HDR

# Data Center Non-Potable Water Use

Dan Sampson

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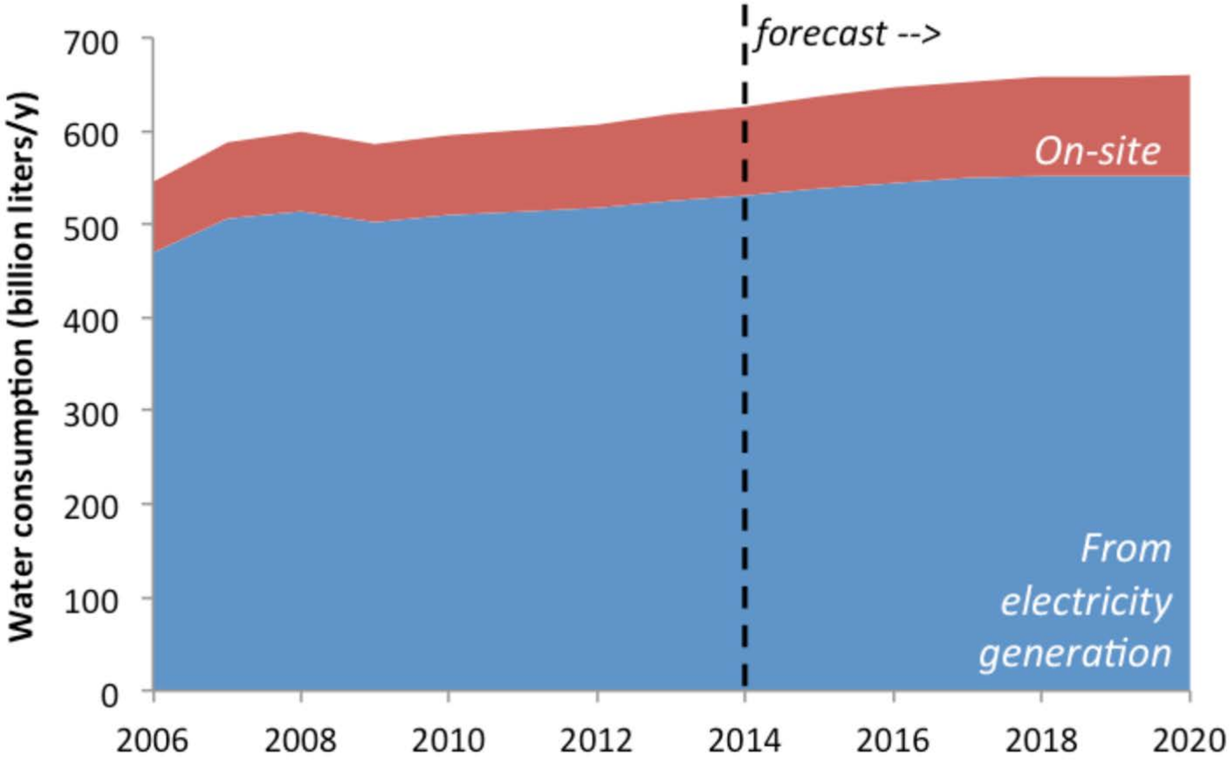
HDR

# Data Center Water Consumption

- Off-site - 2 gal/kWh
- On-site - 0.46 gal/kWh
- Today's focus is on-site, but sustainability initiatives may benefit from thinking outside of that box.




Source: United States Data Center Energy Usage Report. Berkely, CA: Ernest Orlando Lawrence Berkely National Laboratory.

# Data Center Cooling

- Many specific methods, but three basic approaches:
  - Adiabatic (evaporative coolers)
  - Chilled water loops (cooling tower)
  - Ambient air
- Adiabatic vs. Chilled Water Loops – very different treatment requirements

# Adiabatic Cooling

- Potable water usually allows:
  - 3-6 cycles of concentration without exceeding limits
  - No specialty chemicals
  - Lower biocide dosages
- Nonpotable water:
  - May have high TSS, high TDS, high organics – no guarantees
  - Requires more biocide
  - May require pretreatment (TSS, hardness, TDS, or organics removal)

Adiabatic Cooling System – Typical Limits

| Contaminant | Units | Lower Limit | Upper Limit |
|---|---|---|---|
| Total Alkalinity | mg/L | | 250.00 |
| Calcium | mg/L | 10.80 | 100.00 |
| Chloride | mg/L | | 400.00 |
| Iron | mg/L | | 1.00 |
| pH | s.u. | 6.50 | 8.50 |
| Silica | mg/L | | 100.00 |
| Sodium | mg/L | | 400.00 |
| Specific Conductance | µS/cm | | 3000.00 |
| Total Suspended Solids | mg/L | | 20.00 |

# Chillers with Cooling Towers

- Chilled water loop:
  - Closed loop, very little makeup
  - Small amount of chemical feed
- Cooling Tower:
  - Greater ability to utilize high TDS water
  - May still require TSS and/or organics removal
  - Uses several chemicals (acid, biocide, mineral dispersant, corrosion inhibitor)

# Drivers for Nonpotable Water Use

- Availability – potable may not be available in sufficient quantity
- Reliability – provide a better primary or reliable secondary water supply
  - May not be impacted by freshwater conservation requirements
  - Recycled water – relatively drought-proof, ration-proof supply
  - Need to consider mechanical reliability of supply and distribution system
- Sustainability (recycled water) – no consumptive freshwater usage
- Cost – may be less expensive (requires detailed analysis including treatment costs)
- Required by regulation

# Nonpotable Water Sources

- Other freshwater
  - Surface impoundments & lakes
  - Rivers & streams
  - Wells
- Recycled/recovered water
  - Municipal
  - Industrial

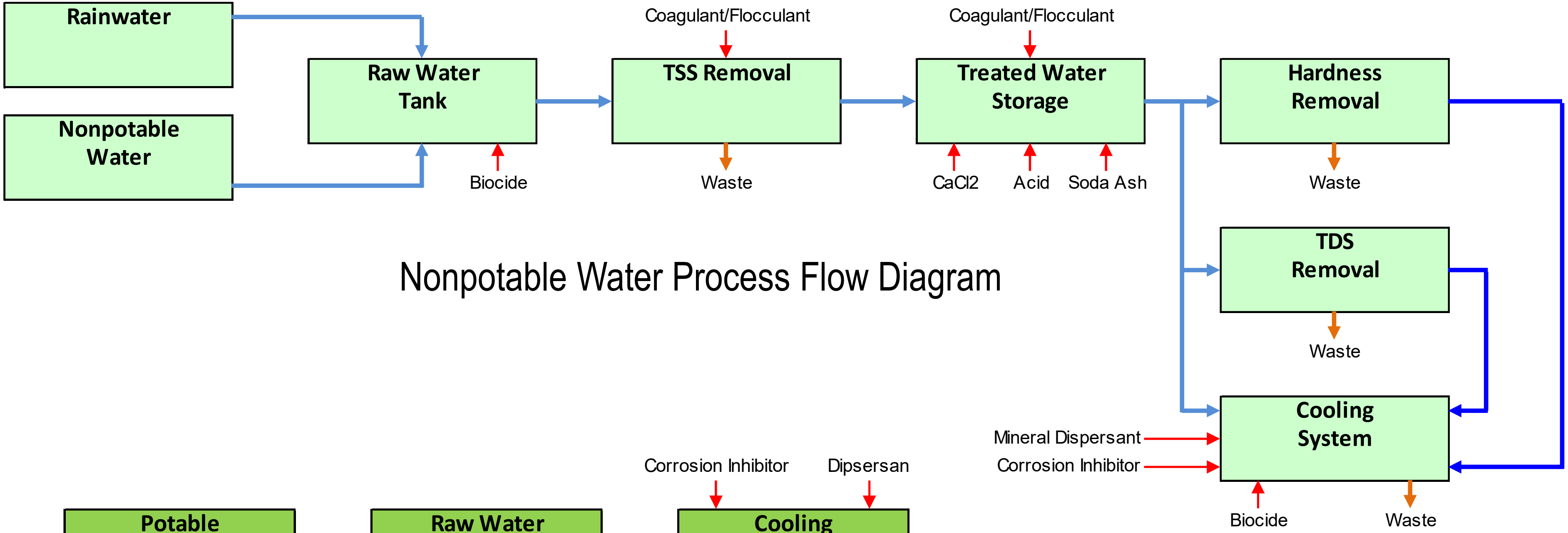
# Nonpotable Water

- Usually contains higher concentration of:
  - Soluble and insoluble salts (sodium chloride, calcium carbonate)
  - Higher TSS (except most well waters)
  - Organics
- Variable quality (surface and recycled waters)
- Corrosion, scaling, and salinity concerns and may dictate treatment and usage options

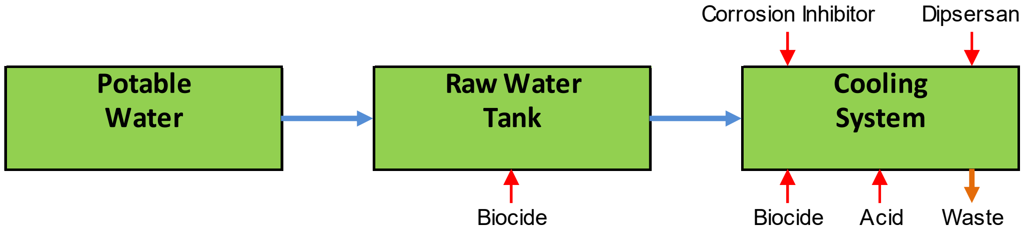
# Water Costs, Concerns, and Risks

- Costs vary widely depending on source
- May cost less than fresh water on $/gal basis, but may require substantially more treatment (operating and equipment costs may increase)

# Water Costs, Concerns, and Risks




Nonpotable Water Process Flow Diagram



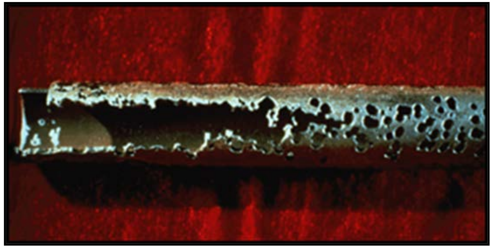

Potable Water Process Flow Diagram

# Concerns and Risks

- Easiest use is cooling tower makeup
  - Other uses (high purity water production or adiabatic cooler makeup) may require additional equipment
- Contaminant Concerns
  - Higher microbial potential (compared to potable water)
  - Salinity also higher (modern cooling water treatments can usually mitigate)
  - Organic contaminants vary widely (ammonia, nitrate, nitrite, TOC, etc.) – mitigate with pretreatment or in-situ treatment
  - Microbial control and biocide selection/feeding critical (microbial dispersant may be required)

# Concerns and Risks - Cooling

- Inorganic Contaminant Concerns
  - Phosphate
    - If high, may cause scale
    - Sequestration possible with pretreatment
    - May be possible to operate tower with high phosphate
    - Modeling tools and expertise required
  - Chloride
    - Increases risk of general corrosion and stress corrosion cracking (SS)
    - Materials of construction must be checked, maybe changed
  - Other Scale-Forming Minerals
    - Concentrations vary, may limit cycles of concentration
    - Must evaluate scale, corrosion, and microbial impacts

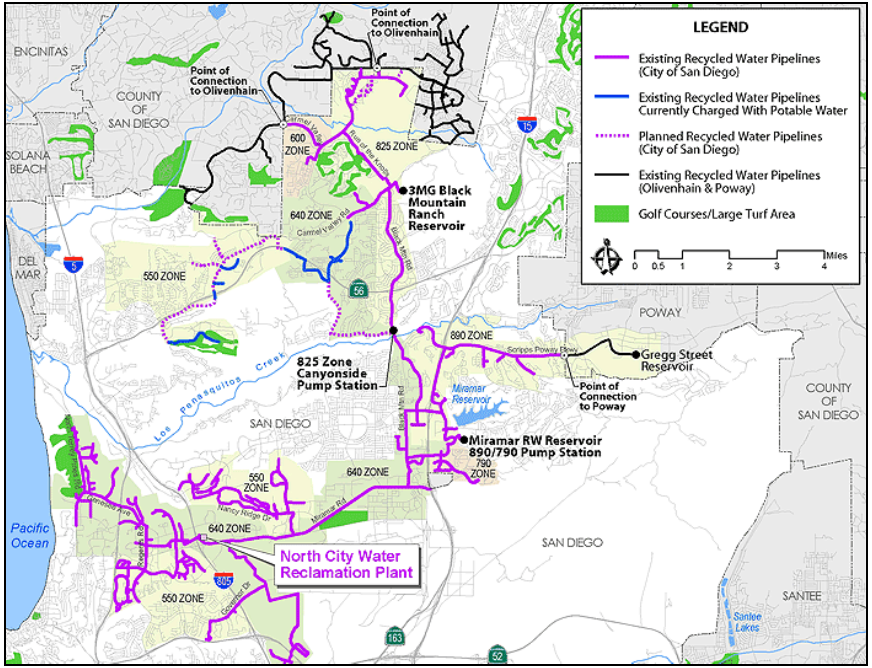


# Concerns and Risks – High Purity Water Production

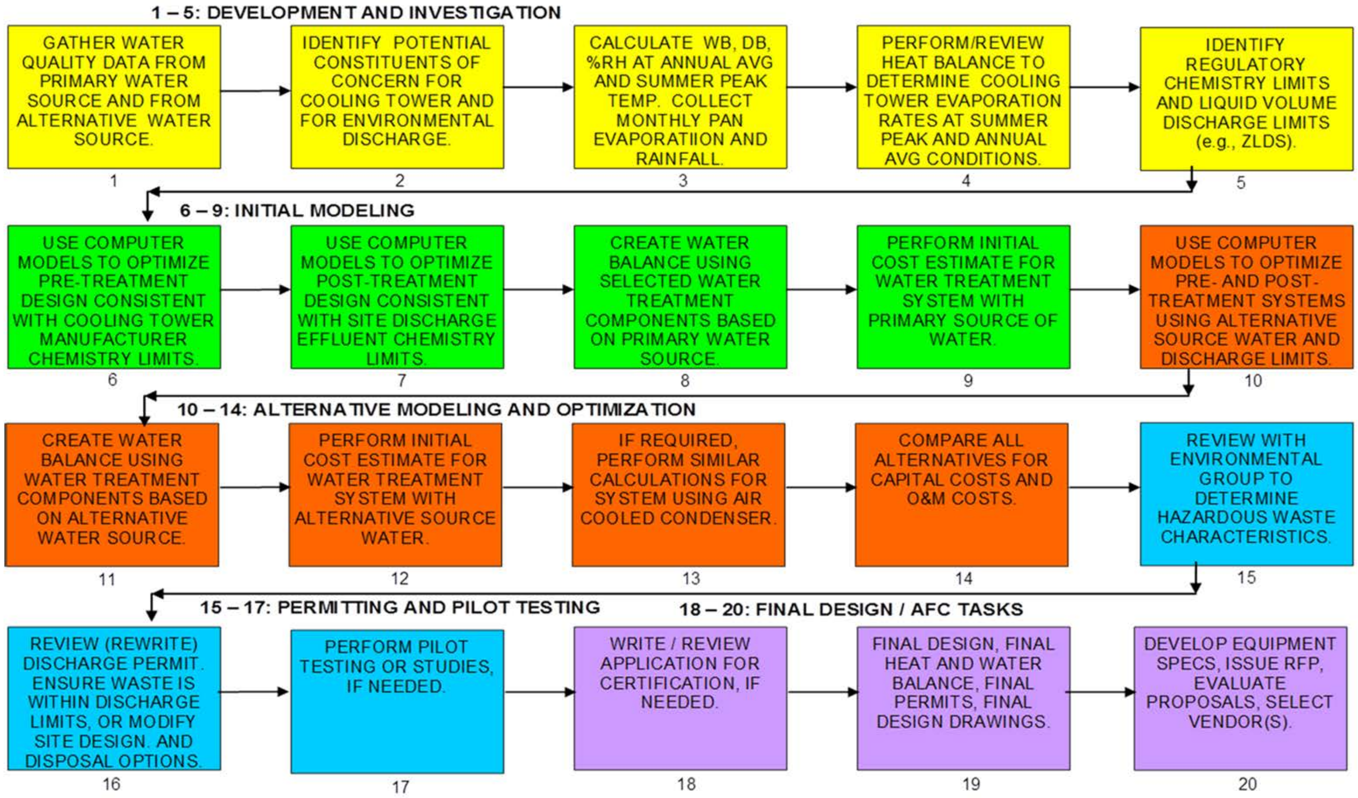
- High Purity Water Production
  - Simple filtration (media filters) usually can’t consistently remove smaller than 10 microns in size – can cause rapid RO fouling if not removed
  - Coagulation/flocculation difficult, membrane filtration usually required
  - Modeling tools sometimes fail
    - Pilot testing or actual operating experience strongly recommended

# Changing from Potable to Nonpotable

- Water Supply Development
- Detailed Engineering
- Installation and Operation

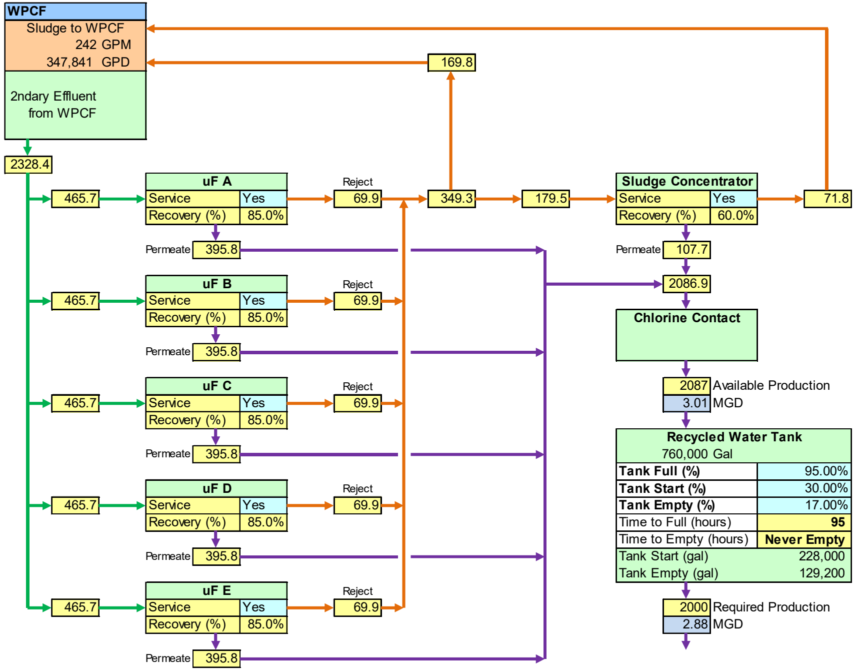


# General Project Process



# Water Supply Development

- Start with project location, end with final conceptual design, water balance, supply/discharge permits, and agreements
- ALL must be final before usage begins, specs are issued, or equipment purchased
- Premature use may result in costly changes, degraded performance, and/or poor efficiency



# Water Supply Development

- Identify suppliers, determine discharge and regulatory requirements
- Discharge and regulatory requirements MUST be determined first
  - Discharge permits may be impacted
  - Regulations may require specific equipment, treatment programs, and monitoring equipment
- Determine availability and CONFIRM discharge permits
  - “Will-serve” letters
  - Firm delivery amounts
  - Model or pilot test to confirm resulting wastewater meets permit limits

# Water Supply Development

- Water quality data
  - Obtain and analyze (again, no guarantees)
  - Determine historical variability, evaluate future change possibilities
  - Evaluate operating and design constraints
    - Mineral solubility analysis
    - Materials of construction
    - Microbial control and monitoring programs
    - Treatment programs
- Plant Water and Chemistry Balances
  - Begin with current process flow diagram and modify
  - Contact suppliers (equipment and chemical) to confirm treatability and technologies (pilot testing if possible)
  - Use updated water/chemistry balance to confirm discharge permit compliance and to negotiate recycled water supply agreements

# Water Supply Development

- Initial studies/calculations determine need for and configuration of additional treatment systems and equipment – creates preliminary design
- Completed preliminary design
  - Used to calculate average and peak water/wastewater flows and chemistry
  - Create nonpotable water utilization plan
  - Calculate "buy-in" fees and obtain budgetary estimates
  - Calculate usage fees
  - Determine infrastructure changes
- Back-track if conditions change
  - Evaluate alternatives and repeat process
  - Hours can save millions at this stage

# Water Supply Development

Detailed tasks vary, may include:

- Assess suitability of existing piping configurations and water systems
- Conceptual design for incorporation of new infrastructure into existing equipment
- Assess need for civil work
- Pressure testing of selected lines and/or systems
- Determine site-specific regulatory requirements and systems
- Fire system assessments and impact mitigation
- Recommendations for onsite infrastructure improvements
- Discharge permit review and investigation, especially potential impacts associated with higher recycled water total dissolved solids (TDS)

# Detailed Engineering

- Begins with completed water development, ends with engineering package and final utilization plan
- Required work varies widely, depends on
  - Existing infrastructure (pipelines, treatment plants)
  - Planned use (cooling tower makeup, adiabatic cooler makeup)
  - Water quality
  - Work can be minor (install back-flow preventers, local pipelines) or major (build entire water plant and distribution system)
- Detailed engineering tasks
  - Determine treatment system capacity, redundancy, and tank sizes
  - Equipment budgetary estimates and specifications

# Detailed Engineering

Common mechanical changes:

- Influent pressure regulator and strainer installation
- Meter installation
- Potable water separation requirements
- Backflow prevention
- Review materials of construction and corrosion concerns (distribution system, pipelines, cooling tower, & heat exchangers)
- Review and modify cooling tower design (mist eliminators, for example)
- Modifications to tower basin level control, irrigation systems, make up water systems for boilers and demineralizers
- Chemical feed and control systems review and modification (number and capacity of feed systems)

# Installation and Operation

- Procurement and construction management
  - Management often overlooked (“just another pipeline”)
  - Should be formal and detailed
  - Many projects fail at this stage (no driver, everybody gets lost, and the installed system/equipment doesn’t work)
- Establish a baseline
  - MUST compare key performance indicators before and after the change
  - Eliminates perception as a failure mechanism

# Installation and Operation

- Operational Changes
  - Personnel training
  - Monitoring programs
  - Operating procedure updates
- Chemical Changes
  - New chemical feeds
  - Biocide selection
  - Microbial dispersants
  - Anti-foam

# Picking the Right Project

| Potential Use Area | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Capital Cost Improvements (Rank 10=Highest Cost) | 6 | 3 | 5 | 1 | 2 |
| Operating Cost Impact (Rank 10-Highest Cost) | 6 | 1 | 2 | 5 | 4 |
| Average Cooling Tower Makeup Flow (Rank 10=Lowest Flow) | 6 | 4 | 3 | 1 | 2 |
| Copper Alloys? (1 = Yes) | 1 | 0 | 0 | 0 | 1 |
| Current Cooling Tower Cycles of Concentration | 10 | 6 | 5 | 3 | 4 |
| Time to Connect to Pipeline (Weeks) | 22 | 5 | 14 | 5 | 9 |
| Connection Difficulty (Rank 10=Most Difficult) | 6 | 3 | 5 | 1 | 2 |
| Operating Difficulty (Rank 10=Most Difficult) | 4 | 6 | 2 | 5 | 1 |
| Permitting Risk (Rank 10=Highest Risk) | 6 | 4 | 3 | 2 | 1 |
| Plant Willingness to Change (People Survey) (Rank 10=Least Willing) | 6 | 3 | 4 | 1 | 2 |
| Ranking (Lowest=Best Opportunity to Convert) | 73 | 35 | 43 | 24 | 28 |

# Roadblocks

- Lack of Commitment – address with outreach
- Health Concerns –address with early and detailed training and fact sheets
- Performance Concerns – create baselines before any change for objective evaluation
- 3rd Party Resistance – Involve chemical suppliers and consultants to create win-win situations

# Recent Examples and Lessons Learned

- Use recycled water to replace fresh water for cooling tower makeup without additional treatment
- Use recycled water for whole-plant supply with significant treatment
- Build new recycled water plant to provide whole-plant supply

# Example 1

- Evaluation of potable vs. recycled water for cooling tower makeup
- Recycled water more cost effective, but TDS much higher
- Performed mass and chemical balance, evaluated equipment upgrades, performed total cost analysis

# Example 1

- Different Water Qualities

| Contaminant | Units | Conduct Conv | CaCO3 Conv Factors | Potable Water (Existing Local Supply) | Recycled (Title 22) Water (Calculated) |
|---|---|---|---|---|---|
| Alkalinity-Bicarbonate | mg/L | 0.72 | 0.82 | 102.44 | 122.93 |
| Alkalinity-Carbonate | mg/L | 2.82 | 1.67 | 0.00 | 0.00 |
| Alkalinity-OH | mg/L | 0.00 | 2.94 | 0.00 | 0.00 |
| Barium | mg/L | 0.00 | 0.73 | 0.00 | 0.00 |
| Chloride | mg/L | 2.14 | 1.41 | 79.90 | 119.85 |
| Fluoride | mg/L | 0.00 | 2.63 | 0.00 | 0.00 |
| Calcium | mg/L | 2.6 | 2.50 | 30.10 | 36.12 |
| Magnesium | mg/L | 3.82 | 4.12 | 11.10 | 13.32 |
| Iron | mg/L | 0.00 | 2.69 | 0.00 | 0.25 |
| Nitrate | mg/L | 1.15 | 0.81 | 2.57 | 3.86 |
| pH | s.u. | 0.00 | 0.00 | 7.28 | 7.60 |
| Phosphate | mg/L | 0.00 | 1.58 | 0.06 | 3.00 |
| Potassium | mg/L | 1.84 | 1.28 | 3.09 | 3.71 |
| Silica | mg/L | 0.00 | 0.83 | 16.00 | 19.20 |
| Sodium | mg/L | 2.13 | 2.18 | 54.50 | 81.75 |
| Sulfate | mg/L | 1.54 | 1.04 | 55.00 | 82.50 |
| Total Dissolved Solids | mg/L | | | 354.76 | 486.48 |
| Specific Conductance | umhos/cm | | | 574.32 | 801.60 |
| Free CO2 | mg/L | | | 8.95 | 5.14 |
| Total Cations | mg/L CaCO3 | | | 243.75 | 328.81 |
| Total Anions | mg/L CaCO3 | | | 256.04 | 363.45 |
| Total Hardness | mg/L CaCO3 | | | 120.98 | 145.18 |

# Example 1

- Cooling System Mass and Chemical Balance

| Contaminant | Units | Potable Water | Recycled (Title 22) Water | Softener Waste (Assume RO Reject and 75% Recovery) | Quenched HRSG Blowdown | Evap Cooler Blowdown | Combined Influent | Cooling Tower Blowdown |
|---|---|---|---|---|---|---|---|---|
| **Flow** | GPM | 0.00 | 74.45 | 39.27 | 23.51 | 1.26 | 138.49 | 66.38 |
| **Alkalinity-Bicarbonate** | mg/L | 102.44 | 122.93 | 185.52 | 93.11 | 56.60 | 135.01 | 107.31 |
| **Alkalinity-Carbonate** | mg/L | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Alkalinity-OH** | mg/L | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Barium** | mg/L | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Chloride** | mg/L | 79.90 | 119.85 | 319.36 | 72.63 | 79.91 | 168.04 | 350.00 |
| **Fluoride** | mg/L | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Calcium** | mg/L | 30.10 | 36.12 | 120.31 | 27.36 | 30.10 | 58.45 | 121.74 |
| **Magnesium** | mg/L | 11.10 | 13.32 | 44.37 | 10.09 | 11.10 | 21.55 | 44.89 |
| **Iron** | mg/L | 0.00 | 0.25 | 0.00 | 0.00 | 0.00 | 0.13 | 0.28 |
| **Nitrate** | mg/L | 2.57 | 3.86 | 10.27 | 2.34 | 2.57 | 5.41 | 11.26 |
| **pH** | s.u. | 7.28 | 7.60 | 7.00 | 10.89 | 7.00 | 7.98 | 7.50 |
| **Phosphate** | mg/L | 0.06 | 3.00 | 0.26 | 0.74 | 10.00 | 1.90 | 10.00 |
| **Potassium** | mg/L | 3.09 | 3.71 | 12.35 | 2.81 | 3.09 | 6.00 | 12.50 |
| **Silica** | mg/L | 16.00 | 19.20 | 63.95 | 14.69 | 16.00 | 31.10 | 64.77 |
| **Sodium** | mg/L | 54.50 | 81.75 | 217.84 | 50.45 | 54.51 | 114.78 | 239.06 |
| **Sulfate** | mg/L | 55.00 | 82.50 | 396.23 | 49.99 | 97.59 | 166.08 | 491.59 |
| **Total Dissolved Solids** | mg/L | 354.76 | 486.48 | 1370.46 | 324.21 | 361.47 | 708.45 | 1453.40 |
| **Specific Conductance** | umhos/cm | 574.32 | 801.60 | 2407.09 | 523.98 | 607.18 | 1207.94 | 2615.94 |
| **Free CO2** | mg/L | 8.95 | 5.14 | 30.88 | 0.00 | 9.42 | 2.34 | 5.65 |
| **Total Cations** | mg/L CaCO3 | 243.75 | 328.81 | 974.26 | 223.54 | 243.77 | 493.19 | 1027.21 |
| **Total Anions** | mg/L CaCO3 | 256.04 | 363.45 | 1023.23 | 233.81 | 278.46 | 527.75 | 1117.67 |
| **Total Hardness** | mg/L CaCO3 | 120.98 | 145.18 | 483.57 | 109.97 | 120.99 | 234.93 | 489.32 |

# Example 1

- Chemical and Equipment Upgrades and Cost

| O&M Costs | Units | Concentration | Cost |
|---|---|---|---|
| **Potable Water Cost** | $/1000 Gal | | $4.71 |
| **Recycled Water Cost** | $/1000 Gal | | $1.77 |
| **Tower Blowdown Discharge Cost** | $/1000 Gal | | $0.00 |
| **Sulfuric Acid Cost** | $/Lb | 93.00% | $0.12 |
| **Tower Corrosion Inhibitor** | $/Lb | | $1.50 |
| **Tower Dispersant** | $/Lb | | $1.80 |
| **Tower Anti-Foam** | $/Lb | | $1.25 |
| **Tower Microbial Dispersant** | $/Lb | | $1.30 |
| **Tower Non-Ox Biocide** | $/Lb | | $2.20 |
| **Oxidizing Biocide 1 (Bleach)** | $/Lb | 12.50% | $0.20 |
| **Oxidizing Biocide 2 (Bromine)** | $/Lb | 50.00% | $1.95 |
| **Capital Costs** | | | **Value** |
| **Titanium Condenser Upgrade** | | | $600,000 |
| **Anti-Foam Feed System** | | | $5,000 |
| **Microbial Dispersant Feed System** | | | $20,000 |
| **Non-oxidizing Biocide Feed System** | | | $20,000 |
| **Oxidizing Biocide 2 (Bromine) Feed System** | | | $25,000 |

# Example 1

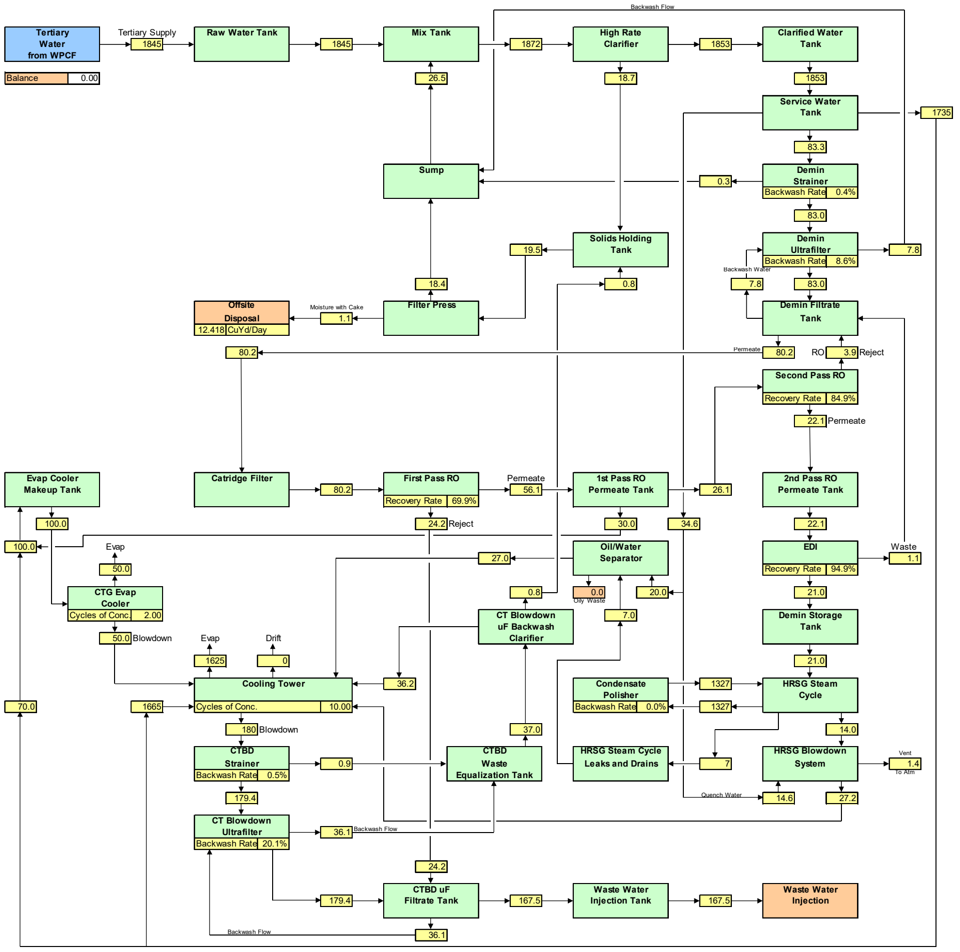
- Operating and Capital Cost Analysis

| Option | CAPEX | OPEX NPV | Total (CAPEX + OPEX NPV) |
|---|---|---|---|
| Option 1A: Wet Cooling, Potable Water, Stainless Steel Condenser | $0 | $1,821,859 | $1,821,859 |
| Option 1B: Wet Cooling, Potable Water, Titanium Condenser | $600,000 | $886,656 | $1,486,656 |
| Option 2: Dry Cooling, Potable Water | $1,844,000 | $0 | $1,844,000 |
| Option 3A: Wet Cooling, Recycled Water, Stainless Steel Condenser | $70,000 | $1,377,772 | $1,447,772 |
| Option 3B: Wet Cooling, Recycled Water, Titanium Condenser | $670,000 | $616,212 | $1,286,212 |
| NPV Term (Years) | | | 30 |
| NPV Interest Rate (%) (Used to Calculate Current Value of Operating Costs) | | | 10.00% |

- Recycled water lowest cost option
- Equipment upgrades required
  - Heat exchanger materials of construction
  - Additional chemical feed systems
  - Additional chemical usage

# Example 2

- Whole-plant supply with cold lime softening for hardness & silica removal
- MANY issues
  - o Vendor detailed design required substantial field revision
  - o Performance test after 1+ years of operation



# Example 2

- Too many problems to list
- Plugging everywhere, often
- Conceptual design sound, vendor detailed design an issue


# Example 3

- New system
- Receives secondary effluent, produces recycled water
- Targets:
  - < 5 NTU from clarifiers
  - <2 NTU from sand filters
  - < 1 mg/l phosphate
  - 5 ppm total chlorine after 450 minute contact time

# Example 3

Conceptual design fine, but vendor detailed design very problematic

- Clarifier and mixing design fractures floc, can’t meet turbidity target from clarifiers or filters (energy gradient)
- Designed to work with one and only one coagulant (ferric chloride)
  - Inadequate mixing time for others
  - Users can’t tolerate high chloride
- Back to the drawing board
  - Substantial re-engineering required
  - Took nearly 2 years to correct
  - Used temporary systems to bridge gap ($1mm/month)

# Lessons Learned

- Major design issues on recent projects
  - Various suppliers
  - Substantial retrofits/reengineering required
- Can't assume systems will work
  - "Caveat Emptor"
  - Check references and pilot test
- Iron-clad performance guarantees with substantial LDs
- Map it out – and follow it

# Questions

Dan Sampson
925.570.0842
Daniel.Sampson@hdrinc.com

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