# Porosity Storage In Ground Reservoir: Closed Loop Cooling Concept (WUE Optimized)

## 1) Executive Summary

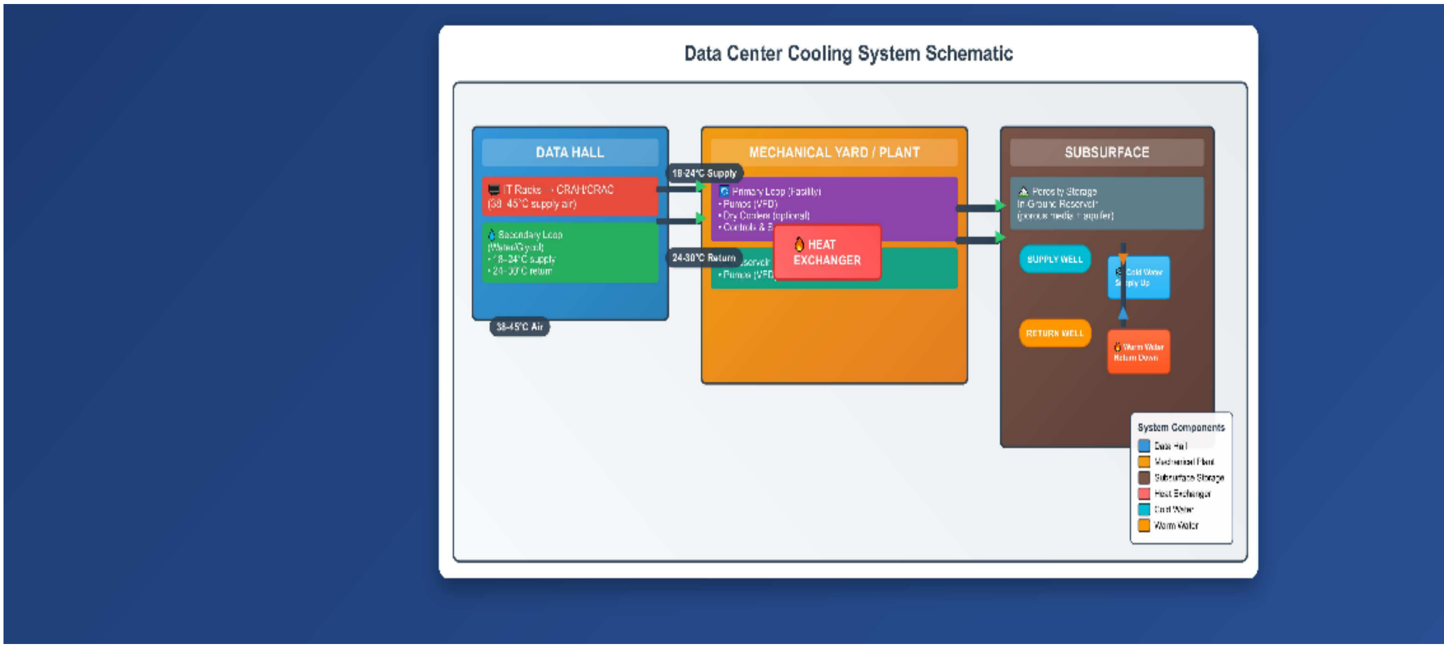
This document outlines a closed loop cooling concept for data centers that leverages a Porosity Storage™ in ground water reservoir (porous geologic media) as a long duration cold thermal resource. The system circulates water through deep intake/return pipes to surface heat exchangers—without evaporative cooling towers—achieving near zero operational water consumption (target WUE 0.00–0.02 L/kWh*) while providing resilient, low carbon cooling.

> *Illustrative range. Actual WUE depends on makeup for seal water, domestic/landscape uses, and any auxiliary systems.

## 2) How It Works (Plain Language)

1. **Cold Reservoir**: A subsurface reservoir (porous formation) stores a large volume of naturally cool water.
2. **Deep Pipes**: Two well strings (or lined shafts) connect the reservoir to the mechanical room: **Supply (cold up)** and **Return (warm down)**.
3. **Heat Exchangers (HX)**: Plate and frame or shell and tube HX transfer heat from the data hall water/glycol loop to the reservoir loop. Loops remain hydraulically isolated.
4. **Pumps & Controls**: VFD pumps modulate flow to match IT load; controls optimize approach temperatures and reservoir state of charge (SoC).
5. **Dry Heat Rejection (Optional)**: Air cooled fluid coolers or adiabatic free mode units trim peak temperatures without consuming water.

## 3) System Schematic (Conceptual)




## 4) Design Basis (Example)

- **Site/Climate**: Temperate to hot dry; wet bulb 22–25°C summer design; groundwater 10–16°C.
- **IT Load**: 10 MW (scalable to 50 MW campus with modular HX banks).
- **Thermal T Targets**: Facility loop 6–8K; reservoir loop 4–6K.
- **Approach (HX)**: 1.5–2.5K (high efficiency plates with N 1 configuration).
- **Redundancy**: N+1 pumps per loop; dual supply/return headers; dual electrical feeds.
- **Controls**: Predictive reservoir SoC, weather forecast optimization, and demand response (DR) integration.

### 4.1 Capacity & Storage (Order of Magnitude)

- **Instantaneous Cooling**: 10 MW 34.1 MMBtu/h.
- **Daily Energy**: 240 MWh(th) / day at full load.
- **Reservoir Buffering** (illustrative):
  - Useful mass ~50,000–200,000 m³ active volume.
  - Effective thermal capacity ( T=6K, cp 4.19 kJ/kg K): ~350–1,400 MWh(th).
  - Provides multi hour to multi day peak shaving; seasonal cold recharging via winter ambient or chillers during off peak.

## 5) Performance Metrics

- **WUE (Water Usage Effectiveness)**: Target 0.00–0.02 L/kWh (near zero evaporation; minor seal water only).
- **PUE (Power Usage Effectiveness)**: Target 1.10–1.18 (high WSE/CHW economization hours, low pump kW/ton).
- **EER/COP Equivalent**: COPsys often > 20 during full free cooling hours; > 8 with dry cooler assist.
- **Grid Impact**: Significant peak demand reduction; DR/VPP compatible via pre cooling.

## 6) Major Subsystems

1. **Reservoir Loop**
   - Dual wells or shafts (supply/return), liners, screens, isolation valves.
   - Submersible or vertical turbine pumps; VFDs; flow rates designed for T.
   - Down hole temp/pressure sensors; anti fouling provisions.
2. **Heat Exchange Plant**
   - Plate and frame HX banks; N+1 trains; by pass and isolation.
   - Non glycol (preferred) or inhibited glycol depending on freeze risk.
3. **Facility Loop**
   - Headers, distribution pumps (VFD), strainers, chemical treatment, air separators.
   - CRAH/Rear Door HX/Direct to Chip cold plates (future ready).
4. **Optional Dry Coolers**
   - Air cooled fluid coolers (free cooling majority hours); adiabatic only for rare extremes.
5. **Controls & Integration**
   - PLC/BMS with reservoir SoC model; weather & tariff APIs; IT load prediction.
   - Safeties: leak detection, pressure interlocks, over temp bypass to auxiliary chillers (if any).

## 7) Operations & Water Stewardship

- No cooling towers; **no routine evaporative make up**.
- Minimize blowdown, drift, and chemical discharge.
- Use non potable water for any incidental needs (e.g., mechanical seal rinse), or closed mechanical seals.
- Conductivity, pH, microbiological monitoring on both loops; biocide compatible with HX metallurgy.

## 8) Geology, Siting & Permitting (Checklist)

- **Hydrogeology**: Porosity/permeability adequate for design flow; thermal dispersion supportive of recharge.
- **Water Quality**: Compatibility with metallurgy; scaling/corrosion indices.
- **Regulatory**: Well permits; reinjection allowances; thermal discharge limits; monitoring wells.
- **Environmental**: Thermal plume modeling; groundwater protection plan; construction dewatering management.

## 9) Phased Delivery (10–50 MW Campus)

1. **Phase 0 – Feasibility**: Desktop hydrogeology, thermal modeling, WUE/PUE business case, ROM capex/opex.
2. **Phase 1 – Pilot Well Pair**: 1–2 MW thermal pilot with full monitoring.
3. **Phase 2 – Module A (10 MW)**: Add HX bank A, pumps, headers, controls.
4. **Phase 3 – Campus Scale (20–50 MW)**: Duplicate trains; expand reservoir contact as validated.

## 10) Risk Register (Top Items)

- **Scaling/Fouling** Mitigate with filtration, chemical program, and HX approach margin.
- **Thermal Depletion** Active SoC management; rotate intake/return; seasonal recharge.
- **Permitting Delays** Early regulator engagement; 3rd party hydro studies.
- **Seismic/Settlement** Structural allowances and flexible connections.
- **IT Load Growth** Modular HX banks and variable pumping capacity.

## 11) Measurement & Verification (M&V)

- Points: flow, T, kW (pumps/fans), reservoir temps/depths, HX approach, WUE counters.
- KPIs: WUE, PUE, kW/ton, DR events served, % free cooling hours, avoided water vs. tower baseline.
- Reporting: API to sustainability dashboards; monthly assurance package.

## 12) Representative Bill of Materials (10 MW module)

- 2× well strings (supply/return) with liners/screens
- 2× reservoir pumps + 1 spare (VFD)
- HX bank (N+1), ~12–16 MW(th) nameplate

- Facility pumps (N+1), expansion/air separator/strainers
- Dry coolers (optional), controls, MCCs, UPS rides through for pumps
- Instrumentation (flow, temp, pressure, vibration), leak detection

## 13) Budgetary ROM (Indicative Only)

- **Subsurface works**: $4–12M (geology dependent)
- **Surface HX/pumps/headers/controls**: $6–10M
- **Optional dry coolers**: $2–4M
- **Total (10 MW module)**: $12–26M (±30–50%)

*Excludes building, electrical distribution, CRAH/IT, land, contingency, financing.

## 14) Glossary

- **WUE**: Water Usage Effectiveness (L/kWh).
- **PUE**: Power Usage Effectiveness.
- **UTES**: Underground Thermal Energy Storage.
- **ATES/BTES/RTES**: Aquifer/Borehole/Reservoir Thermal Energy Storage.
- **SoC**: Thermal state of charge of the reservoir.

## 15) Appendix A – Text Only Diagram (for spec packs)

## 16) Next Steps

- Commission hydrogeologic desktop study; identify candidate formation(s).
- Build a calibrated thermal hydraulic model; set WUE/PUE targets for the business case.
- Plan a 1–2 MW pilot with full M&V before campus rollout.

*Prepared for: Stakeholders evaluating Porosity Storage™ in ground reservoir cooling for sustainable, water lean data centers.*