Groundwater

Project	20-Year NPV (Millions)	Comments
Softeners - Public Education, Characterization, Incentive	**$3.0**	**Partial Compliance**
Fallow 300 ac (low water quality) Farmland	**$3.0**	**Potential Social Impacts – Undesirable**
Collect, Disinfect, Inject High Quality Surface Water	**$6.6**	**State Water Policy Impacts – Undesirable**
Blend High Quality Surface Water with Effluent	**$9.0**	**State Water Policy Impacts – Undesirable**
Change to Activated Sludge Treatment	**$12**	**Full Compliance**
Pump and Treat Groundwater (w/ RO)	**$14**	**Full Compliance**
Treat Effluent with EDR	**$27**	**Full Compliance**
Change to Surface Potable Water	**$55**	**Full Compliance**
Soften Potable Water at Well Heads	**$62**	**Full Compliance**

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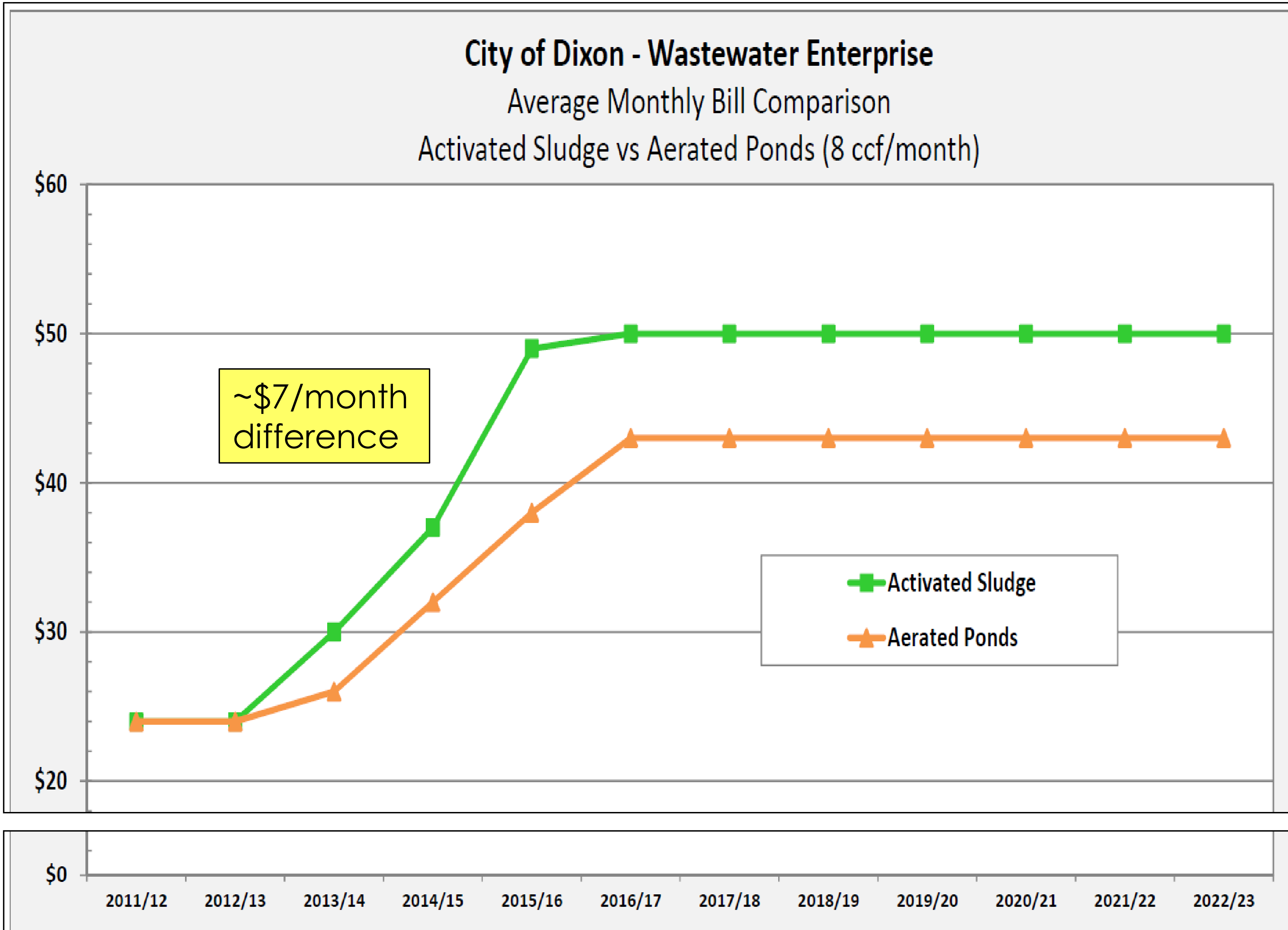
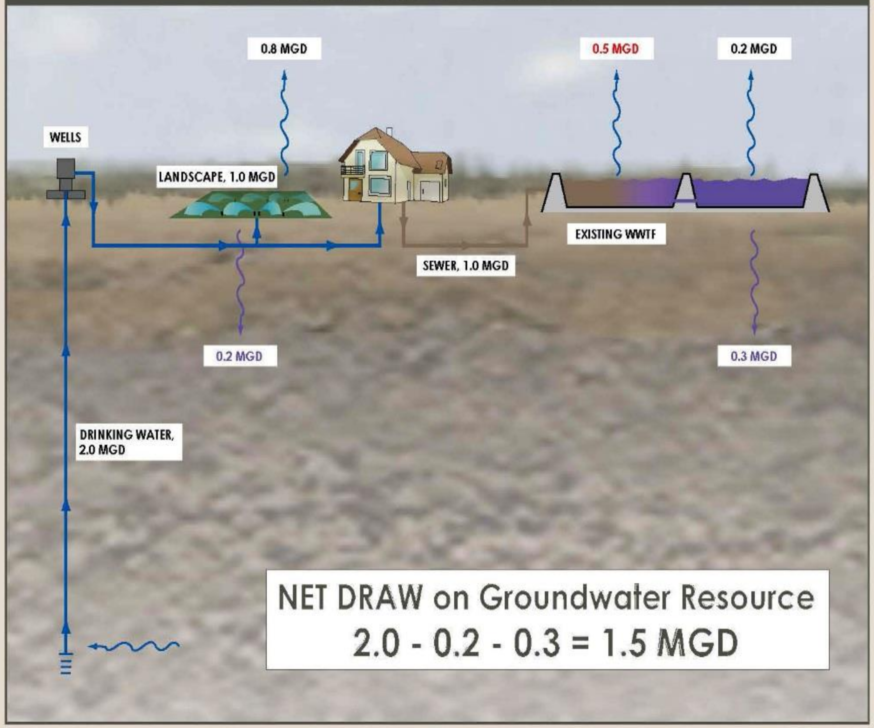
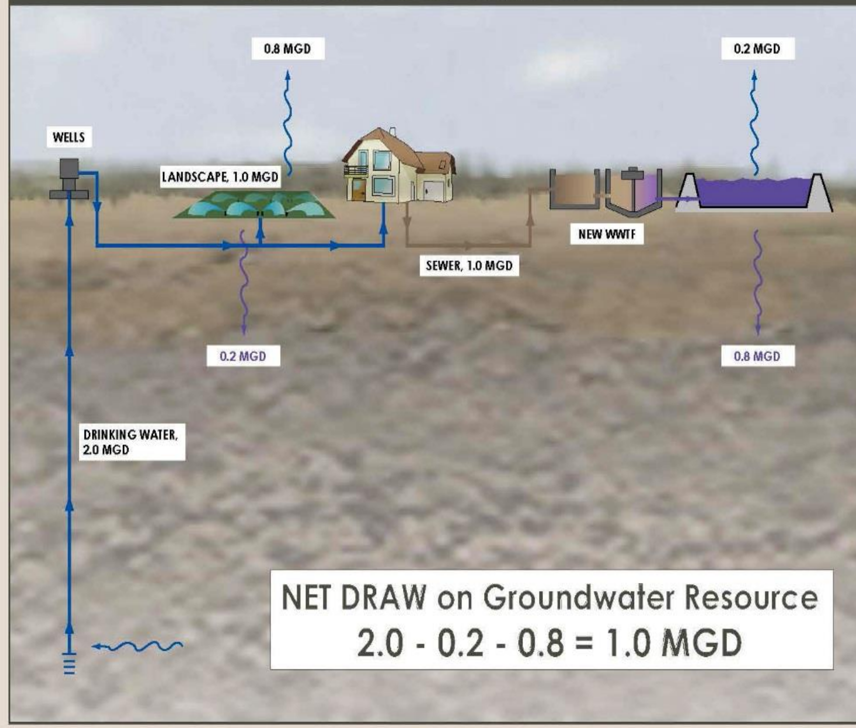

City of Dixon - Wastewater Enterprise
Average Monthly Bill Comparison
Activated Sludge vs Aerated Ponds (8 ccf/month)
$60
$50
$40
$30
$20
$0
~$7/month difference
Activated Sludge
Aerated Ponds
2011/12
2012/13
2013/14
2014/15
2015/16
2016/17
2017/18
2018/19
2019/20
2020/21
2021/22
2022/23

Building for the future by improving the quality and quantity of our local groundwater resource.

Existing City of Dixon WWTF



City of Dixon WWTF Improvements



A Regional Water Conservation Project,

that cuts salinity and slashes City water consumption 33%.......*forever.*

Dixon Summary

- Softener Exchange resulted in ~50% reduction of salt loading and ~20% salinity

- Permit compliance/BPTC is achieved with a shift to activated sludge treatment
  - The WWTF Project conserved about 33% of annual City's water resource that would otherwise evaporate, *and keep it for local benefit*.
  - Both the quantity <u>and</u> quality of the local groundwater is improved

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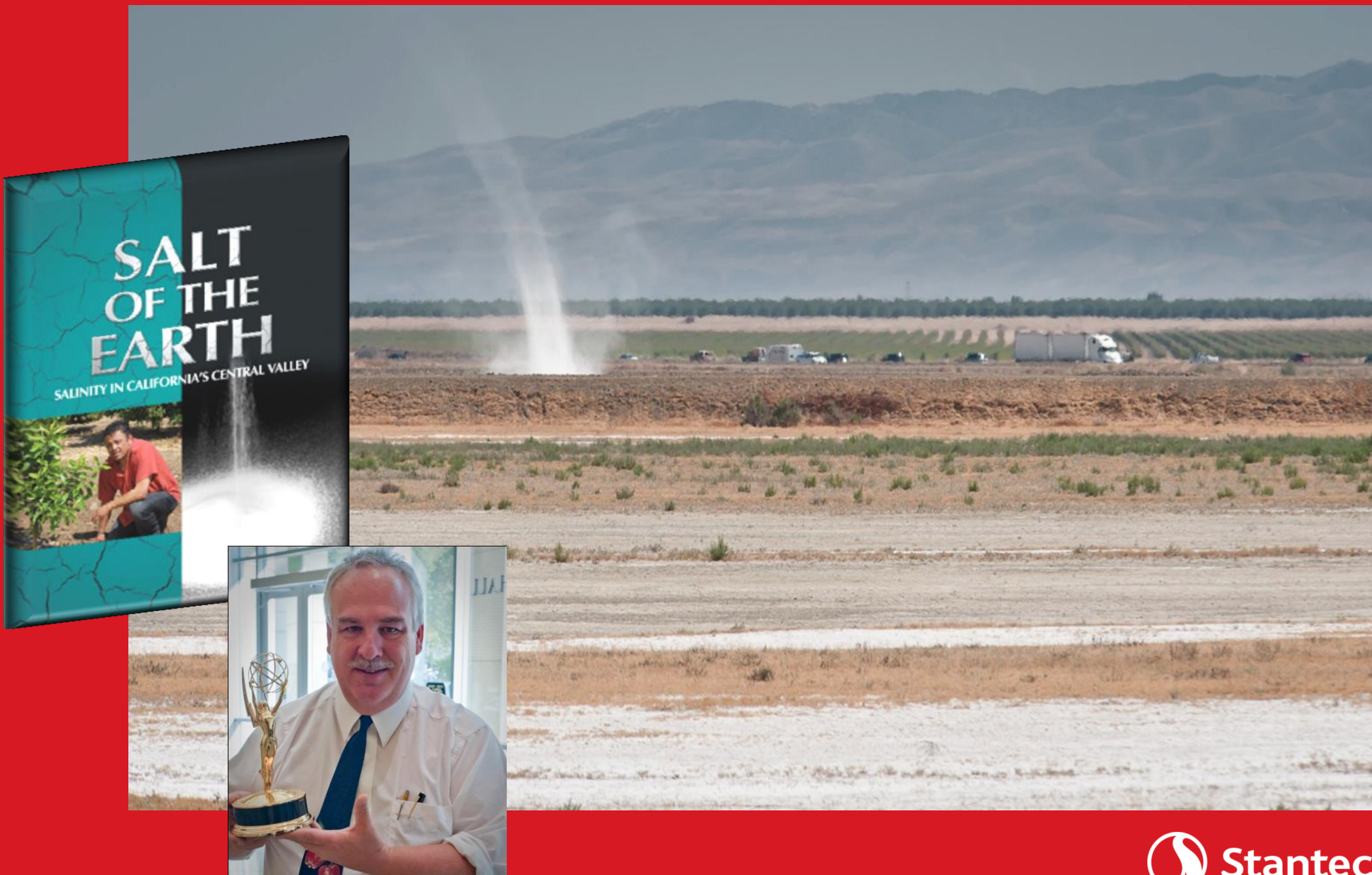
CV SALTS
Central Valley Salinity Alternatives for Long-term Sustainability



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CV_SALTS - Salt and Nutrient Management Plan Implementation

- Groundwater Management Zone Policy
- Nitrate Management Strategy
- ACP Guidelines Policy
- Salinity Management Strategy
- Salinity Variance Policy
- Drought Policy
- Exemptions Policy

More Information:
www.cvsalinity.org

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Salinity Management – Other Case Studies

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Salinity Management – City of Newman

Project Background

- Located in Central Valley, California
- Effluent is disposed via reclamation and crop irrigation
- High salinity in underlying shallow groundwater

Salinity Management Solution

- Alternative source water for blending to match leaching fraction salinity to background conditions
- Maximized the local beneficial use of effluent for agricultural irrigation

Salinity Management – Water Efficiency in Agricultural Operation

Converting 3,800 acres to pressurized system with automated ordering resulted in:

- 30% reduction in on-farm water use
- 30% increase in crop yields

Stantec developed a predictive tool for long-term salinity management

2014 WatSave Technology Award –
International Committee on Irrigation & Drainage

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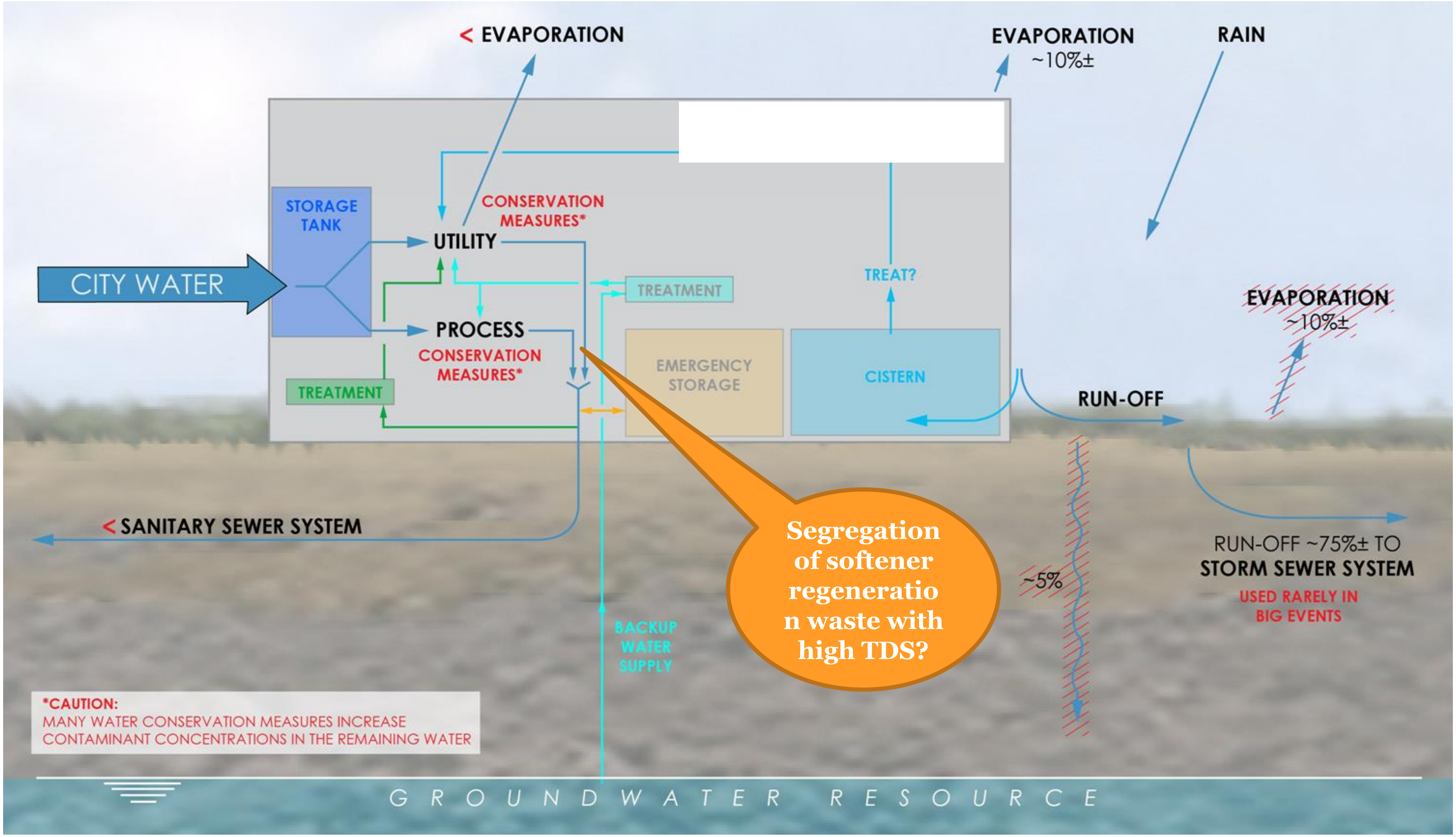
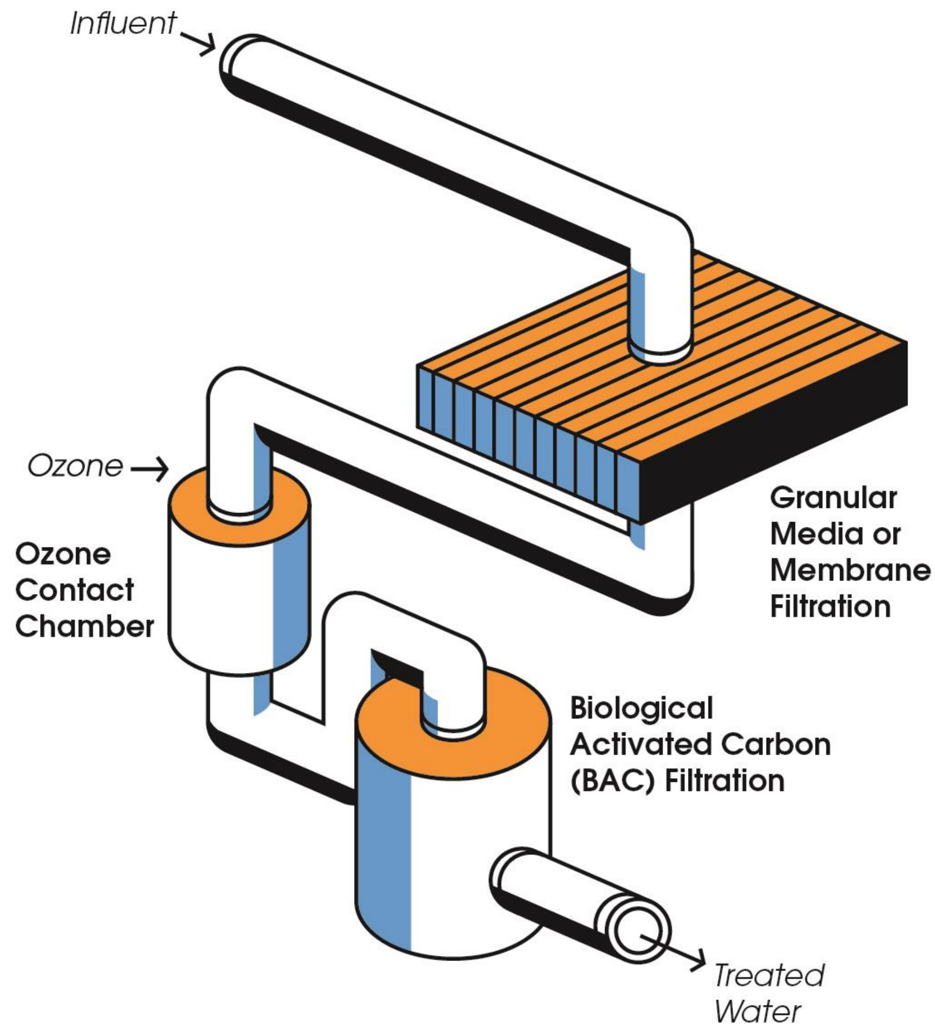
Salinity Management – Industrial Facility



Management of Chemicals and Emerging Concern (CECs)

Ozone-BAC: Alternative to RO AWTF

- Most refractory organics destroyed, not concentrated in brine stream
- No brine stream generated needing treatment and/or disposal
- Lower capital cost
- Lower energy utilization and O&M cost



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MF-Ozone-BAC Effluent Water Quality

Group	Constituents	Units	Secondary Clarifier Effluent	Membrane Filter Effluent	Ozonation Effluent	BAC Effluent	Blank
Hormones	Estradiol	ng/l	5.9	3.4	1.9	1.8	2
	Estrone	ng/l	65	11.9	0.52	0.5	0.5
Pharmaceuticals	Gemfibrozil	ng/l	45.7	35.3	0.2	0.2	< 0.080
	Ibuprofen	ng/l	4.4	6.4	< 0.39	< 0.39	< 0.39
	Naproxen	ng/l	20.5	17.9	< 0.25	< 0.25	< 0.25
	Triclosan	ng/l	54.7	2.2	< 1.2	< 1.2	< 1.2
	Diazepam	ng/l	2.7	2.8	0.18	< 0.14	< 0.14
	Fluoxetine	ng/l	3.2	2.4	2	< 0.080	< 0.080
	Primidone	ng/l	140	129	4.6	< 0.6	< 0.6
	Trimethoprim	ng/l	270	130	< 2.4	< 2.4	< 2.4
	Atorvastatin	ng/l	14.3	5.5	< 0.11	< 0.11	< 0.11
	Azithromycin	ng/l	323	102	< 22	< 22	< 22
	Caffeine	ug/l	25	10.8	< 0.042	< 0.042	< 0.042
	Ciprofloxacin	ng/l	363	247	< 14	< 14	< 14
	Cotinine	ng/l	54.5	20.5	14	2.3	0.49
	Meprobamate	ng/l	385	343	43.5	3	< 1
	Sulfamethoxazole	ng/l	930	833	6.0	< 0.25	< 0.25
	Methadone	ng/l	65.3	33	0.3	0.13	< 0.4
	Atenolol	ng/l	953	890	10.6	< 1	< 1
	Carbamazepine	ng/l	258	247	0.98	0.8	0.8
	Dilantin	ng/l	253	150	3.1	< 1	< 1
	Diclofenac	ng/l	96	109	< 0.5	< 0.5	< 0.5
	Amoxicillin	ng/l	1633	1020	0.74	ND	ND
	Phenytoin	ng/l	390	343	3.9	ND	ND
	Salicylic Acid	ng/l	25	32.67	28	20.67	48.67
Flame Retardants	TCEP	ng/l	620	545	445	< 3.4	< 3.4
	TCPP	ng/l	2100	2400	1400	< 2.7	< 2.7
	TDCPP	ng/l	633	623	627	0.695	3.23
Industrial EDCs	Bisphenol A	ng/l	18	22	< 0.27	< 0.27	2200
	Octylphenol	ng/l	31	< 25	< 25	< 25	< 25
	Nonylphenol monoethoxylate	ug/l	1.1	0.87	< 0.87	< 0.87	< 0.87
Organics	DEET	ng/l	115	125	2.56	< 0.60	1.2
	Musk Ketone	ng/l	47	38	< 25	< 25	< 25
	BHA	ng/l	76	42	< 1	< 1	< 1
	Atrazine	ng/l	1.3	1.5	0.5	< 0.25	< 0.25
	Benzophenone	ng/l	203	173	< 50	< 50	< 50
	1,4-Dioxane	ug/l	1.53	1.5	0.3	0.4	< 0.13
Ozone Byproducts	Formaldehyde	ug/l	9.2	9.8	133.3	5.8	2.4
	Acetaldehyde	ug/l	3.5	2.1	31.0	< 1	< 1
	Ethyl Glyoxal	ug/l	3.3	3.1	41.3	3.9	< 1.1
	Methyl Glyoxal	ug/l	3.3	3.4	27.0	3.7	< 0.5
	Propanal	ug/l	<0.7	<0.7	3.5	< 0.7	< 0.7
	NDMA	ng/l	1	0.9	7.9	< 0.28	0.385

Detected Not Detected QA/QC Interference

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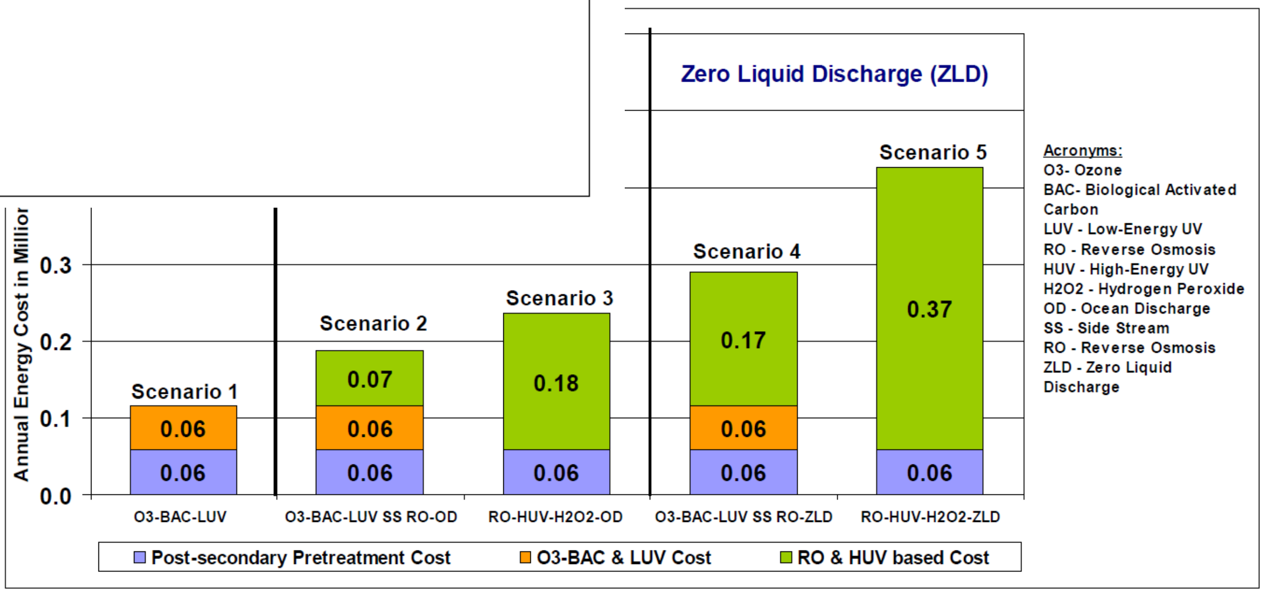
Table 1: Relative Capital Costs

Technology	Preliminary Relative Capital Cost
O3-BAC-LUV	$ 1.0x
O3-BAC side-stream RO-OD	$ 1.4x
RO-H2O2-HUV-OD	$ 1.7x
O3-BAC-LUV side-stream RO-ZLD	$ 2.5x
RO-H2O2-HUV-ZLD	$ 3.3x

Acronyms:
O3: Ozone
BAC: Biological activated carbon
LUV: Low-energy UV
RO: Reverse Osmosis
H2O2: Hydrogen Peroxide
HUV: High-energy UV
OD: Ocean discharge
ZLD: Zero liquid discharge

MGD (Unit Power Cost = $0.14/kWh)



Ozone-BAC Technology Development

2008 - 2011

Reno-Stead WRF Ozone-BAC Pilot Project

Stantec/City of Reno team demonstrated Ozone-BAC as an equally effective alternative to RO for CEC and regulated contaminant removal.

2015 - 2018

WE&RF 15-10 Ozone-BAC Optimization Project

Stantec/American Water/Washoe County team is investigating DBP formation of Ozone-BAC effluent and BAC EBCT Optimization.

2016 - 2020

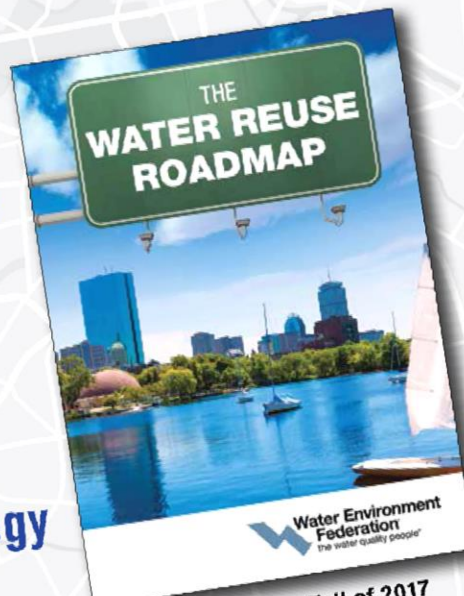
UNR Project – Demonstration of IPR Treatment Trains

UNR/Reno Regional Team will conduct "Membrane Free" IPR demonstration projects based on Nevada IPR Regulations.

The Water Reuse Roadmap

PRIMER

Essential practices to make water reuse an element of a diverse and resilient water management strategy



Book coming Fall of 2017