# HPC &AI Water Usage: Findings from 11 Supercomputing Centers

Survey Respondents: Michael Feguson- LANL, Tiziano Belotti- CSCS, Fumiyoshi Shoji- RIKEN, Daniel Hackenberg,-TU Dresden, Chris DePrater- LLNL, Mani John- KAUST, Michele Toni- ECMWF, Suzy DiMont- NLR, David Grant- ORNL, Hiren Gandhi- LRZ, and Matt Anderson- INL
Poster Authors: Steve Gu, Reed College, Stuart Nystrom, Nalco Water, Paula Paciorek, Alliance for Water Efficiency and many others from the EE HPC WG Water Management Team

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## BACKGROUND

Large-scale, high-density AI and HPC computing is driving higher thermal loads, making water availability, permitting, and community impact important siting considerations. While the HPC community has made substantial progress in power and energy management through metrics such as PUE, water use is less consistently monitored and tracked. Historically, evaporative cooling improved energy efficiency at the cost of increased water consumption. Yet operational data and baseline practices for HPC water management remain limited. Establishing these baselines will help facilities better understand and manage water consumption as an engineering choice.

## OBJECTIVE

This study establishes an operational baseline of real-world water management practices across 11 global HPC facilities, examining how cooling systems, metering, water sourcing and discharge, water chemistry, and conservation strategies affect water consumption and efficiency. It also identifies the technical, economic, and operational factors that enable or limit further water conservation.

## METHODS

A team of HPC practitioners, industry vendors, academics, and water conservation organizations developed a 35-question survey on water consumption and management. The survey was sent to 23 major supercomputing sites across different geographies and water-scarcity conditions. Of 12 responses, one site was excluded because it was still under design and construction, leaving 11 operational facilities. All responses were self-reported by identified site representatives. No systematic bias was identified, although the results point to opportunities to improve future survey

## RESEARCH QUESTIONS

The survey covered facility characteristics, cooling systems, PUE, water consumption and metering, WUE, major water uses, water sources and discharge pathways, and water costs. It also asked about water scarcity and risk assessments, cooling tower blowdown and cycles of concentration, chemical treatment, and the effects of scale, corrosion, microbiological growth, and other water-quality issues. Respondents rated barriers to conservation, reported conservation strategies and their impacts, described future plans, and identified opportunities for collaboration.

## TABLE 1. RESPONDENT FACILITIES *

| Facility | Flagship System | Nov'25 TOP500 Position | Nov'25 GRN500 Position | Top500 Power (kW) |
|---|---|---|---|---|
| LLNL | El Capitan | #1 | #23 | 29,685 |
| ORNL | Frontier | #2 | #34 | 24,607 |
| RIKEN | Fugaku | #7 | #110 | 29,899 |
| CSCS | Alps | #8 | #21 | 7,124 |
| KAUST | Shaheen III | #18 | #18 | 1,980 |
| LANL | Venado | #22 | #25 | 1,662 |
| TU Dresden | Capella | #73 | #6 | 445 |
| INL | Teton | #85 | #115 | 1,565 |
| LRZ | SuperMUC-NG | #91 | #247 | Not provided |
| NLR | Kestrel | #98 | #251 | Not provided |
| ECMWF | HPCF | #227 - #230 | #154 - #157 | 4,800 |

## TABLE 2. OPERATIONAL CHARACTERISTICS *

| Facility | Cooling Method | Annual Water Usage (m3/y) | WUE (L/kWh) | Water Stress (WRI 4.0) | Sources |
|---|---|---|---|---|---|
| LLNL | Evaporative | 568,000–757,00 | Not Provided | High | Municipal Potable |
| ORNL | Evaporative | 207,251 | >1.5 | Low | Municipal Potable |
| RIKEN | Evaporative | 634, 000 | 4.2–4.7 | Low | Municipal Potable |
| CSCS | Lake | 8,063,347 | Not Provided | Low | Raw Surface Water |
| KAUST | Evaporative | Not Provided | Not Provided | Very High | Desalinated Seawater / RO |
| LANL | Evaporative | 190,000 | >1.5 | Very High | Reclaimed Wastewater / Municipal |
| TU Dresden | Hybrid / Adiabatic | 6,750 | 0.44 | Low-Medium | Municipal Potable |
| INL | Evaporative | 37,305 - 39,792 | <1.0 | Medium-High | Municipal Potable |
| LRZ | Hybrid / Adiabatic | 85,979 | >1.5 | Low / Low- | Groundwater (Well) |
| NLR | Evaporative | 32,986 | 1.569 | High | Municipal Potable |
| ECMWF | Hybrid / Adiabatic | 21,840 | 0.471 | High | Municipal /Groundwater |

## TABLE 3. EVAPORATIVE COOLING BLOWDOWN & COC

**Blowdown & Cycles of Concentration (COC)- *Optimizing Tower Efficiency to Minimize Water Losses***

- **15% – 33%** of total facility water is lost directly to cooling tower **blowdown**.
- **Only 4 of 9** evaporative sites actively track their blowdown volume and COC.

**How Cycles of Concentration (COC) Work**

As water evaporates to cool the data center, dissolved minerals remain behind. **Cycles of Concentration (COC)** measures how many times water recirculates before mineral buildup requires flushing (**Blowdown**).

$$B = \frac{E}{\mathrm{COC} - 1} \quad | \quad \text{Total Makeup Water } (M) = E + B$$

$E$= Water lost to Evaporative cooling , $B$= Water discharged as Blowdown , COC= Cycles of Concentration

**Example: NLR (Kestrel)**

- **Total Annual Makeup ($M$):** $32{,}986\ \mathrm{m}^3$, **Annual Blowdown ($B$):** $4{,}744\ \mathrm{m}^3$, **Operating COC:** ≈ 7 COC

$$\text{Blowdown Fraction} = \frac{B}{M} = \frac{4{,}744\ \mathrm{m}^3}{32{,}986\ \mathrm{m}^3} \approx \mathbf{14.4\%}$$

$$\text{Formula Check at COC} = 7\text{:} \quad B = \frac{E}{7-1} = 0.167E \Longrightarrow \frac{B}{M} = \frac{0.167E}{1.167E} \approx \mathbf{14.3\%}$$

**Takeaway:** By maintaining a high COC ≈ 7, NLR limits blowdown loss to under **15%** of total water makeup. Lowering COC (e.g., to COC = 3) would nearly double blowdown loss to **33%**.

## TABLE 4. WATER QUALITY ISSUES

| Water Quality Issue | Impact Level | Affected Sites | Operational & Thermal Impact |
|---|---|---|---|
| Corrosion | 1 Major, 6 Minor | 7 Sites (NLR, LANL, RIKEN, TU Dresden, LLNL, INL, LRZ) | Deteriorates cold plates, piping, and heat exchangers; increases surface roughness and pumping energy penalties; leak risks. |
| Scale & Mineral Deposits | 3 Major, 2 Minor | 5 Sites (LANL, NLR, RIKEN, INL, LRZ) | Calcium, magnesium, and silica precipitate on heat transfer surfaces; acts as a thermal insulator and forces lower cycles of concentration (COC). |
| Microbiological Growth | 1 Major, 3 Minor | 4 Sites (CSCS, RIKEN, INL, LRZ) | Biofouling degrades cooling loops and introduces health risks. |

## TABLE 5. BARRIERS TO CONSERVATION

| Barrier | Major | Minor | Operational Examples |
|---|---|---|---|
| Physical | 6 sites | 1 site | NLR removed thermosyphon due to space |
| Economic | 5 sites | 2 sites | Low rates ($0.26–$4.80/m$^3$, ave. $2.12/m$^3$) |
| Water Quality | 2 sites | 4 sites | LRZ has extensive chemical treatment |
| Water | 1 site | 4 sites | KAUST reliance on-site seawater |
| Environmental | 2 sites | 2 sites | LANL chlorine neutralized for wetland discharge |

## FINDINGS

### Cooling Architecture and WUE

Two out of 3 hybrid/adiabatic facilities have low WUE. Most of the evaporative facilities cluster near the industry WUE average. CSCS uses Lake Lugano, returns water with a once through-loop, and does not measure WUE.

### Measurement

Eight sites reported a WUE number or range for the survey, but only 5 sites reported that they measure WUE. Water metering is a constraint for accurate WUE reporting. Only 4 of 9 evaporative sites track cooling-tower blowdown and cycles of concentration (COC).

### Blowdown

Cooling-tower blowdown accounts for approximately 15–33% of total facility water use at the surveyed evaporative sites. Increasing COC through appropriate water treatment is key for reducing water loss.

### Space and Cost Constraints

Physical space and cost were each cited by 7 of 11 facilities as barriers to additional water conservation. These constraints can limit deployment of recovery, treatment, and cooling technologies even when conservation opportunities exist.

### Water Quality

Scale, corrosion, and microbiological growth affect cooling-system operation at multiple sites. Effective water treatment and chemistry management are important to maintaining higher COC and efficient heat transfer.

### Water and Energy

Some water-conservation strategies require additional energy. Water efficiency should therefore be evaluated together with energy efficiency rather than optimized independently.

**REFERENCES:**
**The Green Grid (2011).** *Water Usage Effectiveness (WUE™): A Green Grid Data Center Sustainability Metric*. White Paper #35.
**ISO/IEC (2022).** *Information technology — Data centres key performance indicators — Part 9: Water usage effectiveness (WUE).* ISO/IEC Standard 30134-9:2022.
**World Resources Institute (2023).** *Aqueduct 4.0 Water Risk Atlas: Baseline Water Stress Dataset*. WRI, Washington, DC.
**Siddik, M. A. B., Shehabi, A., & Marston, L. (2021).** The water use of data center workloads in the United States. *Environmental Research Letters*, 16(6), 064010.
**Los Alamos National Laboratory (2024).** *Sanitary Effluent Reclamation Facility (SERF) Data-Center Case Study*. U.S. Department of Energy, OSTI Report.

### * TABLE 1&2 NOTE

The survey did not collect WUE methodology or power data. TOP500 HPL peak power may not correspond to the IT energy used to calculate WUE.

The EE HPC Working Group is an international community focused on improving energy efficiency and sustainability in high-performance computing.