Waste to Watts

Repurposing Perched Groundwater for Data-Center Cooling

Google Henderson Data Center Water Project

Feasibility Study

Civil and Environmental Engineering
University of Nevada, Las Vegas

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Abstract

Data centers require large volumes of water for cooling. In the arid Las Vegas Valley, potable water is scarce and new demands from industrial facilities threaten to strain municipal supplies. Google's Henderson data center reportedly consumed about 352 million gallons of water in 2024471667168122707†L274-L285, highlighting the need for alternative sources.

The *Waste to Watts* project evaluates whether perched groundwater captured in the C–1 channel can serve as a supplemental cooling-water source. Field sampling showed total dissolved solids (TDS) in the range 1,800–5,870 mg/L with elevated sulfate and chloride levels663784305775668†L205-L211. These values far exceed typical potable water and require treatment before use663784305775668†L228-L233.

This paper presents a literature review on regional water-quality constraints and ion-exchange treatment, describes field sampling and laboratory analysis, outlines the design of an ion-exchange (IX) and reverse osmosis (RO) treatment train, and evaluates the feasibility of using treated perched groundwater for data-center cooling. Updated calculations show that the baseline cooling towers require roughly 1.59×10^8 gallons of makeup water per year (~302 gpm)866669823841526†L1703-L1733. Introducing 80 gpm of treated perched groundwater reduces potable demand to about 222 gpm—an estimated 26% savings—while maintaining thermal performance866669823841526†L1703-L1736. Detailed evaluation of IX and RO alternatives demonstrates that mixed-resin ion exchange can be designed to meet high TDS and nitrate loads, but regeneration costs and brine management remain significant; RO achieves 85% recovery, reduces TDS by over 98%, and delivers permeate suitable for cooling866669823841526†L2666-L2684866669823841526†L2779-L2791866669823841526†L2810-L2821. The paper compares these strategies and recommends a modular treatment system that balances cost, recovery, and water-quality objectives.

1. Introduction

The Las Vegas Valley sits within the Lower Colorado River Basin, a region facing chronic water scarcity. Rapid development and the proliferation of data centers have increased competition for limited supplies. Henderson hosts one of Google's largest data centers, and like other facilities it relies on water-intensive evaporative cooling systems. Water consumption has drawn attention as the generative artificial intelligence boom drives more computing loads; public records indicate that Google's Henderson site used roughly 352 million gallons of water in 2024471667168122707†L274-L285. In Nevada—the driest U.S. state—such usage demands innovative strategies to conserve potable water.

At the same time, perched groundwater accumulates in engineered channels around Las Vegas. This high-salinity water is generally discharged to storm drains because its total dissolved solids often exceed 2,000 to 7,000 mg/L (sometimes up to 10,000 mg/L)663784305775668†L228-L233 and contains constituents such as sulfate, boron, fluoride, and selenium that corrode infrastructure663784305775668†L228-L233. The *Waste to Watts* project explores whether this underused resource can be treated and repurposed for industrial cooling, reducing demand on municipal supplies while mitigating corrosive impacts on public sewers. A similar approach has been adopted in some jurisdictions, with data centers using recycled or reclaimed water for cooling to reduce potable use.

This paper summarises the project objectives: (1) characterise perched groundwater quality, (2) review ion-exchange and water treatment literature relevant to high-TDS waters, (3) design and evaluate alternative treatment trains comprising ion exchange (IX), reverse osmosis (RO), and blended configurations, and (4) estimate the potential for potable-water savings when integrated into the Henderson data-center cooling towers.

Figure 1: Conceptual site context for perched groundwater capture and the Google Henderson data center (placeholder for site map or context illustration).

Figure 2: High-level concept for repurposing perched groundwater as cooling-tower make-up via on-site treatment (placeholder for process overview).

2. Background and Literature Review

2.1 Regional Water Quality Constraints

The Las Vegas Wash and its tributaries carry some of the highest mineral loads in southern Nevada. Studies report median sulfate levels around 1,500 mg/L and total dissolved solids approaching 3,000 mg/L179139270618051†L32-L48. Perched groundwater collected along the C–1 channel exhibits TDS values ranging from 1,800 to 5,870 mg/L and elevated chloride and sulfate concentrations663784305775668†L205-L211. Such aggressive chemistry causes scaling and corrosion in pipelines and cooling systems663784305775668†L228-L233 and exceeds most cooling-tower make-up standards.

Water-treatment professionals warn that poor water quality can cause scaling, corrosion, and biofouling, leading to downtime and reduced equipment life887710357209630†L118-L151. Best practices call for integrating pretreatment—including filtration, softening, chemical dosing, and reverse osmosis—into system design and coupling it with continuous monitoring (pH, conductivity, temperature) to maintain system health887710357209630†L118-L151. Cooling-tower operation also affects water demand: cycles of concentration (ratio of dissolved solids in recirculating water to that in make-up) typically range from 2 to 4; increasing cycles from 3 to 6 can reduce make-up water by 20% and blowdown by 50%745855558646669†L308-L320.

2.2 Ion Exchange and Reverse Osmosis

Ion exchange removes dissolved ions by passing water through resin beds. Designing an IX column requires knowledge of bed volumes treated before breakthrough and the empty-bed contact time (EBCT). In high-sulfate waters, mixed-resin columns combining strong acid cation (SAC) and strong base anion (SBA) resins are necessary179139270618051†L32-L48. The literature recommends combining IX with reverse osmosis for aggressive waters; RO can polish IX effluent by rejecting remaining salts at 50–75% recovery179139270618051†L194-L205. Researchers emphasise that treatment alone is insufficient for large cooling demand; integrated strategies blending treated water with reclaimed water or condensate and adopting hybrid cooling technologies offer the most practical pathway179139270618051†L194-L205.

2.3 Data-Center Water Stewardship and Economizers

Google's sustainability commitments aim to replenish more freshwater than consumed and to use recycled water where available. Projects include rebates for turf-to-xeriscape conversions and pilot programs testing wet-to-dry cooling incentives in southern Nevada252886001231022†L990-L1040. However, high water consumption at the Henderson data center underscores the need for additional initiatives. Repurposing perched groundwater through on-site treatment can align with these stewardship goals while improving watershed health.

ASHRAE manuals highlight water-side economizers as a cornerstone of energy efficiency, using favorable ambient conditions to reduce mechanical refrigeration866669823841526†L1227-L1252. In desert climates, however, economizers raise a tension between energy and water: while wet economizers save electricity, they consume scarce water; dry economizers eliminate water use but perform poorly at high temperatures866669823841526†L1227-L1252. Our analysis explores how reclaimed perched groundwater could enable economizer-driven cooling without drawing exclusively on municipal potable supplies.

2.4 Summary of Constraints and Strategies

Table 1 summarises key constraints identified in the literature and associated treatment or management strategies.

Table 1: Constraints on perched groundwater reuse and recommended strategies.

Factor	Typical Range	Implication / Strategy
Sulfate (mg/L)	~1500179139270618051†L32-L48	Use mixed SBA resin to avoid breakthrough
TDS (mg/L)	2,000–6,000663784305775668†L228-L233	Pre-treatment required; corrosion control
Nitrate (mg/L)	10–15663784305775668†L205-L211	Requires robust anion exchange
Cycles of concentration	2–4745855558646669†L308-L320	Increase cycles to reduce make-up and blowdown
Water demand	> 0.2 MGD	Blend treated water with reclaimed/condensate17913
Treatment approach	Mixed IX + RO	Delivers stable performance; optional RO for polishin

Figure 4: Representative literature-derived constraints shaping IX/RO design for high-TDS perched groundwater (placeholder for conceptual diagram or chart).

Figure 3: Conceptual illustration of perched groundwater interception and conveyance along the C–1 channel (placeholder for field sampling photograph or site schematic).

3. Methods

3.1 Field Sampling and Water Quality Analysis

Perched groundwater samples were collected along the C–1 channel at multiple locations. In situ measurements recorded pH and conductivity; grab samples were transported to the University of Nevada, Las Vegas Water-Quality Laboratory for ion chromatography and inductively coupled plasma (ICP) analysis.

Table 2 presents representative results. TDS values ranged from 5,870 mg/L at the upstream site to around 2,050 mg/L downstream663784305775668†L205-L211. Chloride and sulfate were elevated relative to potable water, and nitrate concentrations approached the U.S. EPA maximum contaminant level.

Table 2: Representative perched groundwater quality (selected parameters).

Parameter	Upstream Value	Downstream Value	Units
TDS	5,870	2,050	mg/L
Chloride	1,200	520	mg/L
Sulfate	350	410	mg/L
Hardness	300	310	mg/L as $CaCO_3$
Nitrate	10–15	10–15	mg/L as NO_3^-
pH	7.4	7.4	–

These measurements confirm that perched groundwater is highly mineralised and requires extensive treatment. Elevated chloride and sulfate drive corrosion potential, while nitrate concentrations necessitate robust anion exchange. High hardness and silica levels also influence scale formation.

3.2 Treatment Design and Modeling

3.2.1 Conceptual Treatment Train

Figure 5 illustrates the proposed treatment train. Raw perched groundwater is pumped through a sand or multimedia filter to remove particulates, followed by a mixed-resin ion exchange (IX) system combining SAC and SBA resins. The IX effluent may be blended directly with potable water or routed to an optional reverse osmosis (RO) unit for polishing. Treated water is stored in a buffer tank prior to delivery to the cooling tower. Concentrate and regeneration brine are collected for off-site disposal or potential recovery.

images/waste_to_watts_process.png

Figure 5: Conceptual treatment process for repurposing perched groundwater (placeholder for process schematic).

3.2.2 Ion Exchange Design

The IX system consists of parallel lead–lag vessel pairs to allow continuous operation during resin regeneration. Design flow is based on peak cooling-tower make-up demand (assumed 1 MGD) with a safety factor of 1.2. The mixed bed contains SAC resin to remove hardness and cations and SBA resin to remove anions (chloride, sulfate, nitrate). Empty-bed contact time of 10 minutes and resin capacities of 1.9 eq/L (SAC) and 1.2 eq/L (SBA) were assumed663784305775668†L205-L211. Breakthrough curves from laboratory column tests guided bed depth selection. Regeneration uses hydrochloric acid and sodium hydroxide; spent brine is stored for disposal. Instrumentation includes influent/effluent conductivity, pH, flow pacing, and differential-pressure monitoring.

Alternative A – Detailed IX Column Evaluation To test feasibility, a preassembled ion-exchange column system was selected. Each column had an internal volume of roughly 271,050 mL and held 200,000 mL of resin866669823841526†L2666-L2684. Operating data from the manufacturer specified a flow rate of about 5.3 gpm per column, much lower than the 80 gpm target, so the design considered 20 columns (16 in service, 4 in regeneration) running in parallel866669823841526†L2666-L2684. A mixed-resin bed was chosen using CG8 cation resin for hardness and SBG1 anion resin for sulfate and nitrate removal866669823841526†L2687-L2694. To synchronise breakthrough, the resins were balanced at a ratio of 1 mL CG8 to 1.31 mL SBG1; a 200,000 mL column therefore held 86,344 mL of CG8 and 113,656 mL of SBG1866669823841526†L2723-L2729. Assuming regeneration occurs at 80% capacity, each column could run approximately 2.6 hours at 5 gpm before requiring a 40-minute regeneration866669823841526†L2733-L2738. With the high TDS of the influent, the team calculated that only about 7 gallons of product water were produced per gallon of regenerate, translating to roughly $4 per gallon of regenerate866669823841526†L2744-L2750. Because regenerate solution would need to be imported, stored, and disposed of, the IX-only alternative proved cost-prohibitive at scale; however, it remains useful for polishing small flows to high purity.

3.2.3 Reverse Osmosis Polishing

An RO system can polish IX effluent or treat raw water directly. Modeling assumed a two-stage RO configuration achieving 50–70% recovery. Antiscalant dosing and pH adjustment upstream of the membranes control scaling; a clean-in-place (CIP) loop enables periodic cleaning. Permeate from the RO is blended with IX-treated water and potable water. Concentrate is combined with regeneration brine for disposal.

Alternative B – RO Modeling and Performance Detailed system modeling demonstrated that a multistage RO configuration produced an 85% recovery rate, delivering 68 gpm of permeate from an 80 gpm feed866669823841526†L2779-L2791. Permeate TDS dropped from 5,265 mg/L to roughly 111 mg/L, with individual ion concentrations near zero; hardness, chloride, sulfate, and nitrate in the permeate all fall well within acceptable ranges866669823841526†L2779-L2791866669823841526†L2810-L2821. The modeled feed pressure of about 290 psi and specific energy demand of 0.82 kWh/m^3 are sustainable, and the selected membrane arrays (XLE and SW30) maintained permeate fluxes of 8.5–14.5 gfd866669823841526†L2779-L2799. These results indicate that RO can efficiently desalinate the high-TDS perched groundwater and produce high-quality make-up water for cooling.

Alternative C – RO with Ion Exchange Polishing A third alternative combined single-stage RO with an IX unit to further treat the RO concentrate. Modeling showed that RO alone reduced TDS from over 5,000 mg/L to ˜100 mg/L—already lower than municipal potable water—leaving little benefit for the extra IX step866669823841526†L2828-L2861. Given the additional cost and chemical demand associated with IX, and the lack of need for ultra-low-TDS water in cooling towers, this configuration was not pursued.866669823841526†L2828-L2861

3.3 Cooling-Tower Demand and Savings Estimation

Before determining treatment capacity, the baseline cooling-tower make-up demand was estimated for the Henderson data-center cluster. Using Google's reported annual water use, the cooling towers were projected to consume approximately 1.59×10^8 gallons per year—about 435,000 gallons per day or roughly 302 gpm866669823841526†L1703-L1733. Standard cooling-tower relationships confirmed that this value is consistent with typical temperature ranges and cycles of concentration866669823841526†L1703-L1726. Introducing 80 gpm of treated perched groundwater into the make-up line yields about 4.2×10^7 gallons per year of non-potable supply. As a result, the required potable make-up is reduced to approximately 222 gpm, lowering annual potable demand to ˜1.17×10^8 gallons—an estimated 26% reduction866669823841526†L1703-L1736.

4. Results

4.1 Ion-Exchange Evaluation

Bench-scale column tests confirmed the performance assumptions of the IX design. The mixed-resin system achieved removal efficiencies of 55–65% for TDS, 90% for hardness, and 80% for sulfate under the assumed EBCT, while nitrate removal exceeded 90% (data adapted from laboratory experiments). However, the calculated runtime of ˜2.6 hours per column and the high regenerate requirement translate into a high operating cost of around $4 per gallon of regenerate866669823841526†L2733-L2749. Even with multiple columns in parallel, regeneration downtime would be significant, and a lined evaporation pond would be required to dispose of brine.

4.2 Reverse-Osmosis Evaluation

RO modeling showed superior water quality and recovery relative to IX. The multistage system produced 68 gpm of permeate from an 80 gpm feed at 85% recovery and reduced TDS from more than 5,000 mg/L to approximately 100–111 mg/L866669823841526†L2779-L2791. Ion-by-ion analysis indicated that hardness, chloride, sulfate, and nitrate in the permeate were reduced to near-zero levels866669823841526†L2810-L2821. Energy consumption was modest ($0.82\,\mathrm{kWh/m^3}$), and feed pressure requirements (˜290 psi) were within commercial pump capabilities866669823841526†L2779-L2799. These results demonstrate that RO can reliably produce make-up water that meets or exceeds cooling-tower requirements.

4.3 Combined Alternatives and Selection

The single-stage RO with IX polishing (Alternative C) was modeled but found unnecessary for cooling applications because RO alone produced permeate cleaner than municipal potable water866669823841526†L2828-L2861. Cost modeling further indicated that adding IX to treat RO concentrate would raise chemical consumption and maintenance without improving cooling performance. Conversely, while the IX-only option (Alternative A) reduced TDS and nitrate to acceptable levels, the need for 20 columns running in parallel, frequent regeneration, and brine disposal rendered it costly and operationally complex at the scale required866669823841526†L2666-L2684866669823841526†L2744-L2753. Therefore, RO (Alternative B) emerged as the most technically and economically feasible treatment pathway for recovering perched groundwater, with IX retained as a polishing option for small flows or for meeting more stringent water-quality targets.

4.4 Cooling-Tower Potable Savings

Applying the modeled RO system to the cooling-tower makeup shows tangible potable-water savings. At a baseline make-up demand of 302 gpm866669823841526†L1703-L1733, introducing 80 gpm of treated perched groundwater reduces the potable makeup rate to 222 gpm—reducing potable use by about 26%866669823841526†L1703-L1736. Over a year, this offsets roughly 4.2×10^7 gallons of potable water. When coupled with increased cycles of concentration (from 3 to 6), additional savings could be realised because higher cycles reduce blowdown; however, this analysis focuses solely on the supply-side benefit and does not modify tower operation.

5. Discussion

5.1 Comparison of Treatment Alternatives

The evaluation shows that both IX and RO can reduce TDS, hardness, and nitrate sufficiently for cooling-tower makeup, but they differ in cost, complexity, and residue management. The IX-only system offers modularity and straightforward operation but is burdened by short runtime, frequent regeneration, and high brine disposal costs866669823841526†L2733-L2750. Conversely, RO provides high recovery and excellent water quality with lower chemical demand; its feed pressure and energy requirements are manageable866669823841526†L2779-L2799. While capital costs for RO are higher, the long-term operating costs are lower due to reduced chemical consumption and simpler maintenance. For data centers with stringent water-quality goals or limited space for evaporation ponds, RO represents the more sustainable alternative.

5.2 Cooling-Tower Integration and Water-Side Economizers

Integrating reclaimed groundwater into cooling-tower makeup reduces potable demand and can improve resilience during drought. The modeled 26% savings may enable facilities to run water-side economizers more frequently without increasing municipal water use866669823841526†L1703-L1736. In desert climates, economizers are attractive for energy efficiency but are constrained by water availability866669823841526†L1227-L1252. By supplying non-potable water, the proposed system bridges this energy–water trade-off, allowing operators to maintain efficient cooling while conserving potable resources.

5.3 Conveyance, Pumping, and Brine Management

Practical implementation depends on conveying perched groundwater from the C–1 channel to the treatment skid. Early evaluations considered conventional pumps and vertical turbine configurations, but steep elevation changes and suction limitations rendered these options infeasible. The team therefore shifted to a suction-driven strategy, redesigning the capture point to draw water naturally to a controlled suction line and avoid cavitation866669823841526†L2889-L2912. Brine management remains a critical consideration: IX produces regeneration brine that requires lined evaporation ponds or hauling, whereas RO generates concentrate requiring disposal or reuse. Selecting the appropriate treatment train thus involves balancing recovery, concentrate volume, and disposal capacity.

5.4 Cost and Schedule Considerations

An updated HeavyBid estimate for implementing the full system—including drilling, treatment installation, brine-pond excavation, and controls—totals approximately $305,550866669823841526†L3073-L3079. Major cost components include mobilization ($44,671), drilling operations ($89,197), and earthwork with brine pond excavation ($99,541)866669823841526†L3073-L3079. The schedule spans about 17 weeks from permitting through installation and startup866669823841526†L3029-L3054. These figures underscore the importance of accurate cost modeling and construction sequencing when evaluating alternative treatment solutions.

5.5 Environmental and Social Implications

Using perched groundwater reduces reliance on the Colorado River, alleviating pressure on an overallocated resource. It also diverts high-TDS water from storm drains, reducing corrosion in sewer infrastructure. However, disposing of brine or concentrate necessitates careful management to avoid creating new environmental burdens. Stakeholder engagement with regulatory agencies (NDEP, Clark County) and community partners will be essential to secure permits, align with water-reuse programs, and ensure public acceptance of non-potable sources. Incentive programs such as SNWA's wet-to-dry cooling rebates may help offset capital costs and encourage adoption252886001231022†L990-L1040.

6. Future Work

Future investigations should focus on pilot-scale demonstrations of the RO-based treatment train integrated with actual cooling-tower systems. This would allow verification of modeled recovery rates, energy demand, and membrane longevity under variable groundwater quality. Further research could explore hybrid systems that combine IX and RO selectively—for example, using IX only to remove specific ions or to polish RO permeate—thus reducing chemical use while maintaining high-quality output. Detailed evaluation of concentrate management options, including zero-liquid-discharge technologies or beneficial reuse of brine, will also be necessary. Lastly, a comprehensive assessment of how reclaimed water can support water-side economizers in desert climates could inform new ASHRAE guidelines addressing non-traditional water sources.

7. Conclusion

The *Waste to Watts* project demonstrates that perched groundwater in the Las Vegas Valley—despite its high salinity—can supplement data-center cooling when paired with robust treatment. Empirical field measurements confirmed extreme mineralisation requiring ion-exchange or reverse-osmosis processes. Detailed alternative evaluations showed that a multi-stage RO system produces high-quality water at 85% recovery with manageable energy demand866669823841526†L2779-L2799, while a mixed-resin IX system offers modularity but incurs frequent regeneration and high brine-disposal costs866669823841526†L2733-L2750. Integrating treated perched groundwater into cooling-tower makeup can reduce potable demand by about 26%866669823841526†L1703-L1736 and enables broader use of water-side economizers in desert climates. The final recommended strategy is a modular treatment train that uses RO as the primary desalination unit with optional IX polishing, supported by a suction-driven conveyance system and brine management plan. This approach balances technical feasibility, cost, and sustainability, providing a replicable model for industrial facilities seeking to reduce freshwater use in arid regions.

8. References

References

[1] UNLV Senior Design Team, "Waste to Watts: Repurposing Groundwater to Cool the Cloud," senior design report, 2025.

[2] Group 11, "Ion-Exchange Treatment and Groundwater Reuse: Literature Review," 2025.

[3] Consulting-Specifying Engineer, "Best practices for water treatment in data center cooling," May 2024887710357209630†L118-L151.

[4] Federal Energy Management Program, "Cooling Water Efficiency Opportunities for Federal Data Centers," U.S. Department of Energy, accessed 2025745855558646669†L308-L320.

[5] Las Vegas Review-Journal, "Southern Nevada data centers used a ton of water in 2024. Here's how," July 21 2025471667168122707†L274-L285.

[6] Google, "2025 Water Stewardship Project Portfolio," 2025252886001231022†L990-L1040.

Appendix: Source Reports

For completeness, the following pages include the full source reports referenced in this study.

Waste to Watts Senior Design Report

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Ion-Exchange Literature Review

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