NITRATE TREATMENT TECHNOLOGY WORKSHOP
Sponsored by
State Water Resources Control Board (SWRCB)
and
California Department Public Health (CDPH)
September 4 & 5, 2013
Byron Sher Auditorium
Second Floor CalEPA Building
1001 I Street
Sacramento, CA 95814
(Public Webcast: http://www.calepa.ca.gov/broadcast)

Day One

Morning Session

***Updated!* As of: 8/28/2013**

Part I

8:30 – 9:00	**CHECK-IN**	
9:00 – 9:15	I.	Opening Remarks (15 minutes) – Frances Spivy-Weber, Vice Chair, SWRCB and Mark Starr, DVM, MPVM, DACVPM, Deputy Director for Environmental Health, CDPH
9:15 – 9:25	II.	Nitrate in Groundwater and its Effects (10 minutes) – John Borkovich, Senior Engineering Geologist, SWRCB
9:25 – 9:50	III.	Regulatory Requirements / Health Concerns (25 minutes) – Mark Bartson, Supervising Engineer and Eric Miguelino, M.D., Research Scientist, CDPH
9:50 – 10:10	**BREAK**	
10:10 – 10:35	IV.	Impacts to Small Disadvantaged Communities and Case Studies (25 minutes) – Jeanette Pantoja, Water and Land Use Community Worker, California Rural Legal Assistance, Inc. and Omar Carillo, Policy Analyst, Community Water Center
10:35 – 11:00	V.	Challenges for Treatment of Nitrates / On-going Nitrate Treatment Studies (25 minutes) – Chad Seidel, Manager of Water Technology, Jacobs Engineering
11:00 – 11:25	VI.	Disposal Options for Treatment Residuals from Drinking Water Treatment Systems (25 minutes) – Rob Busby, Supervising Engineering Geologist, Central Valley Regional Water Quality Control Board – Sacramento Office
11:25 – 11:50	VII.	Biological Treatment - General Overview (25 minutes) – Eugene Leung, Senior Sanitary Engineer, CDPH

LUNCH ON YOUR OWN (11:50 AM – 1:05 PM)

Part II

Technical Presentations

Technical presentations at a minimum should include the following and will be limited to 20 minutes and additional five minutes for questions and answers for a total of 25 minutes:

1. Costs: system purchase price, installation costs, O&M costs
2. Effectiveness of treatment for other co-contaminants, such as arsenic or pathogens
3. System reliability
4. Suitability for small water system (minimum treatment capacity)
5. Strength and quantity of brine/residuals if applicable
6. Brine/residuals disposal options if applicable
7. Location(s) of existing system installation(s)
8. Quality of treatment system waste stream (volume, pollutant concentrations)

Disclaimer: The presentations are intended as a guide of nitrate treatment technologies and should be used as an informational tool only. The contents of the presentations are solely the responsibility of the presenters/authors and do not necessarily represent the official views of the State Water Resources Control Board and the Department of Public Health. The selection and design of the most appropriate nitrate treatment alternative for a particular water system depends on a variety of factors and requires the expertise of experienced professional engineers. Discussion of proprietary technologies is intended to provide information about treatment alternatives and does not imply endorsement.

Day One

Afternoon Session

***Updated!* As of: 8/28/2013**

Residential Level Treatment Technology (rescheduled)

1:05 – 1:30	VIII.	Smart Water Systems For Distributed Deployment (25 minutes) – Yoram Cohen, Professor, Chemical and Biomolecular Engineering, University of California, Los Angeles

Innovative Biological Treatment Technologies for Nitrate

Summary: Biological treatment of nitrate relies on bacteria to transform nitrate to nitrogen gas. A major advantage of biological treatment is the avoidance of waste brine disposal. Substrate or media for the bacteria to grow on and an electron donor are key elements for treatment technologies of this type. Variations of biological treatment lie in the type and/or form of substrate used and electron donor used, as well as its delivery method.

1:30 – 1:55	IX.	A Novel Biotechnology for Treatment of Nitrate in Water (25 minutes) – Ali Dorri, Director of Business Development, Microvi Biotech, Inc.
1:55 – 2:20	X.	Nitrate Treatment with ARoNite™, a Novel Hydrogen-Based Biological Reduction Process (25 minutes) – David Friese, ARoNite™ Technology Director, APTWater, Inc.
2:20 – 2:40	**BREAK**	
2:40 – 3:05	XI.	Utilization of a Fluidized Bed Bioreactor for the Treatment of Nitrate Laden Water to Potable Water (25 minutes) – Todd S. Webster, Ph.D., P.E., Regional Vice President – West, Envirogen Technologies, Inc.
3:05 – 3:30	XII.	Drinking Water Test at West Valley Water District Site (25 minutes) – Peter Hall, Chief Engineer, MIH Water Treatment Inc.
3:30 – 3:55	XIII.	Efficient Destruction of Multiple Groundwater Contaminants Using the BIOTTTA™ System (25 minutes) – Jess Brown, R&D Practice Director, Carollo Engineers
3:55 – 4:20	XIV.	Biological Nitrate Treatment – Experience and Insights from Two Demonstration Studies (25 minutes) – Issam Najm, President, Water Quality & Treatment Solutions, Inc. (WQTS)
4:20 – 5:00	XV.	Responses to Audience Questions and Technical Discussion (40 minutes)

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Day Two

Morning Session

***Updated!* As of: 8/28/2013**

8:30 – 9:00 **CHECK-IN**

9:00 – 9:10 I. Opening Remarks – Recap of Day 1; Overview of Day 2 (10 minutes) – Gita Kapahi, Facilitator, Director, Office of Public Participation, SWRCB

9:10 – 9:40 II. Challenges Facing Small Systems and Point-of-Use Devices (30 minutes) – Cindy Forbes, Principal Engineer and Eugene Leung, Senior Sanitary Engineer, Drinking Water Program, CDPH

Residential Level Treatment Technologies

Summary: Point-of-Use (POU) and Point-of-Entry (POE) treatment devices rely on many of the same treatment technologies used in centralized treatment plants. However, while centralized plants treat all water distributed to consumers to the same level, POU and POE treatment devices treat only a portion of the total flow. A POU device treats only the water intended for direct consumption (drinking and cooking), typically at a single tap or a limited number of taps, while a POE device treats all the water entering a single home, business, school, or facility.

POU treatment devices may be an interim treatment option for public water systems while a POE or centralized treatment system is designed and installed. POE treatment devices may be an option for public water systems where central treatment is not affordable.

Nitrate POU – Reverse osmosis treatment units are used to treat only the water intended for direct consumption.

9:40 – 10:20 III. NSF/ANSI Certification of Point-of-Use Devices (40 minutes) – Representatives from NSF International and Water Quality Association

10:20 – 10:40 **BREAK**

10:40 – 11:10 IV. Environmental Justice Group's Experience with POUs (30 minutes) – Abigail Solis, Community Projects Coordinator and Shen Huang, Technical Engineer, Community Water Center

11:10 – 12:00 V. Responses to Audience Questions and Technical Discussion (50 minutes)

LUNCH ON YOUR OWN (12:00 PM – 1:15 PM)

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Day Two

Afternoon Session

***Updated!* As of: 8/28/2013**

Centralized Treatment Technologies

1:15 – 1:25	VI.	Ion Exchange Treatment Background (10 minutes) – Chad Seidel, Manager of Water Technology, Jacobs Engineering
1:25 – 1:50	VII.	Small Water System Economics for Near Zero Liquid Waste Denitrification (25 minutes) – Phil Chandler, Managing Director and Mike Waite, Director of Technology, Ionex SG Limited
1:50 – 2:15	VIII.	Innovative Ion Exchange Solutions for the Treatment of Nitrate Laden Water to Potable Water for Small Communities (25 minutes) – William Schwartz, P.E., Process Engineering Manager, West Region, Envirogen Technologies
2:15 – 2:40	IX.	Nitrate in Groundwater; IX & Catalyst Water Treatment Solutions (25 minutes) – Charles Drewry, National Sales Manager, IX/ISEPWater Treatment Solutions, Calgon Carbon Corporation
2:40 – 3:05	X.	Orica Watercare's EnviroPak and Nitrate Technologies (25 minutes) – Scott Ostrowski, Western Regional Manager, Orica Watercare, Inc.
3:05 – 3:25	**BREAK**	
3:25 – 3:35	XI.	Selective Electro Dialysis (10 minutes) – Eugene Leung, Senior Sanitary Engineer, CDPH
3:35 – 3:55	XII.	Other Treatment Technologies (20 minutes) – Chad Seidel, Manager of Water Technology, Jacobs Engineering
3:55 – 4:35	XIII.	Responses to Audience Questions and Technical Discussion (40 minutes)
4:35 – 4:50	XIV.	Closing (15 minutes) – Frances Spivy-Weber, Vice Chair, SWRCB and Mark Starr, DVM, MPVM, DACVPM, Deputy Director for Environmental Health, CDPH

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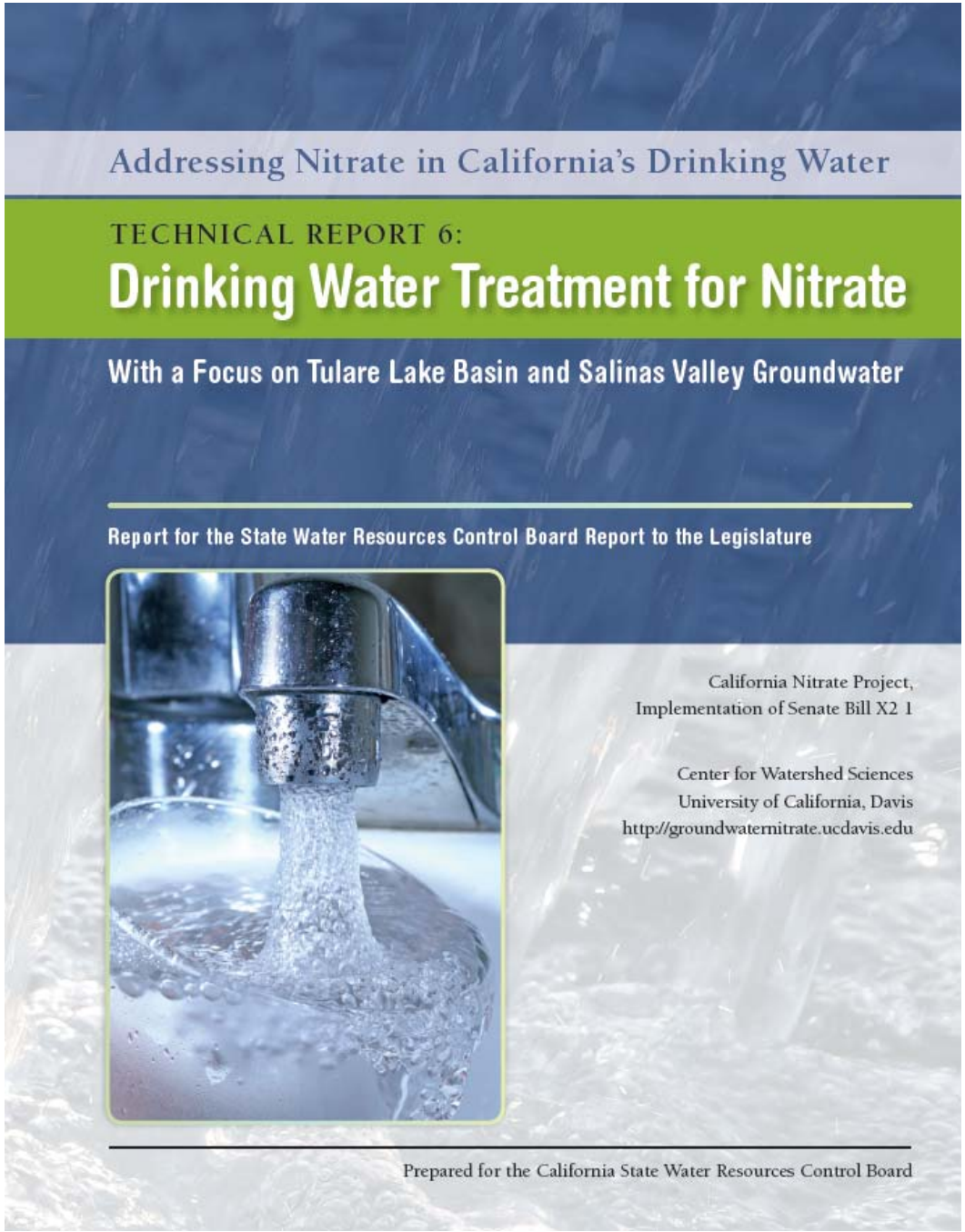
Select Pages, Tables and Charts from Technical Report 6:

Drinking Water Treatment for Nitrate

Full report maybe downloaded from:
http://groundwaternitrate.ucdavis.edu/



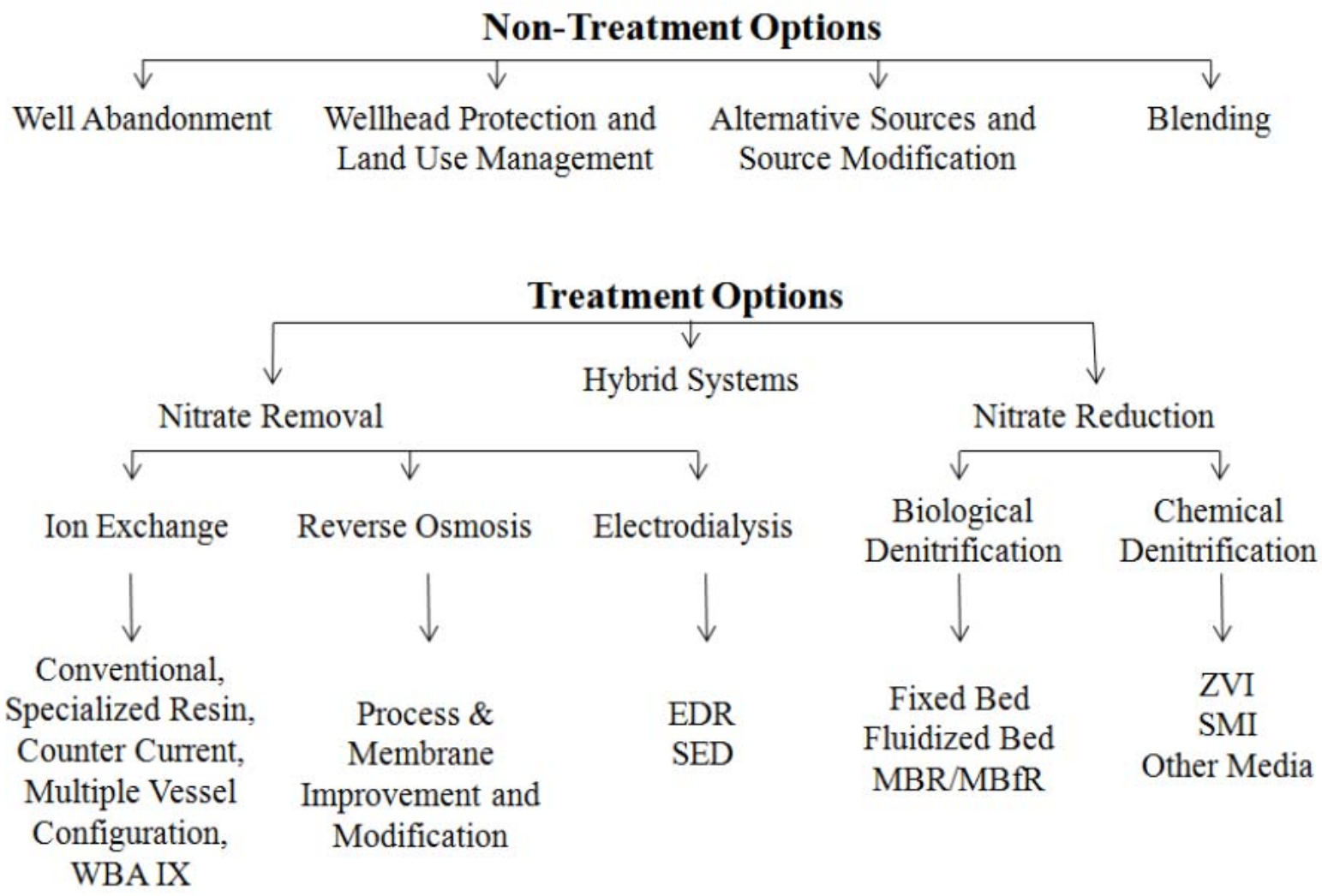


Figure S.1. Summary of nitrate management options.[4]

Table 2. Potable water treatment options for nitrate management (adapted from WA DOH 2005).

	Ion Exchange	Reverse Osmosis	Electrodialysis	Biological Denitrification	Chemical Denitrification
Full-scale Systems	Yes	Yes	Yes	Yes	No
Treatment Type	Removal to waste stream	Removal to waste stream	Removal to waste stream	Biological reduction	Chemical reduction
Common Water Quality Design Considerations	Sulfate, iron, manganese, total suspended solids (TSS), metals (e.g., arsenic), hardness, organic matter	Turbidity, iron, manganese, SDI, particle size, TSS, hardness, organic matter, metals (e.g., arsenic)	Turbidity, iron, manganese, TSS, hydrogen sulfide, hardness, metals (e.g., arsenic)	Temperature and pH, anoxic conditions	Temperature and pH
Pretreatment Needs	Pre-filter, address hardness	Pre-filter, address hardness	Pre-filter, address hardness	pH adjustment, nutrient and substrate addition, need for anoxic conditions	pH adjustment
Post-treatment Needs	pH adjustment	pH adjustment Remineralization	pH adjustment Remineralization	Filtration, disinfection, possible substrate adsorption	pH adjustment, iron removal, potential ammonia control
Waste/Residuals Management	Waste brine	Concentrate	Concentrate	Sludge/biosolids	Waste media, Iron sludge
Start-up Time	Minutes	Minutes	Minutes	Initial plant startup: Days to weeks After reaching steady state: Minutes	Minutes
Water Recovery	Conventional (97%) Low brine (Up to 99.9%)	Up to 85%	Up to 95%	Nearly 100%	Not demonstrated full-scale
Advantages	Nitrate selective resins, common application, multiple contaminant removal	Multiple contaminant removal, desalination (TDS removal)	Multiple contaminant removal, higher water recovery (less waste), desalination, unaffected by silica	No waste brine or concentrate, nitrate reduction rather than transfer to a waste stream, high water recovery, and potential for multiple contaminant removal	No waste brine or concentrate, nitrate reduction rather than transfer to a waste stream, and potential for multiple contaminant removal
Disadvantages	Potential for nitrate peaking, high chemical use (salt), brine waste disposal, potential for disinfection byproduct (DBP) formation (e.g., NDMA)	Membrane fouling and scaling, lower water recovery, operational complexity, energy demands, waste disposal	Energy demands, operational complexity, waste disposal	Substrate addition, potentially more complex, high monitoring needs, possible sensitivity to environmental conditions, risk of nitrite formation (potential incomplete denitrification), post-treatment to address turbidity standards and 4-log virus removal (state dependent)	Inconsistency of nitrate reduction, risk of nitrite formation (potential incomplete denitrification), reduction to ammonia, lack of full-scale systems, pH and temperature dependence, possible need for iron removal

Table A.6. Advantages and disadvantages of the five major treatment options for nitrate removal.

	Advantages	Disadvantages
Ion Exchange	• Years of industry experience, • Multiple contaminant removal, • Selective nitrate removal, • Financial feasibility, • Use in small and large systems, and • The ability to automate.	• The disposal of waste brine, • The potential for nitrate dumping specifically for non-selective resin use for high sulfate waters, • The need to address resin susceptibility to hardness, iron, manganese, suspended solids, organic matter, and chlorine, and • The possible role of resin residuals in DBP formation.
Reverse Osmosis	• High quality product water, • Multiple contaminant removal, • Desalination (TDS removal), • Feasible automation, • Small footprint, and • Application for small and POU applications.	• The disposal of waste concentrate, • Typically high capital and O&M costs, • The need to address membrane susceptibility to hardness, iron, manganese, suspended solids, silica, organic matter, and chlorine, • High energy demands, and • The lack of control over target constituents (complete demineralization).
Electrodialysis/ Electrodialysis Reversal	• Limited to no chemical usage, • Long lasting membranes, • Selective removal of target species, • Flexibility in removal rate through voltage control, • Better water recovery (lower waster volume), • Feasible automation, and • Multiple contaminant removal.	• The disposal of waste concentrate, • The need to address membrane susceptibility to hardness, iron, manganese, and suspended solids, • High maintenance demands, • Costs (comparable to RO systems), • The need to vent gaseous byproducts, • The potential for precipitation with high recovery, • High system complexity, and • Dependence on conductivity.
Biological Denitrification	• High water recovery, • No brine or concentrate waste stream (nitrate reduction rather than removal to waste stream), • Low sludge waste, • Less expensive operation, • Limited chemical input, • Increased sustainability, and • Multiple contaminant removal.	• The need for substrate and nutrient addition, • High monitoring needs, • Significant post-treatment requirements, • High capital costs, • Sensitivity to environmental conditions (sometimes), • Large system footprint (sometimes), • High system complexity (sometimes, can be comparable to RO), • Lack of full-scale systems in the U.S., • The possibility of partial denitrification, • Permitting and piloting requirements, and • Slower initial start-up, which could cause challenges for wells with intermittent run time.

Chemical Denitrification	• Conversion of nitrate to other nitrogen species (no brine or concentrate waste stream),
	• The potential for more sustainable treatment,
	• High water recovery (higher than RO according to Cleanit®-LC), and
	• Multiple contaminant removal.
		• The potential reduction of nitrate beyond nitrogen gas to ammonia,
		• The possibility of partial denitrification,
		• The possible dependence of performance on pH and temperature,
		• The possible need for iron removal, and
		• The lack of full-scale chemical denitrification systems resulting in:
		  ○ Unknown reliability,
		  ○ Unknown costs, and
		  ○ Unknown operational complications.

MCL may lead to the selection of one treatment option while nitrate levels just above the MCL may be more cost-effectively addressed with a different treatment option. Table 19 lists several scenarios as an example of appropriate options based on influent nitrate level and water system characteristics.

Table 18. Comparison of major treatment types.[1]

Concerns	IX	RO	EDR	BD	CD	Priorities	IX	RO	EDR	BD	CD
High Nitrate Removal						High Hardness Not a Major Concern					
High TDS Removal						Reliability					
Arsenic Removal						Training/ Ease of operation					
Radium and Uranium Removal						Minimize Capital Cost					
Chromium Removal						Minimize Ongoing O&M Cost					
Perchlorate Removal						Minimize Footprint					
						Industry Experience					
						Ease of Waste Management					

Good	→	Poor	Unknown (blank)

[1] Ion Exchange (IX), Reverse Osmosis (RO), Electrodialysis Reversal (EDR), Biological Denitrification (BD), Chemical Denitrification (CD). This table offers a generalized comparison and is not intended to be definitive. There are notable exceptions to the above classifications.

Table 19. Influence of nitrate concentration on treatment selection.[1]

Option	Practical Nitrate Range	Considerations
Blend	10 – 30% above MCL	Dependent on capacity and nitrate level of blending sources.
IX	Up to 2X MCL	Dependent on regeneration efficiency, costs of disposal, and salt usage. Brine treatment, reuse, and recycle can improve feasibility at even higher nitrate levels.
RO	Up to many X the MCL	Dependent on availability of waste discharge options, energy use for pumping, and number of stages. May be more cost-effective than IX for addressing very high nitrate levels.
BD	Up to many X the MCL	Dependent on the supply of electron donor and optimal conditions for denitrifiers. Ability to operate in a start-stop mode has not yet been demonstrated in full-scale application; difficult to implement for single well systems. May be more cost-effective than IX for addressing high nitrate levels.

[1] Based on contact with vendors and environmental engineering consultants.

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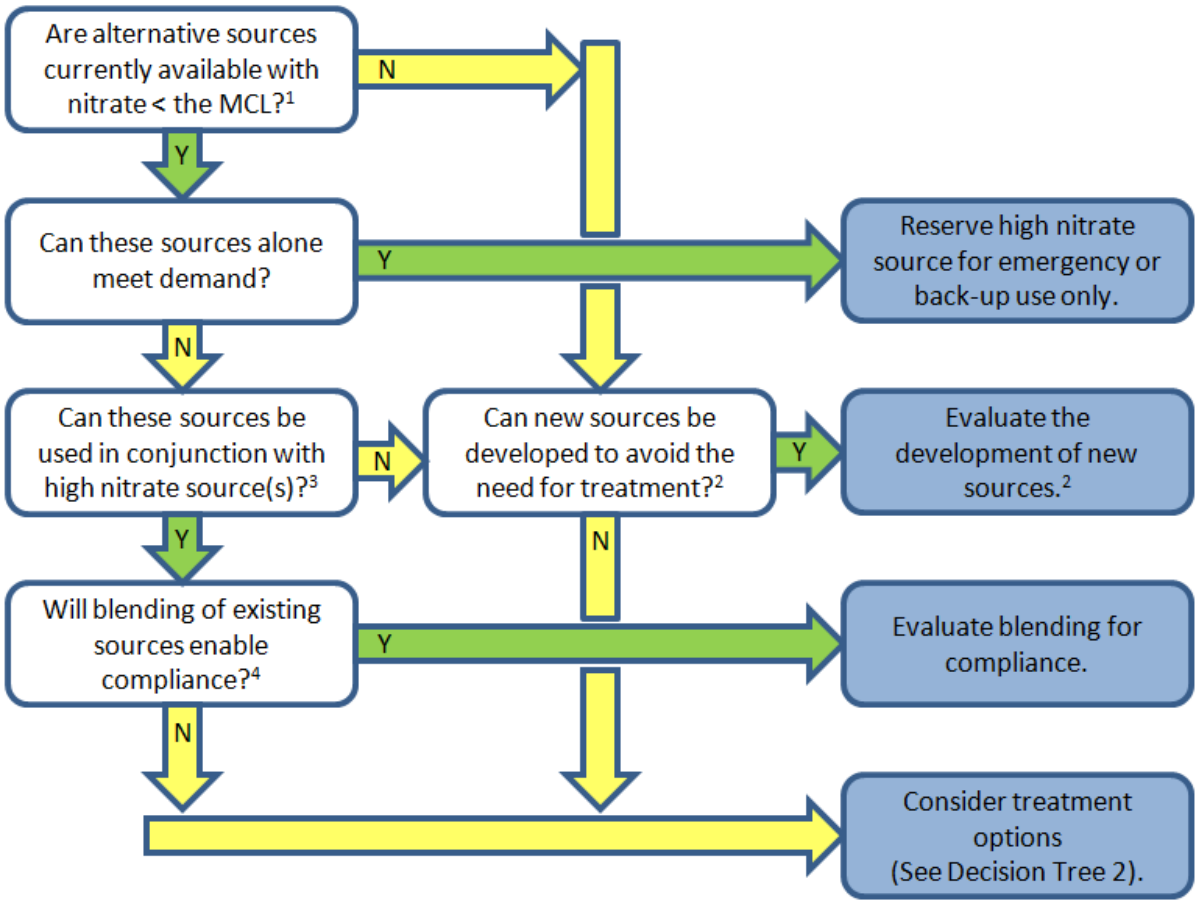
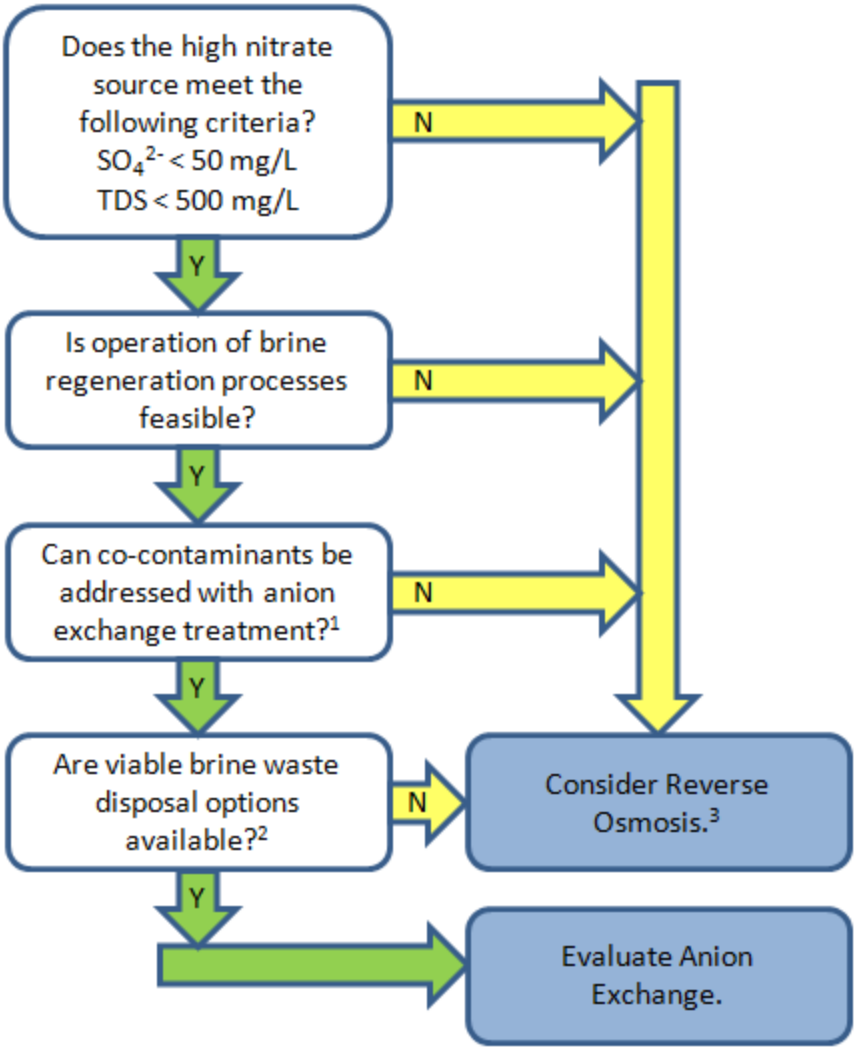
7.2 Decision Trees



1. Currently available sources could include additional existing wells or surface water.
2. Potential new sources could include new well development, surface water, consolidation with nearby system(s) or connection to an existing nearby system.
3. Are there any obstacles to using sources together? For example, is the alternative source a great distance from the high nitrate source?
4. Is there a feasible blend ratio to provide compliant water that would consistently meet demand taking into consideration potential co-contaminants and seasonal variation in demand and/or water quality?

Figure 36. Decision Tree 1 - Options to address nitrate impacted drinking water sources (adapted from U.S. EPA 2003b, WA DOH 2005a, and WA DOH 2005b).



1. In addition to nitrate, certain co-contaminants can be addressed simultaneously through anion exchange treatment (e.g., arsenic and perchlorate); however, specialized resin may be required for different constituents.
2. Viable options can include disposal to sewer, evaporation ponds, and a brine line.
3. Reverse osmosis can address certain co-contaminants that anion exchange cannot and generally results in a less concentrated waste stream. For systems serving < 500 people, POU reverse osmosis is another option to consider.

Figure 37. Decision Tree 2 - Anion exchange (adapted from USEPA 2003, WA DOH 2005a, and WA DOH 2005b).

3.4.1 Biological Denitrification - Design Considerations

Table 11 summarizes key design considerations in the application of biological denitrification.

Table 11. Summary of design considerations for biological denitrification for nitrate removal in potable water.

Pretreatment	• Substrate and nutrient dosing • pH adjustment

Post-Treatment	• Carbon adsorption for organic carbon removal
	  ○ Carbon adsorption is not always required
	  ○ Residual substrate removal can be accomplished via biological filtration
	• Aeration
	• Filtration
	• Disinfection

Chemical Usage	• Possible pH adjustment • Substrate and nutrient addition • Coagulant/polymer use to meet turbidity standards • Disinfection

O&M	• Historically operator intensive
	  ○ Operator demands can be minimized with latest design configurations
	• Constant monitoring required to assure efficient removal, microbe health, etc.
	• Monitoring of nitrite and ammonia will also be necessary due to the potential for incomplete denitrification
	• Management of chemicals
	• Waste sludge storage and disposal
	• New plants can be highly automated
	• Historically viewed as operationally complex
	  ○ More unit processes than IX
	  ○ New design configurations can minimize complexity (e.g., fixed bed)

System Components	Important process considerations include (Dördelmann 2009): • Dosage requirements of substrate and nutrients • Reactor configuration and governing equation of the biological process • Aeration to remove nitrogen gas and provide oxygen • Filtration to remove particulate matter • Activated carbon may be used to remove substrate residual and avoid DBP formation (for heterotrophic systems) • Disinfection
Waste Management and Disposal	• Sludge disposal – Biological solids and residual organic matter • No waste brine or concentrate as in separation processes
Limitations	• Requires anoxic conditions • Chemical management • Few examples for nitrate removal in the U.S. • Post-treatment requirements • Operator training • Intermittent use of wells may be challenging due to the need for acclimation of microorganisms

Table 6. Summary of design considerations for reverse osmosis.

RO Membranes	• Thin film membranes - Higher rejection rates, lower pressures than CTA membranes • Cellulose triacetate membranes (CTA) - Tolerant of low chlorine levels • Hollow fiber membranes - Compact configuration • Ultra-low pressure RO membranes (ULPRO) • Consider rejection rate, water recovery, and frequency of cleaning • Multiple contaminant removal

Pretreatment	• Prevent membrane damage, scaling and biological, colloidal, and organic fouling
	• Scaling
	  ○ Acid (e.g., sulfuric acid) and/or anti-scaling agents (e.g., poly-acrylic acid)
	  ○ Water softening
	• Biological fouling
	  ○ Upstream disinfection, but dechlorination to prevent membrane damage
	  ▪ Reducing agent (e.g., sodium bisulfate) or activated carbon
	• Colloidal fouling
	  ○ Pre-filtration to remove suspended solids
	  ○ Chemical treatment to keep suspended solids in solution

Post-Treatment	• Avoid corrosion
	  ○ Adjust pH, restore alkalinity for buffering capacity (see remineralization) and/or add corrosion inhibitor (e.g., poly-orthophosphate blend)
	• Remineralization
	  ○ Blending, pH adjustment, addition of caustic soda, bicarbonate, sodium carbonate, phosphates, and/or silicates
	• Blending, disinfection, and storage

Chemical Usage	• pH adjustment, up and down (acids and bases) • Anti-scalants • Cleaning chemicals (acids and bases)

O&M	• Frequency of membrane cleaning depends on water quality and membrane used
	  ○ Typically once a month for 1 hour
	• Management of chemicals and pre-filtration system
	• Waste storage and disposal
	• Membrane replacement/membrane life
	  ○ Up to 20 years or more with appropriate pretreatment and maintenance
	• Monitoring of nitrate levels and membrane flux rate
	• Automation can be feasible
	• Low operational complexity (though higher than IX depending on pretreatment needs)

System Components	• Maximize water recovery while minimizing energy use
	  ○ Pressure range of 100 to 200 psi
	  ○ Based on system size and feed water quality
	• Key system configuration parameters are system flow rate, number of membranes/stages, system footprint, flux rate, water recovery rate, pump selection and sizing, pressure requirement, cleaning frequency

Waste Management and Disposal	• Significant cost of waste brine/concentrate disposal of greatest concern for inland systems • Management options include sewer or septic system, drying beds, trucking off-site, coastal pipeline, deep well injection, and advanced treatment • Disposal options can be limited by waste brine/concentrate water quality (e.g., volume, salinity, metals, and radionuclides) • Optimization of recycling and treatment of waste brine/concentrate • Higher water recovery (more costly) to minimize waste volume (tradeoff between energy costs and disposal costs)
Limitations	• Need to prevent membrane scaling, fouling, and damage ○ Hardness, iron, manganese, suspended solids, silica, and chlorine • High energy demands • Disposal of waste concentrate • Complete demineralization (no control over target constituents)

Water Quality

While regulated by operational pressure, the water recovery rate depends largely on feed composition. Problematic constituents include sulfate, calcite, calcium sulfate dehydrate (gypsum), silica, colloids, and microorganisms (Cevaal et al. 1995; Elyanow & Persechino 2005; Tarabara 2007). Filtration upstream of the RO membranes is required to remove suspended solids. The life of the RO membranes and prefilters, and the frequency of membrane cleaning are also directly dependent on water quality and the efficiency of pretreatment measures.

Treatment efficiency can be compromised by membrane fouling. Anything that decreases available membrane surface area can limit the passage of water through the membrane and decrease water recovery. The four main types of membrane fouling are scaling, colloidal fouling, biological fouling, and organic fouling. When the salt concentration in the feed water exceeds the saturation point at the membrane surface, precipitation of solids on the membrane can diminish the removal efficiency (Elyanow & Persechino 2005). Scale forming constituents,[14] such as precipitates of silica, calcium, barium, and strontium salts pose a significant threat to RO by limiting the membrane surface area

[14] Pretreatment options to prevent scaling include the addition of acid and/or anti-scaling agents and water softening. By decreasing the pH, the prevalent form of the carbonate cycle is bicarbonate rather than the carbonate ion. The precipitation of calcium carbonate will therefore be limited by the concentration of the carbonate ion. Note: the addition of acid helps only if the scale forming constituent is calcite, due to the speciation of carbonate (Lenntech, 2009c). Anti-scaling chemicals can function in three ways: threshold inhibition, crystal modification, and dispersion (Lenntech, 2009c). Threshold inhibition occurs when the anti-scalant increases the solubility of a potential scalant to super saturation, allowing for a greater concentration to remain in solution. Crystal modification refers to the interference of negatively charged functional groups on the anti-scalant with salt crystal formation and membrane attachment. Anti-scaling chemicals can also promote dispersion of crystals by attaching to them and increasing their negative charge. The most economical means of membrane scale control will depend on the system, but typically the use of anti-scaling agents alone or in combination with acid addition is the most financially prudent option. The third alternative to prevent membrane scaling is to remove the problematic constituents from the water entirely. Water softening can be used to replace calcium and magnesium cations with sodium ions. Generally the most expensive option, this requires the addition of a water softener upstream of the membranes and will result in an additional brine waste stream.

Table 4. Summary of design considerations for conventional IX.

Resin Selection	• Generic SBA resins for maximum exchange capacity (for low sulfate)
	  ○ Less expensive than nitrate selective resins
	  ○ Less frequent regeneration due to higher capacity (in the absence of co-contaminants)
	  ○ Nitrate dumping potential
	• Nitrate selective resins to avoid nitrate dumping (for high sulfate)
	  ○ More expensive than generic resins
	  ○ Longer bed life
	  ○ More nitrate removed per unit of waste brine

Pretreatment	• Filtration to remove iron, manganese, TSS, and organic matter to prevent resin fouling • Water softening (anti-scalant, acid, or water softener) to prevent scaling • Dechlorination to prevent resin oxidation[10]
Post-Treatment	• Chloride : alkalinity ratio and dezincification[11] • Chloride : sulfate ratio and galvanic corrosion[12] • Potential pH adjustment and restoration of buffering capacity to avoid corrosion
Chemical Usage	• pH adjustment (caustic soda or soda ash) • Regenerant brine, salt consumption
O&M	• Frequency of regeneration depends on water quality and resin type • Fresh brine preparation and waste disposal • Resin loss and replacement: 3 – 8 year lifetime (WA DOH 2005; Dow 2010c) • Continuous or frequent monitoring of nitrate levels • Backwashing to dislodge solids

System Components	• Fixed bed versus continuous regeneration
	• Key system configuration parameters are system flow rate, bed swelling, bed depth, backwash flow rate, and rinse requirements
	  ○ Vessels in parallel or in-series
	  ○ Co-current or counter-current regeneration

Waste Management and Disposal	• Significant cost of waste brine disposal is of greatest concern for inland systems • Close proximity to coastal waters is beneficial for brine disposal • Management options can include sewer or septic system, drying beds, trucking off-site, coastal pipeline, deep well injection, and advanced treatment • Disposal options can be limited by waste brine water quality (e.g., volume, salinity, metals, and radionuclides) • Optimization of recycling and treatment of waste brine is desirable
Limitations	• Need to manage resin fouling ○ Hardness, iron, manganese, suspended solids, organic matter, and chlorine • Competing ions (especially sulfate) • Disposal of waste brine • Possible role of resin residuals in DBP formation

[10] The resin can be degraded by oxidation; the functional amine groups on the resin surface are susceptible to oxidation which can lead to diminished capacity (Dow 2010d).

[11] As nitrate and other anions displace chloride on the resin, chloride is released to the product water, leading to the potential for taste issues and dezincification (Kapoor & Viraraghavan 1997). Dezincification refers to the ability of product water to dissolve zinc from brass and is dependent on the ratio of chloride to alkalinity (> 0.5 can be problematic). By restoring alkalinity, the dezincification potential can be minimized.

[12] Galvanic corrosion can result in the release of lead from brass and galvanized solder-copper connections and is associated with a high ratio of chloride to sulfate (> 0.58 can be problematic) (Edwards et al. 1999; Edwards & Triantafyllidou 2007).

3.3.1 Electrodialysis - Design Considerations

Table 8 summarizes key design considerations in the use of ED for nitrate removal from potable water.

Table 8. Summary of design considerations for electrodialysis/electrodialysis reversal.

Membranes	• Use of anion and cation exchange membranes • Selective membranes ○ Monovalent versus multivalent • Consider water recovery and frequency of cleaning

Pretreatment	• Lower pretreatment requirements because this is not direct filtration
	• EDR systems can avoid or limit chemical use
	• Prevention of scaling and fouling
	  ○ Filtration to remove suspended solids
	  ○ Treatment for iron and manganese removal
	  ○ Water softening or use of anti-scalants or acid to prevent scaling

Post-Treatment	• pH adjustment to avoid corrosion (if acid used to prevent scaling) • Disinfection
Chemical Usage	• Possible pH adjustment (acids and bases) • Possible anti-scalants • Possible cleaning chemicals

O&M	• Highly automated
	• Frequency of membrane cleaning depends on water quality and membrane used
	  ○ Polarity reversal (electrodialysis reversal) multiple times per hour minimizes fouling
	  ○ ED systems can require weekly cleaning
	• Management of chemicals and pre-filtration system
	  ○ Including electrode compartment rinse solution
	• Waste storage and disposal
	• High monitoring demands
	• Potentially higher operator demand than IX and RO, due to system complexity

System Components	• Maximize water recovery while minimizing energy use • Key aspects of the system are pretreatment requirements, number and configuration of electrodialysis stacks and stages, membrane selection and configuration, operating voltage and pressure, reversal frequency (for EDR), gas venting of anode and cathode compartments, disinfection, “brine loop, electrode rinse loop, concentrate discharge, and dosing station” (Hell et al. 1998, p. 178).
Waste Management and Disposal	• Concentrate disposal of greatest concern for inland systems ○ Close proximity to coastal waters is beneficial for brine/concentrate disposal • Management options include sewer or septic system, reuse for irrigation, drying beds, trucking off-site, coastal pipeline, deep well injection and advanced treatment • Disposal options can be limited by waste brine/concentrate water quality (e.g., volume, salinity, metals, and radionuclides) • Optimization of recycling and treatment of waste concentrate
Limitations	• Need to prevent membrane scaling and fouling ○ Hardness, iron, manganese, and suspended solids • Disposal of waste concentrate • High system complexity

Introduction

If you are reading this document, perhaps you manage or regulate one of the more than 50,000 small community water systems in the United States and its territories. Maybe you provide technical assistance, training, or other services to these systems. You might even work for a local, state, or federal regulatory or financial agency.

No matter what you do, you probably know of small systems that provide excellent drinking water at a reasonable cost. You probably also know of small systems that are struggling to maintain operations. They, too, want to provide good service and safe water to drink. Unfortunately, some of these systems are physically run-down or exhibit poor source water quality. Most of these type systems service customers who cannot afford big rate increases to address or correct these issues. You may also know of systems that are operating with no immediate problems, but are concerned about their ability to continue providing the best possible service.

Systems that are having problems now, or those that are worried about the future, may need to evaluate all options available to them. These options may include restructuring of system/management operations, utilization of appropriate technology, financial assistance (grants or loans), training, and technical assistance. Most systems will probably find they need some combination of these options to resolve these issues.

Drinking water systems, especially those small systems which serve 3,300 or fewer customers, face a wide array of challenges in providing safe, reliable, and affordable drinking water to their customers. These challenges include adapting to new regulatory standards, the need to upgrade or replace aging infrastructure, source water availability and protection issues, and increasing budgetary constraints.

Changes to the operational, managerial, or institutional structure of a water system, commonly referred to as “restructuring,” can offer several effective options to address these challenges. Restructuring options can range from relatively minor changes in a system’s procurement processes to transferring ownership of a system through consolidation or regionalization (see Diagram #1).

Each water system is unique in its own way, resulting in no “one-size-fits-all” restructuring solutions. It is important for states and water systems to work together to choose a restructuring strategy that will be most appropriate to meet the system’s needs. The spectrum of restructuring options represents a broad, flexible array of solutions that could address the challenges faced by systems and improve the technical, managerial, and financial capabilities of most water systems.

Source: Restructuring and Consolidation of Small Drinking Water Systems
Office of Water (4606M), EPA 816-B-07-001, October 2007
www.epa.gov/safewater

Restructuring can improve capacity in a number of important ways:

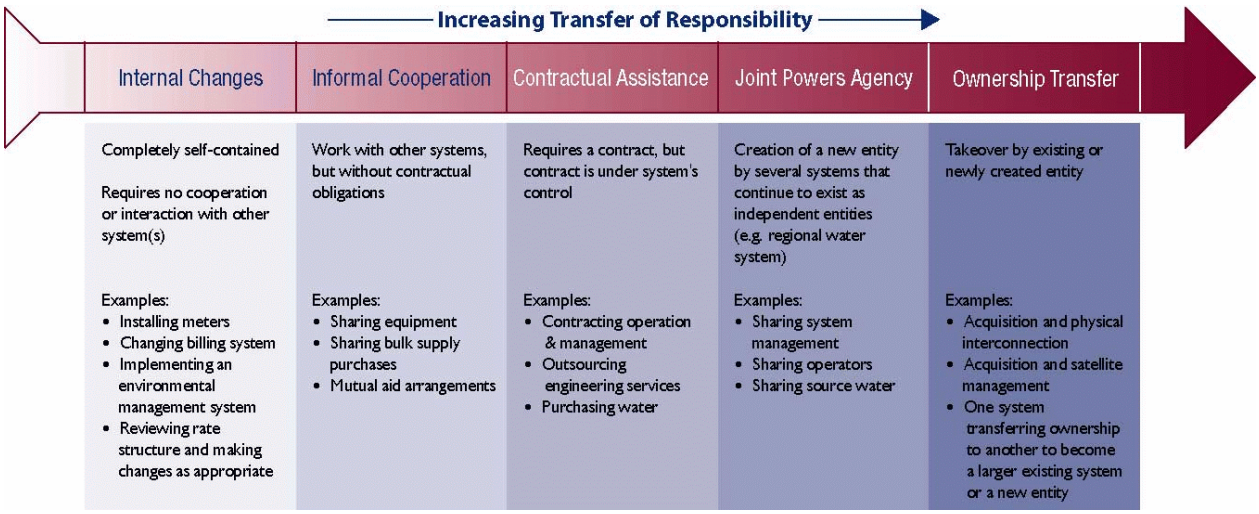
Technical capacity improvements can include increasing access to higher quality/quantity source water; sharing, upgrading, or building new infrastructure; developing more efficient treatment technologies; and opening access to a certified operator and additional expertise.

Managerial capacity improvements can include increasing expertise in water system planning/operations and enhancing systems' financial, accounting, and asset management practices.

Financial capacity improvements can include reducing costs, achieving greater economies of scale through shared services, and increasing systems access to funds through new partnerships. In addition, systems that consider consolidation or restructuring may receive preferential treatment in loan or grant programs (e.g., higher priority for Drinking Water State Revolving Fund [DWSRF] loans).

Restructuring can be an effective means to help small water systems achieve and maintain technical, managerial, and financial capacity, and to reduce the oversight and resources that states need to devote to these systems. One key mechanism that a state can use to consider and promote the use of restructuring activities is its water system capacity development program. States enact statutes or regulations that require new systems to demonstrate their need to exist or their inability to connect to a nearby existing system. A few other states require existing systems to act as mentors to new systems or takeover new systems that cannot consistently demonstrate adequate capacity.

Diagram #1: The Restructuring Spectrum



In addition to state capacity development programs, some state primacy agencies have promoted restructuring activities through collaboration between other state agencies such as the public utility or public service commissions. Examples of these relationships can be found throughout Appendix B.

System No.	Name of Treatment Facility	System Location	Capacity, gpm	Treatment Processes	
3310083	Chino II Desalter	Mira Loma	10,400	RO, IX and blending	RO, IX, Blend
3310037	Temescal Desalter	City of Corona	10,500	RO using polyamide thin-film composite (TFC) membranes (Dow/Filmtec BW30LE-440/BW30-40), followed by blending	RO, Blend
3310075	Arlington Desalter	Norco	5,000	RO using polyamide TFC membranes (Model 8822HR-400P, Koch Membranes, Wilmington, MA), followed by blending	RO, Blend
3610075	RO treatment plant	Mira Loma	4,639	Reverse Osmosis (RO) utilizes spiral thin-film composite polyamide membranes (CPA3 membranes was used prior to Nov 2001. ESPA2 membranes have been used since Nov 2001)	RO, Blend
4901154	Reverse Osmosis Treatment Plant	Petaluma	10	Osmonics E2 RO	RO
4200943	Reverse Osmosis	Santa Maria	0.7	Reverse Osmosis	RO
5610007	Water Campus	Oxnard	19,500	Reverse Osmosis	RO
5710006		Woodland		Well Packer with online nitrate analyzer	None
1910142	Columbia Plant	San Dimas		Nitrate treatment via Layne environmental with Rohm and Haas regenerable ion exchange resin using flat-head design vessel and fractal distribution.	IX
1910142	Highway Plant	San Dimas		Nitrate treatment via Basin Water modular regenerable ion exchange system with Purolite resin	IX
1910028	Glenwood Plant		1600	Ion exchange system	IX
2710010	Well 15-01	Salinas		Nitrate Selective Ion exchange system	IX
2710010	Well 21-01	Salinas		Nitrate Selective Ion exchange system	IX
2710010	Well 108-01	Salinas		Strong base anion resin Type 1 Ion exchange system	IX
5105004	NA	Source	15 gpm	Softening/Ion Exchange	IX
3310021	Teagarden IXTP	Mira Loma	3,500	Ion Exchange followed by Blending	IX
3310021	Wells 17&18 IXTP	Mira Loma	2,000	Ion Exchange followed by Blending	IX
3310044	Anita B. Smith IXTP	Rubidoux	3,000	Ion Exchange followed by Blending	IX

3610850	Nitrate IX for all wells	Chino	2,500	Purolite A-400 IX resin (chloride form)	IX
3610064	Plant 132 IX treatment	San Bernardino	1,000	Basin Water IX. Use a strong base Type 1 anion exchange resin manufactured by Purolite (A-400E)	IX
3610073	IX treatment facility (for Well 12E and 17E)	Yucca Valley	800	Process media: A-400E manufactured by Purolite Co.	IX
1910001	GWTP	Alhambra	Design capacity: 7000	Ion exchange (with bypas)	IX
1910126	Anion Exchange Plant (AEP)	Pomona	9,000	Anion Exchange followed by blending	IX
1910126	Ion Exchange Plant at Well 29	Pomona	400	Anion Exchange	IX
1910126	Ion Exchange Plant at Well 37	Pomona	800	Anion Exchange	IX
1910062	Amherst Treatment Plant	La Verne	2,575	Anion Exchange	IX
1910039	Plant B6 for Wells B6C and B6D (standby); Wells B25A, B25B, B26A, and B26B	14104 Corak Street, Baldwin Park	7,800	Calgon ISEP	IX
1910022	Perris Island Water Treatment Plant (Well 1)	City of Pomona	306	Add an ion exchange treatment system for the removal of perchlorate and nitrate in groundwater from Well 1	IX
1910022	Perris Island Water Treatment Plant (Well 1)	City of Pomona	306	Add an ion exchange treatment system for the removal of perchlorate and nitrate in groundwater from Well 1	IX
4210016	Evergreen #1 Well Ion Exchange Unit	Orcutt	550	Ion Exchange	IX
4010004	IX \Treatment Plant	Grover Beach	1000	Ion Exchange	IX
4210021	Tanglewood #1 IX Treatment Plant	Santa Maria	550	Ion Exchange	IX
1910126	Monk Hill Treatment Plant	Pasadena	7000	Blending	Blend

Useful links

Nitrate Fact Sheet
http://www.waterboards.ca.gov/water_issues/programs/gama/docs/coc_nitrate.pdf

AB 2222 Report – Communities that Rely on Contaminated Groundwater
http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/index.shtml

UC Davis Report for the SWRCB SBX2 1 Report to the Legislature
http://groundwaternitrate.ucdavis.edu

SWRCB Report to the Legislature – Recommendations Addressing Nitrates in Groundwater
http://www.waterboards.ca.gov/water_issues/programs/nitrate_project/docs/nitrate_rpt.pdf

Drinking Water Information Clearinghouse (DRINC) Portal
http://drinc.ca.gov/dnn/Home.aspx

State Water Resources Control Board Website
http://www.waterboards.ca.gov

California Department of Public Health Website
http://www.cdph.ca.gov

UC Davis Center for Affordable Technology for Small Water Systems
http://smallwatersystems.ucdavis.edu

SBX2 1 Tulare Draft Report
http://www.tularecounty.ca.gov/cao/assets/File/Management%20and%20Non-Infrastructure_DRAFT.pdf

Nitrate Treatment Technology Workshop
September 4-5, 2013
Sacramento, CA
Evaluation Form

Please take a few minutes of your time to complete this survey.
Your comments and suggestion will help us improve future workshops.
(If additional writing space is needed please use the back side of this form.)

1. How did you hear about this workshop?

2. If you represent a drinking water system, how many connections do you serve?

3. Were your expectations met and questions answered at this workshop?

   ☐ Yes – (Please explain):

   ☐ No – (Please explain):

4. Please list other treatment technologies that you know of that were not included in this Workshop.

5. Are you or anyone you know interested in having a similar workshop at a location other than Sacramento? If yes, provide alternate locations.

6. What was most helpful at this workshop?

7. What was least helpful at this workshop?

8. How can we improve future workshop/s?

9. What was your greatest hurdle in attending this workshop?

10. Please provide your contact information below if you would like to be contacted for further information:

    Name _____ Organization_____

    Phone number _____email address:_____

11. Other comments: