

# Hydro Hall of Fame: Honoring Three 100-Year-Old Facilities

*The 1998 Hydro Hall of Fame inductees stand as a testament to the enduring quality of hydropower as a generating source. They are the 11-MW Snoqualmie Falls Plant No. 1 in Washington State, the 22-MW DeCew Falls Plant in Ontario, Canada, and the 1.5-MW Cuero Plant in Texas.*

Established in 1995, the Hydro Hall of Fame honors hydroelectric facilities that share, among other things, the common quality of longevity. Their continued operation illustrates the reliability and durability of hydropower projects.

The 1998 inductees into the Hydro Hall of Fame have unique stories, illustrating that hydropower use differs greatly throughout North America.

Puget Sound Energy's 11-MW Snoqualmie Falls Plant No. 1 was built 100 years ago in the Pacific Coast region of the U.S. In this region, coastal mountain ranges near developing settlements meant that hydropower was key to the development of Seattle and other area cities. Snoqualmie Falls Plant No. 1 was part of this region's growth. The plant also has the distinction of being the first in the world to have a completely underground generating station.

Ontario Hydro's 22-MW DeCew Falls plant, which also celebrates its centennial this year, serves a region where hydro plays an important role in power generation. The facility is Ontario Hydro's oldest generating station still in operation. When the plant was built 100 years ago, it was seen as a monument to Canadian engineering and business expertise. Today, the plant is a working part of Canada's hydroelectric heritage.

The 1.5-MW Cuero plant, which stands deep in the heart of Texas, has

managed to survive a century in a state devoted to power production using oil, gas, and coal. The public's interest in

and South West Services, based in Tulsa, Oklahoma, to provide renewable energy to its customers.



**Snoqualmie Falls: 1998 Hall of Fame Inductee**

Each year more than 1.5 million people visit Snoqualmie Falls in Washington State near Seattle. The thundering waterfall, 100 feet higher than Niagara Falls, leaves visitors awed. Snoqualmie Falls Generating Station No. 1 entered service in 1898 and still operates today.

green power has given the privately owned plant a new lease on life. The Cuero plant has a contract with Central

These three plants join eight others that previously have been inducted into the Hydro Hall of Fame. Previous inductees, their capacities (in MW), locations, and year in service are:

- Bridge Mill Power Station, 1.7, Pawtucket, Rhode Island, 1896;
- Columbia Canal Hydro Plant, 10.6, Columbia, South Carolina, 1896;
- Fulton Hydro Station, 1.25, Fulton, New York, 1884;
- Lanesboro Electric Power Plant, 0.24, Lanesboro, Minnesota, 1895;
- Pelzer Mills Lower Hydroelectric Project, 3.3, Williamston, South Carolina, 1895;
- Stairs Station, 1.2, Salt Lake City, Utah, 1895;
- T.W. Sullivan Plant, 16, Oregon City, Oregon, 1895; and
- Vulcan Street Hydroelectric Central Station, 0.0125, Appleton, Wisconsin, 1882.

Though each inductee has a different history, they have much in common. These plants have provided reliable, low-cost electricity for decades. Today's technology is dependent on electricity, and hydropower plays an important role. Hydropower is particularly important because it is sustainable, renewable, and provides clean power without emissions. The fact that these three facilities are operating 100 years after they were constructed is testament to the enduring quality of hydropower as a electricity source.

# Snoqualmie Falls No. 1:

*World's First Underground Generating Station Celebrates Centennial*



The Snoqualmie Falls Hydroelectric Plant No. 1, located on the Snoqualmie River about 25 miles east of Seattle, has carved a prominent place for itself in the annals of hydroelectric history. The plant, which celebrates its centennial in 1998, was the first in the world to have a completely underground electric generating station. It also was the first hydroelectric facility in the region to utilize a natural waterfall. The plant demonstrated the potential for other hydroelectric projects in the Cascade Mountain Range. Construction of the project reflected significant engineering and technological accomplishments. For example, the project is recognized as unique for combining a high waterfall with a power plant constructed in a cavity behind the base of the falls.

## Setting the Stage

The demand for power in Seattle grew

enormously in the last two decades of the nineteenth century. In 1885, Mitchell and Spalding Company developed the first centralized electricity production for Seattle, Bellingham, Tacoma, and other cities in western Washington State, where a number of different local customers were served from a common generation site. Numerous small systems were developed in less populated areas of the state to power lumber mills, coal mines, and food processing plants. Seattle's hilly terrain motivated the replacement of horse-drawn streetcars with electrified streetcars, beginning in 1889. This followed the introduction of incandescent lighting by the Seattle Electric Light Company in 1886.

One person involved in the development of electrified transportation was Charles H. Baker, a civil engineer who had previously been employed by the

Seattle, Lake Shore and Eastern Railroad. While working for the railroad, Baker had become familiar with the Snoqualmie Valley. Baker believed that the 268-foot-high Snoqualmie Falls could be used as a source of hydroelectric power. Although the falls were more than 25 miles from Seattle and Tacoma, the construction of the Niagara Falls power plant in northern New York State (completed in 1895) demonstrated the feasibility of locating a generating plant at a site removed from urban and industrial areas and transmitting the electricity long distances.

Baker also realized that consolidation of the main streetcar lines, bankrupted by the financial panic of 1893, could produce the electrical load and revenue needed to make the construction of a power plant at Snoqualmie Falls economically feasible. In 1897, he obtained an option to buy the necessary property at Snoqualmie Falls and all but one of the streetcar lines in Seattle.

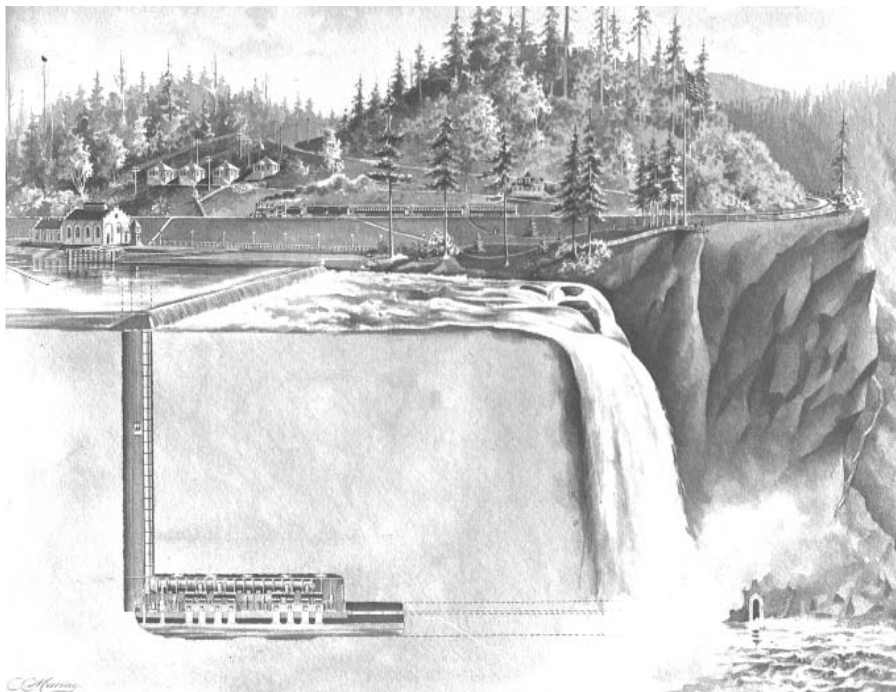
Baker presented his power plant proposal to his father, William Taylor Baker, president of the Chicago Board of Trade, who organized the financial backing for the project. The Bakers agreed to form the Snoqualmie Falls Power Company as equal partners and to keep their agreement secret. The titles to the real estate, water rights, and equipment were put in William Baker's name to protect them from debts incurred by Charles as a result of the 1893 financial panic.

## Constructing the First Underground Electric Generating Station

Construction of the Snoqualmie Falls power plant began in April 1898 under the sole direction of Charles Baker. None of the work was contracted out, and the laborers worked three shifts around the clock.

Because of the problems associated with exposing generating machinery to constant mist and seasonal freezing weather, Baker decided to place the generating plant in a cavity hollowed out 270 feet beneath the Snoqualmie River, and 300 feet upriver from the edge of the falls. This internal location would ensure a dry generating plant with a constant temperature regardless of external weather conditions.

Workers used compressed air drills to bore intersecting vertical and horizontal shafts through basaltic rock and to excavate the internal cavity. The vertical shaft (10 feet wide by 27 feet high) pro-



This artist's rendering of the Snoqualmie Falls Hydroelectric Project, located 25 miles east of Seattle, shows the underground cavity generating station, excavated out of solid rock 270 feet below the Snoqualmie River. During construction, the site was a working village, with company housing and dormitories for the workers.

vided access to the cavity for the elevator, penstock, and power lines. The horizontal shaft (12 feet wide by 24 feet high by 450 feet long) became the tunnel for the tailrace and catwalk that led from the cavity to the high-water mark at the base of the falls. The excavation of the vertical shaft required the construction of a cofferdam to prevent flooding in the event of high water.

Workers removed the excavated rock through the vertical shaft with a hoist. The cavity, which measured 200 feet long, 40 feet wide, and 30 feet high, housed the generating equipment and control room. Workers lowered the equipment into the cavity using only a cable because a crane was not available at the site until 1901.

About 150 feet downriver from the plant intake, workers built a 217-foot submerged concrete gravity dam to raise the low water elevation by 6 feet at the intake. The dam rested on the bottom of the river on a natural rock ledge about 3 feet high and was constructed during low water.

New technology made it possible to gain maximum benefit from western water sources, often characterized by high head conditions and a low volume of water. The placement of the four generators within the cavity below Snoqualmie Falls meant that the availability of high head did not require an elaborate water conveyance system of dams, flumes, pipelines, canals, embankments, and dikes, which often characterize other western hydroelectric power plants. The downward flow of water through the 270-foot-long, 7.5-foot-diameter penstocks produced the high head necessary to generate power. After workers conquered the enormous construction challenges, the plant was completed and began generating electricity at the end of 1898. The plant supplied the first commercial power to Seattle and Tacoma on July 31, 1899.

In 1901, Baker formed the Seattle Cataract and Tacoma Cataract companies to sell the power purchased from the Snoqualmie Falls Power Company. The plant supplied most of the electrical needs of Seattle's and Tacoma's 120,000 residents and small communities near switching stations along the main transmission line.

### Baker's Downfall and a New Owner

Under Baker's leadership, the Snoqualmie Falls Power Company was unable to make a profit. Baker had



In 1900, the grounds of the Snoqualmie Falls Hydroelectric Project resembled a park, and the Transformer House was characterized by stepped end parapets, a gable roof, and tall, arched windows. The small building with the pointed roof housed the elevator to the underground generating station. (Courtesy Museum of History and Industry)

failed to consolidate completely the competitive and unregulated Seattle streetcar market. In addition, he faced continued criticism from business rivals that the power supply from his plant was unreliable. Then in 1903, a fire destroyed the transformer house and damaged all but one of the generators. The fire put the plant out of operation for 36 hours, and repairs limited power output for three weeks. To compound Charles' problems, William Baker died in 1903

and his secret partnership with his son wasn't recognized in the courts. As a result, Charles Baker was denied any interest in the Snoqualmie Falls Power Company.

The courts liquidated the company's assets and the Snoqualmie Falls Power Company was succeeded by the Snoqualmie Falls and White River Power Company. The new owners added a fifth generator to the plant in 1905. This increased plant capacity by 5 MW.

## Technical Information *Snoqualmie Falls No. 1*

### General Information

*Location:* Near the town of Snoqualmie, about 25 miles east of Seattle

*Owner:* Puget Sound Energy

*Capacity:* 11 MW

*Head:* 270 feet

*Type of Project:* Run-of-River

*Average Streamflow:* 2,684 cubic feet per second

*Annual Generation for both Snoqualmie No. 1 and No. 2:* 299,000 megawatt-hours

*On-Line Date:* 1898; first commercial generation on July 31, 1899

### Equipment

**Turbines** (5 units)

4 multiple runner, horizontal, Pelton impulse-type waterwheel turbines, 300 rpm

1 horizontal Francis-type, single discharge, 300 rpm

**Generators** (5 units)

4 horizontal shaft, stationary field generators, three-phase, 60 cycle, 2,000 volts

1 conventional rotating field, horizontal-type generator, three-phase, 60 cycle, 2,000 volts

### Construction

**Intake**

2 7.5-foot-diameter, 270-foot-long steel penstocks

**Powerhouse**

Constructed in a cavity excavated out of the rock 270 feet below ground  
200 feet long, 40 feet wide, 30 feet high

**Transmission**

115-kV lines connected to Puget Sound Energy's grid

After the Pacific Coast Power Company bought the White River property, the Snoqualmie Falls Power Company and the Seattle and Tacoma Cataract Companies consolidated to form the Seattle-Tacoma Power Company. In 1912, the Stone and Webster Managerial Association acquired the Seattle-Tacoma Power Company. The company was incorporated as Puget Sound Traction, Light & Power Company, a forerunner of Puget Sound Power & Light Company (Puget Power), which became Puget Sound Energy in 1997.

Numerous modifications have been made to the Snoqualmie Falls Hydroelectric project over the years to keep the equipment current. In 1910, a second Snoqualmie Falls plant was built one-

quarter mile downstream from the first plant. Plant No. 2, which was enlarged in 1957, contains two generating units, bringing the total capacity of the combined Snoqualmie Falls Hydroelectric projects (plants 1 and 2) to 42 MW.

### Snoqualmie Falls Plant No. 1 Today

Today, the Snoqualmie Falls Hydroelectric Project is located within Snoqualmie Falls Park. The 2-acre park ranks second to Mount Rainier among the state's scenic attractions. More than 1.5 million visitors a year view the waterfall, which is 110 feet higher than famed Niagara Falls. Since 1967, Puget Sound Energy has undertaken extensive development of recreational facilities at the park. Improvements include an

observation platform above the river, a trail to a lower observation deck, and picnic areas. An independently owned lodge, restaurant, and gift shop are also at the site.

Park visitors are awestruck by the thundering waterfall—just as Charles Baker was more than 100 years ago. Baker's appreciation for the waterfall's power motivated him to begin plans to accomplish an engineering project that is still impressive by today's standards—Snoqualmie Falls Generating Station No. 1.

—By *Connie Freeland*, regulatory technical specialist, Puget Sound Energy Inc., P.O. Box 97034, OBC-14N, Bellevue, WA 98009-9734; (425) 462-3556.

## DeCew Falls No. 1:

*Part of Canada's Hydroelectric Heritage*



**D**eCew Falls Generating Station No. 1 in St. Catharines, Ontario, Canada, is part of a strong hydroelectric heritage. The facility is Ontario Hydro's oldest generating station still in operation. Built in 1898 by the Cataract Power Company, the station was purchased by Ontario Hydro in 1930. Water to power the station is drawn from the Welland Canal at Allandburg, which is 65 miles from Toronto, and transported through a system of man-made, company-owned canals and the Lake Gibson Reservoir.

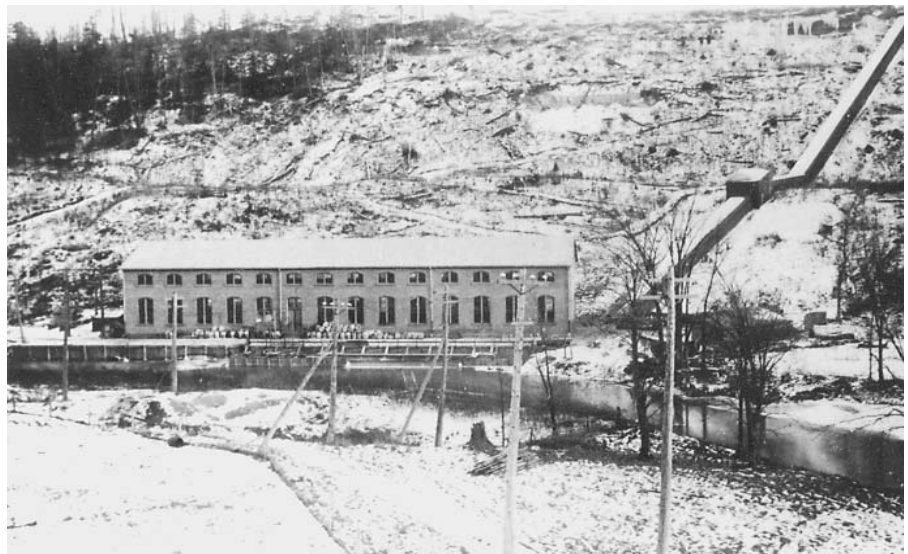
### Sharing the Vision

In July 1896, John Patterson, a lumber mill operator and property developer in the town of Hamilton, Ontario, (at the west end of Lake Ontario), devised a plan to harness the power of DeCew Falls and transmit electric power to Hamilton. He convinced four other men to help him launch the Cataract Power Company of Hamilton five months before the occurrence of the first long-distance transmission of electricity from Niagara Falls to Buffalo. The other founding members of the company were

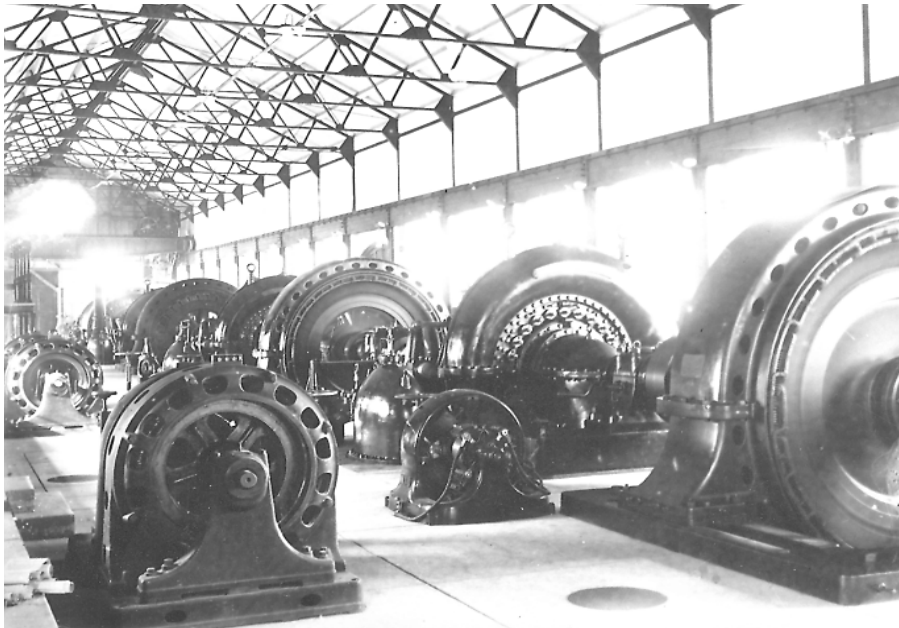
Hon. John Gibson, a lawyer, member of the legislature, and later Lieutenant-Governor of Ontario; John Moodie, owner of the Eagle Knitting Company who financed much of the venture; John

Dickenson, a contractor and member of the legislature; and John Sutherland, a contractor and former employee of the Grand Trunk Railway.

Patterson's original plan was to develop an electric power plant at DeCew Falls on Beaverdams Creek. However, in July 1897, the partners toured the site and determined that the natural flow in Beaverdams Creek was too low, that water could be diverted from the Welland Canal (which was built by local entrepreneurs in 1829 to carry ship traffic between Lake Erie and Lake Ontario), and that a location of about a half of a mile to the east



The powerhouse at the 22-MW DeCew Falls Plant No. 1 was built in 1898 and is part of Ontario Hydro's oldest generating station still in operation. The facility is located in St. Catharines, Ontario, Canada.



The original generators at DeCew Falls Plant No. 1 were designed by the Royal Electric Company of Montreal. The company also designed the plant, the transmission line to the nearby town of Hamilton, and the transformer station in Hamilton.

provided an additional waterfall of 80 feet—the total drop at the site is 261 feet.

### Pursuing the Venture

A water supply of 100 cubic feet per second from the Welland Canal for the new plant was leased by the Cataract Power Company of Hamilton from the Dominion of Canada under an agree-

ment signed on October 8, 1897. Construction then began on the 4-mile-long water diversion canal. The “Klondyke,” as it was known locally, carried water across the Beaverdams Valley in a wooden flume that was up to 40 feet high to three already existing storage reservoirs totaling 32 acres. A single steel penstock 6 feet in diameter supplied water to the original turbines.

## Technical Information

### *DeCew Falls No. 1 Hydro Plant*

#### General Information

*Location:* St. Catharines, Ontario, on the Welland Canal

*Owner:* Ontario Hydro

*Capacity:* 22 MW

*Head:* 265 feet

*Average Streamflow:* 1,200 cubic feet per second

*Type of Project:* Diversion canals and reservoir system

*Average Annual Generation:* 72,000 megawatt-hours

*On-Line Date:* August 25, 1898

#### Equipment

**Turbines** (4 units)

Francis

Manufactured by J.M. Voith

257 rpm

5,000 horsepower

**Generators** (4 units)

Manufactured by Canadian Westinghouse Co.

Synchronous

3 phase; 60 Hertz; 2,400 volts

#### Construction

**Powerhouse**

Constructed of iron and brick with galvanized iron over wood roof

42 feet wide; 174 feet long

**Headworks**

4 intake gates

Electrically operated

**Transmission**

44-kV line extending 1/4 mile, stepped up to 115 kV and then ties into the Ontario Hydro grid

The Royal Electric Company of Montreal was hired by the Cataract Power Company of Hamilton to design the plant, its two 1-MW generators and 1,700-horsepower turbines, the transmission line to Hamilton, and the transformer station in Hamilton. Plant construction began on October 5, 1897. Lone & Farrell of Hamilton built the 35-mile, 22,400-volt transmission line along a right-of-way secured from the Grand Trunk Railway. Finally, the project came together on August 25, 1898, when electricity was transmitted from the plant over the line to Hamilton to power local industry and the electric railways.

Two additional turbine-generators (of 2 MW each) completed the original development in 1903. Demand for electricity continued to grow. In 1904 and 1905, the Cataract Power Company contracted with Westinghouse Electric and J.M. Voith to supply four 5-MW turbine-generators. These new units required an increase in water supply and expansion of the Lake Gibson reservoir. Cataract Power Company was responsible for the expansion. In 1911, the powerhouse was completed with the final two turbine-generators (of 5 MW each). Total plant capacity was 36 MW.

### DeCew Falls Today

DeCew Falls Generating Station No. 1 was acquired by the Hydro-Electric Commission of Ontario (later renamed Ontario Hydro) on August 14, 1930. The original four generators continued to operate until they were retired in 1967. Two of the 5-MW generators are no longer operating. The remaining four operating generators can generate 22 MW of electricity.

When electricity was needed to power industry during World War II, the commission responded by building DeCew Falls Generating Station No. 2. Its two generators went into service in 1943 and 1947, and generate more than 140 MW annually.

When DeCew Falls Generating Station No. 1 was built 100 years ago, it was seen as a monument to Canadian engineering and business expertise. Today, the plant is a working part of Canada's hydroelectric heritage.

—By Bob Osborne, public affairs officer, Ontario Hydro, P.O. Box 219, Queenston, Ontario LOS ILO Canada; (905) 357-6903.

# The Cuero Hydroelectric Plant:

*A Maverick in Texas*



The dam at the Cuero hydroelectric plant near Cuero, Texas, was built 100 years ago by men who defied convention and were willing to take risks. In 1984, after sitting idle for nearly 20 years—and after having suffered serious damage from several floods—the 1.5-MW plant at the dam site was painstakingly restored by two entrepreneurs. The plant's current owners face what may be the greatest challenge to date—helping the hydro facility carve out a profitable niche in a state devoted to power generation from oil, gas, and coal.

## A Dam Takes Shape

Plans for the dam began to develop when brothers Otto and August Buchel consulted with George Westinghouse at the 1893 World's Fair about the superiority of alternating current (AC) over the then widely used direct current (DC). Convinced by Westinghouse's logic, the brothers built the AC generation and distribution system in 1898. The 10-foot-high dam was built on the Guadalupe River 100 miles east of San Antonio. The gamble paid off when the facility effectively generated electricity

and provided irrigation for strawberry and cotton crops on the surrounding land, which was owned by the Buchel family. (One risk August Buchel didn't anticipate was the risk to his personal safety. He died at the plant six months after its dedication when his watch chain caught in the machinery's open cog wheels.)

After the Buchel brothers, a succession of six owners operated the plant. Then in 1965, damage from a flood brought the plant to a standstill. It sat idle for nearly 20 years. In 1984, the power generation potential of the plant caught the eye of a local business owner who needed power for a new ice manufacturing plant. The plan was to take water from the river, generate electricity for use at the ice plant, and sell any excess power. It turned out to be a monumental task.

## Restoring the Plant

Repeated damage from high water and financial setbacks inhibited the project's progress. In 1989, Jimmy Parker, a Texan who had restored two similar plants on the San Marcos River, was asked to help with the project. Parker

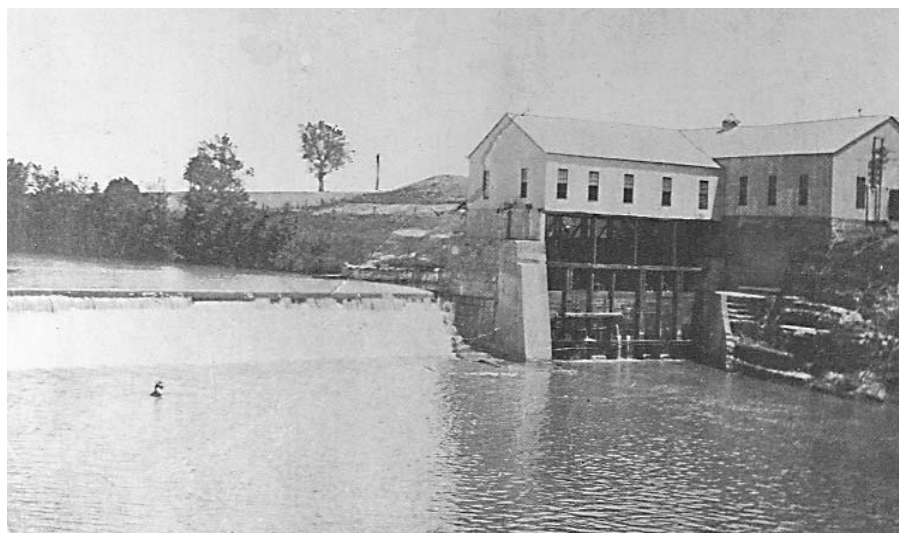
also had built another hydro plant for private use on Onion Creek near Austin, Texas, and had served as a consultant in the field of electricity generation and energy use efficiency. With Jimmy Parker and his wife Linda heading the project, Cuero Hydroelectric, Inc. was incorporated in 1990. During the next four years, in the midst of substantial flooding, they rebuilt the facility. They disassembled and repaired the turbines and governors, and designed state-of-the-art control systems. Nearly every part of the facility was rebuilt, including the dam. Finally, in the winter of 1993, the Cuero hydro plant was back in operation.

The Parkers signed a contract with the city of Cuero in December 1991 based on energy, demand, and backup with a variable rate, depending on whether the power is generated during peak electricity use periods. So far, the plant has generated a total of more than 29 million kilowatt-hours.

## A 'David' among 'Goliaths'

The Cuero plant is the only small hydroelectric plant in Texas (with a capacity greater than 50 kW) that is not owned by a utility or river authority. In 1995, the Parkers changed the name of the company owning the plant to Small Hydro of Texas to reflect this fact. Further upgrading has since been completed, including rewinding and upgrading each generator; driving steel piling for the downstream apron; and raising the dam 3 feet.

The project has benefited from the public's growing interest in "green power." The Parkers were approached by Central and South West Services, based in Tulsa, Oklahoma, about the possibility of contracting with Small Hydro of Texas to provide renewable energy to its customers. Central and South West Services mailed information about renewable energy to all its customers in Texas, Oklahoma, and Arkansas through a marketing program called "Clear Choice." Through the program, a customer can pay an extra \$5 per month to purchase 250 kilowatt-hours of renewable energy and prevent approximately 3,000 pounds of carbon dioxide and nitrogen oxide emissions (which would be produced by fossil-fueled plants) from entering the environment. For the customer, this has an environmental effect similar to not driving their car 1,500 miles. Customers can pay up to \$20 more per month to



This photograph shows the 100-year-old dam at the Cuero Hydropower Plant as it appeared in 1908. The 12-foot-high dam was constructed of stone and concrete in a staircase design. The facility is owned by Small Hydro of Texas.



The plant sat idle for 30 years after it was nearly destroyed by flooding. In 1990, Jimmy Parker and his wife Linda rebuilt the facility. Modern switchgear was added. The generators, governors, and turbines were completely refurbished, upgrading the plant to 1.4 MW. In the winter of 1993, the Cuero hydro plant was back in operation.

prevent a larger amount of emissions from entering the environment.

A customer survey revealed that the most interest in the program came from San Angelo, Texas, where 0.5 percent of the residents indicated they were willing

to pay extra to participate in a green program.

After the marketing program, Small Hydro of Texas and Central and South West Services entered into a contract in 1996. Small Hydro of Texas is paid 3.15

cents per kWh for power purchased under the Clear Choice program.

A pilot green power program is currently underway with interested residents of San Angelo. Central and South West Services plans to request a tariff from the Texas Public Utility Commission in the fall of 1998, allowing the utility to offer green power to all its customers in Texas, Oklahoma, and Arkansas. The Parkers hope that the Cuero plant's years of generation will encourage other individuals in the state to develop abandoned hydro sites and restore them to useful energy production. Approximately 40 such sites, of varying size and condition, exist in Texas.

The Cuero hydroelectric plant has had a colorful past. With growing interest in green power, the plant's future looks optimistic. The Parkers hope to continue the facility's maverick tradition.

—By Jimmy and Linda Parker, owners, *Small Hydro of Texas, HCR 64, Box 6B, Cuero, TX 77954-9780; (512) 275-9395.*

## Technical Information

### *Cuero Hydroelectric Plant*

#### General Information

*Location:* On the Guadalupe River, 3 miles northwest of the town of Cuero, Texas

*Capacity:* 1.5 MW

*Head:* 15.9 feet

*Average Mean Flow:* 1,100 cfs

*FERC License Exemption Number:* 5147

*Owner:* Small Hydro of Texas, Inc., Jimmy C. Parker, president

#### Equipment

##### Turbines (3 units)

Fixed blade Francis-type manufactured by Allis Chalmers

800 horsepower at 80 percent efficiency of generator and turbine

370 cfs rated flow

##### Generators (3 units)

600 kVa synchronous

Manufactured for Allis Chalmers by Westinghouse (Delco-style)

Vertical shaft

200 rpm

3-phase, 2,400 volt

36-pole with DC exciters

##### Governors

Hydraulic governors manufactured by Sorensen

#### Construction

##### Powerhouse

61,000 square feet

Steel frame

Concrete floor

Sheet metal roof and exterior

##### Penstocks (3)

5-foot-thick exterior walls made of stone and concrete

1-foot-thick interior walls made of reinforced concrete

3-foot-thick steel reinforced concrete floor

##### Gates

Two gates per penstock

10 feet wide, 22 feet high

Wooden

Raised by 5-ton electric hoist

Lowered by weight and hydraulics when needed

##### Tailrace

2-foot-thick steel reinforced concrete floor

60 feet wide

Extends 50 feet downstream

##### Dam

Original dam of stone and concrete construction

Capped with concrete, reinforced with 5/8-inch steel rods on 6-inch centers horizontally and vertically, anchored to original dam by steel rods drilled 1 foot into original structure

30-foot-base, 15.9 feet high, 139-foot overflow section with a 4-foot-wide crest, 140-foot non-overflow bulkhead, 80-foot steel piling anchor into earth bank

Forebay and main dam foundation fronted by 15-foot steel pilings driven into hard clay

##### Tailwater Skirt

139 feet wide by 50 feet downstream by 2-foot-thick reinforced concrete with 2-foot-wide by 6-foot-deep concrete beams along the perimeter and across the center

##### Trashrack

1/4-inch by 4-inch steel bars welded in 4-inch centers by 20 feet high installed in front of penstocks

##### Log Diversion

Pre-stressed concrete beam 4 feet high by 6.5 feet wide by 99 feet long across the forebay

##### Transmission

Utility-run 12,470-kV line runs 70 feet to utility breaker