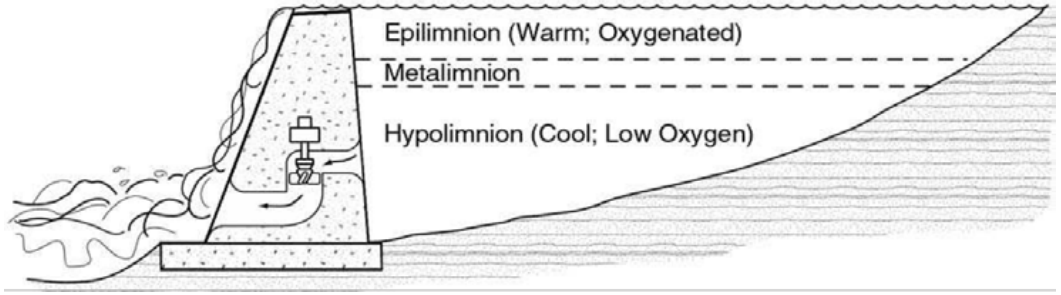
BUREAU OF RECLAMATION

Water Temperature Control of Reservoir Release Flows

2020 Technology Search Results

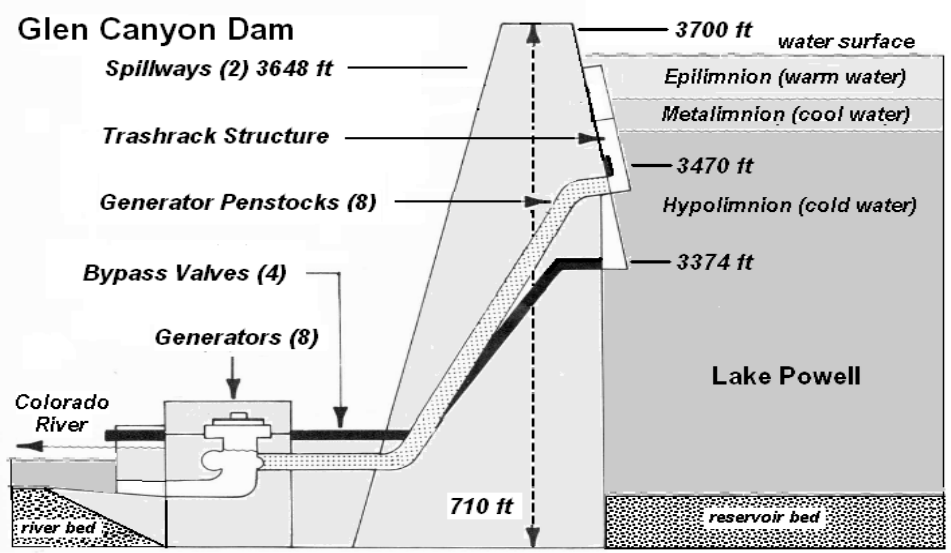
Background

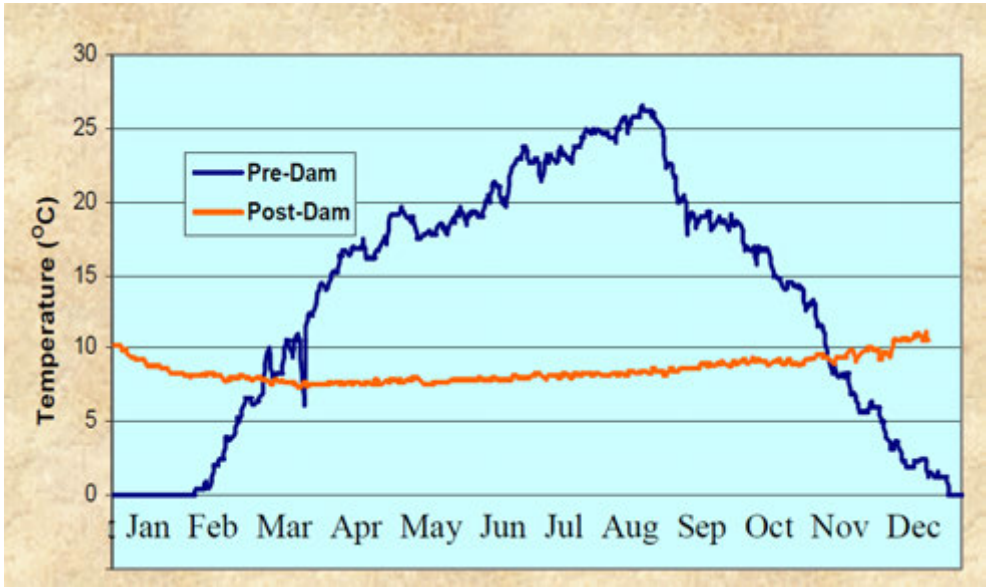


- Reclamation must address temperature control of reservoir release flows to comply with water quality requirements and biological opinions, and to reduce potential impacts to species protected under the Endangered Species Act.
- Reclamation currently employs selective withdrawal devices and operational techniques at many facilities to meet downstream temperature requirements.
- New ideas and technologies are needed to reduce installation and maintenance costs and to better or more easily meet temperature objectives.

Glen Canyon Dam Background

- 560 ft water depth when full
- Primary flow release through 8 power penstocks (3470 ft)
- Can also release through spillway (3648 ft) and 4 bypass valves (3374 ft)
- Pre-dam temperatures 0-30 deg C; post-dam releases 7-12 deg C





Research Approach

- Compile information on how water temperature is currently controlled at dams (state-of practice)
- Conduct Technology Search to seek all ways that water temperature is controlled in any industry that may be applicable to dams (out-of-box ideas)
- Determine if Reclamation should run a prize competition to seek additional solutions

Current Technologies at Dams

Gated selective withdrawal systems – rigid steel structures on upstream face of dam to enclose penstock intakes and release water from various elevations

Examples: Shasta Dam, Folsom Dam, Jordanelle Dam, Flaming Gorge Dam, Hungry Horse Dam, Cougar Dam, Applegate Lake

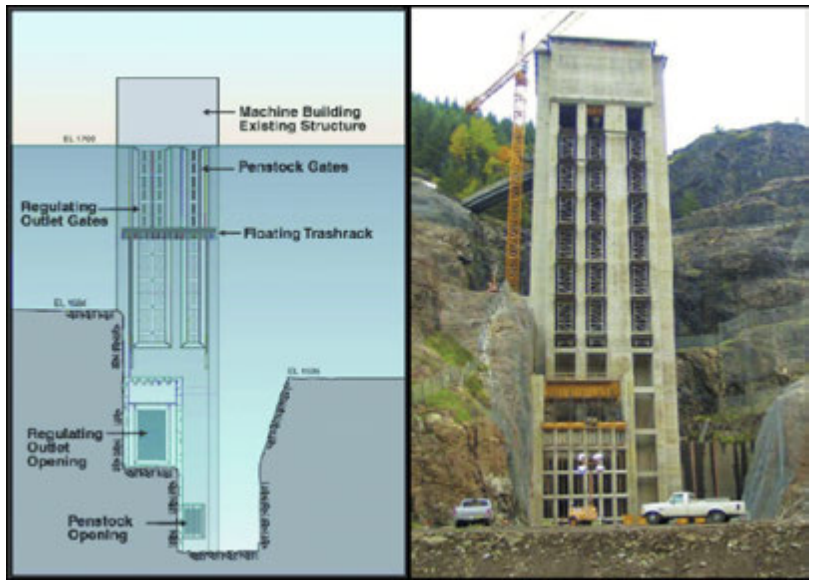


Image from USACE

Current Technologies at Dams

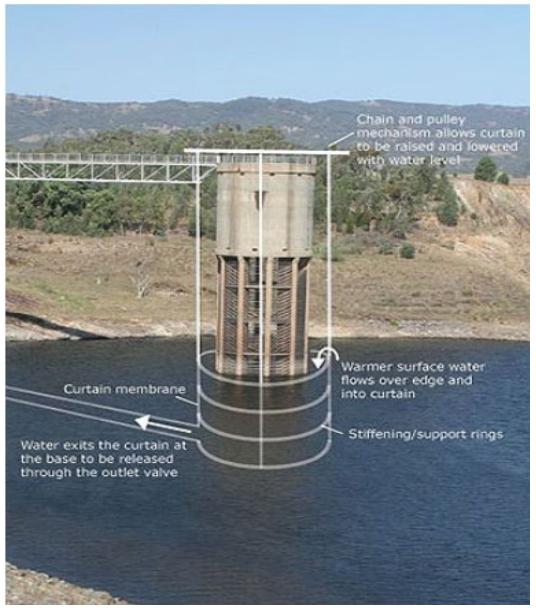
Fixed flexible temperature curtains – submerged curtain positioned for water flow over or under to control outflow temperature

Examples: Lewiston Reservoir, Whiskeytown Lake

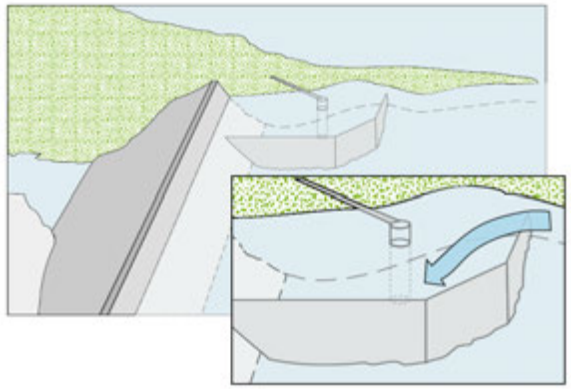
Photograph from BCI Construction USA, Inc., Lewiston Reservoir

Adjustable flexible temperature curtains – pulley system allows raising and lowering of submerged curtain

Example: Burrendong Dam (Australia)



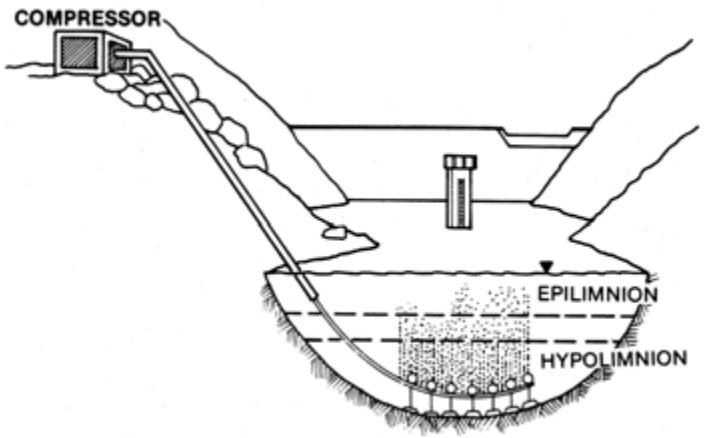
Photograph from WaterNSW, www.waternsw.com.au/projects/burrendong



Sherman, Bradford. 2000. "Scoping Options for Mitigating Cold Water Discharges from Dams". CSIRO Land and Water, Canberra, Australia.

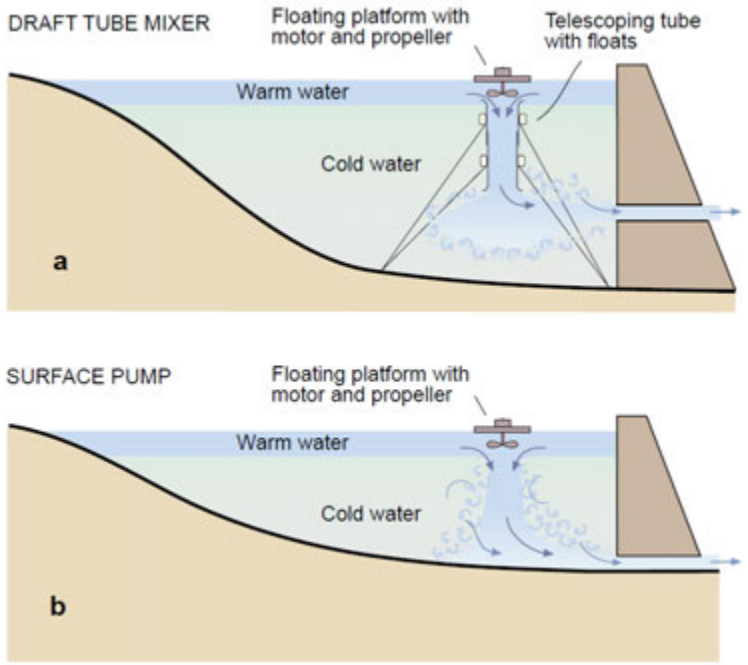
Current Technologies at Dams

Destratification devices – induces large-scale circulation or mechanical mixing



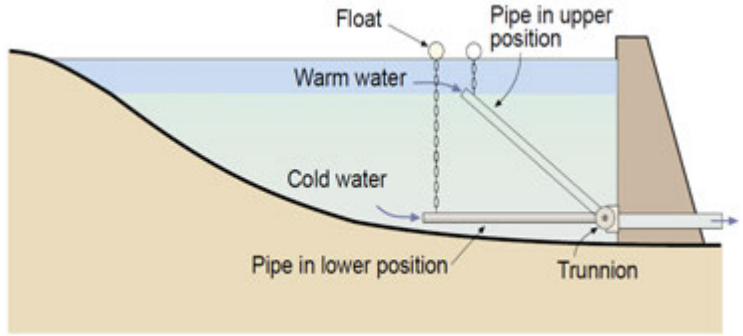
Schematic from USACE

Surface pumps and draft tube mixers – top-down circulation approach



Sherman, Bradford. 2000. "Scoping Options for Mitigating Cold Water Discharges from Dams". CSIRO Land and Water, Canberra, Australia.

Floating intakes – hinged pipes positioned to draw water from different levels



Sherman, Bradford. 2000. "Scoping Options for Mitigating Cold Water Discharges from Dams". CSIRO Land and Water, Canberra, Australia.

Current Technologies at Dams

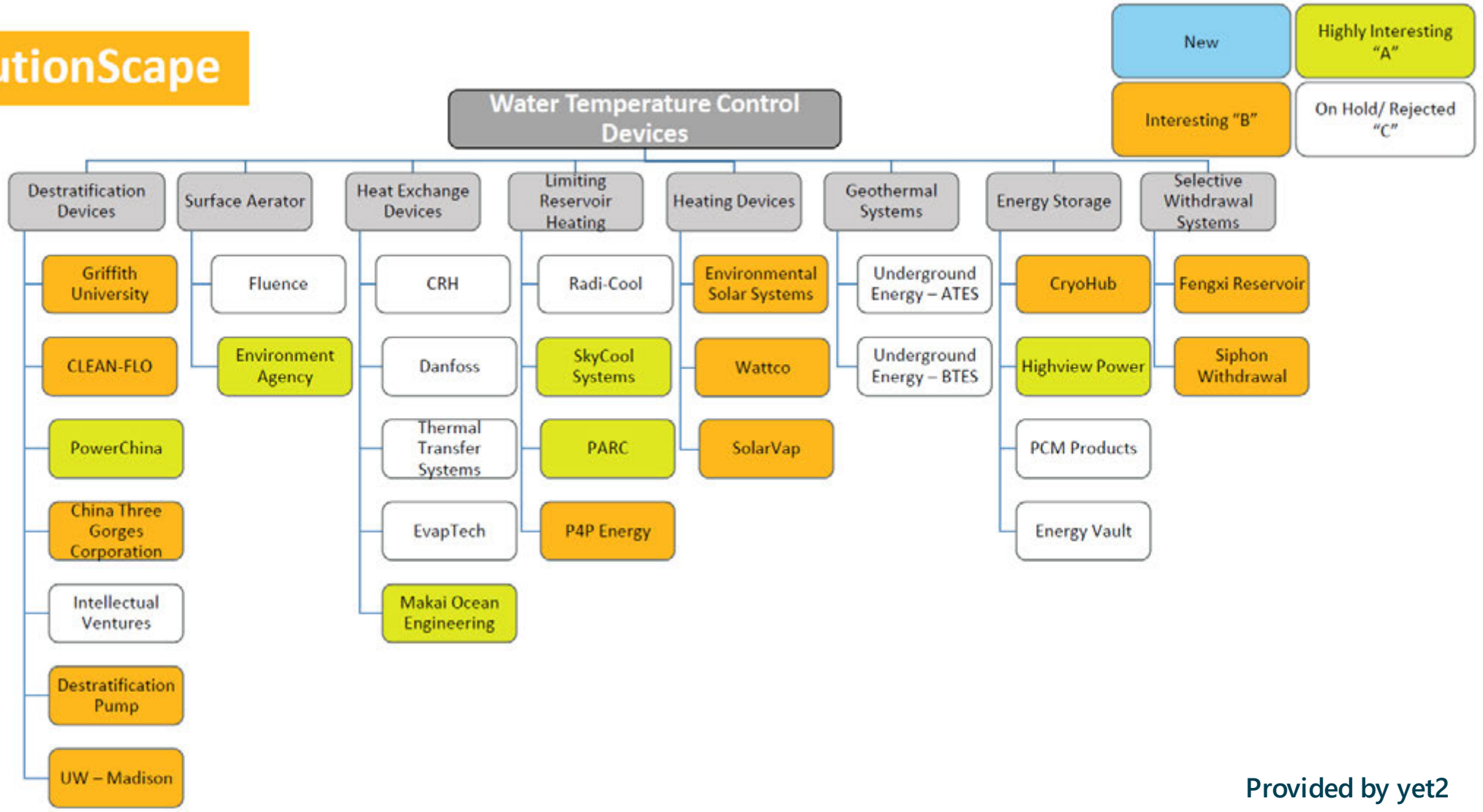
- Warming basins – shallow water bodies that warm water via sun exposure
- Multi-level outlets – fixed openings at several levels above intakes
- Low-level outlets – direct flow release to river that bypasses turbines; potential to bifurcate between river outlet and penstock or add turbines in river outlets
- Reservoir fill, circulation, and release strategies – guide curve changes, inflow routing, supplemental releases, concentration of flow through one gate, release strategy optimization, hypolimnetic withdrawal

Technology Search Methodology – yet2

- Define:
  - Ways water temperature is controlled (cooled or heated) in any industry that can be related to large water resources projects
  - Could involve direct heating or cooling of fluids or methods to prevent warming or cooling of fluids
  - Any stage of development
  - Cost is not a factor
- Scout: Proactively scour global markets through their network and database and receive submissions to posted Technology Need.
- Filter: Discuss and refine findings with Reclamation at set-points. Determine Reclamation use case and partner potential.
- Engage: Prioritize promising technologies and coordinate introductions.

Summary of Solutions

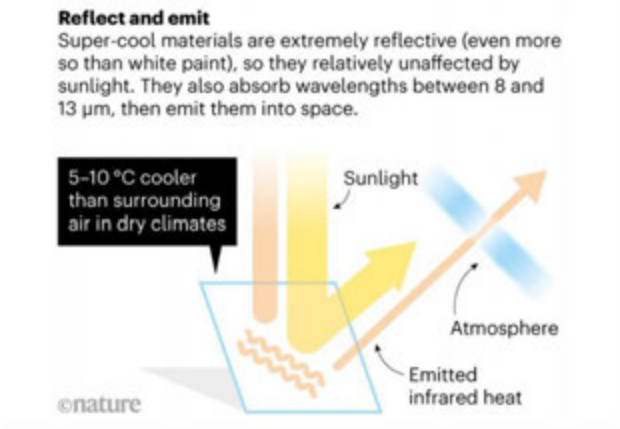
SolutionScape



Provided by yet2

Limiting Reservoir Heating: SkyCool Systems

- Uses radiative cooling to passively cool water. Multi-layer optical film reflects about 97% of sunlight while simultaneously emitting the surface's thermal energy to the atmosphere. Currently applications in cooling buildings (refrigeration, HVAC).
- Reclamation use case: coat penstocks; large area land-based or floating panels

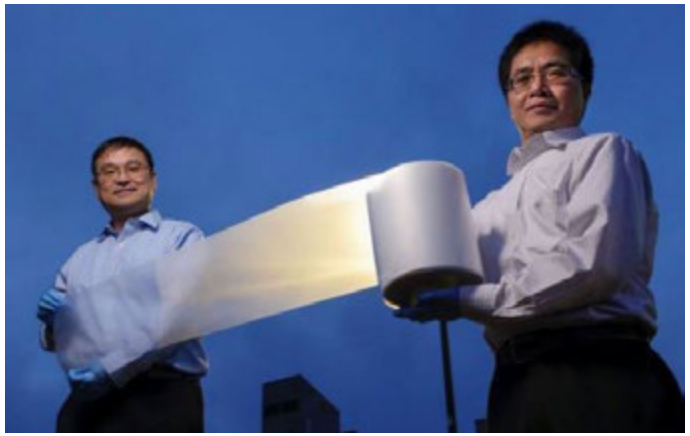


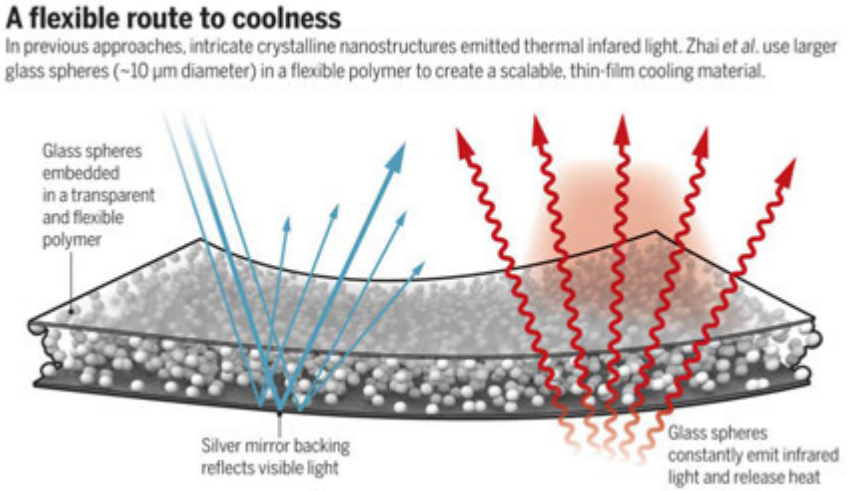
http://skycoolsystems.com/

Information provided by yet2

Limiting Reservoir Heating: Radi-Cool

- Passive cooling of surfaces with see-through polymer interspersed with glass beads that emits energy as infrared radiation and reflects solar light.
- Reclamation use case: coat penstocks; large area land-based or floating panels



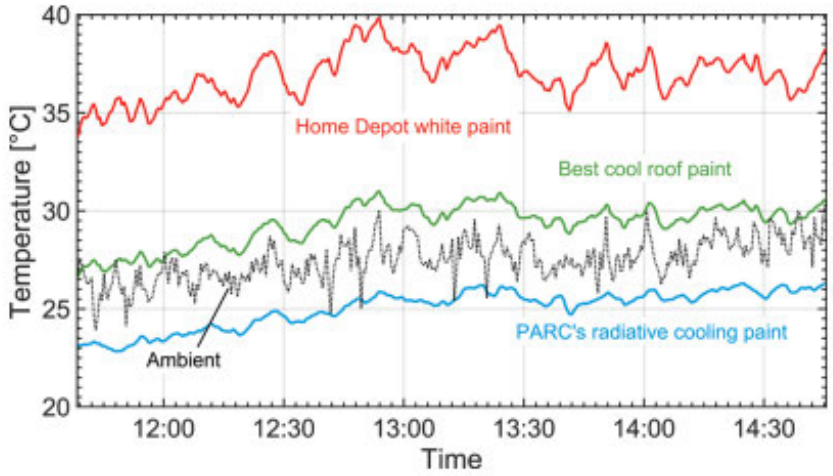


http://radi-cool.com/

Information provided by yet2

Limiting Reservoir Heating: PARC

- “Self-cooling”paint consisting of engineering metaparticles
- Reclamation use case: coat penstocks; large-area land-based or floating panels



https://www.parc.com/technologies/self-cooling-paint/

Information provided by yet2

Limiting Reservoir Heating: P4P Energy

- Lightweight solar panel suspension system for canal shading prevents evaporation water loss
- Reclamation use case: covering canals

P4P Punjab in-canal project under construction

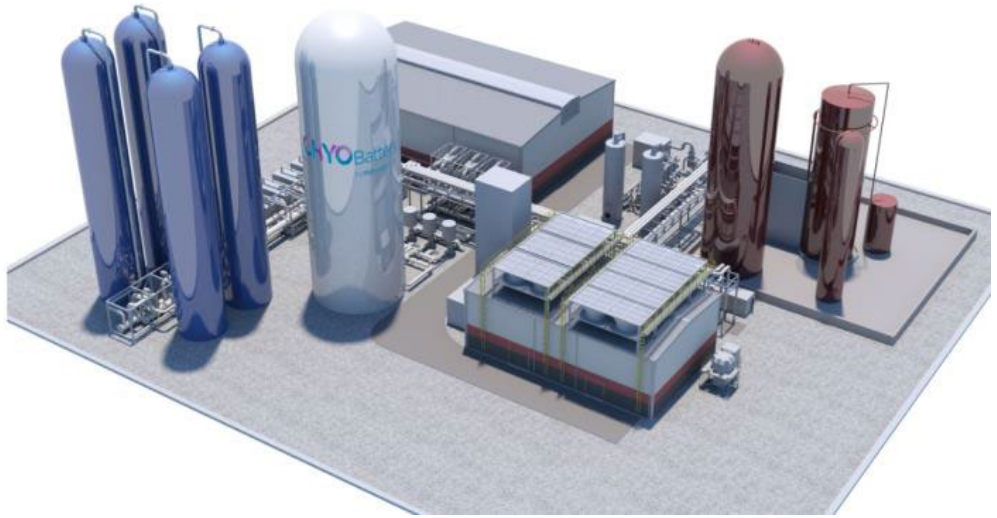
P4P in-canal solar structure providing shade, Punjab, India

http://p4penergy.com/

Information provided by yet2

Energy Storage: Highview Power

- Liquid air energy storage technology uses electricity to cool air until it liquified. The liquid is stored in tanks and then reheated to its gaseous phase such that the gas can turn a turbine to generate electricity.
- Reclamation use case: use liquid air energy storage to store excess energy from dam and use to cool downstream water



https://www.highviewpower.com/

Information provided by yet2

Energy Storage: CryoHub

- Liquid air energy storage technology using cryogenic liquids currently applied to industrial refrigeration.
- Reclamation use case: use liquid air energy storage to store excess energy from dam and use to cool downstream water

https://cryohub.eu/en-gb/

Information provided by yet2

Energy Storage: PCM Products

- Phase Change Materials (PCMs) allow for temporary storage of thermal energy through the process of freezing and melting. Heat or cold can be stored from one process and used later for another application.
- Reclamation use case: energy storage

FlatICE Container Design

TubeICE Container Design

http://www.pcmproducts.net/

Information provided by yet2

Energy Storage: Energy Vault

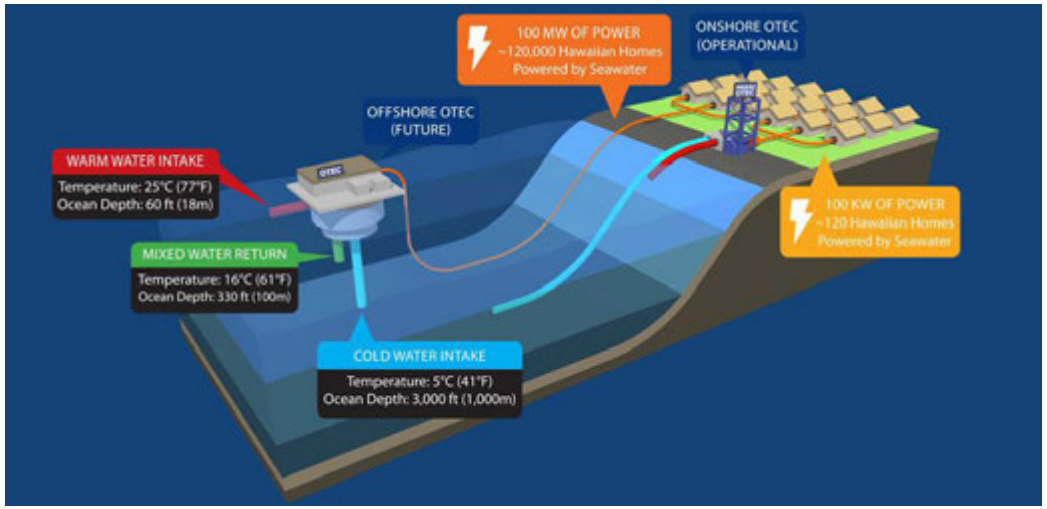
- Gravitational energy store uses a crane to lift composite blocks to create a tower. Energy is stored in the elevation gain.
- Reclamation use case: energy storage system can be used to power heating/cooling systems

https://energyvault.com/

Information provided by yet2

Heat Exchange: Makai Ocean Engineering

- Specializes in marine pipelines with applications in ocean thermal energy conversion, seawater air conditioning systems, desalination, powerplant cooling, wastewater, and transmission pipelines. Designed deepest large diameter seawater pipe intake in the world.

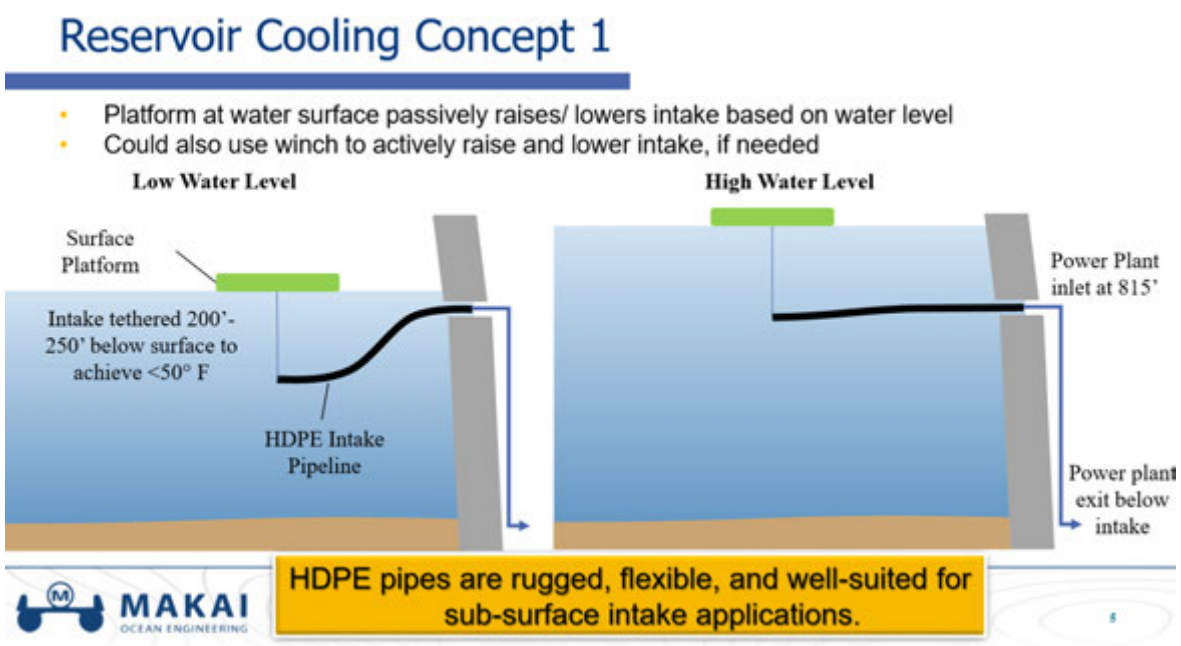


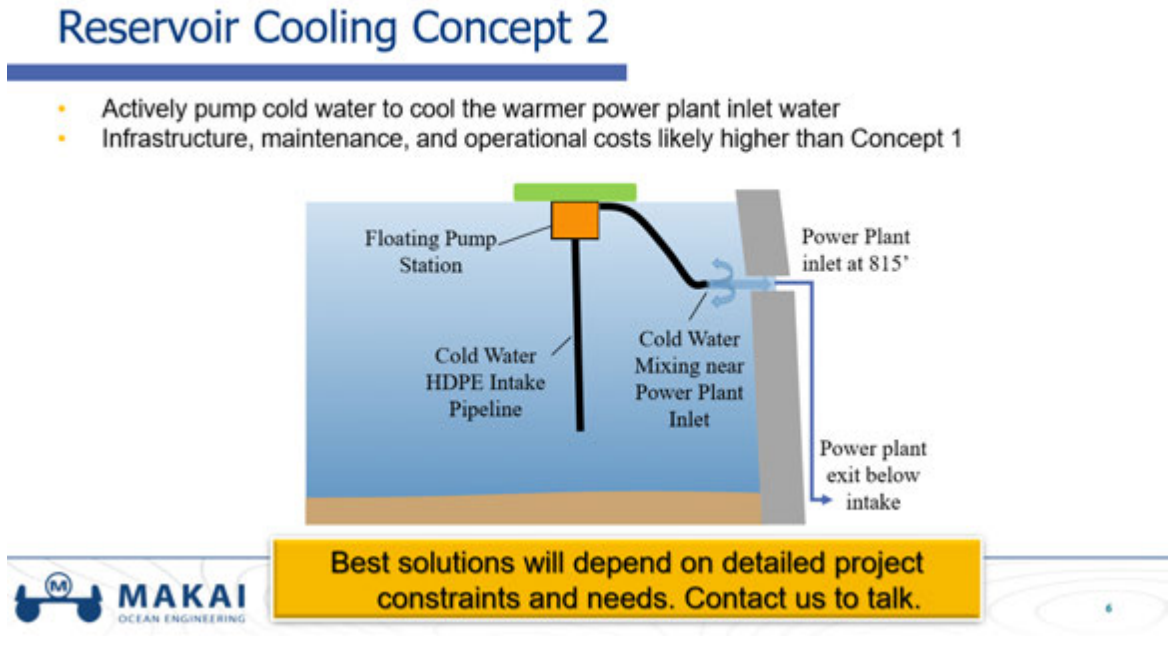
https://www.makai.com/

Information provided by yet2

Heat Exchange: Makai Ocean Engineering

- Reclamation use case: floating intakes and cold water pumping



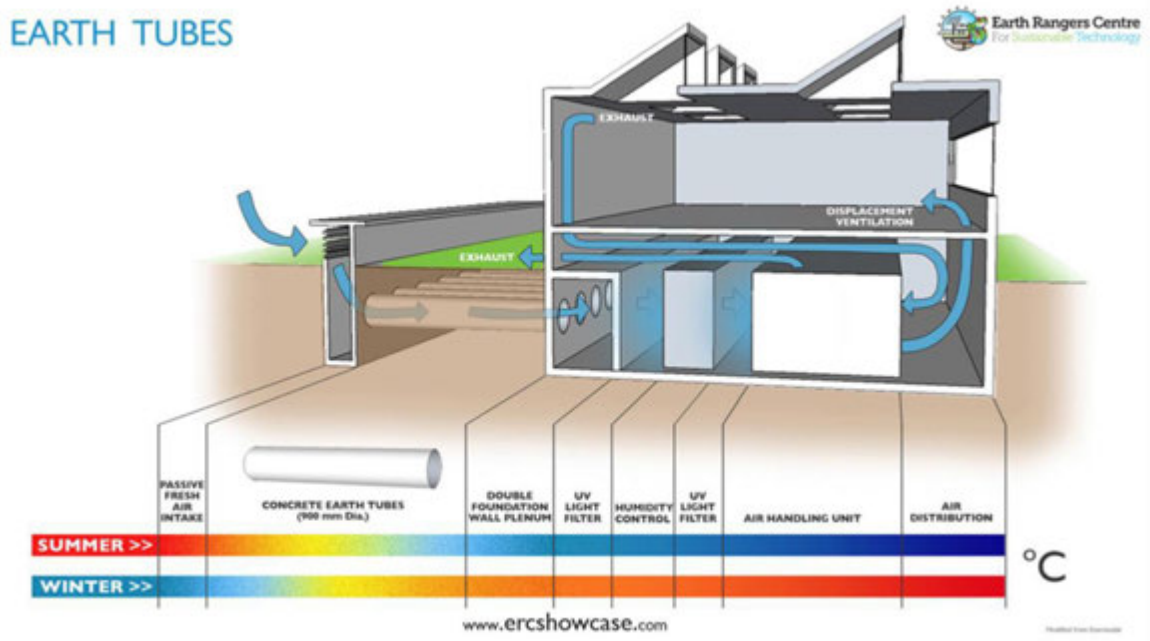


https://www.makai.com/

Information provided by yet2

Heat Exchange: CRH

- Underground concrete earth tubes use geothermal energy to reduce heating/cooling load on buildings using earth-air heat exchanger processes.
- Reclamation use case: harness temperature of earth to passively cool or heat water



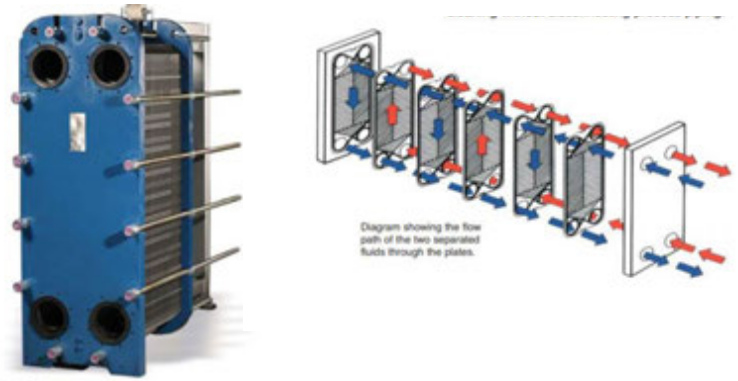
https://www.crh.com/

Information provided by yet2

Heat Exchange: Thermal Transfer Systems

- Specializes in heat exchangers such as cooling towers using evaporative cooling.
- Reclamation use case: use heat exchangers to cool reservoir water depending on water volume and temperature reduction required.

Cooling Tower



Heat Exchanger

https://www.thermaltransfersystems.com/

Information provided by yet2

Heat Exchange: Evaptech

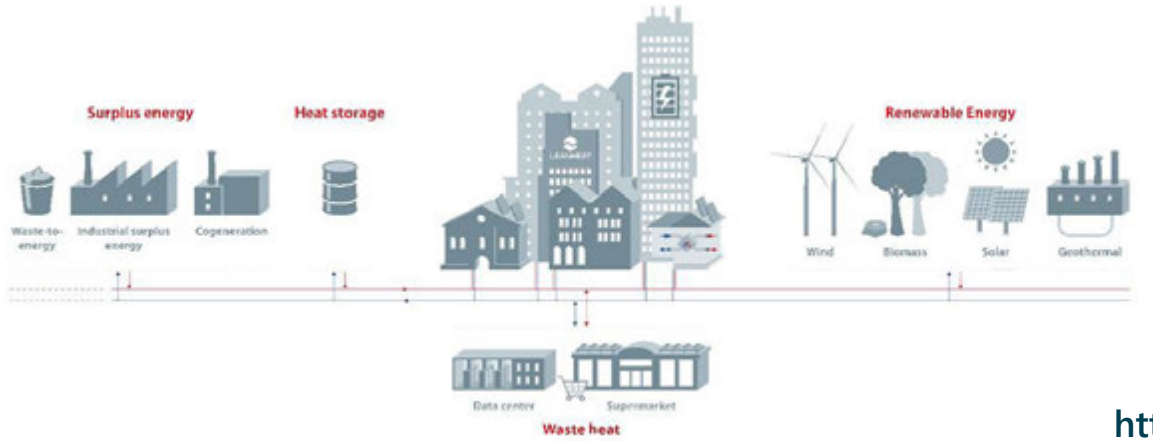
- Cooling tower designer that uses evaporative cooling to reduce water temperature. Textured PVC sheets strips away heat.
- Reclamation use case: evaporative cooling for reservoir release flows

https://www.evaptechinc.com/

Information provided by yet2

Heat Exchange: Danfoss

- District-wide systems heat water at central location and distribute it through a system of underground pipes.
- Reclamation use case: heat or cool water by routing water through district heating system

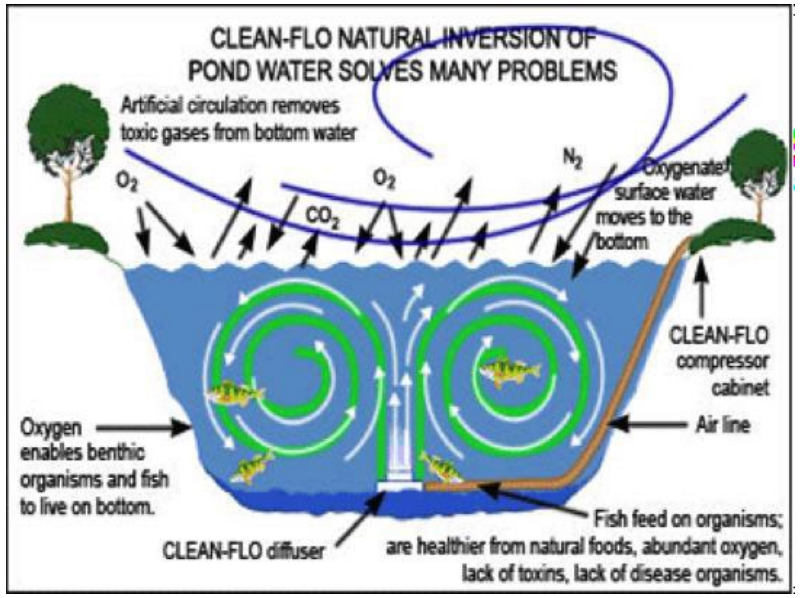


https://www.danfoss.com/en-us/markets/district-energy/dhs/district-heating/

Information provided by yet2

Destratification Devices: CLEAN-FLO

- Water aeration systems using a ceramic diffusers to completely mix surrounding water and even distribute dissolved oxygen. Application of 120 ft deep water body in Puerto Rico.
- Reclamation use case: near-dam aeration systems for reservoirs; partial mixing achievable by varying speed of motor to manage desired change in temperature



https://www.clean-flo.com/winter-pond-aeration-for-ice-prevention/

Information provided by yet2

Destratification Devices: Griffith University

- Dynamic Reservoir Simulation Model (DYRESM), a one-dimensional hydrodynamic model, used to predict the vertical distribution of temperature in reservoirs. Used to determine the effectiveness of artificial destratification by air-bubble plumes to reduce evaporation loss from reservoirs.
- Reclamation use case: employ hydrodynamic modeling for artificial destratification

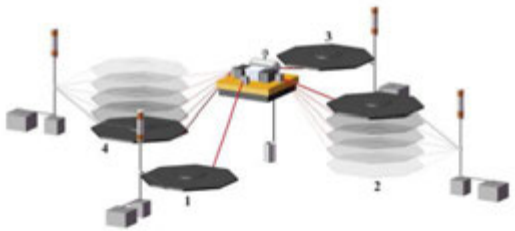
Helfer, Fernanda, Fernado P. Andutta, Jose A. Louzada, Hong Zhang, Charles Lemckert. 2018. Artificial destratification for reducing reservoir water evaporation: Is it effective? Lakes & Reservoirs. Volume 23, Issue 4.

https://onlinelibrary.wiley.com/doi/abs/10.1111/lre.12241

Information provided by yet2

Destratification Devices: UW-Madison

- Gradual Entrainment Lake Inverter (GELI) homogenizes lake temperature using a large flat disk with a geomembrane that moves vertically through the water column. Centralized air bladder drives movement.
- Reclamation use case: localized destratification



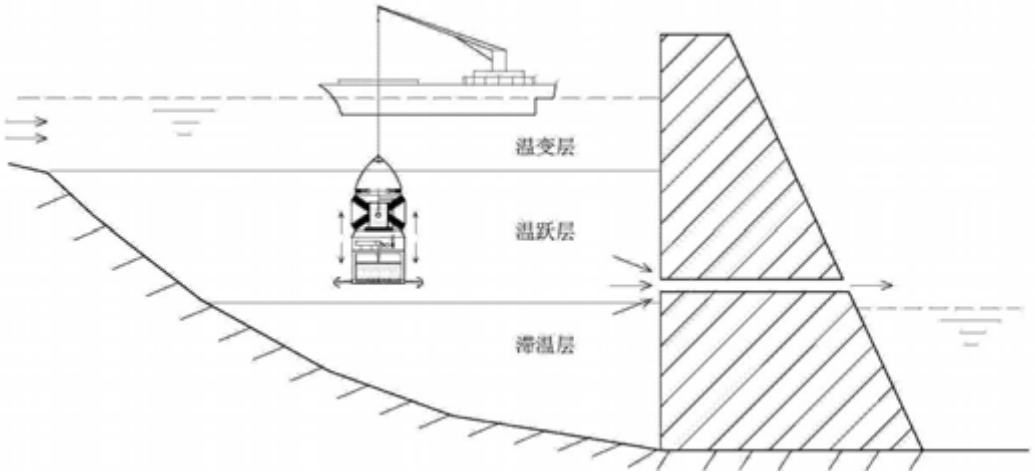
Smith, Colin A., Jordan S. Read, M. Jake Vander Zanden. 2018. Evaluating the "Gradual Entrainment Lake Inverter" (GELI) artificial mixing technology for lake and reservoir management. Lake and Reservoir Management. Volume 34, Issue 3.

https://www.tandfonline.com/doi/abs/10.1080/10402381.2018.1423586

Information provided by yet2

Destratification Devices: Three Gorges Corporation

- Intelligent water temperature destratification device that self-adjusts within the thermocline and performs up-and-down reciprocating movement to break the thermocline.
- Reclamation use case: improvement of aeration systems



https://www.ctg.com.cn/

IP:CN103572733B

Information provided by yet2

Destratification Devices: PowerChina

- Intelligent destratification device decides best position in thermocline based on water density and breaks stratification by aeration.
- Reclamation use case: improvement of aeration systems

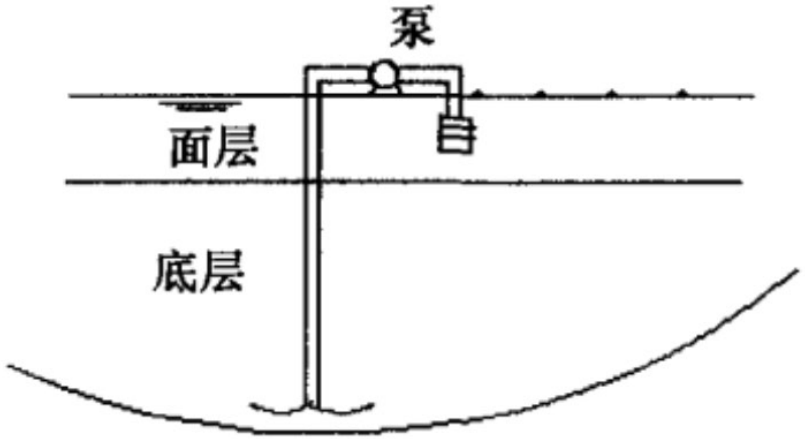
http://ghidri.powerchina.cn/

IP:CN208834191U(publishedon05/07/2019)

Provided by yet2

Destratification Devices: Destratification Pump

- Water destratification through pumping surface water down to bottom layer.
- Reclamation use case: localized destratification



Paper published in Nanjing, China, 2007

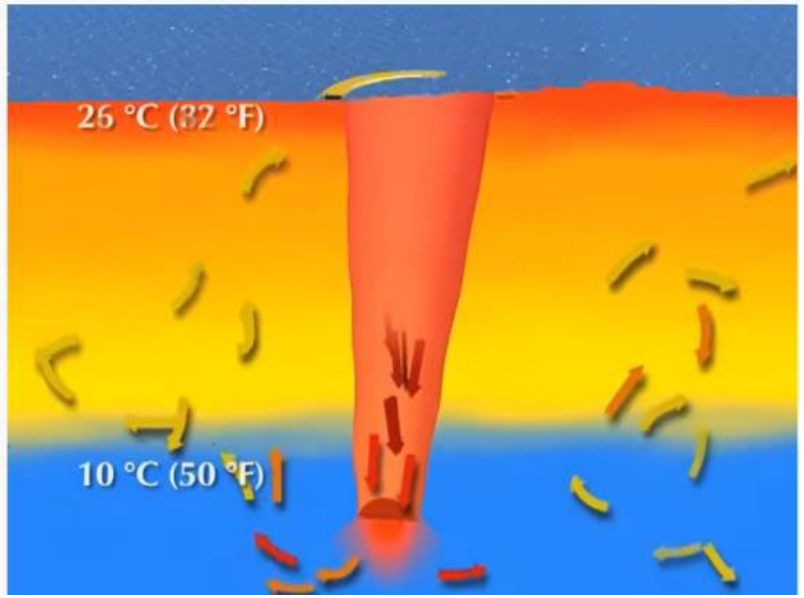
https://wenku.baidu.com/view/47c58044ad02de80d4d840a6.html

IP: TBD

Provided by yet2

Destratification Devices: Intellectual Ventures

- Invention “Salter Sink” harnesses energy from waves to cool ocean surface temperatures in hurricane-prone areas. Ocean waves overtop a large, buoyant ring which forces cooler water from the bottom. Temperature mixing occurs.
- Reclamation use case: similar application in reservoirs



https://www.intellectualventures.com/

Information provided by yet2

Surface Aerator: Environment Agency

- Spray ponds use spray coolers as an improvement to reduce area of the pond and cool pond temperatures.
- Reclamation use case: improvement on cooling ponds

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291077/scho0610bsot-e-e.pdf

Information provided by yet2

Surface Aerator: Fluence

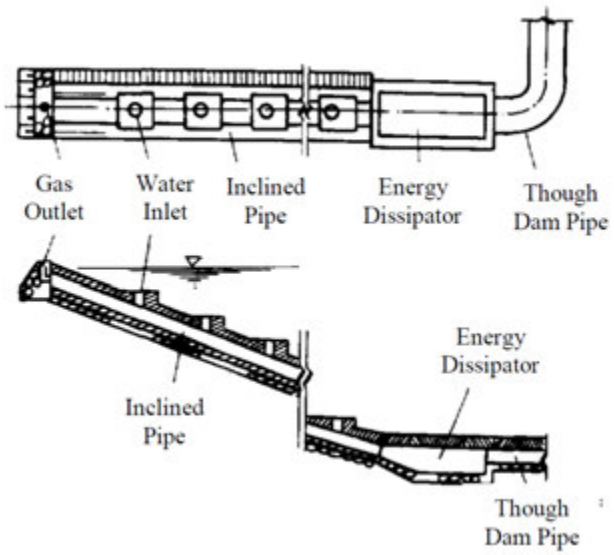
- Surface aerators (paddle wheel, bubblers, fountains, agitators) and subsurface aerators to destratify lakes and improve water quality
- Reclamation use case: temperature and oxygen mixing

https://www.fluencecorp.com/aerators/

Information provided by yet2

Selective Withdrawal Systems: Fengxi Reservoir

- Inclined pipe with multiple inlets at different depths placed on the upstream slope of dam or bank slope of a reservoir.
- Reclamation use case: alternative for selective withdrawal system

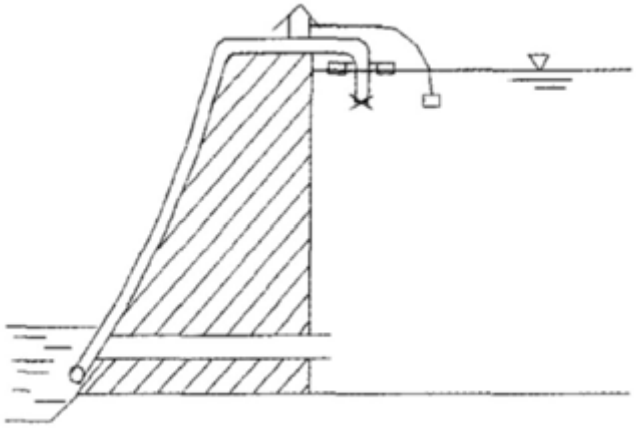


https://www.59baike.com/a/181960-46

Information provided by yet2

Selective Withdrawal Systems: Siphon Withdrawal

- Withdraw warmer water from top layer of the reservoir with a siphon pipe that bypasses turbines
- Reclamation use case: increase downstream temperatures



Review paper “Reservoir stratification and improvement methods”, by Lili Wu from Hohai University, Nanjing, Jiangsu, China.

Published in *Hydropower Station Design* 09/2007

https://wenku.baidu.com/view/47c58044ad02de80d4d840a6.html

Information provided by yet2

Heating Devices: Environmental Solar Systems

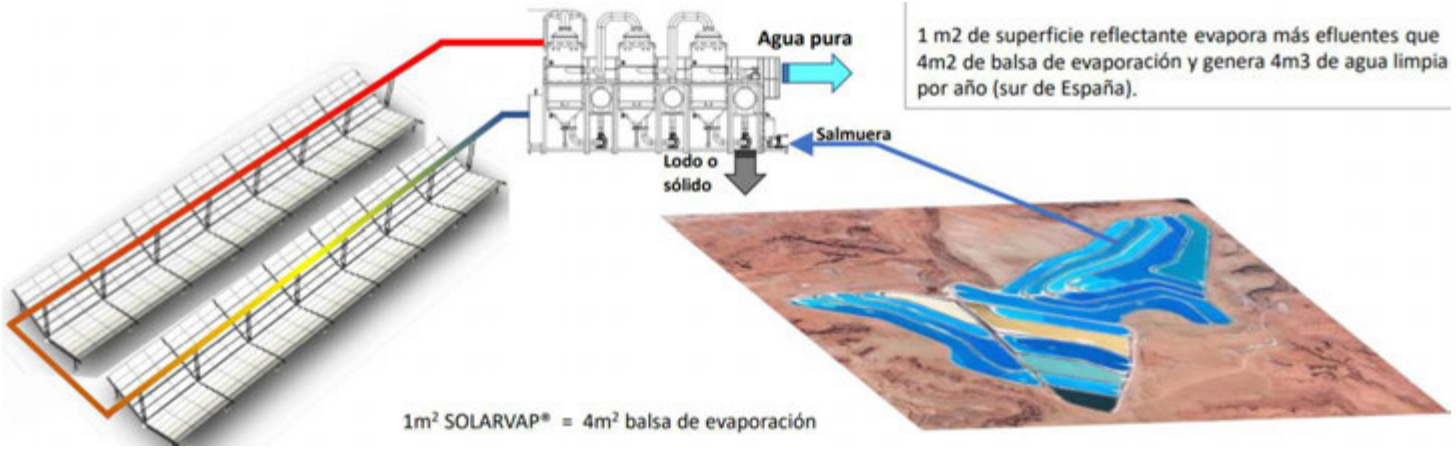
- Parabolic solar troughs concentrate solar energy to heat up water pumped through the receiver tube.
- Reclamation use case: use solar troughs to heat up release water

https://www.parabolicsolartrough.com/

Information provided by yet2

Heating Devices: SolarVap

- Uses solar systems to power sustainable water desalination systems.
- Reclamation use case: use concentrated, industrial scale solar power to heat or cool downstream water



https://solarvap.net

Information provided by yet2

Heating Devices: Wattco

- Direct heat transfer using immersion heaters with electric heating elements. Currently used in industrial tanks.
- Reclamation use case: heaters inside penstocks or immersion heaters in tailrace

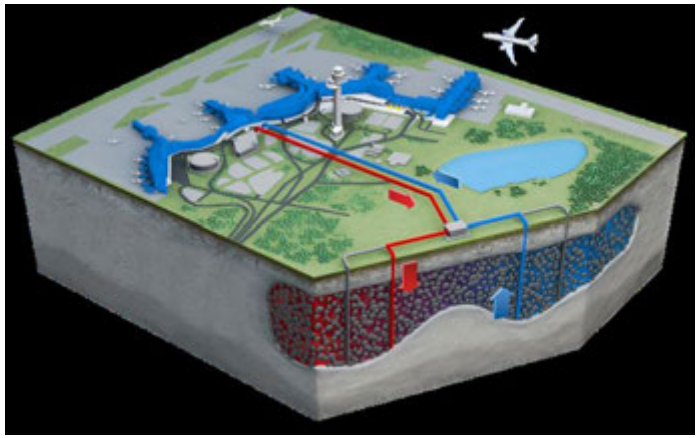
https://www.wattco.com/product_category/immersion-heaters/

Information provided by yet2

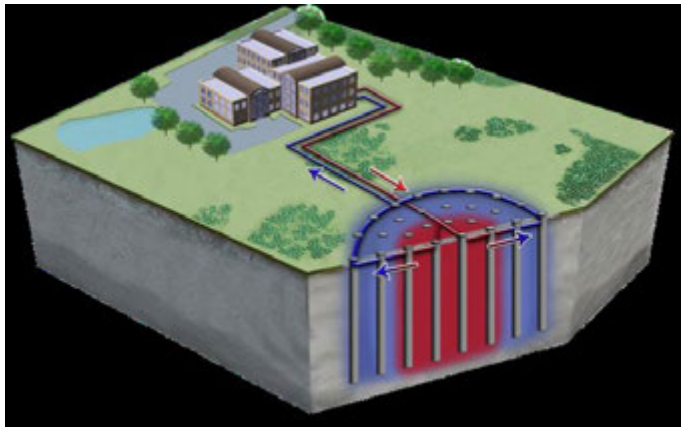
Geothermal Systems: Underground Energy

- Aquifer Thermal Energy Storage – Open-loop geothermal technology relies on seasonal storage of cold and/or warm groundwater in a suitable aquifer with thermal wells.
- Borehole Thermal Energy Storage – Closed-loop geothermal technology using drilled boreholes as ground heat exchanger.

ATES Summer Operation – Cooling



BTES Summer Operation – Cooling



https://underground-energy.com/our-technology/

Information provided by yet2

Conclusions

- Technology Search was successful in finding out-of-box ideas
- No single solution will be successful at all sites
- Many solutions from other industries were not scalable for large applications
- Passive solutions may not meet temperature goals by themselves, but could be paired with active solutions
- Next Steps:
  - Knowledge transfer to spread results
  - Local staff will need to determine if use case makes sense at specific dams
  - Prize competition is not planned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