Dedicated to the increase and diffusion of knowledge about how the nation's lands are apportioned, utilized, and perceived.

The Lay of the Land

The Center for Land Use Interpretation

WINTER 2023

The greatest thing a human soul ever does in this world is to see something and tell what it saw in a plain way. Hundreds of people can talk for one who can think, but thousands can think for one who can see. To see clearly is poetry, prophecy, and religion, all in one. - John Ruskin

GETTING OFF STREAM

PUMPED STORAGE HYDROPOWER IN THE USA

The Seneca Pumped Storage Project in Pennsylvania is one of a few dozen hydroelectric projects in the USA featured in the Center's exhibit *Off-Stream: On the Trail of Pumped Storage*. CLUI photo

DEEP IN THE HILLS ACROSS the country are massive reservoirs of potential energy known as pumped storage hydropower, where water is lifted hundreds of feet up by the largest pumps in the land into isolated off-stream holding ponds, in order to have the water fall back down, a few hours later, day after day. Pumped storage spends energy to make energy, leveling out the supply and demand of the grid.

Pumped storage was developed in the 1960s, and continued with the construction of large-scale power plants, as a way to capture excess energy at periods of lower demand, usually at night, and release it during the day, when the need and value of the energy increases. It also serves as an instantly available back up, in case a major electrical producer, such as a nuclear power plant, suddenly shuts down. But today, as more variable sources of energy come online, like intermittent wind and solar, pumped storage becomes even more important as a reservoir to hold and release energy when the wind stops blowing, and the sun stops shining. There are currently dozens of projects proposed for development in the USA, though it will take years to permit and construct them.

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IN THIS ISSUE

LETTING OFF STEAM

GEOTHERMAL POWER IN THE USA

The CLUI exhibit *Venting the Earth: Looking at Geothermal Energy* examined geothermal power plants in the USA, like this one owned by CalEnergy, near California's Salton Sea. CLUI photo

WHILE THE SUN SPRAYS THE planet with free energy from above, another fire rages beneath us, at the center of the earth. Pressure from the planet's core, burning at the same temperature as the surface of the sun, pushes molten rock and heat outwards and upwards. Volcanoes demonstrate this in dramatic ways, but at other locations, like hot springs and geysers, this internal heat escapes more passively. In these places, and even in others where surface activity is hardly visible, geothermal heat is harnessed and converted into electricity.

Shallow, temperate geothermal wells are in widespread use to warm (and cool) individual buildings, simply by drawing the consistent temperature found underground to the surface to help offset the seasonal variations above ground. However, producing electricity at a large scale generally involves turning heavy turbines, requiring higher geothermal temperatures and pressures to be tapped.

continued on next page

Editor's Note

Welcome to newsletter 46. Over this past year the CLUI has continued to examine the energy spectrum, from the eternal internal combustion of the earth's molten core, escaping through geothermal cracks, to the shifting surficial flows and ponds of pumped hydropower. Everything is motivated by energy, the ultimate shared medium. It is the U and the US. What got us all here, and how we will get out. The gas for the bus. We are glad you are with us on this trip, however long and strange it may be.

Geothermal plants at the Geysers. CLUI photo

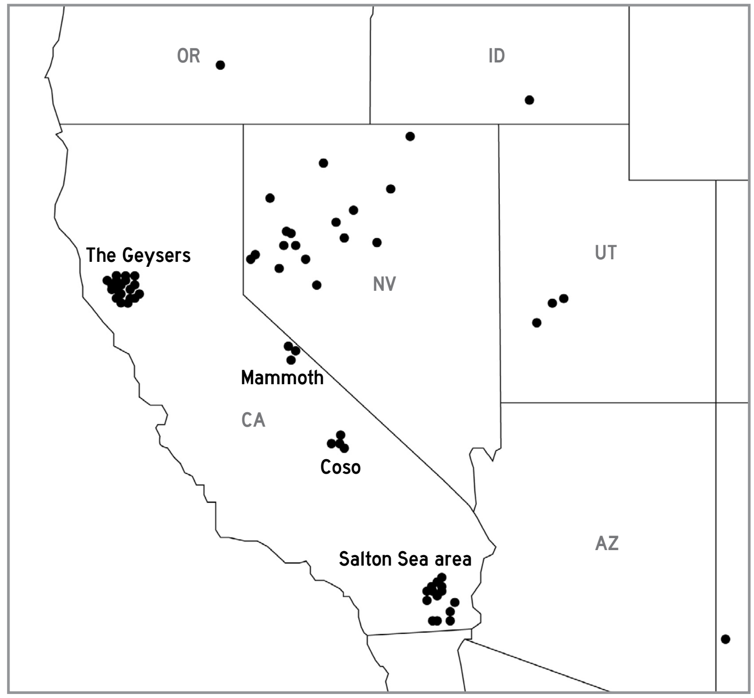
Regions with abundant tectonic activity and thin crustal areas in the US are widespread, especially in the West. Despite this, less than half a percent of the total supply of electricity in the USA is produced by geothermal plants (and the USA leads the world—with around 25% of the global utility-scale geothermally-produced electricity). To say there is room for growth in geothermal is, so to speak, an understatement.

Though the Department of Energy and the Environmental Protection Agency consider geothermal energy a renewable resource, there are side effects from drilling dozens of wells thousands of feet into the earth and letting the steam and pressure out (even if most of the water is re-injected into the aquifer, which it tends to be). These effects include a net loss of water through steam, diminishing and cooling the aquifer (even though some of the steam is collected by condensation); the collection of potentially harmful minerals at the surface (extracted from the water as it passes through power plants); and the effect on the subterranean stasis, including lowered pressures, possibly problematic along active fault lines where the risk of earthquakes already exists.

A proposed form of geothermal production, known as enhanced geothermal systems, involves drilling deeper wells and stimulating them with fracking technologies. While this might open up nearly the entire nation to geothermal energy, not just the relatively thin parts of the earth's crust, its deployment is controversial.

Distribution pipes at the Geysers. CLUI photo

Nonetheless, and for the time being, current methods of producing geothermal energy are among the least destructive means of producing electricity at grid-scale, and are relatively easy to build quickly. They are something to look at, at least.



Geothermal plants in the continental USA.

Geothermal: Where It's At

At the moment there are around 75 utility-scale geothermal facilities in the USA that convert the internal heat of the earth into electricity, with 70% of that production in California, 25% in Nevada, and the remaining five percent coming from five other western states. Some are scattered around, but most are found in clusters, often at places that were developed as hot springs resorts more than a century ago.

The largest geothermal energy production site in the nation, and likely in the world, is the Geysers, in Northern California. The Geysers geothermal area, in the rolling hills north of Santa Rosa, was a famous hot springs and tourist attraction, visited by the likes of Mark Twain and Theodore Roosevelt. The first geothermal well was drilled in 1920.

Overlook display at the Geysers. CLUI photo

In 1960 the first modern utility-scale geothermal electricity plant opened there, and many soon followed, totaling more than 30 at the peak. By 1987 the site produced more than 2,000 megawatts of power, similar to the output of the largest coal-fired power plants.

When the reservoir of heated water diminished, output declined. By the mid-1990s, output was at less than half of its peak, but even then the Geysers was still the largest geothermal complex in the world.

Today the subterranean geothermally heated water is being replenished by two pipelines, more than 40 miles long, that bring wastewater from nearby communities. This water is injected into the ground, enabling 15 plants to make a total of more than 1,000 megawatts of power at the Geysers.

CalEnergy geothermal plant near the Salton Sea. **CLUI photo**

With 15 plants producing as much as 760 megawatts collectively, Imperial County, in the southeast corner of California, is the second largest concentration of geothermal energy production in the nation. Ten of the facilities are near the southern end of the Salton Sea, where all but one of them are owned by CalEnergy, a subsidiary of Berkshire Hathaway.

The third largest geothermal energy production site in the nation is at Coso Hot Springs, in the eastern part of California, on the edge of the China Lake Naval Weapons Station, where four plants are operated by a private company, producing up to 275 megawatts.

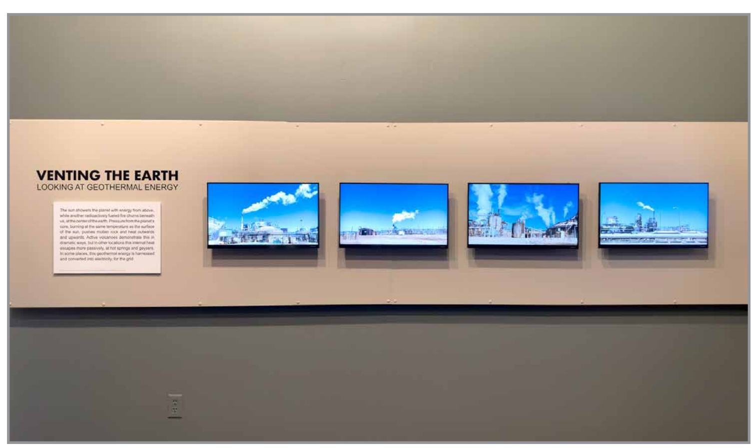
The gate to Coso geothermal plants. **CLUI photo**

Geothermal plants at Mammoth. **CLUI photo**

Further up the Owens Valley, the Mammoth Geothermal Complex, near Mammoth Hot Springs, has three plants, with another on the way, and produces up to 40 megawatts.

Nevada, the second biggest geothermal energy state, has around 25 plants, scattered in the northwest part of the state, producing as much as 750 megawatts total. The largest plant, McGinniss Hills, produces 138 megawatts, with the rest averaging around 40 megawatts. The remaining five percent of national geothermal output, outside of California and Nevada, are from less than a dozen small plants in Utah, Oregon, Hawaii, Idaho, and New Mexico. ♦

Signage at the Brady geothermal area in Nevada. **CLUI photo**



Video portraits of geothermal plants were featured in the CLUI exhibit *Venting the Earth: Looking at Geothermal Energy*. **CLUI photo**

HYDROELECTRIC MECCA
NIAGARA FALLS

Like a dipstick displaying the hydraulic head between the top and the bottom of Niagara Falls, the Prospect Point Observation Tower is the penstock for the flow of tourism on the US side of the falls. Up to eight million visitors a year line up on the gangplank and stream through elevators to head into the soaking vapor on the Maid of the Mist boats, at the base of the tower. While tourists migrate towards the falls, local hydroelectric projects have been all about how to avoid them. CLUI photo

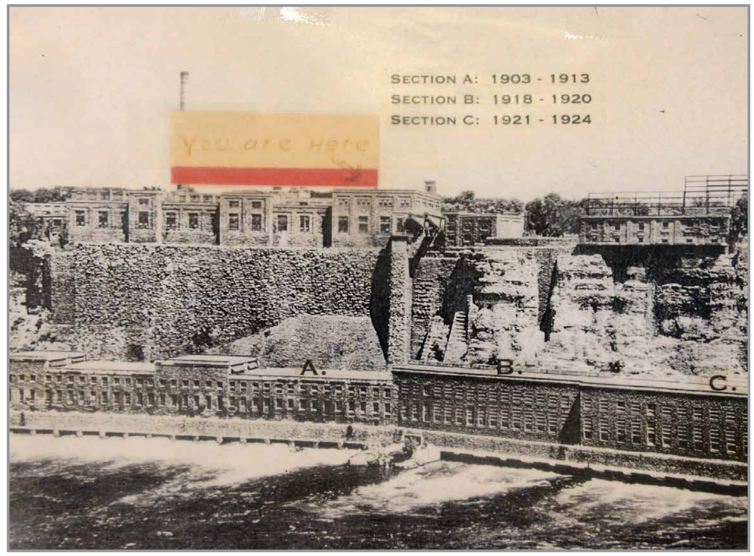
NIAGARA FALLS IS THE PROGENITOR of mega-hydropower in the USA, and in many ways still reigns the realm. Its river, the Niagara, only 35 miles long, drains Lake Erie (and the rest of the drainage basin of the Great Lakes all the way west to Minnesota) into Lake Ontario, dropping dramatically 325 feet from end to end, and nearly all of it at the falls. This hydraulic head has been the biggest and lowest hanging power fruit to pluck from the earliest industrial days of America's Eden.

While inspiring many grand visionary plans and capitalist utopias, Niagara Falls—the falls and the community that shares the name—became something else entirely. Some might say it's a rotten tourist ruin, with crummy motels and casinos feeding on the dead wastes of a fallen industrial empire, an epic ode to a society gone astray. To others it's a monument to innovation, where humans rose to the level of the colossal forces of nature, becoming like gods. To still others it stands as a pre-human wonder, proving the dominance of the forces of nature, above all, putting us in our place, down to size, like ants in hi-vis rain gear plying the misty trails at the bottom of the falls.

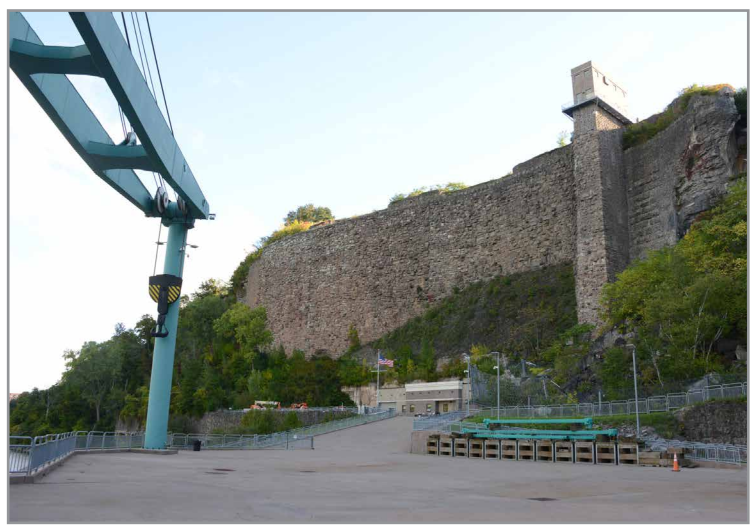
Niagara Falls is, of course, all these things, and more. But at its base it is a hydropower mecca, where the forces of "nature" (whatever that is anymore), meet the forces of "mankind" (whatever that is anymore), head on, stupendously.

Apart from the tourist industry, development at Niagara Falls has always been about how to avoid Niagara Falls. First for transportation, by the Erie Canal, which opened in 1825, and ended its westward trek across New York State at Tonawanda, ten miles upstream from the falls, on the Niagara River. Then, on the Canadian side, the Welland Canal, which opened in 1829, and runs parallel to the river, connecting Lake Ontario to Lake Erie directly, raising ships up and down the 325-foot elevation difference between them through a staggering battery of locks.

For hydropower, and the industrial development it made possible, there were three principal diversions of the flow around the falls, on the American side, each representing a different stage of history and technology (the Canadians, meanwhile, did their own thing at a similar scale). Each has left its mark on the place in different ways, as they leap-frogged one another, leaving outmoded monuments to rot underground, and building concrete dams that rival the Pyramids in scale.



As shown in this image from a New York State Park display, the Schoellkopf Power Station was built at the bottom of the gorge, half a mile downstream of the falls, where mills and plants were developed along the Hydraulic Canal, the first major diversion of water around the falls. CLUI photo



The remains of the Schoellkopf Power Station at the base of the gorge were removed in 1962, when the area was cleaned up during the third wave of hydroelectric transformation at Niagara Falls. Today the power station site is accessed by the old elevator shaft on the edge of the gorge (right), and is the winter home of the Maid of the Mist tour boats, which are picked out of the river with a giant crane (left). CLUI photo

Hydraulic Canal

The first significant diversion was the hydraulic canal, which opened in 1861. A surface canal 35 feet wide, eight feet deep, and nearly a mile long, it started a mile upstream of the falls and ran through town to the bluffs above the gorge, a half mile downstream of the falls. By diverting water from the canal and discharging it at a lower elevation through pipes and trenches along the gorge, businesses along its path powered mills for a variety of industries. Most of these mills were clustered along the top of the gorge, discharging water down the cliff, making a kind of second, industrial Niagara Falls, spectacular especially in winter, when it formed a massive drapery of ice along the 210-foot-tall cliffs of the gorge.

The first hydroelectric plant in the region was installed in a flour mill on the bluff in 1881, and provided power to streetlights illuminating downtown. It was built using Charles Brush's carbon arc lighting system, powered by a DC generator, spun by flowing water. Similar versions of the Brush system were being installed for municipal lighting in several cities and towns in the Northeast and Midwest around this time.

Bigger hydroelectric plants were built later along this stretch of the gorge (which some refer to now as the Historic Mill District, as it was soon to be replaced by a bigger industrial area upstream). These plants, known as the Schoellkopf Power Plants, built in stages over decades, were clustered next to the river at the base of the cliffs, fed by falling water from above, enclosed in penstock pipes. When completed in 1924, the three adjacent plants lining the base of the cliff comprised the largest privately owned hydroelectric plant in the world, generating more than 400 megawatts.

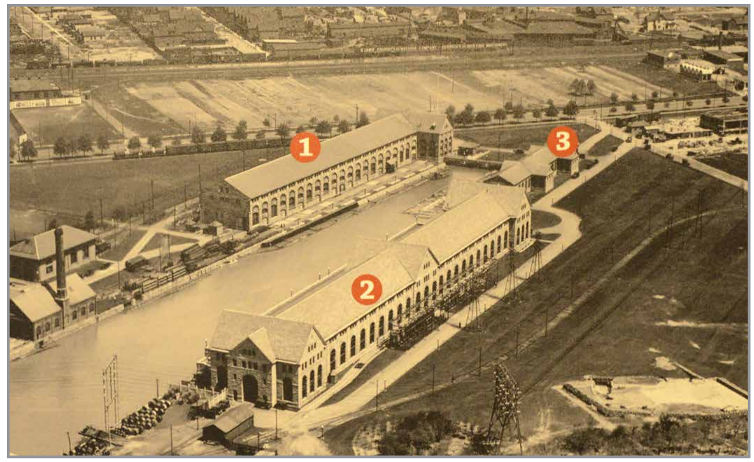
On June 7, 1956 a rockslide along the battered and poorly engineered cliffs of the gorge destroyed two of the three Schoellkopf Power Plants. There was only one fatality, miraculously. This sudden loss of power production at the falls led to the passing of the emergency Niagara Redevelopment Act, where much, much bigger plants and canals would be made as part of the third wave of hydrodevelopment at Niagara Falls.

By the early 1960s, the Hydraulic Canal had been filled in, its era over. The historic mill district it enabled at the top of the gorge has been demolished, and most of the land is now part of Niagara State Park. The mile-long canal connecting it to the river above the falls now has parking lots and buildings on top of it, and its upstream end is paved over as John Daly Boulevard. The boulevard terminates at a traffic circle connecting the riverway and the Niagara Scenic Parkway, and is a transportation gateway to the city, park, and falls, built on the shore of the river with fill from modern hydropower excavations.

Hydraulic Tunnel

Upstream a few hundred yards from the rotary is the stub of the canal that fed the second major hydropower diversion of the river: the hydraulic tunnel, and the Adams Power Station. The canal diverted water from the river a few hundred yards inland, to a deep vertical excavation, dropping 150 feet down to a tunnel, 21 feet wide and 6,500 feet long, dug under the city, leading to an outfall on the other side of the falls, at the base of the gorge. At the base of the 150-foot drop were wheel pits, housing turbines, spun by the falling water, connected to shafts that rotated electrical generators in a powerhouse at ground level.

This operation, the Adams Power Station, came online in 1885, and was the first large-scale electrical generating station in the world to use alternating current (which Nikola Tesla had developed and proven as a superior technology to direct current, aggressively promoted by Thomas Edison).



This image, from a New York Power Authority display, depicts the three Adams Power Station buildings clustered around the canal bringing water from above the falls to the plant at the upstream end of the Hydraulic Tunnel: 1) the Adams Power Station's first powerhouse, which went into operation in 1895; 2) the second powerhouse, which was added in 1904; and 3) the transformer building. CLUI photo

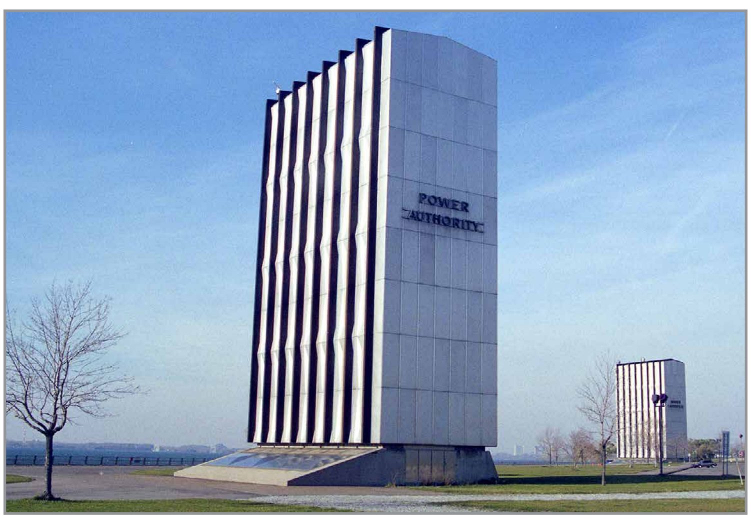
The transformer building, designed by McKim, Mead and White, is the only remaining structure from the Adams plant. Though it is in disrepair, there is talk of turning it into a museum about the site's important hydropower history. CLUI photo

Early DC power diminished as it traveled through wires, limiting the distance from plant to customer to a few miles. Not so with AC, and the power generated at the Adams Station was connected throughout the region, including Buffalo, spurring the industrial development there. It was the first plant to enable the transmission of electricity to occur in the manner that quickly became the norm: large centralized power plants feeding cities, and places far away, through a network of high-tension lines and substations. Some consider the Adams Station the first true hydroelectric plant in the world.

The hydraulic tunnel system and the power plant were part of a successful industrial development plan for a two-mile stretch of riverfront, extending upstream from the power station. The industrial area continues to this day, with occupants including a Linde industrial gas plant, that once generated material for the Manhattan Project, and a chemical complex operated by Solvent, DuPont, and Olin, that made chlorine, caustic soda, and other organic chemicals, directly on the river. Portions of the site have been addressed by the EPA Superfund program. Also located here is Occidental Chemical's Niagara Falls Complex, which earlier, as Hooker Chemicals, became famous for its disposal of toxic wastes at Love Canal, located a few miles upstream.

The façade of the main entry of the Adams Power Plant was moved to Goat Island, to form a gateway into the park's concession area. CLUI photo

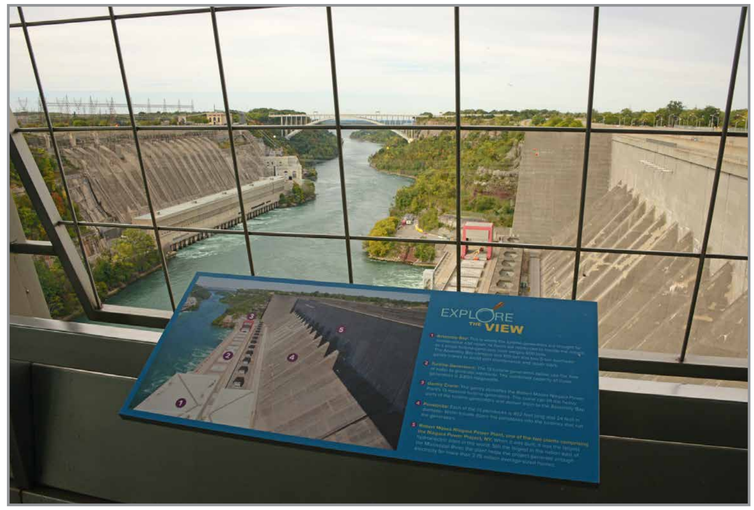
The Adams Power Station was expanded with a second powerhouse, and operated until 1927, when the latest Schoellkopf Power Plant in the gorge took much of its business. The Adams Power Station operated intermittently after that too, and was brought back online to help fill the power gap when the Schoellkopf Power Plant was destroyed in 1956. Adams was terminally obsolete by 1961, when the massive Niagara Power Project went online. At that time, too, the city wastewater treatment plant next to it was expanded, and most of the plant was demolished. The tall arched entryway of the Adams Power Station was relocated to Goat Island, at the top of the falls, and reconstructed stone by stone to become the Power Portal, a gateway between parking lot and park, and part of a memorial to the power of the falls, in front of a large bronze statue of a seated Nikola Tesla.



The two intake towers for the Niagara Power Project are located on the river, across the highway from the Occidental Chemical Plant. The intakes control how much water flows over the American side of Niagara Falls, and how much is diverted into the Niagara Power Project. A few years ago the "Power Authority" lettering was removed. CLUI photo

Robert Moses' Parting of the Waters

When the rockslide knocked out the Schoellkopf Power Plant in 1956, local and state planners went into action to reassess and rebuild the hydropower of the Niagara Falls. The plan that was drawn up, called the Niagara Power Project, included the biggest hydropower plant since the Grand Coulee Dam. Led by the notorious New York master planner and power broker Robert Moses (who transformed modern New York City) the plan would transform the city of Niagara Falls and the park overlooking the falls and the gorge.



The Robert Moses Power Plant (on the right, across from a similar plant on the Canadian side of the river), as seen from the Power Vista, at the downstream end of the Niagara Power Project. CLUI photo

The Niagara Power Project begins two and a half miles upstream of the falls, on the shore next to the Occidental Chemical plant, at a site sometimes called Intake Park, where two towers control valves that divert water from the river into two massive underground pipes that feed the power plants below the falls. The parallel pipes run through the city, just under the surface, in an open swath of ground a few hundred feet wide, undeveloped except for high tension line towers, recreation fields, and crossings by roads and rail.

The pipes drain into the Robert Moses Forebay, an interstitial reservoir nearly a mile long, with a hydropower plant on either end. The Lewiston Power Plant, at one end, is a pumped storage plant, which lifts water out of the forebay into a 1,900-acre reservoir, which drains back through the plant to make electricity during the day, when it is more in demand, and more valuable. The Robert Moses Power Station, at the other end, with a capacity of 2,000 megawatts, is the third largest hydroelectric plant in the nation.

The Power Vista, accessed by a skybridge over the Robert Moses Parkway (also known as the Niagara Scenic Parkway), perched atop the gorge, with a view up and down the river, is the *ne plus ultra* of hydropower visitor centers in the USA. CLUI photo

All this was created in three years, ending in 1961, led by Robert Moses, head of the New York Power Authority. It is celebrated in the Power Vista, an elaborate visitor center operated by the Authority, dramatically perched above the Niagara River Gorge, overlooking the Robert Moses Plant, and the equally large Adam Beck Plant, operated by the Canadians, on the opposite side. Upstream a few miles are the distant mists of Niagara Falls. ♦

A mural by Thomas Hart Benton looms above the lower level of the Power Vista. The mural, commissioned by Robert Moses, shows the Franciscan missionary Father Louis Hennepin delivering the gospel at Niagara Falls in 1678. According to a nearby plaque, Father Hennepin was the first white man to see and describe the falls. CLUI photo

GRAND RAPIDS

HYDROPOWER FIRST IN FURNITURE CITY

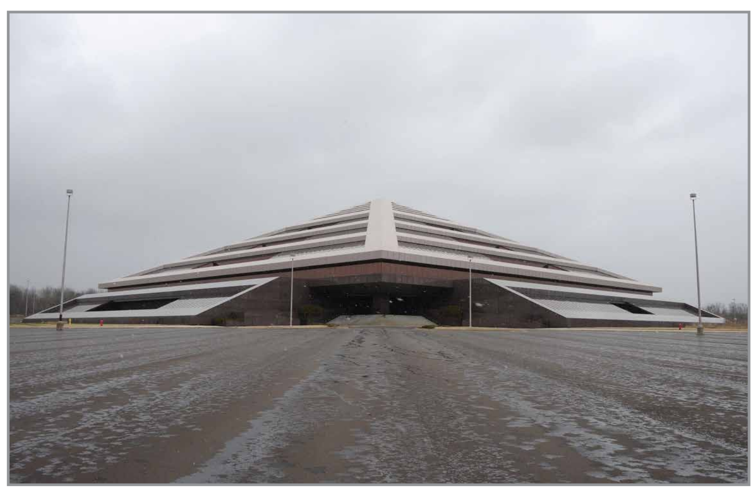
The site of the "first commercial central station hydroelectric power plant in the USA" at Grand Rapids, Michigan, is now a riverfront park across from downtown, containing recreated Indian mounds and Gerald Ford's tomb. CLUI photo

WHAT SOME CONSIDER THE FIRST commercial hydroelectric plant in the USA was not at Niagara Falls, but at the Midwestern city of Grand Rapids, Michigan, where, in July 1880 the Grand Rapids Electric Light and Power Company began operations. Power came from a turbine at the Wolverine chair factory, driven by a waterwheel in the West Side Power Canal, next to the factory. DC electricity produced there was wired to 16 electric arc lamps that illuminated outdoor street lights in front of a strip of businesses, including clothing stores, a hotel, and an opera house.

The device that provided the electricity was developed by Charles Brush, and was known as a Brush generator and arc light system. It was becoming well known at the time, and Brush arc light systems were also installed in other cities during the period, including one at Niagara Falls in 1881. The one installed in Grand Rapids was just the first one to be installed that was driven by a waterwheel, with power provided to more than one business. (It should be noted, though, that another site, the Vulcan Street Plant, an Edison DC plant at a mill in Appleton, Wisconsin, opening in 1882, is also called the "the first commercial central station hydroelectric plant in world" because it more clearly sold its power to a variety of commercial and residential customers, more like future hydroelectric plants would).

Grand Rapids is on the Grand River, the longest river in Michigan, 250 meandering miles from its headwaters to Lake Michigan, where it drains at Grand Haven. The rapids on the river, known as Grand Rapids, disappeared as dams flooded them, ponding water to run through power canals to run mills—mills that made furniture that made the city of Grand Rapids, while destroying the Grand Rapids themselves. Logs floated down the river from upstream forests, became furniture in the mills, which then became companies, that became some of the largest furniture companies in the world, like Herman Miller, Haworth, and Steelcase, all of which are still active and based in the region.

Times are changing in Grand Rapids though, like everywhere. The furniture industry, especially the wooden furniture industry, largely moved overseas and south, to places like North Carolina. The companies that have stayed in Grand Rapids are based in warehouse factories in the suburbs and neighboring towns. Today the largest employers in Grand Rapids are health care companies, retail grocery corporations, and other municipal and service industries, which is commonly the case across the land. ♦



An example of the further dissolution of industries can be found in an office park near the airport in Grand Rapids. Steelcase, the giant office furniture company, built a pyramid-shaped corporate development center on the suburban beltway in 1989, and used it until 2010. In 2016 a data center company called Switch bought it, renamed it ***The Pyramid***, and claims that it's the largest data center in the northeast (as well as the most advanced data center on the planet). Switch has a flair for drama, and national geography: it calls its southwest data center campus in Las Vegas *The Core*; its southeast data campus in Atlanta *The Keep*; and its northwest data center campus outside Reno *The Citadel*. CLUI photo

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In the meantime, these few dozen pumped storage facilities, many of which have been around for half a century, constitute 95% of the storage capacity of the electrical grid, nationwide. They continue to operate, in the background, like infrastructural leviathans, breathing in and out.

In pumped storage hydroelectric plants, the turbines that generate electricity from water flowing into them can be reversed and function as pumps, lifting the water back up to the reservoir. Otherwise, pumped storage is similar to a regular hydroelectric plant operating in connection with a dam and a reservoir along a river. Some of the 40 major pumped storage projects in the USA simply are hydropower plants with additional reversible generators that provide the option of moving water backwards on a river flooded by multiple dams and reservoirs, to manage water levels and supply, as well as produce power.

23 of the 40 major pumped storage projects in the country, however, use a specially built upper reservoir to hold water pumped up to it—a reservoir that is not on an existing waterway, and is thus off-stream—while its lower reservoir is usually created by a dam on an existing river. These off-stream reservoirs are like bubbles off of the otherwise contiguous hydrology of the nation.

Another form of pumped storage uses both an upper and a lower reservoir that are isolated from existing waterways (referred to in the industry as a closed-loop system). While this type of pumped storage is found in Europe and in other parts of the world, there are no closed-loop systems in the USA. This, however, is likely to change. Though there hasn't been a major pumped storage project built in the USA since 1995, most of the several dozen proposed pumped storage projects currently under review are of the closed-loop type.

Many pumped storage projects have a Francis-type reversible pump/turbine impeller on display on the grounds outside the plant, such as this one at Muddy Run in Pennsylvania. One of these is installed on each of the generating units inside the plant, and enables it to produce electricity rotating in one direction, and to pump water when run in the other direction. CLUI photo

Some pumped storage facilities have helpful interpretive signage, overlooks, and visitor centers, such as the TVA's Raccoon Mountain Pumped Storage Project in Tennessee. CLUI photo

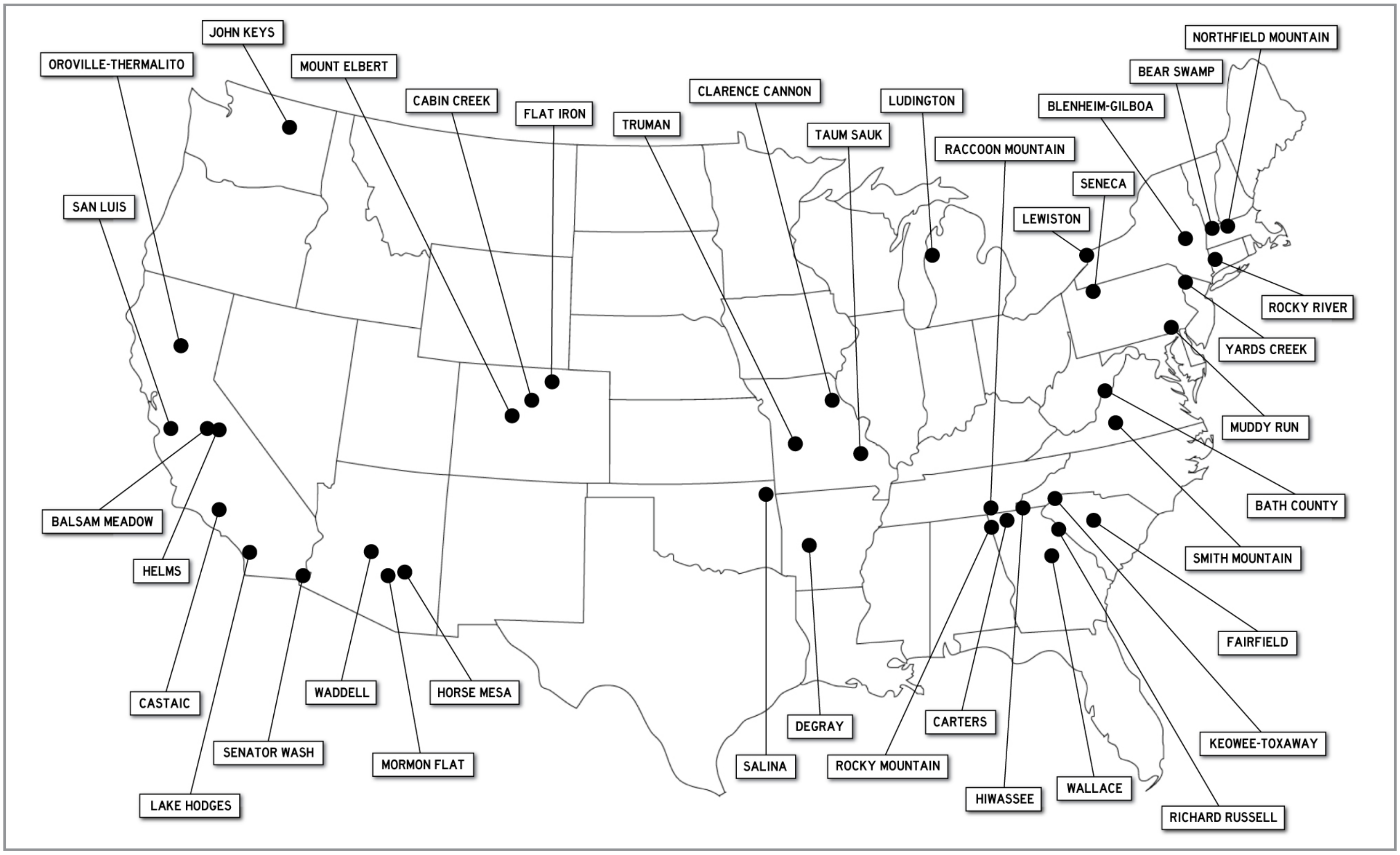
Other pumped storage facilities enjoy a low profile, with no access at all, and little to identify them beyond a sign at the gate. Several seem to have permanently shuttered their visitor facilities too, such as at Yards Creek in New Jersey. CLUI photo

Visiting Pumped Storage

Visiting pumped storage sites is like going on a safari to see immobile land beasts in their native habitat. The genre is monolithic and simple, and in a way uniform and redundant. However, each site is unique, and expressive, in its way.

Some are in remote places, relishing their obscurity, as many critical infrastructure sites do. Roads dead-end at security gates, where faceless queries are fielded through intercoms, with little opportunity to witness their wonders. Others engage grandly in public relations, building overlooks with interpretive signs, and visitor centers that rival science museums and attract school field trips.

Though nearly identical in function, each site says different things about the region and context it is in, and about the relationship between the industry that supplies energy, and those it serves—the people who supply the demand.



MAJOR PUMPED STORAGE SITES IN THE USA

Starting in the Northeast

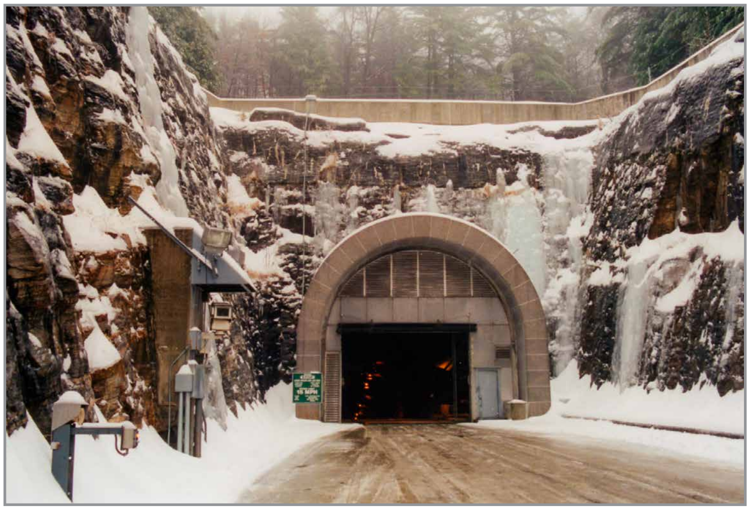
The first pumped storage hydroelectric project built in the USA is the Rocky River Power Station on the Housatonic River in western Connecticut. The powerhouse opened in 1929, and continues to generate as much as a modest 31 megawatts to this day. The plant's two generators can reverse, to pump water from the river up to a reservoir called Candlewood Lake, located 200 feet above the river's elevation.

The reservoir was built between 1926 and 1928. Dams had to be constructed and 4,500 acres of trees were cleared to create the basin, which covers eight square miles. Hundreds of people, living and dead, were relocated, including 35 families in the small town of Jerusalem. When the Rocky River Station started pumping water into the basin, it created the largest lake in Connecticut. Today the lake is a popular recreation site, and is lined with homes and private property.

FirstLight operates another pumped storage project, 120 miles away in western Massachusetts, near the town of Northfield. Unlike at Rocky River, however, most of the facilities are out of sight, at least to visitors, and the 320-acre upper reservoir is off limits, atop Northfield Mountain.

The Rocky River Station is easy to find, located on Highway 7, north of New Milford, Connecticut. It was built by the Connecticut Light and Power Company, and is now operated by FirstLight, a regional renewable energy company. CLUI photo

The penstock at Rocky River is a 1,000-foot-long, 15-foot-wide pipe that connects the plant to the reservoir, and is topped by a standpipe that allows water to escape during a surge in pressure. CLUI photo



The powerhouse at Northfield Mountain is deep inside the mountain, and all the pipes and penstocks are underground too, bored through solid granite. CLUI photo

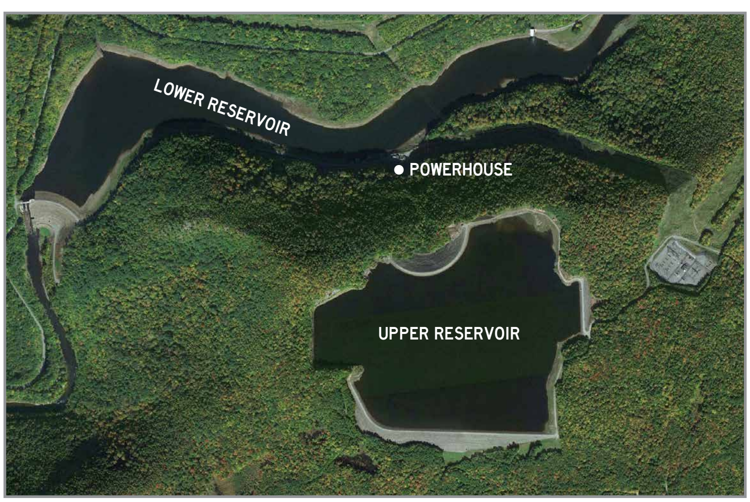
Though the Bear Swamp facilities are off limits, and hard to see, there is a visitor center located across the river from the powerhouse, which is also hard to see, as it is underground, and has been closed for a while. CLUI photo

The Northfield Mountain Pumped Storage Project took four years to build, and when it opened in 1972 it was one of the largest pumped storage facilities in the world. Today it is one of the ten largest pumped storage plants in the USA.

Water is pumped in and out of the Connecticut River at an unmarked intake/outfall. Filling the reservoir takes 11 hours, and draining it takes eight hours, using all four pump/turbines in the power station. This generates as much as 1,168 megawatts of power on the way down, but consumes around 30% more than that on the way up.

Like many other pumped storage plants of this era, Northfield Mountain was constructed to balance the power grid for a nearby nuclear power plant, in this case Vermont Yankee, a few miles up the Connecticut River, just over the state line, in Vermont.

25 miles further west as the crow flies into the Berkshire Mountains is Bear Swamp, the third of three pumped storage projects in New England. Like Northfield Mountain, the upper storage reservoir at Bear Swamp was constructed on a hill several hundred feet above a dammed river, in this case the Deerfield River, which serves as the lower reservoir.



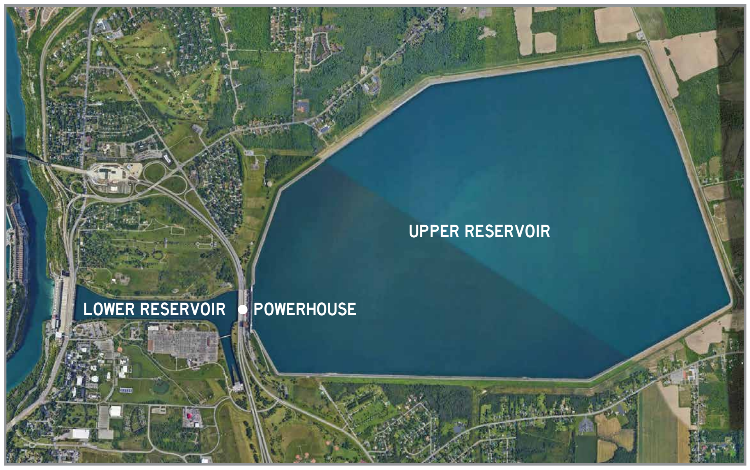
The Bear Swamp Pumped Storage Project. Base map: Google Earth image

The Deerfield River is a very hard working river. Though only 70 miles long, it drops more than 1,000 feet through the hilly northern Berkshires, and has ten dams along its course, each producing electricity, and, for decades, its waters cooled a nuclear power plant, which has since been removed. It is also a hard playing river, with busy recreational rafting and kayaking taking advantage of the controlled releases from its dams, starting below the Fife Dam, which forms the lower reservoir for the Bear Swamp Pumped Storage Project.

A restricted access road across the top of the dam leads to the Jack Cockwell Station, the powerhouse for the project, which is located underground, below the upper reservoir atop Rowe Mountain. Construction started in 1968, and was completed in 1974. The plant has two pump/turbines that together generate 600 megawatts, enough to power around 60,000 homes, at least for the few hours that it takes to drain the reservoir.

75 miles west of the Berkshires, and past the Hudson River Valley, lies Schoharie Creek, and the Blenheim-Gilboa Pumped Storage Project, one of two pumped storage projects in New York State. The Blenheim-Gilboa Pumped Storage Project has an upper storage reservoir 1,000 feet above the creek on Brown Mountain, and uses a dammed portion of Schoharie Creek as a lower reservoir.

Blenheim-Gilboa's powerhouse is on the riverbank at the base of Brown Mountain, where its upper reservoir is located. There are four pump/turbines that both lift water to the upper reservoir and produce 1,100 megawatts of electricity when water flows back down through them. CLUI photo



The Lewiston Pumped Storage Project is comprised of a massive upper reservoir, covering three square miles, and a pump station/power plant. It is part of the bigger Niagara Power Project. Base map: Google Earth image

The plant is owned and operated by the New York Power Authority (NYPA), which operates a visitor center nearby, inside a transformed and repurposed barn, with elaborate interactive displays that describe the project in detail.

The New York Power Authority also operates the other pumped storage plant in the state, the Lewiston Pumped Storage Project, next to the Niagara River. It is part of the larger Niagara Power Project, which includes the Robert Moses Generating Station, one of the largest hydroelectric plants in the nation.

The Niagara Power Project, in turn, is part of the New York Power Authority's statewide electrical production and distribution system, which is described in the NYPA's Power Vista, a visitor attraction that rivals those at Niagara Falls, four miles upstream.

The Lewiston Pump-Generating Plant lies between the upper reservoir and the lower reservoir, known as the forebay. In addition to being the source for the pumped storage operation, the forebay, which holds two billion gallons of water and is nearly a mile long, also feeds the adjacent Robert Moses Power Plant, a 2,000-megawatt hydropower plant directly on the river. The forebay is fed by a conduit which draws water at intakes above Niagara Falls, and runs under the city like a submerged river, for four miles.

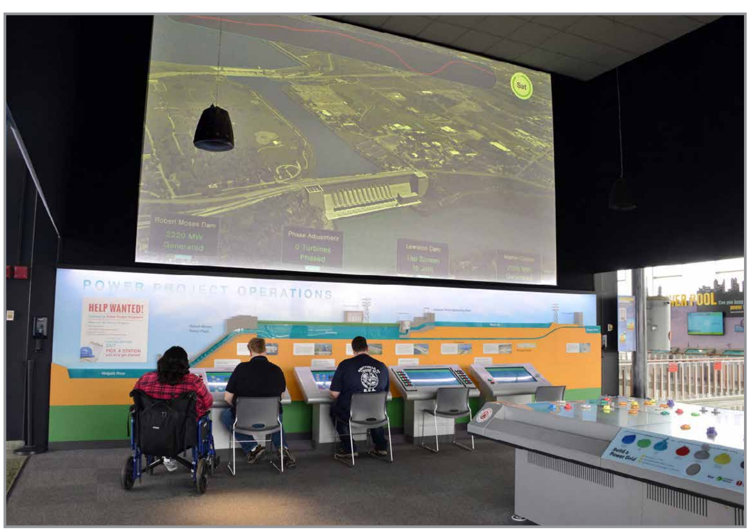
Though not clearly marked, it is possible to visit the actual upper reservoir, by walking up its side, next to a soccer field. What the reservoir lacks in elevation above the power station (less than 100 feet, far less than most pumped power facilities) it makes up for in area—1,900 acres, and in volume—20 billion gallons.

Along the western edge of its six miles of shoreline are the short penstocks at the top of the 1,000-foot-long pumped power station, which functions like a dam in the wall of the reservoir, inside of which are 12 reversible pump/turbines, spinning one way, or the other, adding 240 megawatts to the grid during the day, when demand for power is high.

90 miles south, along the Allegheny River in western Pennsylvania, is the Seneca Pumped Storage Project, one of two pumped storage operations in that state. The plant was built next to the preexisting Kinzua Dam, a large flood control dam built by the Army Corps of Engineers in the early 1960s, that backs up the river into a reservoir 24 miles long, flooding all the way to the Seneca Indian Reservation in New York State.

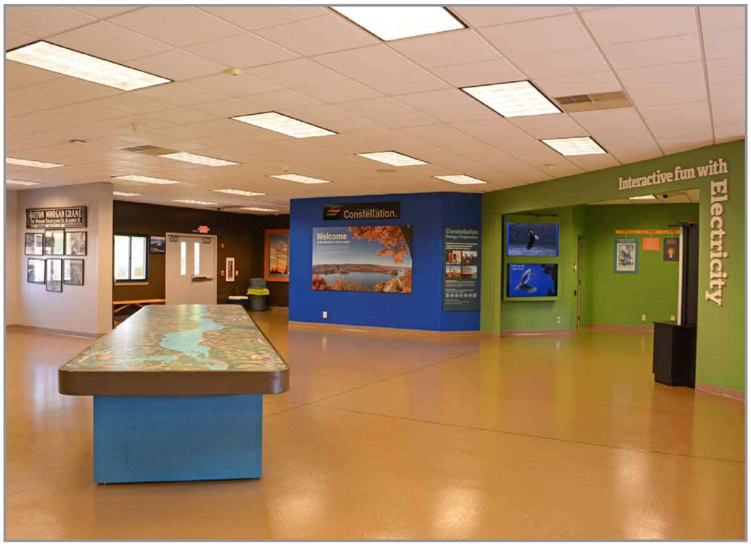
The pumped storage plant is contained in a powerhouse below the dam, discharging into the river at the stilling basin at the bottom of the dam. Inside are two reversible pump/turbines, and a third non-reversible turbine. The plant opened in 1970, and generates 450 megawatts at its peak.

Water enters the plant from an intake built onto the upstream side of the dam, and can be used to generate power directly, or pumped 800 feet upwards to the circular upper reservoir, generally at night, when power demand and cost is lowest. During the day, when demand for electricity increases and its value goes up, the water flows out of the upper reservoir though the same vertical tunnels, to the power station. The water then leaves the station and flows down the Allegheny River unobstructed, all the way to Pittsburgh, 195 miles downstream, where it joins the Monongahela and becomes the Ohio River.



Visitors at the Power Vista can use the simulated control station to try to balance the pumping versus electrical generation at the Lewiston Pump-Generating Plant, switching between "generate" and "pump" based on electrical demand. CLUI photo

The upper reservoir of the Seneca Pumped Storage Project is perfectly round, 2,500 feet across, and 800 feet above the Allegheny River. Google Earth image



The park at Muddy Run's upper reservoir has a visitor center for the project, operated by its owner, Constellation Energy, one of the largest power companies in the USA. In addition to Muddy Run and the nearby Peach Bottom nuclear plant, Constellation Energy has 24 gas and oil power plants, and 13 other nuclear power plants. CLUI photo

At the other end of Pennsylvania, 60 miles west of Philadelphia, is the Muddy Run Pumped Storage Project, which uses a dammed section of the Susquehanna River as its lower reservoir. When it opened in 1968 it was the largest pumped storage plant in the world.

The upper reservoir is a rambling 1,000-acre lake, 400 feet above the elevation of the river, with some recreational activity allowed along its shores, but only on the water that is isolated from the rest of the reservoir by another dam.

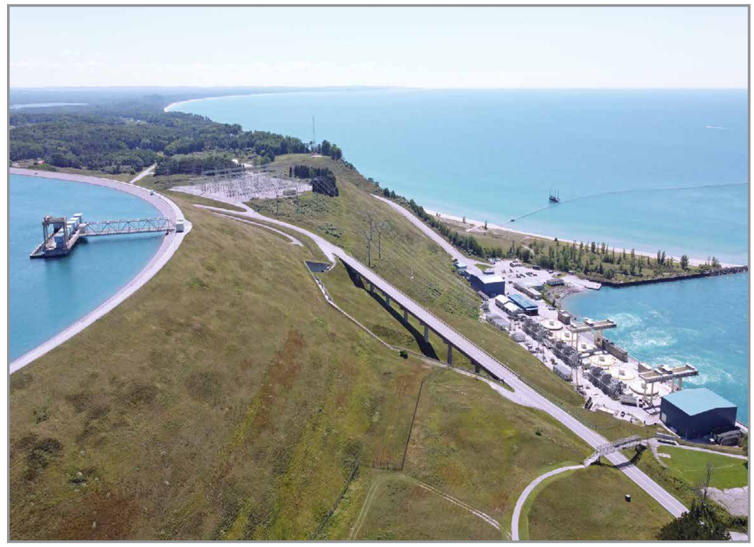
At the southern end of the upper reservoir a canal leads to four large intake towers atop four 25-foot-diameter shafts that bifurcate underground to connect to the eight pump/turbines in the plant, each of which generates 134 megawatts, giving the plant a total output capacity of 1,072 megawatts.

The plant uses a section of the Susquehanna formed by the Conowingo Dam, the last dam on the river before it enters Chesapeake Bay. This section of river also serves as the cooling water for the Peach Bottom Nuclear Power Plant, one of the first commercial nuclear plants in the nation. Muddy Run was under construction when Peach Bottom's first reactor went online in 1966, and two larger reactors opened in 1974.

100 miles north, just over the state line into New Jersey, is the last of the eight pumped storage projects in the northeastern USA, the Yards Creek Project, a 450-megawatt pumped storage operation in the Appalachian Mountains in northwestern New Jersey.

It has an upper and lower reservoir separated by 3,600 horizontal feet, and 700 feet in elevation. An 18-foot-diameter pipe carrying the water up and down slope emerges from underground halfway down the hillside, and splits into three penstocks that connect to three pump/turbines in the plant.

Despite the large population in the Midwest there is only one pumped storage facility there: the Ludington Pumped Storage Plant, on the eastern shore of Lake Michigan. It helps stabilize the electrical grid in the Upper Midwest, which is heavily dependent on nuclear plants (five of them are along the shores of Lake Michigan itself). When Ludington opened in 1973, after four years of construction, it was the largest pumped storage plant in the world.



The Ludington Pumped Storage Plant is the second largest pumped storage plant in the USA. It is located on Lake Michigan, which it uses as its lower reservoir. CLUI photo

The upper reservoir, built on a bluff above the shore, is two miles long, 842 acres in size, 110 feet deep, and holds 25 billion gallons of water, 17 billion gallons of which are considered usable, causing a 67-foot change in water level in the reservoir. Levels in its lower reservoir, Lake Michigan, 360 feet below, are unaffected.

Between the upper and lower reservoirs are six penstocks, each 1,300 feet long and 28 feet wide, just beneath the surface of the 170-foot-tall dike that forms the walls of the upper reservoir. At the bottom, on the shore of the lake, is the powerhouse, with six reversible pump/turbines, each with the capacity of generating 387 megawatts, adding up to 2,322 megawatts total, enough to power a city of 1.6 million people (for a few hours).

Jointly owned by Consumer Energy and Detroit Energy, Ludington has had recent upgrades that have increased its output, and enhanced its interpretive infrastructure, which is robust. There is an overlook above the powerhouse and at the upper reservoir, and other displays at roadside turn-outs, including one of the massive pump/turbine "runners" from inside the plant. CLUI photo

Goin' South

Things do not always go well at pumped storage facilities, though, as was the case at the Taum Sauk project, in southeastern Missouri. The facility opened in 1963, after three years of construction by its owner-operator, Ameren, Missouri's largest utility company. The project consisted of a 55-acre upper reservoir on Proffit Mountain, connected by a 7,000-foot-long tunnel to a power plant, located on a dammed creek, 760 feet lower in elevation.

The upper reservoir was unique, as it was created by building a 120-foot-tall continuous earth-fill dam, resembling a giant above ground pool, which its operators often kept filled to the brim, sometimes just a few feet from the top of the dam.

Early on a December morning in 2005, the reservoir overflowed, and without a spillway, its wall eroded and collapsed. 1.5 billion gallons of water spewed down the hill, scouring the ground of all trees and soil, down to bedrock. The water cascaded through Johnson's Shut-Ins State Park, at the base of hill, then followed the creek bed back to the lower reservoir. The dam at the lower reservoir held, and prevented the flood from reaching the town of Lesterville, where it likely would have done significant damage.

The superintendent of Johnson's Shut-Ins State Park was at home with his wife and three children when the flood flowed through the park for 12 minutes, and washed their house away, but they all survived.

The path of the flood is clearly visible in the park today, and visitors can walk up it to see the scour and the exposed bedrock. The grounds are covered in boulders that came down with the flood, creating a new and unusual attraction. Some of the rocks are as big as a truck. **CLUI photo**

Ameren was declared liable for the accident, as operators knew the water level sensors were unreliable. The company was fined $15 million by the federal government, and have paid more than $200 million in settlements. In 2010 a rebuilt reservoir atop Proffit Mountain went online. Instead of an earth-filled dam, this one was made by the more sturdy roller compaction method, and includes a spillway. It cost $500 million, much of which was covered by insurance.

There are more than a dozen other pumped storage projects in southern states, with the largest cluster around northern Georgia and northern South Carolina. Some of them are part of large regional water management systems, like the Tennessee

Duke Energy, the builder and operator of the Oconee Nuclear Power Plant, and the rest of the Keowee-Toxaway Hydroelectric Project, operates a visitor center called World of Energy, which opened in 1969, when construction started on Keowee-Toxaway. Since then Duke Energy has grown to become one of the largest electrical utilities in the nation, with more than seven nuclear plants and a dozen large coal-fired plants. **CLUI photo**

Valley Authority (TVA). One such system, the Keowee-Toxaway Hydroelectric Project, has two pumped storage projects within it, and is associated with a major nuclear power project as well.

The Keowee-Toxaway Hydroelectric Project is a series of reservoirs, dams, and hydro plants built in the early 1970s, to provide regional flood control and power production, and stable cooling water for the Oconee Nuclear Power Plant. The plant, with three reactors, was the largest nuclear power plant in the world when it opened in 1973.

The Keowee-Toxaway project flooded more than 40 square miles of territory, forming two large reservoirs, the rambling 20-mile-long Lake Keowee, which is heavily developed, and the 7,500-acre Lake Jocasee, which is mostly undeveloped and serves as a storage and flood control reservoir for Duke's system. The dam that forms Lake Jocassee has four pump/turbines in it, which pump water up from Lake Keowee, and generate 774 megawatts of power when it flows back down.

Lake Jocassee is also the lower reservoir for a larger pumped storage project, called Bad Creek, which opened in 1991—one of the

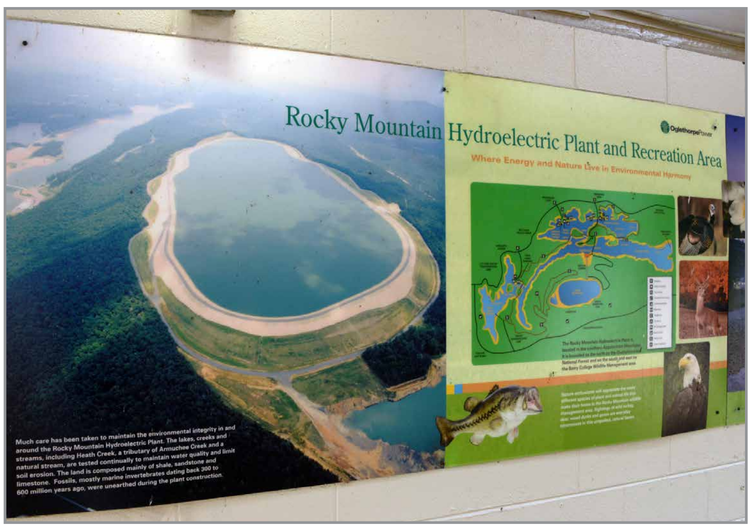
In 1991 the Bad Creek Pumped Storage Project was added as part of Duke Power's regional Keowee-Toxaway Hydroelectric Project. **CLUI photo**

most recently constructed pumped storage projects in the USA. The Bad Creek Hydro Pumped Storage Station pumps water up 1,200 feet from Lake Jocassee to a 370-acre upper storage reservoir, built and operated by Duke Energy. The four pump/turbines in the underground power station produce as much as 1,065 megawatts for a few hours, when water runs back down to Lake Jocassee.

The completion of the dam forming Lake Jocassee in 1970, and flood waters rising behind it, are depicted in the opening sequence of the 1971 film *Deliverance*, an influential film that laments the loss of landscapes to hydroelectric projects in the South (among other things).

There are four pumped storage hydroelectric plants in Georgia, three of which are in dams on existing rivers, and are relatively small. Only one, the Rocky Mountain Hydroelectric Plant, uses an isolated specially constructed off-stream storage reservoir. It is the largest in the state, and the most recent major pumped storage operation to be built in the USA.

Rocky Mountain is located in the southern Appalachian Mountains, in the northwest corner of the state. Construction of the project started in 1977, but stopped in the 1980s, due to financing issues. It was finally finished and opened in 1995, after a total cost of more than one billion dollars.

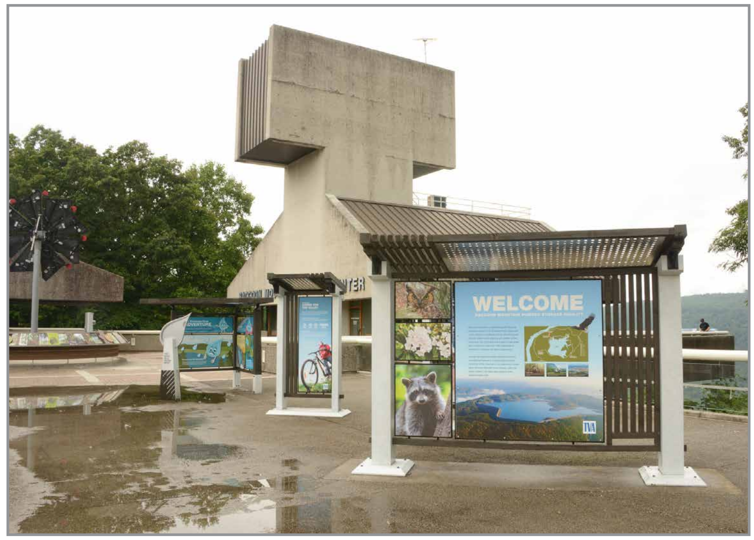


Information panel in the unmanned visitor pavilion at Rocky Mountain. CLUI photo

The project consists of an oblong upper reservoir constructed near the top of Rocky Mountain and a lower reservoir with a power plant, containing three pump/turbines, capable of producing 385 megawatts each, for a total of 1,140 megawatts—making it the seventh largest pumped storage plant in the nation.

The lower reservoir and the land around it offers fee-based recreational activities, such as camping, boating, hunting, and fishing, though these activities are contained within two auxiliary ponds, keeping people away from the lower reservoir, where the powerhouse is. Most of the 5,000 acres owned by the utility company, Oglethorpe Power, are off limits to the public.

The Raccoon Mountain Pumped Storage Project is a few miles west of Chattanooga, Tennessee. It is the largest hydroelectric



Though it is currently closed to the public, the visitor center at the upper reservoir of Raccoon Mountain has an elevator that was built to take the public 1,000 feet down, into the underground powerhouse. CLUI photo

plant built by the Tennessee Valley Authority, which is saying a lot, as the TVA has 30 of them, and was a pioneer in large-scale dam construction. Raccoon Mountain was built between 1970 and 1979, and has a generating capacity of 1,650 megawatts, making it the third largest pumped storage project in the nation.

The TVA is part of the federal government, and the grounds of the Raccoon Mountain operation are welcoming and more open to the public than most. Visitors can circle the upper reservoir by car, driving along the top of the 280-foot-high, mile-and-a-half-long dam, the largest earthen dam built by the TVA.

There are hiking and biking trails, and an overlook providing a view of the intake structure in the upper reservoir. Even the electrical substation for the facility has an interpretive plaque and a viewing bench, and is likely one of the few electrical substations anywhere in the country designed with aesthetic considerations, and to be part of a park.

A visitor center next to the upper reservoir has informative displays inside and out, and a balcony that overlooks the Tennessee River Gorge and Nickajack Lake, the dammed segment of the river that serves as the lower reservoir for the project. The visitor center is at the top of an elevator shaft, and a 1,000-foot-long vertical corridor for the cables carrying the electricity from the plant.

Roads lead to the intake/outfall down below, at the river side, and the public is encouraged to visit, picnic, and fish outside the powerhouse service tunnels, where there are displays and equipment on view to enjoy as well.

The powerhouse inside the base of the mountain has four pump/turbines, each of which can generate as much as 413 megawatts. Water flowing down from the upper reservoir can generate power for 22 hours, and it takes 28 hours to pump it back up to fill the reservoir.

The TVA was established in 1933, as part of the New Deal, and was the largest regional development project in the nation's history. It is still the largest public utility in the country, with dozens of power plants, transformed waterways, and transmission lines covering several southern states.

The largest pumped storage facility in the country is the Bath County Pumped Storage Station in the Allegheny Mountains, on the state line between Virginia and West Virginia. On the surface, it looks like other pumped storage projects, with a medium-sized 265-acre upper reservoir, connected by buried penstocks to a power station, located on the shore of lower reservoir, made by damming a creek.

There is no access for the public at Dominion Energy's Bath County pumped storage plant, the nation's largest pumped storage plant, and signs around the gated grounds warn that it is a "no drone zone." CLUI photo

The difference is inside the power plant, which has six pump/turbines, each with a capacity exceeding 500 megawatts, more than twice a typical size, enabling the plant to produce as much as 3,003 megawatts, making it the tenth largest electrical generating station in the USA, of any kind. It was the largest pumped storage facility in the world until 2021, when a 3,600-megawatt plant opened in China.

The upper reservoir is 1,200 feet above the power station, and its water level sinks 100 feet over the ten hours it takes to drain through the turbines into the lower reservoir. It takes 11 hours to pump the water back up. The plant is 80% efficient, meaning 20% more power is used to pump the water back up. Construction started in the late 1970s, and the plant opened in 1985, costing more than four billion in today's dollars.

The grounds, including the upper and lower reservoirs, are off limits to the public, and information about it onsite is limited to a small kiosk outside the security station at its main entrance. The tattered site map indicates a visitor center on the property, which closed long ago. Two ponds were constructed below the lower reservoir to provide recreation for the public, as required by the plant's construction and federal operating permit. Camping and fishing is permitted, though it requires a small fee.

Way Out West

The west has some pumped storage projects, too, including three in the mountains of Colorado; one built into the Grand Coulee project on the Columbia River in Washington State; and three small ones in Arizona, two of which are built into the continuous line of dam/reservoirs along the Salt River, part of the Salt River Project, which supplies Phoenix with electricity.

And then there is California, where the hydrology has been altered so fundamentally, with pumps moving water from one end of the state to the other, into and out of reservoirs, and over mountain ranges, through a network of thousands of miles of canals, that the whole place is an engineered plumbing project. Within this constructed hydraulic system there are, officially at least, seven pumped storage energy projects, all of which have unique and superlative qualities.

At the top of the state is a pumped storage project that is part of the Oroville-Thermalito Complex, in Northern California, a 12-mile-wide engineered waterworks extending from the Oroville Dam in the east to the Thermalito Afterbay in the west.

The Oroville-Thermalito Complex starts at the Oroville Dam, which captures the flow of the Feather River, as well as tributaries that trickle in from other dams higher up the watershed into the Sierra, forming Lake Oroville, the second largest reservoir in the state, after Lake Shasta. The dam is 770 feet high, and is the tallest in the nation. It took seven years to build, and was dedicated in 1968.

Though the primary function for the Oroville Dam and reservoir is to supply water and control flooding, it also generates electricity. The Edward Hyatt Power Plant, inside a 400-foot-long underground chamber carved inside the rock on the south side of the dam, produces up to 819 megawatts of power. Three of the six generating units have the ability to reverse, pumping water more than 600 feet from the base of the dam, back into Lake Oroville.

Water leaves and enters the plant at the base of the dam in the diversion pool tailrace. This pool runs for three miles, from the base of the dam to the diversion dam, which allows some water to re-enter the channel of the Feather River. The rest is diverted through the Thermalito Power Canal to the Thermalito Forebay, and eventually to the Thermalito Dam, five miles further west.

The intake pipes for the Edward Hyatt Power Plant at the Oroville Dam. The plant is one of two at the Oroville-Thermalito Complex that can pump water as well as produce electricity. CLUI photo

The pumped storage components of the Oroville-Thermalito Complex are addressed along with much more, at the Lake Oroville Visitor Center, one of three State Water Project visitor centers in California. CLUI photo

The Thermalito Dam has a powerhouse with four turbines that generate up to 120 megawatts when it lets the water spill into the Thermalito Afterbay. Three of the turbines in the Thermalito Dam are reversible, and pump water out of the afterbay, raising the level through the entire system for ten miles, back to the Hyatt Plant, which can lift water back up to the Oroville Reservoir, thus regulating water levels throughout the Oroville Thermalito Complex.

The Thermalito Afterbay, the far end of this pumped storage project, is a large shallow off-stream terminal reservoir, covering 4,300 acres, created by a low dam that is 42,000 feet long along its south and west sides, and runs for four miles flat up against Highway 99.

170 miles south, near Los Banos, on the west side of the Central Valley, is the San Luis Reservoir, an even larger pumped storage reservoir—in fact the largest off-stream reservoir in the nation, covering 12,700 acres, with a capacity of more than 650 billion gallons.

The San Luis Reservoir serves as the upper reservoir for a pumped storage hydroelectric project, but its primary function is to store water for federal and state irrigation and drinking water projects. It is the main component of the San Luis Complex, which consists of two reservoirs and two pump/generator plants, and links two statewide aqueduct systems.

Water is pumped into the reservoir by the William R. Gianelli Pumping-Generating Plant at the base of the dam. It lifts water 300 feet into the reservoir, and generates as much as 424 megawatts of power when water flows back down through the plant, into a canal connected to the lower reservoir, called the O'Neill Forebay.

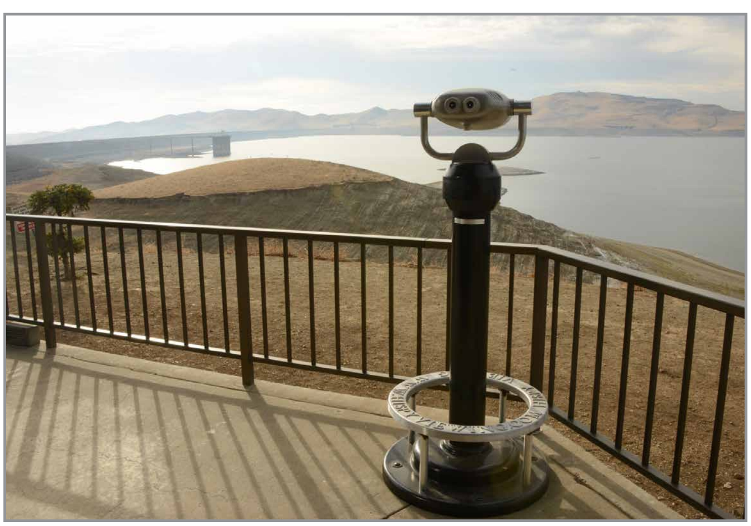
The O'Neill Forebay is fed by two canals, one state, and one federal. The state canal is the California Aqueduct, which brings water from the Delta in Northern California, to Central and Southern California. The California Aqueduct enters the forebay from the north, and leaves from the south, with gates that regulate its flow in and out.

The federal canal feeding the forebay is the Bureau of Reclamation's Delta-Mendota Canal, which brings water from the Delta in Northern California to the farms throughout the Central Valley. The forebay has a small pumping-generating plant that lifts water 50 feet up out of the Delta-Mendota Canal, and generates 25 megawatts when it lets water back into it, though it is only occasionally used for this.

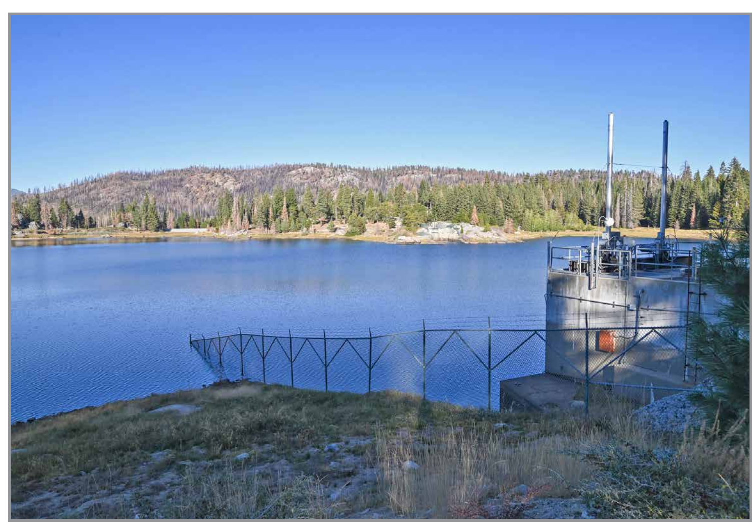
A hundred miles due east, deep in the Sierra, is the Balsam Meadow Pumped Storage Project, one of two pumped storage hydroelectric projects in the Southern Sierra. It uses a preexisting reservoir as a lower reservoir, a small upper reservoir, and a powerhouse between them.

The upper reservoir, also known as the Balsam Forebay, is filled by water pumped up to it from the lower reservoir, known as Shaver Lake, and by water flowing down from another reservoir above it.

The upper reservoir's intake/outfall for the pumped storage project is at the top of a 7,500-foot-long tunnel bored through solid rock. At the other end, down below, is the Eastwood Powerhouse, in a cavity carved out of solid granite, 1,000 feet underground. The



The intake towers at the top of the dam at the San Luis Reservoir are visible from an overlook at the Romero Visitor Center, the second of three State Water Project interpretive centers. The 380-foot-tall dam was completed in 1967, and is the fourth largest embankment dam in the nation. CLUI photo

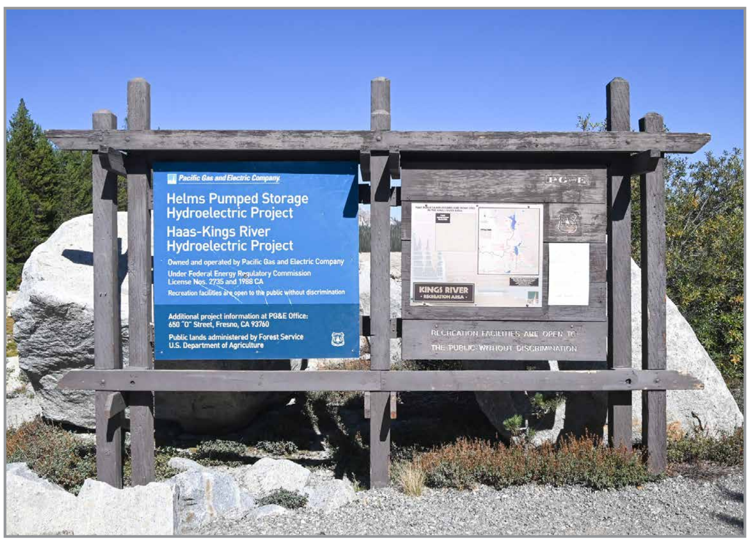


The intake/outfall structure on the shore of the Balsam Forebay. There is little in the way of interpretive material on site at the Balsam Meadow Pumped Storage Project. CLUI photo

powerhouse has just one pump/turbine unit, with the capacity of generating 200 megawatts. Construction started in 1983 and ended in 1987, when the upper reservoir was filled.

Balsam Meadow was the last part of the larger Big Creek Hydroelectric Project, which was developed between 1913 and 1987 to provide power for Los Angeles. Owned and operated by Southern California Edison, one of a few major energy utilities in California, Big Creek has six reservoirs, nine power plants, and miles of underground tunnels connecting them. It generates a total of 1,000 megawatts, which comprises 90% of the company's hydroelectric generation, and 20% of its total electrical generation.

20 miles east is the second of two pumped storage projects in the Southern Sierra, the Helms Pumped Storage Project. It is located at the end of the roads into the mountains, on the edge of the John Muir Wilderness Area, 8,100 feet above sea level. Owned and operated by Pacific Gas and Electric (PG&E), it is the fifth largest pumped storage project in the country.



Between 1977 and 1984, as many as 700 people were engaged in the construction of the Helms Pumped Storage Project, blasting four miles of underground tunnels, most of them 27 feet wide, in solid granite. The chamber hollowed out for the power station is as tall as a ten-story building. CLUI photo

The project uses similarly sized upper and lower reservoirs, three miles apart, connected by a tunnel, with an underground powerhouse near the lower reservoir, capable of producing more than 1,200 megawatts.

Both the upper reservoir, known as the Courtright Reservoir, and the lower reservoir, known as the Wishon Reservoir, predated the pumped storage project. They were built in the late 1950s, as part of a string of hydropower plants along the North Fork of the Kings River known as the Haas-Kings River Project. The pumped storage component was started in the late 1970s, linking the reservoirs by blasting a four-mile-long diagonal tunnel between them, and building an underground pump/turbine plant at the lower end of the tunnel, near the level of the lower reservoir. The project was finally completed in 1984.

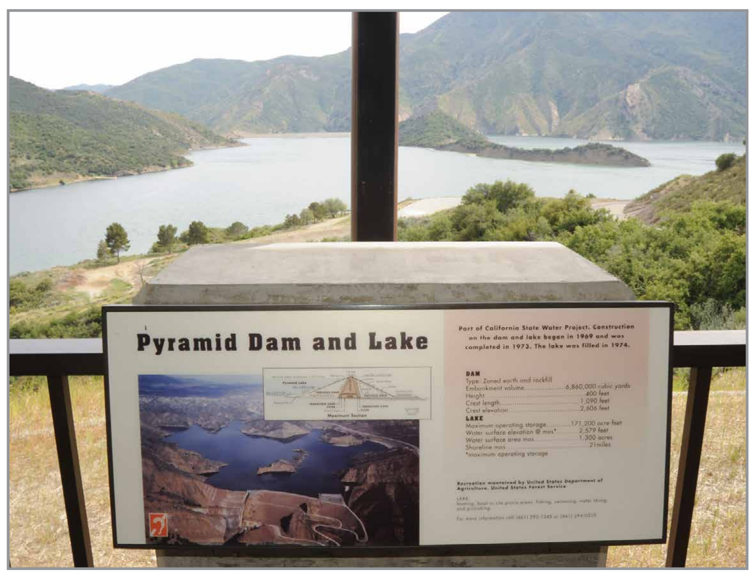
The pumped storage operation was built primarily to provide grid stability in conjunction with the Diablo Canyon Nuclear Power Plant, which PG&E was building at the same time. That plant, 170 miles away on the Central Coast, and featured in the 1979 film *The China Syndrome*, is now the state's only operating nuclear power plant.

South of the Grapevine, at the northern fringe of Los Angeles, next to Interstate 5, is Pyramid Lake, the upper reservoir for the fourth largest pumped storage project in the nation.

Poised at the top of Southern California, Pyramid Lake is filled from above, and below. The California Aqueduct, part of the California State Water Project, carries water from Northern California, pumping it over the Tehachapi Mountains. Emerging from the tunnel at the southern side of the Tehachapi, the aqueduct splits in two, with one portion heading east through the Antelope Valley, and the rest heading west, then south, into Pyramid Lake.

Water flows out of Pyramid Lake through the Angeles Tunnel, a seven-mile-long underground conduit, 30 feet in diameter, into penstocks that feed the Castaic Power Plant, which generates more than 1,550 megawatts at its peak from the plummeting water. Water emerging from the plant enters the Elderberry Forebay, which connects to the adjacent Castaic Lake, the official terminus of the west branch of the California Aqueduct, and a major reservoir of Los Angeles' drinking water.

When the six primary turbines at the Castaic Plant reverse, usually at night when demand for power is at its lowest, they pump water backwards through the penstocks, up more than 1,000 feet in elevation and more than seven miles through the Angeles Tunnel, back into Pyramid Lake.



Overlook of Pyramid Lake, the upper reservoir for the Castaic Pumped Storage Project, from the Vista Del Lago Visitor Center, the third of three State Water Project visitor centers. CLUI photo

There is one last pumped storage project in the state, the Lake Hodges Pumped Storage Project, in the hills east of Encinitas, at the southern end of the sprawl of Southern California. Though it is small in output, producing only 40 megawatts at its peak, it is the most recently constructed pumped storage project in the nation, going online in 2012.

Intake/outfall for the pumped storage plant at Lake Hodges, in San Diego County. CLUI photo

The lower reservoir is Lake Hodges, a dammed portion of the San Dieguito River. The dam was completed in 1918, and the reservoir was sustained only through runoff and rainfall. As San Diego grew, it became dependent on Colorado River water and Northern California water, brought to the region by pipelines and aqueducts.

As concern mounted about being cut off from imported water by an earthquake or system failure, the county established the Emergency and Carryover Storage Project, which included the construction of the Olivenhain Reservoir, to provide more local storage for the region. The new reservoir would in turn feed Lake Hodges, less than a mile away.

The Olivenhain Reservoir was completed in 2003, and is fed by imported water from the Second San Diego Aqueduct, coming from the north. An underground pipeline, ten feet wide and a mile long, was completed in 2008, connecting the Olivenhain Reservoir to Lake Hodges. A few years later the small pumping/generating station on the shore of Lake Hodges went online, capable of pumping water back uphill to the Olivenhain Reservoir. Like some other pumped storage projects in California, and along rivers around the USA, it exists more for water supply management than for electrical generation.

Battery Earth

Pumped storage has been likened to an electric battery, holding potential energy that can be converted to kinetic energy to produce electricity when needed. And though California has more pumped storage than any other state, its energy storage capacity, like that of the nation as well, needs to be substantially developed to meet the demands of a changing, sustainable grid.

To meet this demand, dozens of pumped storage projects have been proposed all over the country, nearly all of them fully off-stream (also referred to as closed-loop), which lessens their environmental impact. Still, only a few have passed the permit process so far, such as the Gordon Butte Pumped Storage Hydro Project near Martinsdale, Montana, and the Swan Lake Energy Storage Project in Klamath Falls, Oregon, which was permitted in 2019, and may go online in 2026, producing 400 megawatts.

Non-continuous energy production like solar and wind is going online right now, however, and energy storage will be required more quickly than pumped storage can be built, it seems. So the race is on to build utility-scale lithium battery storage arrays, so long as the material readily exists to create them. California has the largest of these battery arrays in the country, but they are being built quickly elsewhere as well.

At Moss Landing, California, on Monterey Bay, next to the looming gas-fired power plant that was once the largest power plant in the state, two new and expanding battery storage systems make it the largest utility-scale battery site in the nation, at the moment, with a 400-megawatt output. It is soon to be surpassed by another, near the town of Mojave, California, where the Sanborn-Edwards Solar Project is building a battery storage project capable of providing as much as 700 megawatts of power. For a few hours at a time, at least. ♦

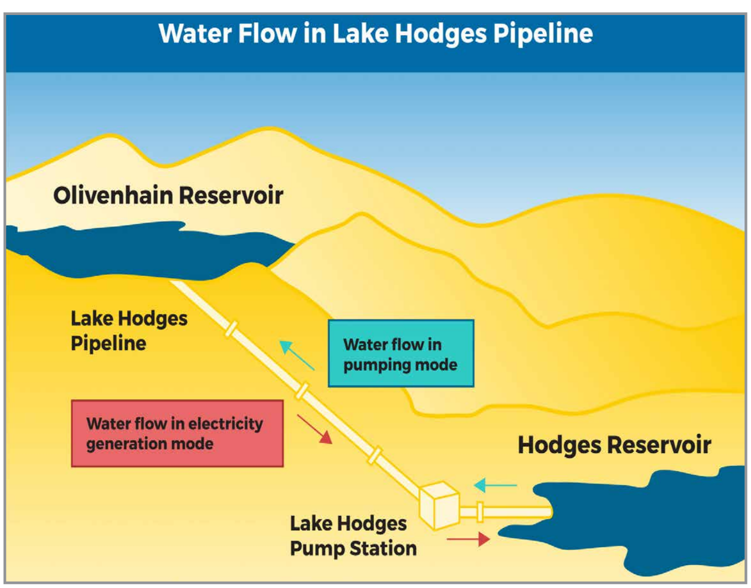


Image: San Diego Water Authority

Rows of boxes of batteries in Saticoy, near Ventura, California, at a battery storage project with a 100-megawatt output capacity. CLUI photo

LITHIUM DREAMS

The only active lithium production site in the USA at the moment is the solar evaporation mine in Silver Peak, Nevada, which has been active since the 1960s, back when one of the uses of lithium was to treat depression. CLUI photo

AS WE SHIFT TO VARIABLE renewable energy sources like solar and wind, the need to store a few hours of energy available throughout the day on a large scale is critical. And while novel ways to store potential energy, like pumped water storage and compressed air storage, are being explored, the batteries of lithium-ion batteries being built across the land that are filling the current need are limited by international supply chains that extend to the sources of lithium itself.

The USA usually ranks pretty low on the list of actual and potential lithium production, far below the dominant suppliers of Chile, Australia, China, and Argentina. But, as with many minerals, lithium is actually fairly common and widespread in small quantities in the ground. Extraction is more a matter of technology, economics, and politics.

The search for mineable sources in the USA is booming. Mining projects have been proposed for northern Nevada, northern Arkansas, North Dakota, Maine, southern Oregon and elsewhere, though nothing has expanded beyond preliminary stages yet. Today there is just one major lithium mining operation in the country, in a remote valley in the western part of Nevada, and it's been operating for half a century.

Silver Peak is a brine extraction operation, where groundwater from this saline valley is evaporated in open ponds, leaving a precipitate that is scooped up and processed to extract the lithium. The mine opened in 1966, and was operated for decades by the Cyprus Foote Mineral Company. The mine covers more than 20 square miles, with more than 20 ponds, where it can take as long as two years to produce a crop of lithium-rich precipitate, which is taken to a plant nearby to be filtered and mixed with lime and soda ash to become lithium carbonate.

More than 5,000 tons of this material is produced at the plant every year, enough for around 80,000 car batteries—a drop in the bucket, on a global scale. Lithium carbonate is shipped to other processing sites around the country, including directly to lithium battery factories.

Silver Peak's current owner is the Albemarle Corporation, an international catalyst chemical company based in North Carolina. Albemarle's roots are in the Ethyl Corporation, founded by General Motors and Standard Oil in 1923 to produce Tetra-ethyl lead, a gasoline additive that reduced engine knock in cars. Leaded gasoline became the norm for decades, before the pollution it produced provoked a movement to ban it.

The extraction of lithium from briny deposits at dry lake beds, and from the mineral-rich deposits around them, is common. The Salton Sea region, for example, is considered to be one of the largest potential reservoirs of lithium in the US, and a number of companies are developing processes for extracting lithium from high pressure and high temperature wells. This area is one of the largest geothermal energy sites in the country, with more than a dozen plants producing electricity from wells thousands of feet deep that bring hot mineral-rich water to the surface, running turbines that produce electricity, then injecting the water back into the ground.

Many of these plants are now owned by BHE Renewables, a division of Berkshire Hathaway, Warren Buffett's holding company, based in Omaha. One of the plants has been converted to a lithium recovery demonstration project, with funds from the State of California and from the Department of Energy. The project extracts lithium from the brine that normally circulates through the geothermal system. If proven successful, other geothermal plants may be converted to do the same.

A few miles away, an Australian company, Controlled Thermal Resources, has constructed the first phase of its Hell's Kitchen Lithium and Power project. The company has completed a geothermal well, and is building a plant to extract lithium, and generate electricity. It is part of an imagined Clean Energy Campus, where co-located corporate partners will manufacture finished lithium-ion batteries on site, and deliver them to the hungry world. The company envisions that this "Lithium Valley," currently the second largest geothermal producer in the country, will someday produce geothermal energy as a byproduct of lithium production. ♦

Controlled Thermal Resources' Hell's Kitchen Lithium and Power project near the Salton Sea. CLUI photo

TIME STAMPS

REVISITING CALIFORNIA THROUGH POSTCARDS

Selections from the Center's collection of postcards, with their rephotography, were featured in an exhibit in Bakersfield, California. CLUI photo

A CLUI EXHIBIT AND TEACHING program exploring the interpretive resource of postcards was presented at California State University Bakersfield in the spring of 2022, as the culmination of a residency there by CLUI program director Aurora Tang, working with Jesse Sugarmann, noted "car artist" and art department chair.

Tang drew from the Center's collection of vintage postcards by Merle Porter, many of which depict places in California's Central Valley, as a point of entry to explore how rephotography and postcards can shape our understanding of place. Students made their own postcards of local places, distinct portraits of Bakersfield, as seen through their choice of landmarks.

Student-created postcards of local points of interest were available to exhibit visitors as a take-away, to keep as a memento or to mail out to someone. CLUI photo

The exhibit *Time Stamps: Revisiting California Through the Postcards of Merle Porter* featured dozens of postcards of California places, paired with contemporary photographs of the same view, taken by the CLUI. The two images, side by side, span the gap between then and now, and unearth surprising, subtle, and revealing patterns of change and stasis.

Over the summer, the Center inventoried, catalogued, scanned, and archived its collection of thousands of Merle Porter postcards, aided by CLUI intern Sofía Rodriguez, a Barnard College student. The Center's efforts to investigate the interpretive potential of place-based postcards continues. ♦

Postcard of Bakersfield, California Merle Porter photo

Rephotography, 2022 CLUI photo

Postcard of Visalia, California Merle Porter photo

Rephotography, 2022 CLUI photo

REPORT ON CLUI REGIONAL FACILITIES

Field program facilitators and students embark on an outing to the former ball mill site, just east of CLUI Wendover, during a weekend gathering about educational creative field programs. CLUI photo

THE CENTER MANAGES A VARIETY of regional facilities that serve as public contact stations, project support centers, and exhibition sites. Some are open with a specific program for just a few months, others for a few years, and some, it seems, perpetually.

CLUI Wendover

The CLUI has operated exhibition and production facilities on the edge of the salt flats at Wendover, Utah, since 1996. A number of university and museum groups visited CLUI Wendover over the 2022 season, hosted by the CLUI. Art and architecture groups came from the University of Utah, Arizona State University, University of Colorado, University of Southern California, and the New York-based Dia Art Foundation. The Texas Tech Land Arts of the American West field program made its annual week-long visit, camping out at the Center's support facilities on the old flightline, across from the Enola Gay Hangar.

Individual artist and architects worked on local interpretive projects at CLUI Wendover over the past year, too, including Lukas Marxt, who filmed and conducted interviews for his ongoing project exploring atomic connections between Wendover and the Salton Sea.

Several groups visited CLUI Wendover over the 2022 season. Some stayed for a few hours, while others stayed for a week or so. CLUI photo

CLUI Wendover also hosted a gathering for educators involved in creative field programs. Building on similar events held in-person in 2018 and online in 2020, the weekend meet-up consisted of presentations, excursions, and discussions around issues unique or shared among the group, as many travel courses are starting to return after two years of the pandemic.

Renovations to the physical plant continued at Wendover over 2022, including a much needed new roof on the studio in September, and a major clean out of clutter from decades of raw material collection. New exhibits were installed in the Exhibit Hall, a building also called the Nurse's Quarters, as it was built to house the base hospital's nurses during World War II. Inside, along with the CLUI exhibits, are displays describing that period, installed by the Wendover Historic Airfield Museum. Access to the building is available year-round by contacting the Museum.

Desert Research Station

At the Center's Desert Research Station, an interpretive outpost in the Mojave, near Barstow, facility work and upgrades continued, including roof repairs, maintenance, clean outs, and repainting. Meanwhile, antenna tests by the Space Song Foundation and others were conducted at the site. Though the facility is technically closed to the public at the moment, it is in the "deserted desert research station" mode of display, and still considered a compelling and visitable destination as such, and as a point of embarkation from which to explore the region, or as a stop on the way.

Representatives from the Space Song Foundation test an antenna-ring prototype on a Joshua Tree at the DRS. Space Song Foundation photo

CLUI Swansea

The Center operates a site on the shore of the dried up Owens Lake, at Swansea, California. Some of the display facilities were open to the public during weekends in February and March of 2022, including the CLUI Owens Lake Land Observatory, as well as the Landscape Morphology Lab, operated by landscape architect and Owens Lake expert Alexander Robinson of the University of Southern California. Curious visitors made the trek to check

CLUI Swansea sits at the eastern edge of Owens Lake. CLUI photo

out the exhibits there, from nearby residents of Lone Pine, to groups from Los Angeles, San Francisco, and beyond (a guestbook entry was signed by a landscape architect from Australia). Over the rest of the year, the Swansea location supported visits by a few educational art and architecture groups, and field work by individual photographers and artists. ♦

Visitors at the Landscape Morphology Lab at CLUI Swansea. CLUI photo

The Center's Owens Lake Land Observatory at CLUI Swansea featured kinetic aerial images of Owens Lake's unique microtopography. CLUI photo

CLUI VISITORS AND VISITATIONS

Classes convened at CLUI LA for seminars and discussions in 2022. CLUI photo

THE CLUI LOS ANGELES EXHIBIT space and office is open to the public during regular hours, and at other times by appointment. Groups that visited over 2022 include classes from local and distant colleges and universities, including: Yale, Virginia Commonwealth University, Columbia University, the Architectural Association School of Architecture, CalArts, Los Angeles Mission College, ArtCenter College of Design, the University of Southern California, and a group of students from across Los Angeles participating in the Getty Marrow Undergraduate Internship program.

CLUI representatives also traveled to give talks over the year, including at the University of Colorado Denver, the University of Nevada Las Vegas, and CalArts, and via Zoom to groups in other places, including the Society for Industrial Archeology, Dartington Arts, Kansas Field Arts Forum, University of San Francisco, Cal State University Bakersfield, and Grand Valley State University.

Though most CLUI programming takes place at our various locations (chiefly, at the moment, Los Angeles, Wendover, Hinkley, and Swansea), the Center's images, videos, and exhibits are also shown at other venues. Last year Nottingham Contemporary in the UK showed images from the CLUI exhibit *Hollowed Earth*, as part of the Hayward Gallery Touring exhibit *Hollow Earth: Art, Caves and the Subterranean Imaginary*. CLUI projects were also featured in a range of publications, including the architecture journal *Log*. ♦

The College of Architecture and Planning at the University of Colorado Denver hosted a CLUI public presentation as part of their fall lecture series. CLUI photo

BOOK REVIEWS

BOOKS NEW TO THE SHELVES OF THE CLUI LIBRARY

Inventor of the Future: The Visionary Life of Buckminster Fuller, by Alec Nevala-Lee, 2022
Hero, charlatan, genius, huckster, prophet, guru… it's now open season on the legacy of Bucky the man, a conflicted character indeed, apparently. He spent his life traveling and pitching plans to save the world through various dymaxionisms and synergeticnesses, leaving his dreams of manufactured metal houses and cars to crash. His domes inspired many to do their own thing, even if it was only to meet together inside domes to talk about saving the world with domes. (Meanwhile America's post-war global power was enhanced by protecting hundreds of radar installations near and far with his radomes—the Department of Defense was his biggest paying customer.) He didn't much care for politics, it seems. Maybe he cared most about his legend, while being his own worst enemy. Like an artist, which is maybe what he was more than anything else.

Whole Earth: The Many Lives of Stewart Brand, by John Markoff, 2022
From the Merry Pranksters to the Long Now Foundation, Stewart Brand has been on the leading edge of the middle of things for a long time. He is a technologist looking for a better way, but not as an oracular visionary preaching a gospel sent from above (like Bucky), but grounded, following something that looks more like steps along the road of common sense (a subjective thing, yes, but we sort of know it when we see it, don't we?). His *Whole Earth Catalog* was a familiar-feeling foundational idea for so many, and his 1994 book *How Buildings Learn* (constructed over several years in a shipping container) was nearly as great. He's not without complexities and contradictions, of course, but now there is this book, to help connect the dots and fill in the blanks.

American Canopy: Trees, Forests, and the Making of a Nation, by Eric Rutkow, 2012
This book is full of interesting things that should be common knowledge, but aren't, like that the oldest living tree in America was discovered *after* it was cut down by a forest service researcher to count its tree rings; that Wisconsin's Great Peshtigo Fire of 1871 was the deadliest forest fire in American history, likely killing more than 2,000 people and burning 2,000 square miles; and that the writer Henry David Thoreau was the son of a pencil maker. It is possible to see the forest of American history through its trees indeed.

Meet Me by the Fountain: An Inside History of the Mall, by Alexandra Lange, 2022
A thoughtful journey through the architectural history of malls, written by Alexandra Lange, a design critic, former *Curbed* architecture writer, and mall user. Though malls may have originated with Victorian enclosures of urban space (or even much, much earlier), the modern mall story told here starts with the classic modernist malls of Victor Gruen, who built the first enclosed climate controlled suburban mall in Minnesota in 1956, and continues through important 1970s milestones like HOK's Houston's Galleria (1971), and Jon Jerde's Horton Plaza, in San Diego (1985), and the Mall of America (1992), also in suburban Minneapolis. The story ends, for the moment, chronologically, where her book begins, with a visit to the recent but long-delayed full opening of the American Dream, in the Meadowlands of New Jersey. The mall is dead. Long live the mall.

Car-Stoppers, by Temporary Services, 2022
A recent pamphlet publication depicting a variety of "car-stoppers": concrete and metal posts (mostly), set in place to protect buildings from being damaged by slow moving vehicles in tight corridors like alleyways. United in function but often differing in form from the outset, car-stoppers develop more individual characteristics over their lives by the marks, bumps, cracks, scrapes, and other scars acquired in their line of duty. They possess a tangible nobility too, serving their selfless function like sacrificial sentinels, or like members of an architectural secret service, taking the bullet, as it were, for the more "important" structures they protect and defend. This is a very local survey, from alleyways around northern Chicago (mostly), and while perhaps phenomenologically exemplary, clearly a more widespread nationwide study of the form is called for. This 36-page color publication is part of the ongoing and compelling output of Half Letter Press and Temporary Services, an independent cultural outfit based in Chicago.

The Company: The Rise and Fall of the Hudson's Bay Company, by Stephen R. Brown, 2020
The fur trade formed the first strands of European incursion into the native continent, and its history is complicated and horrid, involving the Dutch, French, British, Russians, and countless Native populations, spanning 250 years. The Hudsons's Bay Company was one of the largest players, and this book covers their part exhaustively. Initially working from fortified depots on Hudson Bay, at points where rivers lead into the interior like cracks in the continent, much of the Company's network of outposts and routes ultimately fell on what became the Canadian side of the border. But by the early 1800s the Company had expanded through the northern plains and northwestern USA, via the Missouri and Columbia Rivers and their tributaries, and was trading at US ports on the west coast, including Seattle and Astoria. By the 1830s, though, the wave of western migration grew, and the Hudson's Bay Company evolved into a general merchandise retail business, and is still at it today.

Occupying Massachusetts: Layers of History on Indigenous Land, by Sandra Matthews, 2022
Most of the things depicted in this book of site photography seem barely attached to the ground, or about to fall over. Heavy-looking rock monuments, attempting to convey a fixed history, seem more like imported thought bubbles, and the buildings, in this normally deep-rooted land of Massachusetts, are depicted here as temporary sheds and flimsy, disintegrating ephemera. The flotsam of occupation. Another entry in the lengthening line up of publisher George F. Thompson's output, which spans decades and includes some of the best books about places out there.

Nineteen Reservoirs: On Their Creation and the Promise of Water for New York City, by Lucy Sante, 2022
Croton, Ashokan, Schoharie, Rondout, Neversink, Pepacton, Cannonsville: these are the places where New York City is plugged into the ground; its hinterlands; its sacrificial infrastructure; its "Chinatown." Ideally the massively extended watershed of the nation's largest city would be as familiar to the city's residents as its museums, businesses, and cultural landmarks are. This book, written by Lucy Sante, who teaches writing and photography at Bard, gets us a bit closer. Wish though that the designers had decided it was more of a photography book, as many of the great historic photos spanning the spread are lost in the gutter.

Underground Empires: Two Centuries of Exploration, Adventure & Enterprise in New York's Cave Country, by Dana Cudmore, 2021
A recent local history book about one of the oldest show caves in the nation, Howe Caverns in Upstate New York. The cave opened to the public in 1842, a few years after the more famous and mammoth Mammoth Cave in Kentucky, and decades before Luray Caverns in Virginia (with its spectacular stalacpipe organ). Howe, long known as a conservative 1950s-kind of cave development (in contrast at least to Secret Caverns, the ragged underdog cave nearby), has had a new owner since 2007, who has made some changes, such as introducing specialized nude tours, and plans to turn the site into a major resort and casino complex.

Shantyboat: A River Way of Life, by Harlan Hubbard, 1953 (University of Kentucky Press Edition, 1977)
The modesty of the life and art of Harland Hubbard and his wife Anna is an inspiration to those who stumble on this old book, which was helped into a wider audience by this edition with an introduction by Wendell Berry, a Hubbard fan. The Hubbards built a shanty boat in 1944, and with their dogs, floated under their own power down the Ohio and the Mississippi over a few years, playing music, painting, writing, cooking, and living day to day, outside of the economy. Once the journey ended, they settled at Payne Hollow, near Louisville, on a steep bank of the Ohio, where they built a house and lived in the same way for many more years (and he wrote a book about that too). The ruins of their homestead recently changed hands, and an effort to restore their legacy has begun, hopefully not too late for the world.

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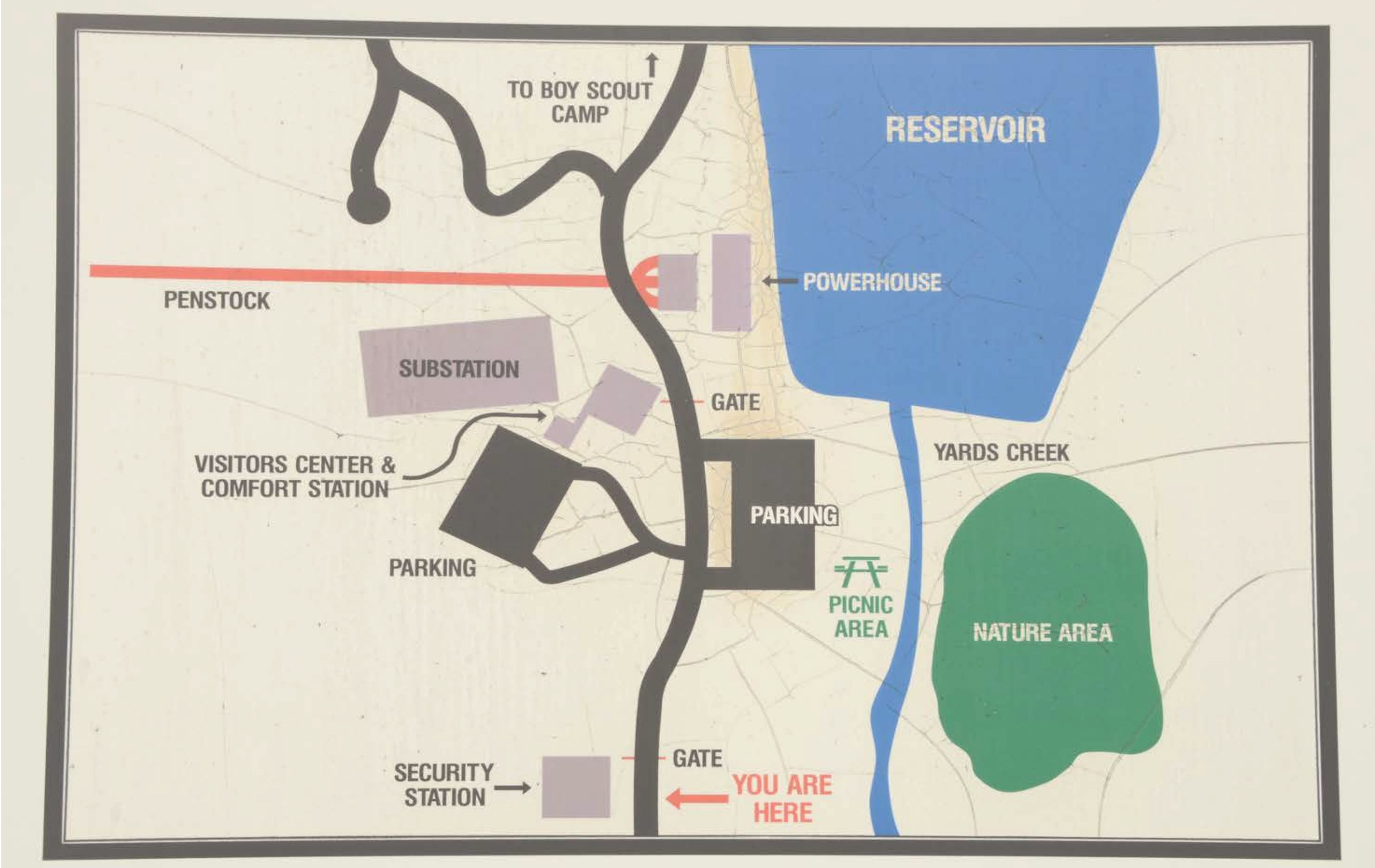

Graphic showing the layout of the now closed public facilities on the grounds of the Yards Creek Pumped Storage Project in New Jersey, near the Delaware Water Gap. CLUI photo

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