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Groundwater Sources

A comparison of Surface and Groundwater Sources

Top 5 Differences Between Surface and Groundwater Sources

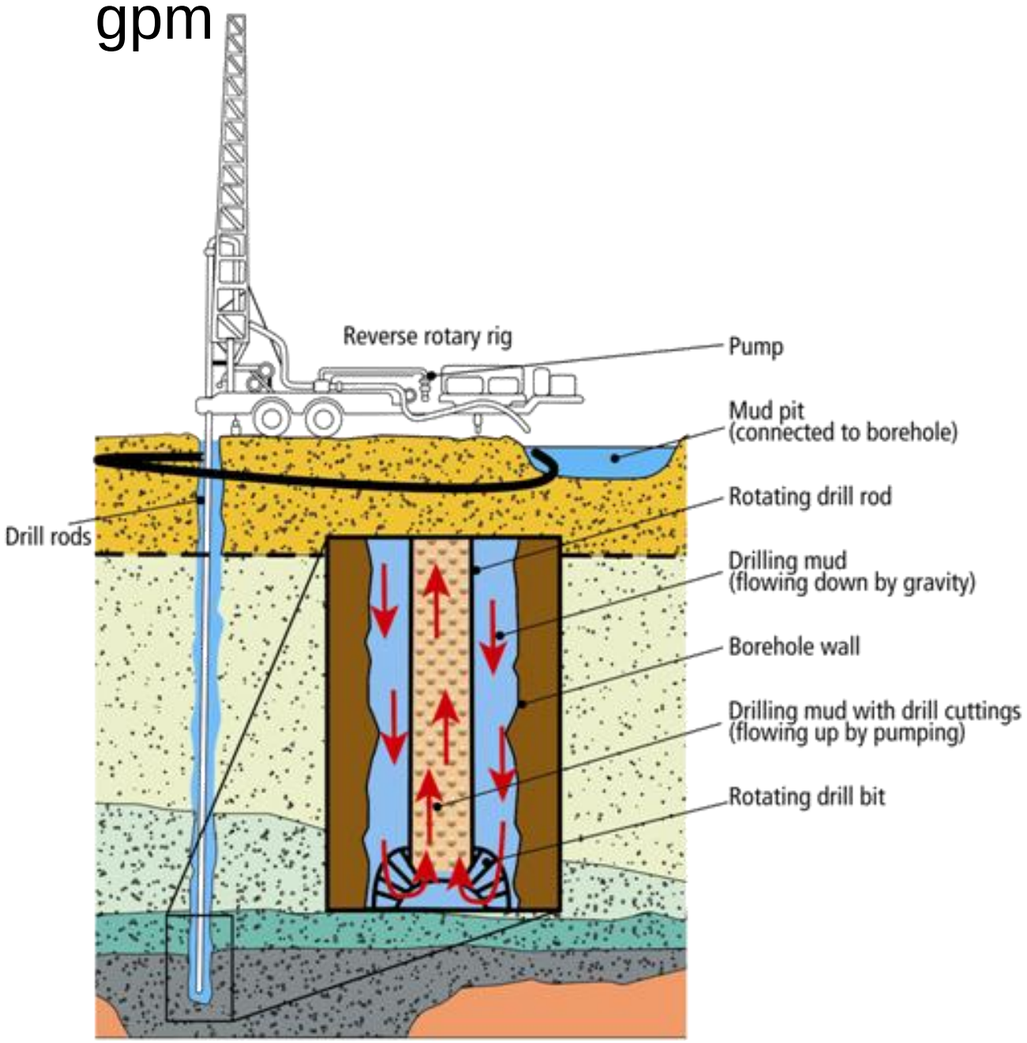
Number

1. Source Capacity
2. Source Protection Issues
3. Storage Potential
4. Regulations
5. Treatment Technologies
   - Iron and Manganese
   - Arsenic
   - Nitrate

1. Source Capacity

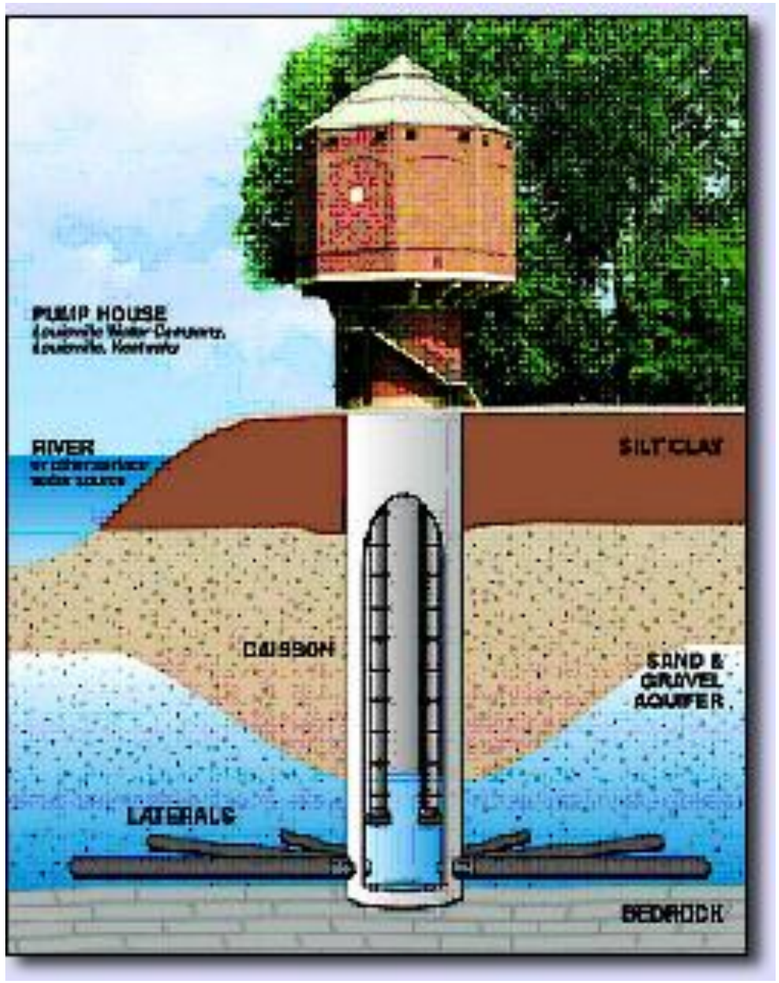
Individual Wells

- 5 to 7,000 gpm
- Most municipal wells 100 to 1,500 gpm

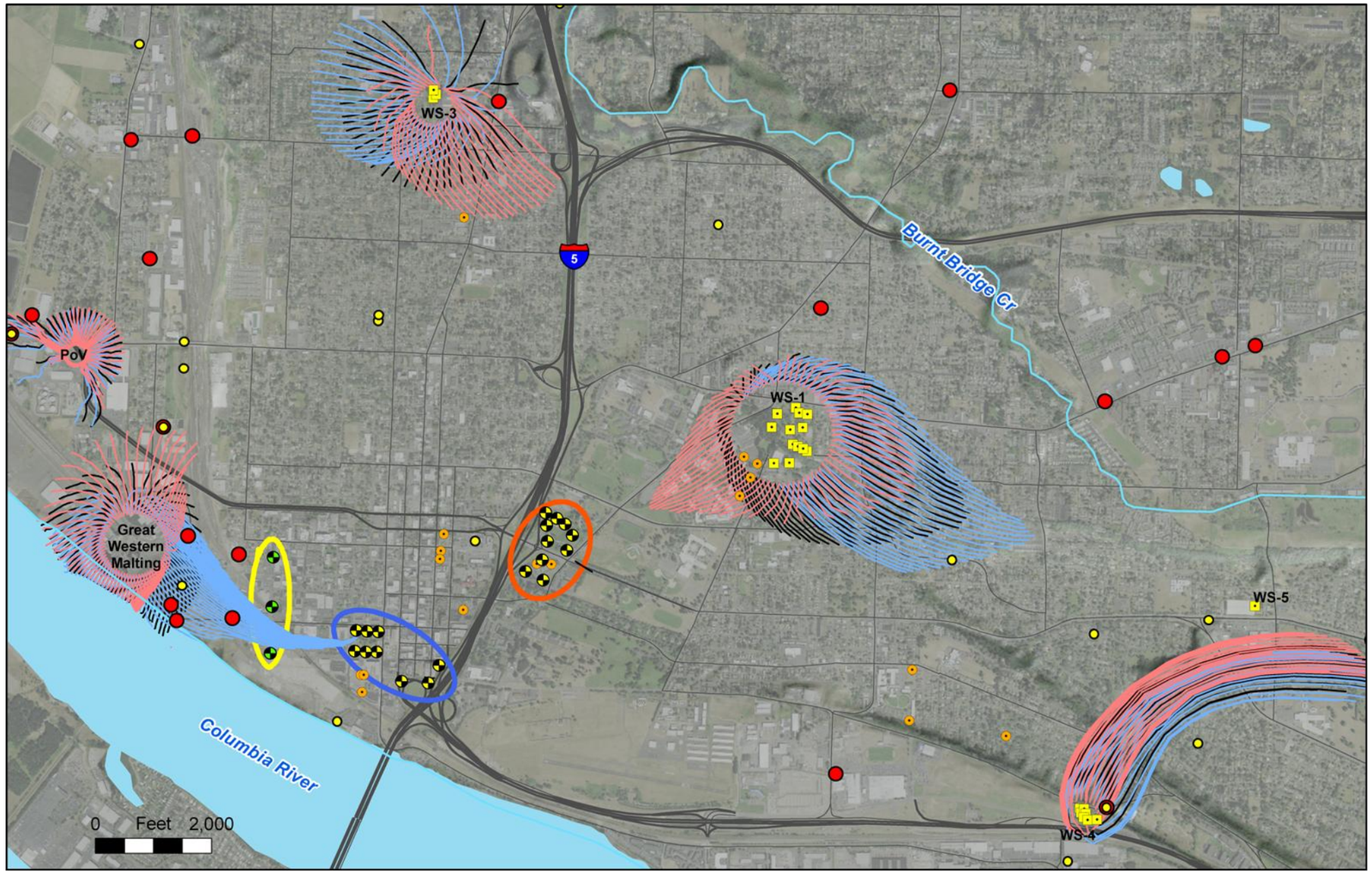


Collector Wells

- 3,500 to 35,000 gpm

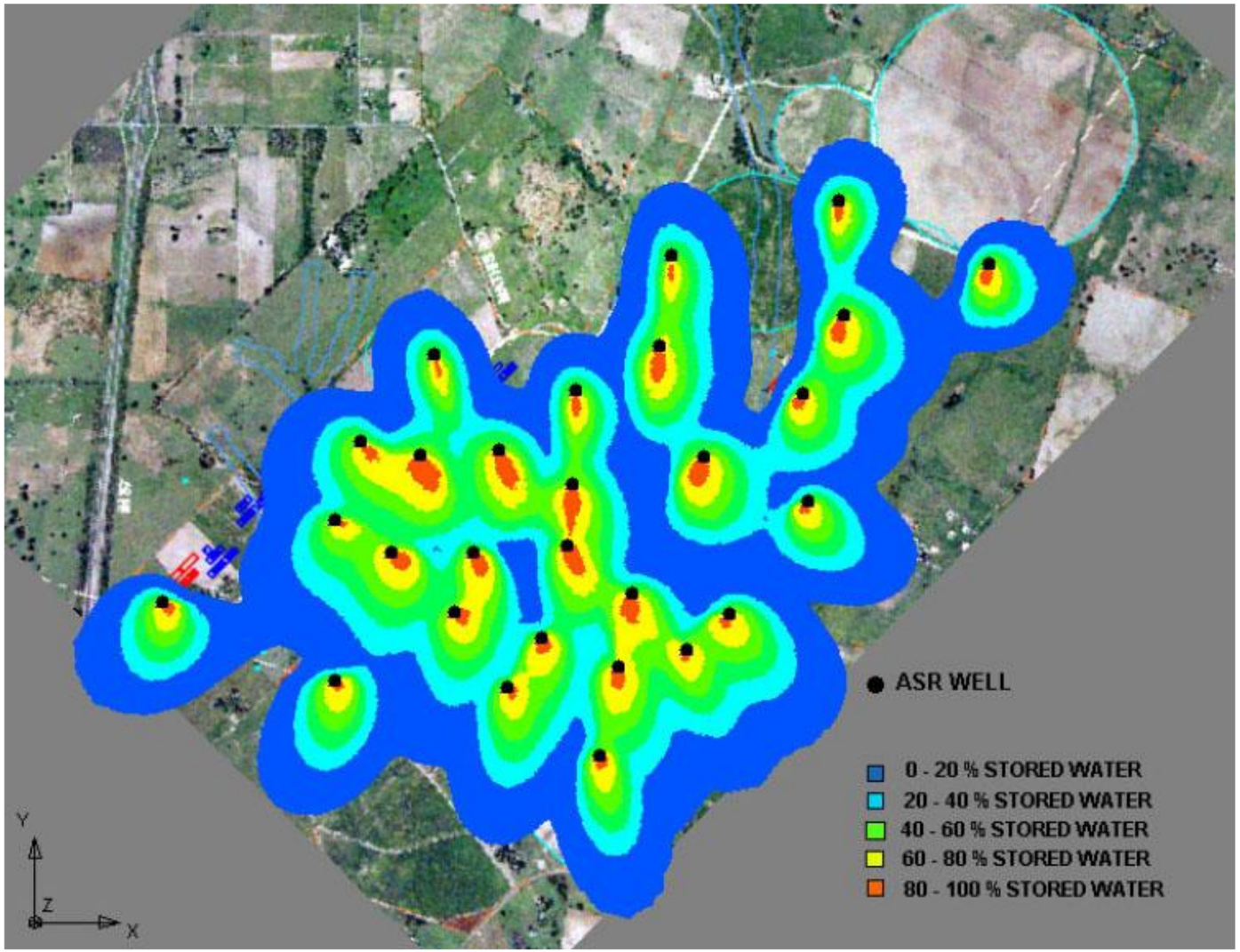


2. Source Protection



- Wellhead Protection Areas
- Wellhead Protection Plans
- Impacts from Pumping

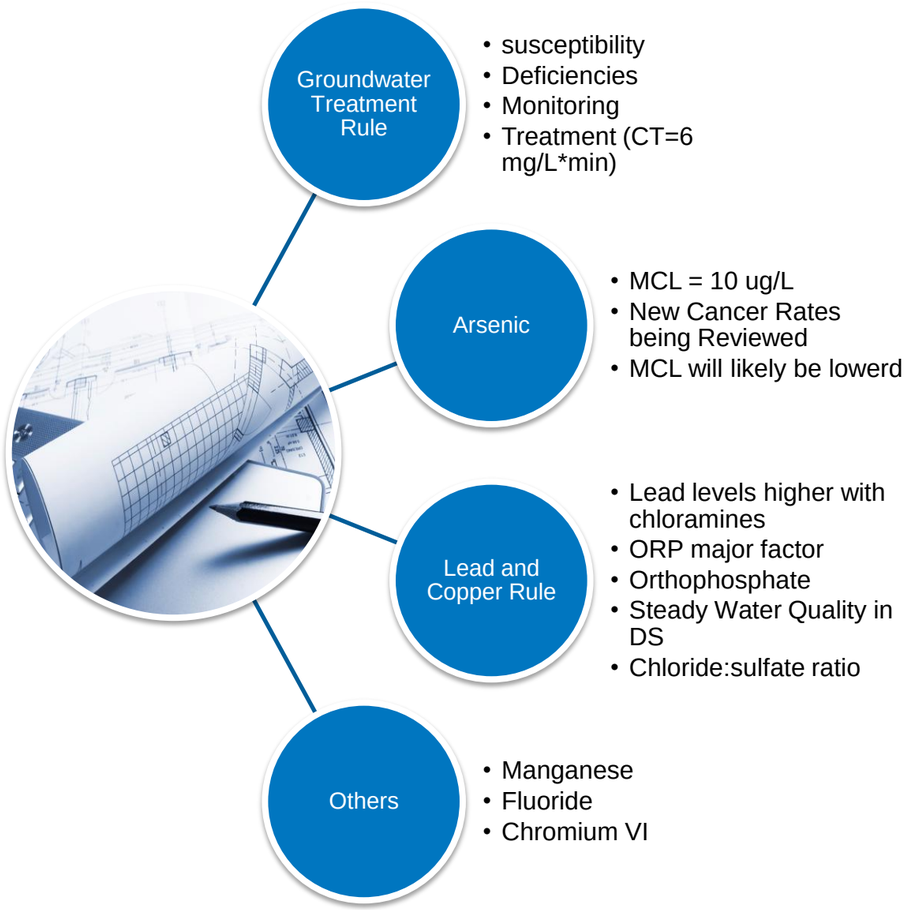
3. Storage



- Aquifer Storage and Recovery
- Store Water for Peak Day
- Change Water Quality

4. Drinking Water Regulations

Regulation	Surface Water	Groundwater	Key Provisions
GW Rule		√	Vulnerability Significant Deficiencies Monitoring Treatment
Stage 2 DDBP Rule	√	√	Identify Worst Sites. MCLs for TTHMs and HAA5
SWTR/IESWTR/ESWTR/LT2ESWTR	√	GWI	GWI Cryptosporidium monitoring & BIN Class
FBW Rule	√	√	FBW Recycling
Arsenic Rule		√	MCL & MCLG
Radionuclide Rule		√	MCLs and MCLGs for RA228+228, gross alpha, beta particle and photon radioactivity, and Ur
LCR	√	√	Als and Guidance
NPDWS	√	√	MCLs
NSDWS	√	√	SMCLs
TCR	√	√	MCLs for Total, Fecal & e-coli



Regulations will continue to Affect Groundwater Utilities

5. Groundwater Treatment Technologies

Primary Contaminants – Microbial

Category	Technology	Giardia Lamblia	Cryptosporidium	Legionella	Heterotrophic plate count	Turbidity	Viruses	Total coliforms	Fecal coliforms	E. Coli
Filter	Coagulation- filtration		✓	✓	✓	✓	✓	✓	✓	✓
Filter	Biological Filtration		✓	✓	✓	✓	✓	✓	✓	✓
Filter	Hydrous Manganese Oxide Filtration									
Filter	Oxidation/precipitation/filtration				✓		✓			
Membrane Processes	Reverse Osmosis	✓	✓	✓	✓	✓	✓	✓	✓	✓
Membrane Processes	Nanofiltration		✓	✓	✓	✓	✓	✓	✓	✓
Membrane Processes	Ultrafiltraiton		✓	✓	✓	✓	✓	✓	✓	✓
Membrane Processes	Microfiltration		✓	✓	✓	✓	✓	✓	✓	✓
Sorption	Iron Oxides									
Sorption	Manganese Dioxide									
Sorption	Granular Activated Carbon									
IX	Cation Exchange									
IX	Anion Exchange									
IX	Electrodialysis Reversal	✓	✓	✓	✓	✓	✓	✓	✓	✓
Precipitation	Barium Sulfate Precipitation									
Precipitation	Excess Lime Softening									
Precipitation	Pellet Softening									
Precipitation	Aeration									
Chemical Feed Systems	Ozonation	✓		✓			✓	✓	✓	✓
Chemical Feed Systems	Permanganate	✓		✓						
Chemical Feed Systems	Chlorine	✓	✓	✓	✓		✓	✓	✓	✓
Chemical Feed Systems	Chlorine Dioxide	✓	✓	✓	✓		✓	✓	✓	✓
Chemical Feed Systems	Chloramine			✓	✓		✓	✓	✓	✓
Chemical Feed Systems	Ultraviolet	✓	✓		✓					
Chemical Feed Systems	UV - Peroxide	✓	✓	✓	✓		✓	✓	✓	✓
Chemical Feed Systems	Lime									
Chemical Feed Systems	Carbon Dioxide									
Chemical Feed Systems	Soda Ash									
Chemical Feed Systems	Caustic									
Chemical Feed Systems	Silicate									
Chemical Feed Systems	Polyphosphate									
Chemical Feed Systems	Orhtophosphate									
Chemical Feed Systems	Limestone									

Primary Contaminants – Disinfectants & Disinfection By Products

Category	Technology	Bromate	Bromodichloromethane	Bromoform	Chlorite	Chloroform	Dibromochloromethane	Dichloroacetic acid	Haloacetic acids (HAA5)[1]	Trichloroacetic acid	Total Trihalomethanes	Total Organic Carbon (TOC)	Lead and Copper	Lead	Copper
Filter	Coagulation- filtration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Filter	Biological Filtration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Filter	Hydrous Manganese Oxide Filtration														
Filter	Oxidation/precipitation/filtration														
Membrane Processes	Reverse Osmosis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Membrane Processes	Nanofiltration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Membrane Processes	Ultrafiltraiton	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Membrane Processes	Microfiltration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Sorption	Iron Oxides														
Sorption	Manganese Dioxide														
Sorption	Granular Activated Carbon	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
IX	Cation Exchange														
IX	Anion Exchange														
IX	Electrodialysis Reversal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Precipitation	Barium Sulfate Precipitation														
Precipitation	Excess Lime Softening													✓	
Precipitation	Pellet Softening														
Precipitation	Aeration														
Chemical Feed Systems	Ozonation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	Permanganate	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	Chlorine	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Chemical Feed Systems	Chlorine Dioxide	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	Chloramine	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	Ultraviolet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	UV - Peroxide	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Chemical Feed Systems	Lime													✓	✓
Chemical Feed Systems	Carbon Dioxide													✓	✓
Chemical Feed Systems	Soda Ash													✓	✓
Chemical Feed Systems	Caustic													✓	✓
Chemical Feed Systems	Silicate													✓	✓
Chemical Feed Systems	Polyphosphate													✓	✓
Chemical Feed Systems	Orhtophosphate													✓	✓
Chemical Feed Systems	Limestone													✓	✓

Inorganics

Category	Technology	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cyanide	Fluoride	Mercury	Nickel	Nitrate	Nitrite	Selenium	Thallium
Filter	Coagulation- filtration		✓												
Filter	Biological Filtration		✓												
Filter	Hydrous Manganese Oxide Filtration		✓												
Filter	Oxidation/precipitation/filtration														
Membrane Processes	Reverse Osmosis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Membrane Processes	Nanofiltration		✓												
Membrane Processes	Ultrafiltraiton		✓												
Membrane Processes	Microfiltration		✓												
Sorption	Iron Oxides		✓												
Sorption	Manganese Dioxide														
Sorption	Granular Activated Carbon						✓								
IX	Cation Exchange														
IX	Anion Exchange		✓							✓		✓		✓	
IX	Electrodialysis Reversal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Precipitation	Barium Sulfate Precipitation											✓	✓		
Precipitation	Excess Lime Softening		✓												
Precipitation	Pellet Softening														
Precipitation	Aeration									✓					
Chemical Feed Systems	Ozonation														
Chemical Feed Systems	Permanganate														
Chemical Feed Systems	Chlorine														
Chemical Feed Systems	Chlorine Dioxide														
Chemical Feed Systems	Chloramine														
Chemical Feed Systems	Ultraviolet														
Chemical Feed Systems	UV - Peroxide														
Chemical Feed Systems	Lime									✓	✓				
Chemical Feed Systems	Carbon Dioxide									✓	✓				
Chemical Feed Systems	Soda Ash									✓	✓				
Chemical Feed Systems	Caustic									✓	✓				
Chemical Feed Systems	Silicate									✓	✓				
Chemical Feed Systems	Polyphosphate														
Chemical Feed Systems	Orhtophosphate									✓	✓				
Chemical Feed Systems	Limestone									✓	✓				

Organics

Category	Technology	Volatile Organics	Synthetic Organics	Pesticides	Dissolved organic carbon	DBP Precursors	Pharmaceuticals
Filter	Coagulation- filtration		✓	✓	✓	✓	✓
Filter	Biological Filtration		✓	✓	✓	✓	✓
Filter	Hydrous Manganese Oxide Filtration						
Filter	Oxidation/precipitation/filtration						
Membrane Processes	Reverse Osmosis		✓	✓	✓	✓	✓
Membrane Processes	Nanofiltration		✓	✓	✓	✓	✓
Membrane Processes	Ultrafiltraiton						
Membrane Processes	Microfiltration						
Sorption	Iron Oxides						
Sorption	Manganese Dioxide						
Sorption	Granular Activated Carbon	✓	✓	✓	✓	✓	✓
IX	Cation Exchange						
IX	Anion Exchange		✓		✓		
IX	Electrodialysis Reversal		✓	✓	✓	✓	✓
Precipitation	Barium Sulfate Precipitation						
Precipitation	Excess Lime Softening			✓	✓	✓	✓
Precipitation	Pellet Softening						
Precipitation	Aeration	✓					
Chemical Feed Systems	Ozonation	✓	✓	✓	✓	✓	✓
Chemical Feed Systems	Permanganate	✓					
Chemical Feed Systems	Chlorine	✓					
Chemical Feed Systems	Chlorine Dioxide	✓					
Chemical Feed Systems	Chloramine						
Chemical Feed Systems	Ultraviolet						
Chemical Feed Systems	UV - Peroxide	✓	✓	✓	✓	✓	✓
Chemical Feed Systems	Lime						
Chemical Feed Systems	Carbon Dioxide						
Chemical Feed Systems	Soda Ash						
Chemical Feed Systems	Caustic						
Chemical Feed Systems	Silicate						
Chemical Feed Systems	Polyphosphate						
Chemical Feed Systems	Orhtophosphate						
Chemical Feed Systems	Limestone						

Radionuclides

Category	Technology	Gross alpha	Beta and photon emitters[1]	Iodine-131[2]	Combined Radium 226 & 228[3]	Uranium	Strontium 90[2]	Tritium[2]	Radon
Filter	Coagulation- filtration						✓	✓	✓
Filter	Biological Filtration						✓	✓	✓
Filter	Hydrous Manganese Oxide Filtration				✓		✓	✓	✓
Filter	Oxidation/precipitation/filtration								
Membrane Processes	Reverse Osmosis	✓	✓	✓	✓	✓	✓	✓	✓
Membrane Processes	Nanofiltration								
Membrane Processes	Ultrafiltraiton								
Membrane Processes	Microfiltration								
Sorption	Iron Oxides								
Sorption	Manganese Dioxide				✓				
Sorption	Granular Activated Carbon	✓	✓	✓	✓	✓	✓	✓	✓
IX	Cation Exchange								
IX	Anion Exchange								
IX	Electrodialysis Reversal	✓	✓	✓	✓	✓	✓	✓	✓
Precipitation	Barium Sulfate Precipitation	✓	✓	✓	✓	✓	✓		
Precipitation	Excess Lime Softening						✓	✓	✓
Precipitation	Pellet Softening								
Precipitation	Aeration						✓		
Chemical Feed Systems	Ozonation								
Chemical Feed Systems	Permanganate								
Chemical Feed Systems	Chlorine								
Chemical Feed Systems	Chlorine Dioxide								
Chemical Feed Systems	Chloramine								
Chemical Feed Systems	Ultraviolet								
Chemical Feed Systems	UV - Peroxide								
Chemical Feed Systems	Lime								
Chemical Feed Systems	Carbon Dioxide								
Chemical Feed Systems	Soda Ash								
Chemical Feed Systems	Caustic								
Chemical Feed Systems	Silicate								
Chemical Feed Systems	Polyphosphate								
Chemical Feed Systems	Orhtophosphate								
Chemical Feed Systems	Limestone								

Secondary Contaminants

Category	Technology	Hardness	Iron	Manganese	Total Dissolved solids	Chloride	Sulfate	Zinc	Color	Taste and Odor	Aluminum	Copper	Corrosivity	Fluoride	Foaming agents	Odor	pH	Silver
Filter	Coagulation- filtration		✓	✓					✓	✓						✓		
Filter	Biological Filtration		✓	✓					✓	✓					✓	✓		
Filter	Hydrous Manganese Oxide Filtration		✓	✓					✓	✓								
Filter	Oxidation/precipitation/filtration		✓	✓					✓									
Membrane Processes	Reverse Osmosis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓				✓
Membrane Processes	Nanofiltration	✓	✓	✓	✓				✓									
Membrane Processes	Ultrafiltraiton		✓	✓														
Membrane Processes	Microfiltration		✓	✓														
Sorption	Iron Oxides																	
Sorption	Manganese Dioxide		✓	✓					✓									
Sorption	Granular Activated Carbon								✓	✓					✓			
IX	Cation Exchange	✓	✓	✓														
IX	Anion Exchange						✓		✓		✓							
IX	Electrodialysis Reversal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓				✓
Precipitation	Barium Sulfate Precipitation																	
Precipitation	Excess Lime Softening	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓			✓
Precipitation	Pellet Softening	✓																
Precipitation	Aeration															✓		
Chemical Feed Systems	Ozonation								✓	✓					✓	✓		
Chemical Feed Systems	Permanganate								✓	✓						✓		
Chemical Feed Systems	Chlorine									✓						✓		
Chemical Feed Systems	Chlorine Dioxide								✓	✓						✓		
Chemical Feed Systems	Chloramine									✓								
Chemical Feed Systems	Ultraviolet									✓								
Chemical Feed Systems	UV - Peroxide								✓	✓					✓	✓		
Chemical Feed Systems	Lime												✓				✓	
Chemical Feed Systems	Carbon Dioxide												✓				✓	
Chemical Feed Systems	Soda Ash												✓				✓	
Chemical Feed Systems	Caustic												✓				✓	
Chemical Feed Systems	Silicate		✓	✓									✓				✓	
Chemical Feed Systems	Polyphosphate		✓	✓									✓					
Chemical Feed Systems	Orhtophosphate												✓					
Chemical Feed Systems	Limestone												✓				✓	

Iron and Manganese Removal
10 MGD Plant Completed June 2010
$4.5 Million

Southlake Water Treatment Plant

Clark Public Utilities,Vancouver, WA

Treatment Technology	Benefits	Drawbacks
Aeration followed by filtration	•No chemical use •Easy to operate	•Entrained air can interfere with filtration if not broken •May require breaking head and repumping •Not effective for manganese removal or iron complexed with organic material •Low filter loading rates for effective removal •High capital cost
Chlorination followed by filtration	•Chlorine often used for disinfection and present at treatment plant	•May require pH adjustment for manganese removal because of slow reactions at low pH •Low filter loading rates for effective removal •Easy to operate •High capital cost
Ozone followed by filtration	•Strong oxidant, requires little reaction time	•May oxidize manganese to permanganate •May oxidize manganese dioxide–containing media to permanganate •Difficult to operate •High capital and operations and maintenance costs
Chlorine dioxide followed by filtration	•Effective for iron complexed with organic material •No trihalomethane formation	•Generated on site with variety of chemicals •Requires careful operation and maintenance •Chlorite is a by-product •High capital cost
Potassium permanganate followed by filtration	•Strong oxidant, requires short reaction times •Can reform manganese dioxide coating on media	•Causes staining if spilled •May be overfed, resulting in pink or purple water
Biological filtration	•Easy to operate •Low operating cost	•Requires start-up period initially and after prolonged shutdowns •May require two stages for iron and manganese removal •High capital cost
Ion exchange	•Easy to operate	•Only effective on reduced forms of iron and manganese •No preoxidation should occur before ion-exchange unit •Fouling is common •Taste may be less palatable than with other methods •High capital and operating costs
Manganese greensand filtration	•Very effective for manganese •Can achieve high loading rates, but often not done	•Often used in combination with anthracite media for iron filtration •Media may crack •Recommended use with permanganate feed
Oxide coated sand filtration	•Effectiveness depends on type, thickness, and oxidation state of coating •Easy to operate	•Effectiveness depends on type, thickness, and oxidation state of coating AU//correct to have this entry for both Benefit and Drawback •Moderate capital cost
Pyrolusite media filtration	•Easy to operate •Can achieve high loading rates •Low operating costs •Very effective for manganese	•Moderate capital cost
Membrane filtration	•Easy to operate •Can achieve high loading rates	•May cause fouling •Chemical preoxidation must be carefully controlled •Moderate to high capital and operating costs
Stabilization, sequestering	•May reduce precipitation in parts of the distribution system	•Iron and manganese will still precipitate in the distribution system, especially where water stays in the system several days or in hot water systems and appliances •Not effective for high levels of iron and manganese
Lime softening	•Can effectively precipitate iron and manganese	•High capital and operating costs •High levels of solids produced •Requires significant operational oversight and maintenance

Arsenic Removal

Longley Lane WTP

Truckee Meadows Water Authority, Reno, NV

Technology	Benefits	Drawbacks
Conventional filtration	•Common technology Effective, especially when arsenic pre-oxidized and pH kept below 8	•Performance declines above pH 8Arsenic should be pre-oxidized •High coagulant doses sometimes required. •Alkalinity addition may be needed for soft waters and high coagulant doses.
Reverse osmosis membrane filtration	•Removal of As(III) and As(V) •Inorganic, microbial, and organic removal also achieved	•Low recovery and flux rates are typical •Pretreatment and posttreatment required
Nanofiltration	•Removal of As(V) •Microbial and organic removal also achieved •Removal of calcium and magnesium may be achieved	•Sensitivity to water quality •Low recovery and flux rates are typical •Pretreatment and posttreatment required •May not be effective for As(III)
Ultrafiltration	•Flux and recovery rates higher than with reverse osmosis or nanofiltration •Microbial removal achieved •Waste stream can often be sent to wastewater treatment plant	•Removal of particulate As only, unless pretreatment with a coagulant is needed for removal •Preoxidation and pH adjustment may be needed
Coagulation/microfiltration	•Highest flux and recovery rates of membrane processes •Some microbial removal achieved •Waste stream can often be sent to wastewater treatment plant	•Pretreatment with a coagulant is needed for removal •Preoxidation and pH adjustment may be needed
Activated alumina	•Less sensitive to water quality than ion exchange •Longer run times than ion exchange	•pH adjustment often needed •Aluminum levels may increase in finished water •Hazardous chemicals needed for regeneration •Residuals handling is difficult with concentrated high-pH liquid stream
Ion exchange (anion exchange)	•Works better at higher pH levels than activated alumina •Nitrate removal can also be achieved	•Sulfate levels may reduce run times •Higher arsenic levels may leach from resin near end of run •Requires regeneration and handling of concentrated brine solution
Iron-based sorbents	•Arsenic in backwash water is usually very low •Relatively easy disposal of solids •Some adsorbents have a fairly high sorption capacity	•Periodic media replacement required •Cost and length of media use before replacement is needed is dependent on water quality •Capacity decreases with increasing pH
Titanium-based sorbents	•Arsenic in backwash water is usually very low •Relatively easy disposal of solids •Some adsorbents have a fairly high sorption capacity •Works over wide range of pH	•Periodic media replacement required •Cost and length of media use before replacement is needed is dependent on water quality
Lime Softening	•Effective removal at pH above 11. •Coagulants can be added to aid co-precipitation.	•High concentration of solids produced •Some systems can require significant operational oversight

Nitrate Treatment

Anion Exchange Vessels Under Construction

Glendale, AZ

Nitrate Treatment Alternative	Benefits	Drawbacks
Anion exchange	•Many commercially available systems •Lowest capital cost •Relatively easy to operate •Easy to automate •Also removes arsenic	•High total dissolved solids liquid waste stream •Efficiency is dependent on water quality
Biological removal	•No brine waste	•Requires postfiltration •Few commercially available systems •Requires carbon source and nutrients
Nanofiltration	•Relatively easy to operate •Also softens water and removes some inorganics and organics	•May require extensive pretreatment •Requires significant maintenance •Operates at high pressure •Relatively high capital and operating costs
Reverse osmosis	•Relatively easy to operate •Also softens water and removes many inorganics and organics	•May require extensive pretreatment •Requires significant maintenance •Operates at high pressure •Relatively high capital and operating costs
Electrodialysis reversal	•Lower pressure requirements than other membrane systems •Provides softening and removal of other inorganics and organics	•May require extensive pretreatment

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