Battle Creek Hydroelectric System
Battle Creek and its tributaries
Shasta and Tehama Counties
California

Red Bluff Vicinity

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PHOTOGRAPHS

HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Department of the Interior
Washington, D.C. 20240

HISTORIC AMERICAN ENGINEERING RECORD

Battle Creek Hydroelectric System

CA-2

Location: Volta, South, Inskip and Coleman Powerhouses are located along Battle Creek and its tributaries in Shasta and Tehama Counties, northern California.

Date of Construction: Volta (1901); South (1910); Inskip (1910); Coleman (1911).

Present Owners: Pacific Gas and Electric Company

Present Use: The original powerhouses are being demolished and replaced by new fully automatic powerhouses.

Significance: The Battle Creek hydroelectric system was a typical turn-of-the-century California hydroelectric system, characterized by high head plants, the use of the impulse wheel as a prime mover, and long water gathering networks.

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ABBREVIATIONS

CRRC	California Railroad Commission
CSA	California State Archives (Sacramento, California)
CSMB	California State Mining Bureau
JE	Journal of Electricity, Power and Gas
NCPC	Northern California Power Company
NCPC-C	Northern California Power Company, Consolidated
PG&E	Pacific Gas and Electric Company
R/V	Rates and Valuations Department Records, Pacific Gas and Electric Company

INTRODUCTION

The status of a particular technology at a particular time often can be best understood through the study of a specific example of that technology which is "characteristic" or "typical". In some ways the subject of this study, the Battle Creek hydroelectric system, can be considered a characteristic or typical turn-of-the-century Pacific Coast hydroelectric development. It shared many of the peculiarities which distinguished Pacific Coast (or more specifically California) hydroelectric engineering practice from hydroelectric practice in the eastern two-thirds of the United States and most of the rest of the world. These characteristics -- high head/low volume plants; long water gathering networks; the use of the impulse wheel; and long distance power transmission -- are reviewed in the opening chapter of this study.

To some extent the company which erected the Battle Creek hydroelectric system, the Northern California Power Company (NCPC), was typical of the many small power companies that emerged in the decades immediately following the development of electric power distribution. Established to meet a perceived need for electric power, Northern California slowly extended its tenacles into surrounding territories and expanded its generating capacity. Like many utilities in the early years of the electric power industry it suffered from periodic excess generating capacity, from the reluctance of certain classes of customers to electrify, from difficulties in raising capital, and from rate wars with other utilities.

Thus the importance of the Battle Creek hydroelectric system and the company which built it does not lie in their uniqueness (although there were some elements unique to both), or in the impact which they had on the electrical power industry or on hydroelectric engineering. Instead it lies in the fact that they were typical of the California electric power industry and representative of California hydroelectric practice at the turn-of-the-century.

CHAPTER I

BACKGROUND:

The Emergence of Hydroelectric Power in California

What elements distinguished a "typical" California hydroelectric plant in the early twentieth century from hydroelectric installations in the eastern two-thirds of the United States? First, California plants were usually supplied with water by a system of canals or ditches miles in length. In the East, by contrast, the artificial water network for a hydroelectric plant usually consisted of no more than a dam and a single, relatively short, head-race. California hydroelectric plants usually utilized medium to high heads (above 200 feet) with low water volumes (almost invariably below 2000 second-feet and often well below 1000 second-feet). The typical Eastern plant was a mirror image of this, operating with low heads and high volumes. East and West also depended on different prime movers. The prime mover most widely applied in California at the turn-of-the-century was the Pelton or free jet tangential impulse wheel. In the East the Francis mixed-flow turbine was favored and impulse wheels with their characteristic high pressure piping and jet nozzles were very rare. Finally, in the East the early electric power companies largely confined both their generating and distribution activities to urban areas. Most power generated was consumed locally (say within a 10 mile radius of the plant) and utilities were very heavily dependent on lighting for their power load. In California and much of the West, on the other hand, power was usually generated at a considerable distance from the consumer. As early as 1900 the transmission of electricity more than 30 miles was common in California, and by 1910 California plants typically transmitted power more than 100 miles. Moreover, electric utilities in the West, far earlier than those in the East, cultivated a highly diversified power load. Many Western utilities developed an agricultural load (farm lighting, electric irrigation pumps) to complement their urban lighting and power loads. [1]

Many of the unique features of California hydroelectric practice outlined above — high head/low volume plants; the use of the impulse wheel; extensive water networks; long distance power transmission -- were, either directly or indirectly, influenced by California's geography.

GEOGRAPHY

Two elements of California's geography strongly influenced the nature of early hydroelectric development in the state -- rugged topography and highly seasonal (and often scarce) rainfall. The latter was a deficit to hydroelectric development; the former an asset which offset it.

Precipitation in California is highly seasonal, partially because the relatively cold Pacific Ocean off the coast yields few rainstorms in the summer months. Only in winter, when the ocean waters are warmer than the land, do moisture-laden clouds move inland with any frequency. Sacramento is typical. The average annual rainfall is only around 20 inches. Very little of this falls during the summer months. The average rainfall in the city during the six months between May 1 and October 31 is only around 10% of the annual average, and in the four months from June through September the figure is much lower — 1.75%. [2]

Becsuse rainfall is concentrated in the winter months, the soil can not absorb the water and most runs off quickly. Without extensive water storage systems most California streams have highly seasonal flows, flooding in winter, reduced to a trickle or even dried up during the summer (see Table 1, following page). Moreover, in many areas, topographical conditions make even the construction of the needed storage reservoirs impractical or prohibitively expensive.

The highly seasonal and often scarce nature of California's rainfall is, however, counterbalanced for power development by the rugged nature of the state's typography. California is a mountainous state. The extreme northern part of the state is completely covered by the Cascade mountains, and the state is enclosed on east and west by two almost parallel ranges -- the Coast Range and the Sierra Nevada. In fact, almost two-thirds of California's surface area is rugged and broken terrain potentially suitable for the development of economical water power.

Running along the Pacific shore is the Coast Range. The peaks of this system have summits some 2000 to 3000 feet high. This system intercepts much of the moisture which moves inland in winter from the Pacific and thus contributes to the scarcity of water in the state's interior. Unfortunately, its relstively flat gradients make large water storage reservoirs impractical. The flow of the area's streams is erratic and the economic development of water power here is difficult (though not impossible).

The Sierra Nevada, however, presents a different picture. The rain that escapes the Coast Range, much diminished in volume, is eventually intercepted by this chain. Its summits are much higher, from 8000 to 14,000 feet above sea level, and its western slope descends at a relatively sharp angle. Streams flowing westward from the Sierra quite frequently drop more than 100 feet per mile, in contrast to the 10 to 15 feet common to streams in the eastern United States (see Tables 2 and 3, two pages below). Over the ages these steeply descending streams have gorged out deep canyons which are separated by high ridges and plateaus which slope more gently westward than the streams. This creates a terrain ideal for power production. Water can be taken from a stream, led by flume, ditch, or canal to the top of a ridge or plateau snd then along it until, some miles downstream, a fall of hundreds of feet has been developed. The water can be dropped, at that point, through penstocks and turbines, back to the original stream. This approach to power generation makes up in high head or fall what California streams lack in volume.

Table 1:

Variable Flow in California Streams: Two Examples

	Mean monthly discharge in second feet in 1909-1910	
	Putah Creek Winters, CA	American River Fairoaks, CA
October	16.2	511
November	59.1	4590
December	745	7670
January	1120	8520
February	644	5240
March	762	10500
April	300	10500
May	87.7	7950
June	26.3	2260
July	7.85	516
August	5.27	213
September	2.67	201

H.D. McGlashan and F.F. Henshaw, Water Resources of California, part 1, Stream Measurements in Sacramento River Basin (Washington, D.C.: Government Printing Office, 1912) [U.S.G.S. Water-Supply Paper 298], pp. 313, 383.

Table 2:

Fall of Rivers in the Eastern United States and in California

	length (miles)	total fall (feet)	fall/mile
EASTERN RIVERS:			
Kennebec	138	1023	7.4
Merrimac	110	269	2.4
Connecticut	375	2038	5.4
Hudson	300	4322	14.4
Passaic	86	240	2.8
Delaware	280	1886	6.7
James	246	463	1.9
Mississippi	2296	1462	0.6
Ohio	963	702	0.7
CALIFORNIA RIVERS:			
Sacramento	399	7000	17.5
Pit	196	4800	24.5
Feather	136	4678	34.4
Yuba	90	6700	74.4
American	118	8500	72.0
Mokelumne	116	8000	70.0
Stanislaus	113	8000	70.8

Henry Gannett, Profiles of Rivers in the United States (Washington, D.C.: Government Printing Office, 1901) [U.S.G.S., Water-Supply Paper 44].

Table 3:

Rate of Fall of Some Typical California Streams in Feet per Mile between 500 Foot Contours

	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	4000-4500	4500-5000	5000-5500	5500-6000	6000-6500
Pit River	27	78	39	24	19	72					
Feather R. middle fork	114	63	74	73	83	94	22				
Yuba River middle fork	74	88	96	89	139	139	250	357	208	104	
American R. middle fork	83	111	178	208	227	218	208	227	88	119	
Mokelumne R.	114	167	96	68	78	96	132	147	208	218	192
Stanislaus R. north fork	96	250	333	357	208	132	139	104	125	357	227

Frederick H. Fowler, Hydroelectric Power Systems of California and Their Extensions into Oregon and Nevada (Washington, D.C.: Government Printing Office, 1923) [U.S.G.S. Water-Supply Paper 493] p. 15

Both the low volume of many California streams and the necessity of making up for this with high heads strongly influenced the development of extensive water gathering or ditch networks. Because water volumes in many streams were low, it was often necessary to divert and collect water from several streams some miles apart by a ditch network until a sufficient volume was available. Even this volume was often rather small. It often had to be led by ditch or canal or flume for thousands of feet up the side of or on top of a ridge or plateau before the head available was high enough to generate a significant amount of power.

In addition to steep falls, the western slopes of the Sierra offer other characteristics favorable to power development. Much of the precipitation that escapes the Coast Range falls on the Sierra at altitudes above 5000 feet in the form of snow. The moisture thus does not immediately flow away as in the Coast Range. Instead it is stored and begins to run off only with the coming of spring and summer warmth. Although the quantity of water stored at high altitudes in the form of snow is not sufficient to give the streams of the Sierra a regular flow, it does help even out flow conditions, decreasing the period of deficient flow and reducing the artificial storage capacity required for efficient bydroelectric power generation.

Thus the comparatively limited water supply available in the California interior and the seasonal nature of California's rainfall, coupled with the state's rugged geography, have strongly influenced both the development of extensive systems for the storage, collection, and diversion of the available water and the erection of high head/low volume hydroelectric plants.

California's geography also influenced the early development of long distance electric power transmission in the state. The streams flowing from the western slope of the Sierra Nevada, as noted, were best suited for power development because of their steep falls and relatively uniform flow. But the rugged nature of the region, its geographical isolation, its poor soil, and its dry summers meant that the western slopes of the Sierra were sparsely populated. California's population and industrial centers were concentrated on the western edge of the state in the few spots where breaks in the Coast Range had provided passable barbors (San Francisco, San Diego, and, thanks to an artificial harbor, Los Angeles). Since the best points for hydroelectric power generation and the largest power markets were many miles apart, California utility companies pioneered in the development of a technology suitable for long distance power transmission.

As this technology emerged between 1895 and 1910 virtually every major California power company eventually sought, either through lines of its own, or through interconnections with other power companies, to tap the large market for electrical energy of the states two major urban centers -- San Francisco and Los Angeles. And aince power lines reaching westward from the Sierra crossed the rich agricultural areas of California's Central Valley, power companies, with small additional investment, could and did deliver electric service to agricultural areas very early. In the East, where generating plants were located relatively short distances from the urban areas where their power was consumed, lines into rural areas would have required a large additional investment. Hence Eastern hydroelectric plants, unlike California hydroelectric plants, seldom served rural areas. [3]

THE MINING TRADITION

California geogrpahy had a major influence on the unique tradition of hydroelectric engineering that grew up in the state around 1900. California's mining heritage, however, also had a significant impact on the emergence of this unique tradition in three specific areas:

(1) the development of the extensive ditch or canal networks typical of many California hydroelectric plants;
(2) the emergence of the tangential impulse or Pelton wheel, the characteristic prime mover of turn-of-the-century California hydroelectric plants; and
(3) the evolution of a legal system favorable to the development of hydroelectric power in California.

Following the discovery of gold in the mountains of California in the mid-nineteenth century, mining became a major industry in the state. Mining has always required large volumes of water, either to wash away unwanted debris from the desired metals and ores, or, in conjunction with water wheels, to power pumps, hoists, and processing equipment. Many mines in the relatively dry interior of California were not adjacent to constantly flowing streams, and thus required rather extensive water gathering and storage systems. By the 1860's over 5000 miles of artificial water courses had been constructed to provide water to mines, and by the 1880's there were 8000 miles of them. Many of these ditches were later incorporated in the hydraulic systems of hydroelectric plants. For instance, one of the canals which provided water to the De Salba hydroelectric plant (completed in 1903-04) was the Butte Creek Canal. The diversion dam that fed water into the canal and the canal itself were built in 1871 by the Cherokee Mining Company to provide water to nearby mines. The Phoenix hydroelectric plant in central California (constructed 1898) derived its water supply from an old mining ditch, and the Halsey plant (completed 1916) in Placer County was dependent for water on the Bear River Canal, originally constructed in the 1850's to supply water for hydraulic mining. Finally, one of the earliest of the five hundred plus companies eventually welded into the Pacific Gas and Electric Company (PG&E), today one of the nation's largest producers of electric power, was the Rock Creek Water Company, which in 1850 constructed a 9 mile long ditch in conjunction with a dam and reservoir to supply the water needs of the mining areas of Nevada County, California. Ultimately most of the hydroelectric systems of northern and central California included at least portions of ditch and reservoir systems originally developed for mining (or in some cases for irrigation). [4]

In addition to ditch networks for gathering, storing, and distributing water, the tangential impulse wheel, the prime mover most frequently used in early California hydroelectric plants, also emerged from the California mining industry. Most California mines in the late nineteenth century relied heavily on water power. It was relatively cheap and available. Steam power, the alternative, was sometimes used, but California has no coal deposits, so the usual fuel for the steam engine had to be imported at considerable cost.

Wood could be used, but it was expensive, especially since most California woods are soft. Oil, used later, did not become an important fuel in the state until after 1900. Thus it was water that usually powered the pumping, hoisting, milling, crushing, drilling, and sawing machinery used in or around mines.

The traditional forms of water wheel -- the wooden overshot and undershot vertical wheels -- were cheap and easy to build, but they were largely low head engines (applicable to heads under 50 feet only) and could not be used effectively under the high head/low volume water conditions common to California mining areas. The water turbine, which could operate under high heads, was built of iron and in the early years of California mining was beyond the ability and means of local craftsmen using local materials. The result of this dilemma was the "hurdy-gurdy" wheel, a water wheel built from local materials with native skills able to utilize high heads. Unlike the turbine, it was built of wood, so that it could be fabricated by local millwrights for a reasonable price. In place of the buckets or flat radial paddles of the conventional wooden vertical wheel it had triangularly-shaped wooden blocks, arranged around the circumference of the water wheel like the teeth of a saw. These teeth were enclosed on the side with rims. Water, in the form of a free jet, was directed against the "teeth" or "buckets" of the wheel through a hole bored in a wooden block at the end of a pipe line or hose. The early hurdy-gurdy wheels probably developed an efficiency of only 30 to 40%, but they were workable and adequate for low power needs.

As the demands for more power and power in larger units increased with the growth of the mining industry, millwrights began to modify the hurdy-gurdy wheel. Bronze or brass tapered nozzles replaced the wooden blocks first used to direct water on the wheels. Some millwrights by the 1870's had also begun to replace the triangular wooden blocks of the wheel with cup-shaped buckets of iron. A portion of the water striking the bottom of the cups flowed up the sides and was dischraged laterally, causing less interference with incoming water than the flat edges of the old blocks. This experimentation eventually led to the highly efficient Pelton water wheel. Around 1880 Lester Pelton, a California millwright, introduced a bucket shaped (in cross-section) like a cursive-script "W", that is, the bucket had curved bottoms, inclined sides, and a raised center that split the incoming jet of water. With this arrangement there was little interference between incoming and outgoing water. The entering water struck the central "splitter", flowed down each of its sides into the interiors of the bucket, and then flowed up the inclined sides to be discharged laterally. The "Pelton" wheel's efficiency was almost double that of the original hurdy-gurdy wheel. [5]

Certain elements of the impulse wheel or Pelton wheel were heavily influenced by other aspects of California mining, notably the hydraulic mining tradition. Hydraulic mining, developed in California in the early 1850's to economize labor, utilized a stream or jet of water under pressure to wash away sand and gravel from gold deposits or to undercut hills where suspected mineral deposits were located. It enjoyed considerable popularity until the 1880's when floods caused by the accumulation of debris from the process in stream beds led to restrictive legislation. The pressure pipes and nozzles used to bring water to and direct water against the impulse wheel are obvious direct borrowings from hydraulic mining practice.

In addition, two of the methods used to control the speed of the Pelton wheel were also adopted from hydraulic mining equipment -- the pivoted ball-and-socket nozzle and the plate used to deflect water jets away from the wheel. [6]

The tangential impulse wheel by the 1880's had become the characteristic water-powered prime mover of California's mining industry. It had been adopted by 1900 as the characteristic prime mover of the state's nascent hydroelectric industry as well. Ideally suited to the high head /low volume conditions frequently found in the West, the impulse wheel was scarcely ever found in the states east of the Rockies where the mixed-flow Francis turbine was the characteristic engine in hydroelectric plants. By 1909 the Pelton Water Wheel Company, the leading manufacturer of impulse wheels, had sold 12,604 wheels to power plants all over the world. Of these 8554 or 68% had been installed in California, Oregon, and Nevada (mostly in California). Only 183 or around 1.5% had been installed in states east of the Rockies. [7] The impulse wheel was clearly characteristic of California practice.

Besides a network of canals and ditches and a prime mover with a means for controlling it, early California miners also left the hydroelectric industry a favorable legal system. In the eastern United States ownership of land fronting on a stream carried with it the right to all the waters naturally flowing in that stream (riparian rights). No one upstream could legally diminish or otherwise alter the flow of the stream by diverting or adding water. In California, early mining practice and the general scarcity of water led to a different legal system — the doctrine of "appropriation".

In the mid-nineteenth century most of California's lands were public lands; no one owned the lands fronting most streams, especially in the mountainous mining districts. Since many mining claims were located some distance from water and there was no one to object, the early miners simply "appropriated" water from streams and diverted it by ditches or canals to where they needed it. Customarily these miners posted notices similar to those used for staking out mineral claims on the spot where they intended to "appropriate" the water indicating the amount they would use. Moreover, these water claims were usually recorded in county files. If recorded and if the water was in fact put to use these claims gave their owners the perpetual right to a certain volume of water from a particular stream or spring. Such claims acquired the force of law in a number of western states and were considered by western courts to be superior to conventional riparian rights. [8]

The general acceptance of the doctrine of appropriation by California lawmakers and courts often allowed miners, and later the developers of hydroelectric power, to generate significant amounts of energy in spite of the relatively small size of available streams. Under the doctrine, for instance, an electric utility with appropriate water rights could divert and/or permanently diminish the volume of water flowing from a number of small streams without having to worry about suits from stream-front property owners downstream. The utility could then collect and combine the flow from a number of small streams until a sufficient volume was available and lead it to any point it felt necessary for power production, even if it meant diverting the flow into a completely different watershed.

THE EMERGENCE OF HYDROELECTRIC POWER IN CALIFORNIA

Despite the steep gradients of California streams, the availability of the impulse wheel, and a favorable legal climate, most of California's early electrical generating plants were steam rather than water powered. The electric central power station first emerged in urban areas where returns on capital investment were greatest and, in California, these urban centers were on the seacoast, far from the mountain streams with the greatest hydropower potential.

It was only following the emergence of alternating current and the ability to transmit power at high voltages that hydroelectric power became a feasible alternative to steam power in California's population centers. Alternating current began to replace direct current in the mid-1880's, and by the early 1890's German engineers had successfully transmitted current 112 miles along an experimental line from Lauffen to Frankfurt at 12,000 volts (12 kV) from a 225 kilovoltampere (225 kVA) water-driven alternator. The emergence of long distance electrical power transmission was greeted with enthusiasm by California utility entrepreneurs. Plagued by the high cost of imported coal and the even higher cost of timber fuel, they quickly recognized that this new technology offered the possibility of tapping the power potential of inland mountain streams.

California's first commercial hydroelectric plant was erected near Redlands, in the heart of the orange growing district in the foothills of the San Bernardino mountains. In 1891 the president of a small Congregational college (Pomona College), C.G. Baldwin, organized a company, and in conjunction with William Decker, an engineer, erected a small plant which tapped San Antonio Creek. This installation, opened in 1891 or 1892, transmitted power to Pomona, a distance of around 14 miles. Its transmission lines were extended to San Bernardino, 30 miles away, in 1892. Operating first at 5000 volts and later at 10,000 volts, Pomona was the third hydroelectric plant in the United States to transmit significant amounts of electric power for a considerable distance, and had for a time the longest commercial power line in operation anywhere in the world.

The success of the Pomona plant in producing power and in competing against an existing steam-driven electrical plant encouraged others to enter the field. In 1893 Decker was commissioned to design a similar plant for Mill Creek, in the same area. This plant, placed in commission in September of 1893, transmitted power 7.5 miles to Redlands at 2400 volts and then 23 miles to Riverside at 10,000 volts. The Pomona plant had delivered only single phase alternating current; the Mill Creek plant was the first polyphase alternating current generating station in California and one of the first in the world. At approximately the same time several California mining companies began to erect hydroelectric plants for their own use.

As Table 4 on the following page indicates, through the remainder of the 1890's new hydroelectric plants were erected every year, with steadily higher outputs, steadily greater transmission voltages, and greater transmission

Table 4:

California Hydroelectric Plants to 1900 (Major Commercial Installations)

Note: Available authorities are often in disagreement about specific data relative to the early California hydroelectric plants (e.g., the year they began operation or their initial output). The compilation below thus reflects the authors' judgment of the relative reliability of conflicting sources in certain cases.

	Name	Year	Head (ft.)	Output (kW)	Transm. Voltage (kV)	Distance Transm. (miles)	Turbine Type (I=impulse R=reaction)
1.	Pomona	1891	412	480	10	29	I
	Mill Ck. #1	1893	377	750	11	23	I
	Bodie	1893	350	120	3.5	13	I
	Utica	1895	570	75	2.5	8	I
5.	Folsom	1895	55	3000	11	22	R
	Yreka	1895	40	150	--	4	R
	Nevada	1896	206	600	5.5	15	I
	San Joaquin	1896	1411	1050	11	35	I
	Big Creek	1896	925	300	11	17	I
10.	Newcastle	1896	452	800	16	30	I
	Knight's Ferry	1896	150	1500	17	—	R
	Kern River	1897	202	900	11.5	15	I
	Blue Lakes	1897	1043	1350	10	25	I
	Yuba	1898	292	1980	16	19	I
15.	Azusa	1898	401	1500	16	23	I
	Auburn	1898	?200	300	16	36	I
	Santa Ana	1898	735	3000	33	83	I
	Phoenix	1898	930	1125	17	11	I
	Centerville	1898	577	800	15	32	I
20.	Utica (new)	1898	527	1500	16.5	8	I
	Farad	1899	85	1500	22	30	R
	Kaweah #1	1899	1287	1350	34.6	70	I
	Mill Ck. #2	1899	627	250	33	23	I
	Colgate	1899	702	2700	40	140	I
25.	Kitteridge	1900	25	225	--	—	R

Note: Many plants quickly added to their initial operating capacity and to the distance their power was transmitted. The figures given above are initial outputs and distances transmitted (within the first year of operation).

Authorities: Robert McF. Doble, "Hydro-Electric Power Development and Transmission in California," Association of Engineering Societies, Journal, v. 34 (1905) pp. 75-98; P.M. Downing, "Report of Sub-Committee on Water Power Development on Pacific Coast," National Electric Light Association, Proceedings, 38th Convention (1915), v. 3, pp. 594-601; C.W. Whitney, "Hydroelectric Power Plants of California," California Journal of Technology, v. 7 (1906) pp. 4-23; Frederick Fowler, Hydroelectic Power Systems of California . . . (Washington, D.C.: Government Printing Office, 1923); and Frank E. Bonner, Water Powers of California (Washington, D.C.: Goverment Printing Office, 1928) pp. 180-190.

distances. One of the more important installations in this period was the Folsom plant, put on line in July 1895, using water from the American River. This plant transmitted the entire output from its four 750 kilowatt (750 kW) alternators 22 miles to Sacramento at 11,000 volts, then the highest transmission voltage in commercial use anywhere in the world. By 1899 Sacramento was receiving additional power from the 2000 kW Colgate hydro-plant on the Yuba River. This power was transmitted over a 60 mile line at 30,000 volts, and was then raised to 40,000 volts for transmission an additional 80 miles to the San Francisco Bay area. Shortly after this, in order to transmit even more power into the Bay Area from plants located even further in the interior of the state, California engineers began experimenting with 60 kV (60,000 volt) transmission lines, at a time when transmission of power at even 10 to 20 kV was considered high in the eastern United States. [9]

By 1902 the hydroelectric industry was well established in California. The state had more than twenty-five major operative hydroelectric plants with an installed capacity of over 50,000 kW (see Table 5, following page). Already the unique aspects of California hydroelectric practice were obvious. Most of these plants were high head plants, most used the Pelton or impulse wheel, and, already, these plants were transmitting power longer distances, at higher voltages, than comparable plants in the eastern United States (see Table 4, preceding page). It was against this background that the Battle Creek hydroelectric system emerged in the early years of the twentieth century in Shasta and Tehama Counties in northern California.

Table 5:

Growth of Hydroelectric Production in California to 1902 (Downing)

	Number of Plants	Average Output per Plant (kW)	Total Power Capacity (kW)
1892	1	480	480
1893	2	615	1230
1894	2	615	1230
1895	4	1432	5730
1896	7	1170	8190
1897	9	1382	12440
1898	15	1381	20715
1899	19	1430	27175
1900	20	1435	28695
1901	23	1653	38015
1902	27	1910	51565

Source: P.M. Downing, "Report of Sub-Committee on Water Power Development on the Pacific Coast," National Electric Light Association, Proceedings, 38th Convention (1915) v. 3, p. 513. The figures in this table do not correspond with tabulations made from Table 4 because of the abandonment or enlargement of some of the early stations and because data on many early California hydroelectric stations is given differently by different authorities. Bonner, Water Powers of California, p. 190, for example, lists the total power capacity of California hydroelectric plants for 1900 to 1902 as 30,490; 34,415; and 49,365 kW, instead of the figures given above.

NOTES

[1] Some of the unique aspects of California hydroelectric engineering are briefly mentioned by Frank E. Bonner, Report to the Federal Power Commission on the Water Powers of California (Washington, 1928) p. 11. They are discussed in more detail by Federic A.C. Perrine, "Hydraulic-Power Development on the Pacific Coast," Cassier's Magazine, v. 35 (1908-09) pp. 620-625.

[2] Perrine, "Hydraulic-Power Development," p. 621.

[3] A number of works discuss California's geography and climate and at least touch on the influence these factors had on hydroelectric development in the state, among these are Frederick H. Fowler, Hydroelectric Power Systems of California and Their Extension into Oregon and Nevada (Washington, 1923) [United States Geological Survey, Water-Supply Paper 493] pp. 9-30; Perrine, "Hydraulic-Power Development," pp. 620-622; Bonner, Water Powers of California, pp. 2-9; and H.D. McGlashan and F.F. Henshaw, Water Resources of California, part 1 (Washington, 1912) [United States Geological Survey, Water-Supply Paper 298] pp. 10-12, 26-27.

[4] On the importance of the old mining ditches to the development of hydroelectric systems in California see Charles M. Coleman, P.G. and E. of California: The Centennial Story of the Pacific Gas and Electric Company, 1852-1952 (New York, etc., 1952) pp. 92-101 and passum; Fowler, Hydroelectric Systems of California, passum; and P.M. Downing, "Some Historical Aspects of the Development of Hydroelectric Power in California," unpublished manuscript, pp. 1-2 (PG&E Library).

[5] The two best sources for the evolution of the impulse wheel are W.F. Durand, "The Pelton Water Wheel," Mechanical Engineering, v. 61 (1939) pp. 447-454, 511-517, and Louis C. Hunter, A History of Industrial Power in the United States, 1780-1930, v. 1, Waterpower in the Century of the Steam Engine (Charlottesville, Virginia, 1979) pp. 396-413.

[6] Durand, "Pelton Water Wheel," p. 448; Coleman, P.G. and E., pp. 108, 115. For a review of hydraulic mining practices see: Augustus J. Bowie, A Practical Treatise on Hydraulic Mining in California (New York, 8th ed., 1898).

[7] Pelton Water Wheel Company, The Pelton Water Wheel (San Francisco, 11th ed., 1909) p. 74.

[8] Reviews of California's water laws can be found in: Fowler, Hydroelectric Systems of California, pp. 45-56; Perrine, "Hydraulic-Power Development," pp. 622-623; and A.E. Chandler, "Western Laws of Electricity and Water," JE, v. 28 (1912) pp. 292-294, 308-310, 352-354, 379-381, 403-405, 453-455.

[9] Information on the early history of hydroelectricity in California and data on early California hydroelectric plants can be found in: Fowler, Hydroelectric Systems of California, pp. 1-2 and passum; P. M. Downing,

"Report of Sub-Committee on Water Power Development on the Pacific Coast," National Electric Light Association, Proceedings, 38th Convention (1915), [v. 3] pp. 513-519; Downing, "Historical Aspects," pp. 6-22; Coleman, P.G. and E., pp. 102 ff.; Robert McF. Doble, "Hydro-Electric Power Development and Transmission in California," Association of Engineering Societies, Journal, v. 34 (1905) pp. 75-98; C.W. Whitney, "Hydroelectric Power Plants of California," California Journal of Technology, v. 7 (1906) pp. 4-23, and the issuea of the Journal of Electricity, Power and Gas (JE).

CHAPTER II

BEGINNINGS:

The Emergence of Hydroelectric Power in the Battle Creek Region (1896-1900)

Shasta and Tehama counties were, like most of the rest of northern California, sparsely populated in the late nineteenth century. Tehama County, at the very northern end of California's Central Valley, including a portion of the Sierra Nevada on the east and a portion of the Coast Range on the west, had an economy largely based on ranching and logging. Red Bluff, the county seat and commercial center had scarcely 2500 people in 1890. North of Tehama County was Shasta County, a mountainous region drained by the Sacramento, Pit, and McCloud rivers. Shasta County was economically more diversified than Tehama County, largely because of substantial mineral deposits. But it, too, was thinly settled. In 1890 Redding, the county seat, had a population of under 2000 people. [1]

Just at the turn of the century, however, Shasta County began to experience accelerated growth as her mineral resources began to be mined on a large scale. In 1862 surface deposits of copper, gold, and silver had been simultaneously discovered in the region, and these discoveries had set off a "speculative mania" as hundreds of mining companies wera organized and wildcat exploitation of surface deposits began. Some of these companies were formed to mine surface copper, but gold and silver were the focus of most. The low grade of the copper ore (averaging only 8% copper), the higher value of the gold and silver found in the copper ores, the distance of Shasta County from both copper refineries and markets, a drop in the price of copper, and the high cost of reaching the richer copper veins below the surface combined to discourage serious or sustained copper mining. [2]

Toward the end of the nineteenth century, however, rising copper prices and the decline of returns from gold and silver mining encouraged some Shasta County mining corporations to consider exploitation of the richer copper ore deposits found at deeper elevations. The pioneer in this field was the Mountain Copper Company, which had evolved from a silver mine at Iron Mountain, a few miles northwest of Redding. With s liberal dose of British capital, Mountain Copper Company began mining copper on a large scale in 1896. [3] Within two years copper had become the foundation of the county's mining industry. By 1901 there were fifty-seven copper mines in Shasta. In 1896 copper production had been only 1,847,087 pounds valued at $184,708. In 1901 the figures were 30,999,781 pounds with a value of $4,881,048. Shasta's copper mines had made California the fourth largest copper producing state. The Mountain Copper Company's mine wss the seventh largest American copper mine and the ninth largest in the world. [4]

The expansion of copper mining attracted other industries and stimulatad population growth. Copper smelters were established to process the copper ores being mined. Logging grew rapidly since timber was needed not only for mine shafts, but as a fuel (since coal was expensive in California) to roast and reduce copper ores and to fire the boilers of the steam engines used to power mine machinery. Redding, the commercial center of Shasta County, grew from a city of 1821 people in 1890 to almost 3000 by 1900, an increase of 62%, and continued to grow at a comparable pace in the early years of the twentieth century. [5]

The massive expansion of mining and associated industries, coupled with the growth of the region's urban centers,began to place a strain on the area's fuel resources in the late 1890's. Massive amounts of timber were being consumed to fire the boilers of steam-powered mining machinery and to operate smelters. The Mountain Copper Company alone burned around 30,000 cords of wood annually. [6] The growth of electric lighting in urban areas added to the pressure on fuel resources. Both Redding and Red Bluff by 1900 had small electric lighting plants. In Redding a wood-fueled Corliss steam engine and a small low head hydroelectric plant supplied the power. [7] Red Bluff had two power companies. One used a small nearby stream (Antalope Creek) to generate hydroelectric power; the other used a small oil-fired steam engine and generator. [8] The pressures placed on the local wood fuel supply by urban growth and, to a much greater extent, the mining and metallurgical industries were probably the primary incentive behind the initiation of plans to develop hydroelectric power in Shasta and Tehama counties around the turn-of-the-century.

In 1899 C.W. Waller, a civil engineer, began surveying possible hydroelectric sites on the Pit and McCloud rivers, north of Redding, for "eastern capitalists" who hoped to supply Shasta mines with cheap electric power. Joined by Sidney Sprout, an electrical engineer and a representative of the General Electric Company, Waller in 1900 began to canvass potential demand in the county's mining belt. Shortly after Waller, Sprout, and Francis Smith, president of the Redding Water and Electric Light Company, formed the Mt. Shasta Power and Light Company. In early 1900 this company announced plans for a hydroplant on the Pit River. A 350 foot long dam was to raise the water level 50 feet, diverting water through a 12 to 15 mile long ditch to a point where a 150 foot head was available and 6000 hp (c. 4500 kW) could be produced. [9]

The Mt. Shasta Company's plans were later altered. By 1901 a site on the McCloud River was being considered instead. Ditches and flumes totalling 7.33 miles in length with a capacity of 1000 second-feet were to divert water to a site where a fall of 145 feet was available. Plans were to install 4000 kW of generating equipment at first, expanding the plant later as load grew. [10]

A few months after the formation of the Mt. Shasta Electric Light and Power Company, A.F. Johns, an electrical engineer, also surveyed possible power house locations in the Pit and McCloud river basins. In early 1900 Johns was the prime mover behind the formation of the McCloud River Power Company. This company planned to erect a dam on the McCloud where a fall of 45 feet could be developed. With a projected flow exceeding 2000 second-feet, Johns and his associates hoped to generate around 8000 hp (c. 6000 kW). [11]

In canvassing the mining belt of Shasta County for potential power customers, however, Johns found that most companies were unwilling to sign a power contract unless his McCloud River Company could guarantee uninterrupted service with backup generating capacity. To meet this demand Johns in June 1900 led a pary which surveyed possible power house sites on a small stream called Battle Creek, on or near the boundary of Shasta and Tehama counties. Shortly after,Johns and his associstes created another new company, the Mt. Lassen Electric Company. This company purchased a substantial tract of land in the Battle Creek basin near Shingletown from Harry L. Shannon and announced plans for a 2000 hp (c. 1500 kW) hydroelectric plant. Located at the site of an old water-powered sash and door factory, this installation was intended to supplement the larger plant being considered for the McCloud River. The Battle Creek plant would provide backup service and allow the parent company to guarantee potential customers uninterrupted electric service. It would also protect the larger McCloud River investment by forestalling competitors from developing Battle Creek, a stream with good hydroelectric possibilities. [12]

BATTLE CREEK

Battle Creek was a relatively small tributary of the eastern side of the upper Sacramento River. Approximately 40 miles long with a watershed of 337 square miles, the stream had two principal forks -- North Battle Creek and South Battle Creek. These split from the trunk of the stream around 12 miles upstream from the Sacramento.

Johns was perceptive in sensing the potential of the stream. Much smaller than the Pit and McCloud rivers and with a basin much more accessible to existing transportation systems, Battle Creek required much less capital to develop. This was a very important consideration in sparsely populated northern California at the turn-of-the-century and was a key fsctor in the failure of most esrly schemes to develop the Pit and McCloud rivers (including the plans of the Mt. Shasta and McCloud River companies). Battle Creek also had an advantageous geographical position. Emptying into the Sacramento almost midway between Red Bluff and Redding, lines strung from its watershed could easily reach the mining regions of Shasta County, the agricultural districts bordering the Sacramento River to the south, and both of the region's major urban centers [See HAER drawing, sheet 1 of 21].

There were other things about Battle Creek which made it very attractive for early medium scale hydroelectric development. Like many California streams it had a steep gradient ideal for high head power systems. Originating on the western slope of Mt. Lassen,one of the last active volcanos in the continental United States, Battle Creek fell almost 5000 feet over a distance of less than 50 miles. Even more favorable for power development was the stream's relatively steady flow. This was due to two factors. Much of the precipitation which fell on Battle Creek's watershed fell in winter in the form of snow. This snow melted slowly and drained off into the creek during the lste spring and early summer, instead of running rapidly off in winter. Evening out the stream's flow even more was the volcanic nature of the area's soil. Mt. Lassen, in the distant past, had dumped huge deposits of porous lava and ash over much of the Battle Creek basin. These deposits acted like a sponge, soaking up and storing much of the excess winter rainfall and much of the spring and early summer snow runoff, only gradually returning the water to the surface through thousands of springs. These springs continued to feed Battle Creek through the dry summer and fall months. Together these conditions gave Battle Creek a regularity of flow foreign to most California streams (see Table 6, following page). They made the construction of large and expensive artificial storage reservoirs a much low priority here and further reduced the capital investment necessary to begin tapping the stream's power potential. By way of contrast, in some areas of southern California hydroelectric plants had to depend on storage reservoirs for flow for up to five months out of the year. [13]

Table 6:

Output of Coleman Powerhouse on Battle Creek in millions of kWh per Month from 1920 to 1923 as an Indication of the Relatively Constant Flow of Battle Creek

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Note: Because of the complexity of the ditch system furnishing water to the Battle Creek plants it is difficult to estimate the volume of water available in the stream. However, since the Battle Creek plants are operated so as to use all of the water available, the power output is indicative of the relative amounts of water available to the plants at various times of the year.

	1919	1920	1921	1922	1923	1924
January		4.41	6.43	5.26	5.17	4.57
February		4.16	6.06	5.08	5.12	5.49
March		5.81	6.30	5.34	5.47	4.79
April		5.64	5.78	4.65	5.52	4.93
May		5.89	5.93	5.92	5.54	4.44
June		4.40	5.69	5.67	4.80	3.85
July		4.16	5.57	5.23	4.93	3.83
August		3.98	5.12	4.87	4.45	3.73
September		4.10	4.66	4.25	4.09	3.65
October	4.22	3.56	4.80	4.70	4.62	4.13
November	4.24	3.17	4.83	4.60	4.31	
December	4.84	6.47	5.28	5.16	4.60	
minimum month / maximum month	=	0.49	0.72	0.72	0.74	0.66

Note: The figures above do not completely reflect the natural flow conditions along Battle Creek, since there are several water storage reservoirs (although rather small) which are used to even out flow.

Source: Pacific Gas & Electric Company, "Federal Power Commission; Applications on N.C.P. System," Exhibit I, 1924, in J.O. Burrage to A.H. Markwart, November 10, 1924 (Engineering Central Files, PG&E). This is cited hereafter as FPC-1924 (for Federal Power Commission Application, 1924).

Addendum: Scattered Readings taken on Battle Creek between 1902 and 1910 in the months of August, September, and October indicated flows of between 313 and 423 second-feet. See -- H.D. McGlashen and F.F. Henshaw, Water Resources of California, part 1 (Stream Measurements in the Sacramento River Basin) (Washington: G.P.O., 1912) [U.S.G.S., Water-Supply Paper 298] pp. 385-386.

NOTES

[1] Fowler, Hydroelectric Systems of California, pp. 71, 72, 131.

[2] CSMB, Bulletin 23 (1902) [Lewis E. Aubury, Copper Resources of California] p. 25, and Bulletin 50 (1908) [Aubury, Copper Resources of California] pp. 32, 34, 38, 42; CSMB, 20th Report of the State Mineralogist, v. 20 (1924) p. 422; and "The Copper Industry in Shasta County," Overland Monthly, v. 56 (1910) p. 256.

[3] CSMB, Bulletin 23 (1902) p. 9, and Bulletin 50 (1908) pp. 70-71; also CSMB, 20th Report (1924) pp. 423-424.

[4] CSMB, Bulletin 23 (1902) pp. 9, 51.

[5] CSMB, Bulletin 23 (1902) p. 53; D.N. Honn, "A County That's An Empire," Sunset, v. 10 (1903) p. 229; Fowler, Hydroelectric Systems of California, p. 131.

[6] Redding Free Press, January 18, 1901.

[7] Dave J. Jensen, "Harnessing Shasta County's 'Liquid Gold'," Covered Wagon-1975 (Shasta Historical Society, Redding, California, 1975) pp. 6-7; Fowler, Hydroelectric Systems of California, p. 126.

[8] For Red Bluff's hydroelectric installation see Red Bluff News, February 10, 1899 (The Tehama County Library, Red Bluff, has a photograph of this installation in its photograph collections indexed under "Electricity"); for the steam plant see Red Bluff News, February 3, 1899, and June 23, 1899, plus the San Francisco Call, July 26, 1898.

[9] For the activities of Waller, Sprout, and Smith see: Redding Free Press, December 19, 1899; January 22, 1900; March 6, 1900; March 10, 1900, and Redding Searchlight, February 21, 1900; March 2, 1900; March 6, 1900; March 11, 1900; June 20, 1900. Details on the company's plans for the Pit vary in the newspaper reports.

[10] G.P. Grimsley, "Electric Power Plants in the Mining Districts of Northern California," Engineering and Mining Journal, v. 72 (1901) p. 330.

[11] For Johns' activities see: Redding Free Press, March 1, 1900; March 27, 1900; May 21, 1900; June 14, 1900; December 29, 1900, and Redding Searchlight, March 2, 1900; June 20, 1900. For the plans of the McCloud Company see Grimsley, "Electric Power Plants," p. 330.

[12] The activities of Johns and the Mt. Lassen Company in the Battle Creek area are noted in the Redding Free Press, June 27, 1900, and the Redding Searchlight, June 28, 1900.

[13] Hydraulic conditions in the Battle Creek basin are described by Fowler, Hydroelectric Systems of California, pp. 223-226; Rudolph W. Van Norden, "Northern California Power Company, Consolidated," JE, v. 25 (1910) pp. 107 and passum; Frederick S. Myrtle, "Northern California Power Link of the 'Pacific Service' Chain," Pacific Service Magazine, v. 17 (1928) pp. 75-77; B.D. Wood, Gazetteer of Surface Waters of California, part 1 (Sacramento River Basin) (Washington, 1912) [United States Geological Survey, Water-Supply Paper 295] pp. 9-10; and J.G. White & Co., "Report on Northern California Power Company Consolidated by J.G. White & Co. (to N.W. Halsey & Co., Jan. 29, 1910)," pp. 27-30. The White & Co. report can be found in CRRC, "Exhibits," application no. 156, in the California State Archives, Sacramento . The J.G. White & Company report will hereafter be cited as J.G. White & Co., "Report",without reference to the specific California Railroad Commission document.

CHAPTER III

VOLTA:

The First Plant (1900-1901)

The plans being contemplated by the Mt. Lassen Power Company for Battle Creek never came to fruition. They were thwarted by Harry L. Shannon, the man from whom the properties and water rights which were to form the basis of the Mt. Lassen Company's Battle Creek plant had been purchased. Shannon was a mining engineer who had migrated to California in the early 1870's and had gained experience in hydraulic engineering working with various mining companies. [1] A rather crafty and devious entrepreneur, he saw that there was money to be made speculating in hydroelectric power and set out to insure that he pocketed his share. In September 1900, three months after selling his properties near Shingletown to the Mt. Lassen Company, Shannon purchased the 600 acre "Hestes estate" on Millseat Creek, a tributary of Battle Creek, along with associated water rights. Because the Hestes estate was adjacent to the lands Shannon had sold the Mt. Lassen Company and important for its plans, Johns and his associates attempted to block the sale. But they were unsuccessful. [2]

Local papers reported that Shannon had purchased the properties as the representative of a San Francisco businessman, W.W. Marvin, who, in turn, represented unnamed "eastern capitalists" interested in hydroelectricity. [3] That Shannon intended to develop the new properties in this manner became clear when, a few weeks later, he secured a franchise to erect poles and transmit electricity throughout Shasta County, a franchise which had also been sought by Johns and the Mt. Lassen Company. [4] All of the lands, water rights, and franchises which Shannon had purchased were transferred on October 18, 1900, to a newly organized power company -- the Keswick Electric Power Company. [5] Shannon was named general manager. [6].

The president and the prime mover behind the creation of the company was a San Francisco businessman, Hamden Holmes Noble [see HAER photo 171]. Born in 1844, Noble had migrated to San Francisco in 1864. After working five years as a clerk for a wholesale merchant, he had moved to Nevada and with his own capital engaged in mining and lumbering enterprises. He returned to San Francisco in 1871, joined the San Francisco Mining Stock Exchange, and built up a large mining stock brokerage. He became "one of the foremost brokers" in San Francisco, handling the accounts of a number of prominent California mining entrepreneurs. A respected member of the city's financial circles, he backed a number of highly successful enterprises late in the nineteenth century, the Cypress Lawn Cemetary Association, which he founded in 1892, being among the most lucrative. [7]

Noble's long association with the mining industry made him perceptive to its needs and aware of the opportunities which it offered. His intimate association with prominent mining executives put him in a position to take effective action when a need or an opportunity arose. This occurred in 1900 when the Mountain Copper Company announced plants for a new copper smelter at Keswick, near their Iron Mountain mine. Recognizing that the smelter would need large amounts of power, Noble, in conjunction with Lord Keswick, one of the principal stockholders in Mountain Copper, secured a long term power contract and organized the Keswick Electric Power Company. [8] Armed with the Mountain Copper contract the infant company had little trouble sttracting capital. Within a month of formation well over half of the 100,000 shares of stock issued had been sold at $3.00 a share, largely to Noble's friends and associates. [9]

VOLTA: Construction

Actual design and construction work for Keswick's plant, located on lands purchased by Shannon, proceeded "as fast as money can push an enterprise". [10] By November of 1900 a Westinghouse representative had visited the projected powerhouse site, men had been set to work digging s ditch to convey water from Millseat and North Battle Creeks to the top of the plateau overlooking the site, and crews were chopping trees for use as transmission line poles. [11] By the end of 1900 the Keswick Company had ordered electrical equipment from Westinghouse, signed a $50,000 contract for the installation of 6000 feet of steel penstock, and expanded the force of men and mules excavating its canal system. [12] The magnitude of the project was also enlarged. Original plans had been to install two 750 kW water wheel/generator sets. By early 1901 Keswick had decided to install a third set. Completion of the entire plant was expected by July 1, 1901. [13]

The emergence of the Keswick Power Company undermined Johns' Mt. Lassen Power Company. But the properties near Shingletown it had purchased from Shannon formed the basis for a new challenge to the Keswick Company's plans. In November 1900 the Beckwith Power Company was organized, including among its directors several people earlier associated with the Mt. Lassen Company. The new company quickly formulated plans for a powerhouse on North Battle Creek above the Keswick Company's site and announced its intention of selling power to Shasta County mines and smelters, as well as to a projected electric railroad to be built to transport lumber from the numerous Shingletown area sawmills to Red Bluff. [14]

The Beckwith Company in late 1900 also set men to digging ditches to convey water to the site of its powerhouse. Both companies continued ditch construction into the winter of 1900-1901, much slowed by cold and snow. [15] But in April 1901 the Beckwith Power Company halted work. [16] Why the company collapsed is not clear, but lack of capital was the probable cause.

Beckwith's collapse left Keswick alone in the field. A thirty man force using dynamite, horses, scrapers, and plows had been employed through most of the winter of 1900-1901 excavating ditches and a forebay reservoir, while other crews had surveyed the right-of-way for the power transmission line from the powerhouse to Redding and from Redding to the small town of Keswick, adjacent to the Mountain Copper Company's smelter. [17] These forces were augmented in the spring and summer as construction of the powerhouse and the transmission line began. Masons, mechanics, and engineers, imported from San Francisco, worked in conjunction with local unskilled and semi-skilled labor, so that during the peak of construction activity between seventy and eighty men were employed. [18] Most construction was organized and directed by the power company itself. However, the San Francisco engineering firm of Hunt, Benjamin, Meredith, and Corey was hired to superintend the erection and the testing of the hydraulic and electrical systems, and the penstock was constructed and installed by Schaw, Ingram, and Butcher, a Sacramento pipeline company.[19]

Equipment for the powerhouse and material for the penstocks began to arrive in late March 1901 at Anderson, the railroad siding nearest the powerhouse site. But from Anderson all equipment had to be carried 30 miles over rough terrain. Transporting heavy equipment over the dirt wagon trails and up the steep grades in the Battle Creek watershed caused severe problems and was primarily responsible for delaying completion of the hydroelectric plant beyond the anticipated completion date (July 1). For instance, one of the 31,000 pound generators reached Anderson on July 10, 1901, and was loaded onto a large granite-wheeled wagon pulled by twenty-four horses for transportation to the powerhouse site. In the hilly terrain around Black Butte the wagon broke, delaying delivery and requiring the transfer of the generator to a second wagon, pulled by thirty-four horses [see HAER photo 159]. [20]

While teamsters struggled to haul equipment to the powerhouse, Keswick Company employees under the direction of Harry Shannon and A.J. Rossi made steady progress at the powerhouse site and upstream on the plant's system of ditches. By early August the powerhouse was substantially completed, installation of equipment within had begun, and 1200 of the 6000 feet of penstock had been laid in trenches. By October 10 the plant's water-driven exciter system had been completed, and the plant was able tc provide its own electric lights. Stringing of power lines from the powerhouse to Redding began in late May or early June and by the middle of August 10 of the 29 miles had been stretched and work had begun on the 5 mile extension from Redding to Keswick, where transformers were already in place. [21]

Noble and a representative of the Mountain Copper Company visited the powerhouse, named Volta, to witness the riveting of the last two sections of penstock on October 16. Water was first passed through the penstock on October 20, 1901. [22] Tests of the system, difficulties in stringing the transmission line over the mountainous area from Redding to Keswick, and problems with the installation of the transformers at Redding, however, delayed the start of commercial operations at Volta until late November. [23] Redding first received power from the new plant on November 28, 1901, and Keswick and the Mountain Copper Company's smelters only on December 14. [24] Power lines were soon extended 5 miles westward from Keswick to Iron Mountain, where the company's mine was located.

VOLTA: Layout and Design [25] [See HAER drawings, sheets 3-7 of 20]

Keswick's first powerhouse (Volta) was located a few miles from the small crossroad hamlets of Manton and Shingletown, around 30 miles southeast of Redding. It was situated along Millseat Creek, a half mile above its junction with North Battle Creek. The site was excellent. Paralleling North Battle Creek for some distance north was a ridge, wide at the top and extending with a very moderate slope eastwards towards its headwaters. The fall from the top of the ridge to the powerhouse site was perfect for high head power development — around 1200 feet in a distance of slightly over a mile. A writer who claimed to have visited "practically every water power plant of importance in the West" asserted that "nowhere" had he seen natural conditions so favorable to power development. [26]

Sufficient water rights for the powerhouse had been acquired with the properties Shannon had purchased: 2000 inches (50 second-feet) could be diverted from North Battle Creek; 3000 inches (75 second-feet) from Millseat Creek. [27] To supplement these waters, particularly during the dry months of summer and fall, Keswick had also purchased from neighborhood ranchers rights to withdraw waters from three small tributaries of North Battle Creek -- Berry, Alpine, and Gilpin Creeks — plus a small percentage of flow from a number of already operative private irrigation ditches with water rights on North Battle Creek. [28] Altogether Keswick controlled far more water in 1901 than it needed for Volta's 2250 kW generating capacity, but this excess provided the company with a reserve for future expansion.

To bring water from Battle and Millseat Creeks to the top of the ridge or plateau overlooking the powerhouse Keswick crews dug a ditch (called the Keswick ditch or Keswick Canal) around 3.5 miles long. A dam of loose rocks diverted water from North Battle Creek into this ditch, which carried it in a southwesterly direction, intercepting Berry, Gilpin, and Alpine Creeks before discharging into Millseat Creek [see HAER photos 121 and 122]. A second diversion dam on Millseat Creek channeled the accumulated flow (around 45 second-feet) into the last segment of the Keswick ditch, which carried the water to a forebay reservoir overlooking the powerhouse. [29] (See the table on the following page)

The design of the Volta water system, as well as the powerhouse itself, can be best understood by considering the problems faced by a small power system. A power company with multiple generating plants can tolerate accidents which put a plant temporarily out of commission. The company's remaining plants can pick up its load for at least a short period of time and continue uninterrupted service. A power company with a single plant, however, can not afford accidents. Any shutdown completely deprives all the company's customers of power, discourages potential customers from adopting electrical equipment, and discourages current customers from expanding their dependence on the service, all very serious problems for an infant industry. In the early twentieth century power interruptions also invited the invasion of one company's territory by other power companies willing or able to promise uninterrupted service. Since Volta was the first and only hydroelectric plant of the Keswick Power Company in 1901, Keswick's engineers attempted, in designing the various elements of the plant, to minimize the possibility of complete plant shutdown.

The routing of the Keswick ditch is an example of the utility's attempts to minimize the possibility of breakdown and power interruption. The ditch completely avoided the use of flumes, tunnels, trestles, and steep hillside ditching, since all of these were susceptible to problems (e.g., landslides). [30] The artificial forebay reservoir erected by Keswick at the top of the plateau overlooking Volta is another example.

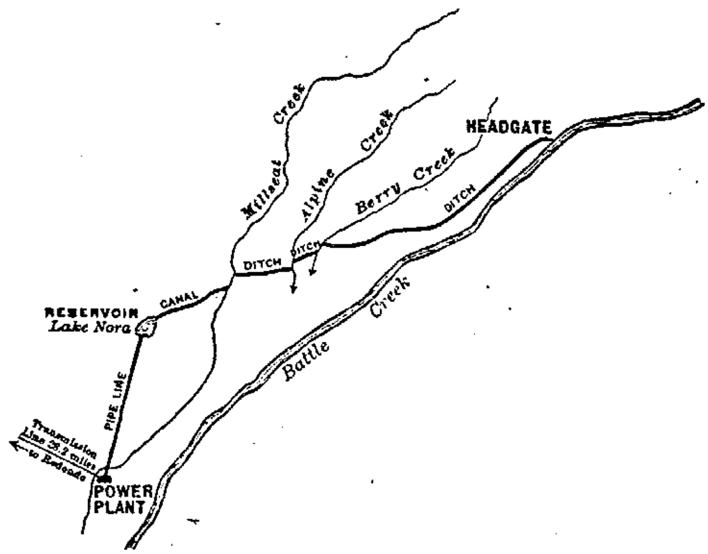


Table 7. The Volta Ditch System, 1901

Source: Electrical World, v. 44 (1904) p. 408.

Some California plants in areas where flow was fairly dependable used simple header boxes at the entrace to a penstock (especially if there were other plants to back it up). Keswick erected an earth dam 1054 feet long, 14 feet high, and 59 feet thick (at base) at the lower edge of a mountain meadow, creating Lake Nora, a combination forebay and storage reservoir. Named after Noble's eldest daughter, Lake Nora covered 3.5 acres and had a storage capacity of 15 acre-feet. [31] Should the ditch system leading water to Volta fail due to blockage or should a section have to be shutdown for cleaning or repair, Lake Nora had sufficient volume to keep the plant operating for six to ten hours. [32] [See HAER photo 120]

Water was carried from the forebay to the power house through a penstock or pipe line almost 7000 feet long. The intake to the penstock was a rock-filled crib with large wooden headgates located near the middle of Lake Nora. Debris was filtered from the water through the use of grizzlies or screens made of iron bars. For 800 feet from the intake the slope was moderate and the water was carried in 42-inch diameter redwood stave pipe. This was not unusual in California hydroelectric practice. Pressures were low on this section and wood stave pipe was much cheaper than steel. Where the ground began to slope sharply downwards the redwood pipe was terminated and linked to 6000 feet of 30-inch diameter lap-welded steel pipe [see HAER photos 152 and 154]. The penstock terminated in a 30-inch diameter, 47 foot long header which paralleled the north side of the powerhouse. Three supply pipes carried water from the header through two hand-operated gate valves to the nozzles of the impulse wheels.

The Volta penstock followed good California practice in most respects. It was well anchored against movement, lateral or sliding, by being buried in a trench. To protect against sudden pressure build ups and possible rupture a stand pipe was installed near the transition from 42-inch to 30-inch diameter pipe. Six automatic relief valves (enclosed in wooden housings to prevent freezing in cold weather) were distributed along the line where slope changed sharply. [33]

The penstock installed at Volta deviated from standard California practice in one significant respect. It used lap-welded rather than lap-riveted pipe. Lap-riveted pipe was generally (but not invariably) preferred in early California hydroelectric plants, because of its record of reliability. Instances of lap-rivetad pipe bursting were rare. Lap-welded pipe, on the other hand, was regarded with suspicion. But lap-welded pipe did have some advantages. Friction losses were lower because there were no protruding rivet heads. In addition it was cheaper. Lap-riveted pipe had to be thicker (and thus heavier and more expansive) than lap-welded pipe to compensate for the weakness introduced by the rivet holes. [34] Since the pipeline was a major cost item in early hydroelectric plants, Keswick engineers may well have decided to take a few, hopafully slight, risks here to reduce expenses. [35]

The exciters and governors at Volta were supplied with water by a system independent of the main penstocks. The exciter water supply came from Millseat Creek. Some distance below the Keswick ditch a small dam and canal diverted water from this stream into a small forebay. A 6-inch pipe carried watar from this forebay under a 400 or 500 foot head to two 18-inch diameter Pelton exciter wheels. Each of these impulse wheels powered a 45 kW Westinghouse dc generator which energized the field coils of the three main generators. There were three governors at Volta, one for each of the generating units, all Lombard type "F". Activated by water pressure, they regulated the speed of the main water wheels by manipulating their pivoted ball-and-socket nozzles, diverting all or a portion of the water jet away from the wheels and out the tailrace. The governor water supply was taken from the spillway of the exciter forebay and stored in a large tank. A 6-inch pipeline led water from this tank under either a 160 foot head or a 250 foot head (authorities differ) through duplicate strainers to each of the governors.

Because of the small size of the pipes used to supply water to the governors and exciter impulse wheels and due to the even smaller diameter of the nozzles which discharged water onto the exciter wheels, governor and exciter systems were very prone to blockage by leaves and other debris. It was to minimize this danger that an independent hydraulic system was used with the governors and exciters at Volta. With an independent supply problems in the governor and exciter water supply could more easily be delt with without having to shut down the main water supply and thus the entire plant. The water for these systems was taken where the water was "crystal clear" and hence less likely to clog small lines than the general water supply. To further insure the purity of the water used for governors and exciters, Keswick installed a revolving screen in early 1903. The flume carrying the exciter and governor water to the exciter forebay was emptied over a rotating cylindrical screen, 54 inches in diameter by 5 feet long with 1/2 or 3/8 inch mesh. A second flume, placed inside this screen and at a right angle to the incoming flume, picked up the filtered water and delivered it to the exciter forebay. To further insure that the governor water was clear, its pipeline was equipped with dual strainers near the powerhouse. The duplicate arrangement allowed one set of strainers to be removed for cleaning while the other was still operative. [36]

The use of two excitar sets at Volta also provided insurance against plant shutdown due to clogging. Should one exciter nozzle become plugged, the other wheel could continue to operate the plant. In addition, one of the exciter sets was coupled to a 50 hp induction motor. This motor was linked to the plant's bus bars and operated at synchronous speed with the attached dc generator during normal operation. But if the water wheel nozzle became jammed with debris, the motor would automatically pick up the load and operate the exciter with current from the main generators without the water wheel. This would allow operators to clean the injured nozzle without shutting down the plant. [37] Thus the governor and exciter systems at Volta, like the ditch system, were designed to minimize the possibility of complete plant shutdown and interrupted electrical service.

The powerhouse at Volta was a massive rectangular structure approximately 86 feet long, 47 feet wide (outside dimensions). Its concrete foundations were laid on stone and hard earth. Its 2 foot thick walls were built up from porous lava rock quarried 1000 feet from the site and laid with lime mortar with unpointed joints. The tailraces, wheel pits, and floors were poured concrete, but the floor spaces around the gate valves, tailraces, and tail pits were simply covered with cast iron plates on cast iron frames for easy access to hydraulic apparatus. Steel trusses (later replaced by wood trusses) carried a galvanized iron roof and a ceiling of suspended sheets of galvanized iron. [see HAER photo 7]

The powerhouse was divided longitudinally into two rooms by an interior fire wall. On the north side of the building, towards the incoming penstock, was a transformer and switchroom around 12 feet wide. The south side of the building was occupied by the 28-foot wide generator/impulse wheel room. Both rooms were provided with large doors for the easy installation or removal of equipment. [38]

The generator room contained the housings for the three 1500 hp Pelton impulse wheels. These wheels had rotors 64 inches in diameter, were mounted on dual bearings, and had extended shafts terminating in heavy cast iron flanges. Their axles were arranged along a common center line across the length of the room. Each of the impulse wheels was linked by flexible rawhide coupling to a 750 kVA, 500 V, revolving armature Westinghouse generator. These machines were operated at 400 rpm and were similarly mounted on two bearings with an extended shaft terminated by a flange. [see HAER photos 19, 21, 23, 24 for Volta interior in 1901]

A flexible coupling was used to link independently mounted water wheels and generators because if the alignment of shafts was not perfect a rigid connection would have caused problems. The flexible linkages (leather strips 10 inches long by 7.5 inches wide by 3 3/8 inches thick) running from pins on the generator flanges to pins on the impulse wheel flanges permitted a slight displacement in shaft alignment due either to foundation settlement or slight error in the original setting of the machines.

Both the selection and the arrangement of the generating units at Volta were probably designed to further minimize the possibility of complete power interruption. The 500 volt Westinghouse generators, for instance, were a conservative selection, the low voltage providing a good guarantee against generator problems due to insulation breakdown. The use of three small units instead of a single large one insured that problems with one generator or one water wheel would not shut down the plant and enabled Keswick to use two units to provide service while the third was kept in reserve for emergencies. Finally, the extended shafts linking water wheels to generators were arranged so that adjacent units could be interchanged. If problems developed with one wheel, its generator could be disengaged and linked up to an adjacent wheel. If problems developed with a generator, its water wheel could be switched over to another generator. [39]

Leads from the three main generators were connected directly to the switchboard by cables running in ducts beneath the floor. This was possible because of the low voltage of the generators (only 500 volts). Simple knife switches at the switchboard were used to link the generators to the stations double transformer bus bars.

Volta had ten 600 kW Westinghouse oil insulated, air cooled, single phase transformers arranged in banks of three with the extra unit held in reserve. Although the smaller and cheaper water cooled transformers were becoming standard in California at the time, air cooled transformers were not uncommon. Air cooling was sdequate for small power units and less subject to problems (e.g., clogging of the water circulation aystem by mineral deposits). The Volta transformers stepped the voltage up from 500 to 22,000. Lines from the transformer secondaries led through high voltage oil switches, designed to protect both generators and transformers from overloads due to current surges or excess voltage, to lightning arrestors, and then out through the walls to a switchyard. Lines initially led from the switchyard 30 miles to Redding, then 7 miles further to the Mountain Copper Company's Keswick smelter, then 6 miles beyond to the Mountain Copper Company's mine at Iron Mountain. [40]

As the firat of the Keswick Electric Power Company's bydroelectric plants and the cornerstone on which future expansion would be based, Volta was designed, as we have noted, to minimize the possibility of ahutdowns. In Noble's words, it was constructed "as thoroughly and aubstantially as possible". [41] While not a large or important plant by later standards, it was a ratber large and modestly important plant by contemporary standards. On a list of thirty-one major California hydroelectric plants reviewed by one author in 1904, Volta operated under the sixth highest bead, was fifth in the distance its power was transmitted, and operated at the seventh highest transmission voltsge. [42] On a list of 106 California hydroplants publisbed in 1907 Volta ranked sixth in power output (Volta's installed capacity had been doubled by this time). [43]

Volta was in most respects typical of turn-of-the-century California hydroelectric practice. It was higb head (1204 feet), low volume (c. 45 second-feet), had a ditch network miles in length, and used impulse wheels instead of Francis turbines. Typical also of California practice was the station's use of banks of single phase transformers and water-activated rather than pump-activated governors. The station's rotating armature generators were a little unusual. But the rotating field generator was just beginning to emerge as the standard design in 1901 and the low voltage of the Volta units certainly made the rotating armature design acceptable. Even the rather pictureaque rubble stone construction of the powerhouse was not uncommon among early California hydroelectric plants.

NOTES

[1] Bailey Millard, History of the San Francisco Bay Region, v. 2 (New York, 1924) p. 206.

[2] Redding Free Press, September 8, 1900; Redding Searchlight, September 9, 1900.

[3] Redding Searchlight, September 8, 1900.

[4] Redding Searchlight, September 9, 1900.

[5] "Deed of Trust: Keswick Electric Power Company to Mercantile Trust Company of San Francisco, Trustee," June 1, 1901 (PG&E, Secretary's Office, document 1569-c); "Deed:Keswick Electric Power Company to Northern California Power Company Consolidated," October 26, 1908, pp. 4-5 (PG&E, Secretary's Office, document 1569).

[6] Shannon was credited by local papers with organizing the new company and enlisting the necessary financial support (Redding Free Press, November 1, 1900; Redding Searchlight, November 16, 1900, and January 18, 1901). What his exact role was is unclear.

[7] San Francisco: Its Builders Past and Present (San Francisco, 1913) pp. 297-300 ("Hamden Holmes Noble") and San Francisco Chronicle, December 20, 1929.

[8] Fowler, Hydroelectric Systems of California, p. 126; CRRC, Transcripts [of Hearings], cases 675, 676, 677, 711, v. 3 (February 2, 1916) p. 122 (testimony of Edward Whaley, Secretary of the Northern California Power Company, Consolidated) (CSA); and CRRC, Decisions, v. 11 (September 1, 1916 to November 30, 1916) pp. 40-41.

[9] Redding Free Press, November 1, 1900.

[10] Redding Searchlight, November 23, 1900.

[11] Redding Free Press, November 1, 1900.

[12] Redding Searchlight, November 16, November 23, and December 12, 1900; Redding Free Press, January 18, 1901.

[13] Redding Searchlight, September 5, 1901, says originally only two generators were to be installed. For the July 1, 1901, completion date see Redding Free Press, January 7, 1901. See also George J. Henry, "Some Recent High-Head Pelton Water Wheel Installations," JE, v. 11 (January 1901) p. 34.

[14] Red Bluff News, November 23, 1900; Red Bluff Daily News, November 21 and November 22, 1900; Red Bluff Daily Peoples' Cause, February 15, 1901.

[15] Red Bluff Daily News, January 21, January 22, January 23, January 30, February 13, and February 24, 1901; Red Bluff Daily Peoples' Cause, February 15, 1901.

[16] Red Bluff Daily News, May 3, 1901.

[17] Redding Free Press, January 18, 1901; Redding Searchlight, March 8, 1901; Red Bluff Daily Peoples' Cause, February 15, 1901.

[18] Red Bluff Daily News, April 17, 1901.

[19] Redding Free Press, October 17, 1901; Red Bluff Daily News, July 22, 1901.

[20] Red Bluff Daily News, March 29, 1901; Redding Searchlight, July 14 and August 9, 1901.

[21] For the progress of construction at Volta see: Redding Searchlight, July 17, July 18, August 2, and September 5, 1901; Redding Free Press, August 1 and August 13, 1901; Red Bluff Daily News, July 25 and September 5, 1901.

[22] Red Bluff Daily News, October 25, 1901; Redding Free Press, October 17, 1901; Redding Searchlight, October 17, 1901.

[23] Redding Searchlight, October 2, 1901; Redding Free Press, November 1, November 26, and November 28, 1901.

[24] Redding Free Press, November 29 and December 16, 1901.

[25] Information on the layout and design of the Volta hydroelectric plant in 1901 was largely drawn from the following sources: "The Northern California Power Company's Transmission," JE, v. 12 (1902) pp. 231-237; "The Northern California Power Company's Systems — I," Electrical World, v. 44 (1904) pp. 407-410; "The Water Power Plants of the Northern California Power Co.," Engineering Record, v. 50 (1904) pp. 506-507; Van Norden, "Northern California Power Company," pp. 112-118 (primarily p. 113); "The 22,000 Volt Transmission Installation Supplying Current to Mines by the Northern California Power Company," Mining Reporter (March 26, 1903) pp. 283-285; J.G. White & Co., "Report," pp. 32-37, 42-43, 52-54; and the Valuation Survey Field Books relating to Volta (dating from period 1912-1916), especially Field Book 1 (H-1) and Field Book 4 (H-28) [R/V].

[26] "Northern California Systems - I," p. 407.

[27] "Deed of Trust: Keswick Electric Power Company to Mercantile Trust Co. of San Francisco, Trustee," June 1, 1901 (PG&E, Secretary's Office, document 1569-c).

[28] Redding Free Press, September 29, 1900, and January 18, 1901; Redding Searchlight, February 3, 1901.

[29] For information of the Keswick Canal c. 1901 and after see: "Northern California Systems - I," pp. 407-408; Fowler, Hydroelectric Systems of California, p. 228; Valuation Survey Field Book H-1 (R/V); NCPC-C, "Valuation Detail Folder no. 5" and "Computation Folder no. 40" (R/V).

[30] "Northern California Systems — I," p. 407.

[31] The data on Lake Nora is drawn from: Fowler, Hydroelectric Systems of California, p. 229; NCPC-C, "Valuation Detail Folder no. 5," p. 37 (R/V); NCPC-C, Valuation Survey Field Book H-1 (R/V); and PG&E, "Federal Power Commission, Applications on N.C.P. System " (attached to J.O. Burrage to A.H. Markwart, November 10, 1924 in PG&E Central Engineering File) [This will hereafter be cited as FPC-1924, for Federal Power Commission, 1924 application.]

[32] "Northern California Systems-I," p. 408; "Water Power Plants," p. 506; "Northern California's Transmission," p. 232.

[33] On the Volta penstock see: "Northern California's Transmission," pp. 232-233; "Northern California Systems - I," pp. 408-409; "Water Power Plants," p. 506; Fowler, Hydroelectric Systems of California, p. 229; and NCPC-C, Valuation Survey Field Book 4 (H-28), pp. 7-13 and esp. 22-29 (R/V).

[34] See, for example, J.P. Jollyman, "Practice in High-Head Hydraulic Plants," National Electric Light Association, 38th Convention (1915) Proceedings, v. 3, pp. 460-461, and J.D. Galloway, "The Design of Hydro-Electric Power Plants," American Society of Civil Engineers, Transactions, v. 79 (1915) p. 1015. Galloway in "Hydro-Electric Power Plants in California," JE, v. 29 (1912) p. 317, asserted: "I have never known one [lap-riveted penstock] to fail".

[35] C.L. Cory noted in commenting on Galloway, "Hydro-Electric Plants in California," p. 363: "It wasn't an easy thing in 1892, and even as late as 1901 and 1902 to get the money necessary to build these plants . . ." Thus money may have been a primary consideration in the decision to use lap-welded pipe.

[36] The Volta exciter and governor systems are described in "Northern California's Transmission," pp. 233-235; "Northern California Systems - I," pp. 409-410; "Water Power Plants," pp. 506-507; Fowler, Hydroelectric Systems of California, pp. 231-232; and NCPC-C, Valuation Survey Field Book 4 (H-28) pp. 36ff (R/V).

[37] "Northern California Systems - I," p. 410; "Water Power Plants," p. 507; Van Norden, "Northern California Power Company," p. 115.

[38] For the layout of the Volta powerhouse in 1901 see the articles in note [25] above and in particular Valuation Survey Field Book 1 (H-1) pp. 1-6; also PG&E drawings 63725 and 64341.

[39] For the water wheels and generators used in the 1901 installation see the items cited in note [25] above and in particular NCPC-C, Valuation Survey Field Book 4 (H-28) pp. 53-54, 71-73; also PG&E drawing 63731.

[40] Only very sketchy descriptions exist of the 1901 Volta electrical layout. See the articles from JE, Electrical World, and Engineering Record cited in note [25] above.

[41] NCPC, 1st Annual Report (1902-1903).

[42] Doble, "Hydro-Electric Power Development in California," fig. 2, following p. 76.

[43] "Some California Power Stations," JE, v. 19 (1907) p. 354. Volta is listed as "Northern California Power Co., 2d Station" and its "electric horsepower" is given higher than it should be (6600 hp instead of around 5600). But this does not significantly alter its rank.

CHAPTER IV

GROWTH AND DEPRESSION:

The Early Expansion of the Northern California Power Company (1902-1908)

INTRODUCTION

In the early twentieth century, in the first flush of expansion, it was not unusual for electric utilities to overestimate the possibilities of the area where they hoped to market power and install considerable excess generating capacity. [1] The Keswick Company fell into this trap. As a result Keswick and its successor companies were caught up in a series of cycles in which over-installation of generating capacity forced the utility to aggressively develop markets for its power. Success in these marketing efforts and other favorable portents then seduced company officials into again overestimating future market possibilities. This led, once again, to the installation of excess generating capacity, thus beginning the cycle anew.

This cycle of over-expansion, strenuous marketing efforts, and overly-optimistic forecasts of the future was repeated several times between 1900 and 1919 when Northern California Power Company, Consolidated, Keswick's successor, was absorbed by the Pacific Gas and Electric Company. In part Keswick's dilemma reflected the nature of the region. Northern California was a sparsely populsted and largely unindustrialized region at the turn-of-the-century. Hydroelectric plants were usually erected in such areas not to satisfy an existing demand but to meet an anticipated demand. And because anticipated demands do not always develop into actual demands, many optimistic forecasts were doomed to failure.

BACKGROUND TO KILARC: The First Cycle of Expansion, Disappointment, and Aggressive Marketing, 1902-1904

H.H. Noble, the president of the Keswick Electric Power Company, acknowledged shortly before Volta went on line that his utility would have considerable excess generating capacity, but optimistically hoped that this surplus would be short lived. [2] Volta was to go on line with 1500 kW, increasing to 2250 in early 1902 when its third 750 kW genersting unit was in place. The guaranteed load of the new company was probably under 750 kW in late 1901, and more than two-thirds of that was supplied to a single customer -- Mountain Copper Company. Thus, even before the Keswick Electric Power Company began selling current, it was forced to aggressively cultivate a market for its power.

Much of the utility's marketing efforts were directed towards the mining industry of Shasta County, for the company had been created specifically to serve its needs. The mining industry, moreover, offered Keswick a very attractive power market. Hydroelectricity was competitive. Keswick could deliver power from Volta at a price one third to one half that of the power derived from the wood-fired or, occasionally, oil-fired engines which most mines and smelters were using. [3] Mining offered utilities an excellent load factor (the ratio of average load to peak load) since mines, worked in three shifts, twenty-four hours a day, had relatively constant power demands. Finally, the current used by mines did not have to be "brought up to the same degree of nicety as ordinary", so less expensive regulating equipment was needed. [4] Although Keswick had some success in finding new customers in the mining areas of Shasta County, mining did have one well recognized shortcoming that made it necessary for the utility to seek a non-mining load as well. Mining was a volatile enterprise. Busts followed booms in rapid succession. One could never predict the price of metals from one year to the next or when a rich vein of ore would play out, causing a major customer to curtail or completely shut down operations.

Urban electric lighting and power systems offered an obvious path towards load diversification and the Keswick Company followed it. In March 1901, months before the completion of Volta, the Keswick Company had purchased the Redding Electric Light and Power Company and the Redding Water Company for $60,000. These gave Keswick an established power market in a major city directly in the path of the transmission lines which were to link Volta and the Mountain Copper Company at Keswick, plus water rights on nearby Cow Creek. [5] To finance this acquisition Keswick issued $200,000 in bonds, which were purchased by the Mercantile Trust Company of San Francisco. Keswick signed in June 1901 a "Deed of Trust", pledging its properties, water rights, franchises, and equipment as collateral. [6]

To further diversify their power market and to further reduce the company's excess generating capacity, Noble and his associates in early 1902 extended power lines south into Tehama County. In 1901 Keswick had secured an option to buy the Tehama Electric Company plant in Red Bluff, but had been unable to secure sufficient capital. In early 1902 negotiations had been renewed, but with little success. [7] In February, however, the Tehama Company's plant burned, plunging more than half of Red Bluff into darkness. Keswick was able to secure the Tehama Company's burned-out plant and undamaged distribution system for $35,000. [8] This purchase gave Keswick another established market. But, perhaps more importantly, it provided the utility with a gateway for reaching down the Sacramento River Valley to the agricultural settlements south of Red Bluff and towards the very lucrative power market of the San Francisco Bay area. [9]

Construction of a 30 mile line linking Red Bluff, through the small river towns of Anderson and Cottonwood, to the Volta-Redding line at Palo Cedro began in February 1902 with a crew of one hundred men. It was completed on April 20, when Red Bluff received its first power from Volta. [10] The Tehama Electric Company did have some lines extending south from Red Bluff to Corning. But Keswick engineers found these lines seriously deficient, requiring reconstruction, so immediate expansion south of Red Bluff was not possible. [11]

The expense of building Volta and the power lines to Redding and Keswick had nearly exhausted the authorized capitalization of Noble's company ($300,000). The indebtedness incurred in buying the Redding utilities in 1901 eliminated the possibility of bringing in new capital through a bond issue. [12] Thus the decision to purchase the Tehama Electric Company and to build new power lines linking Volta with Red Bluff and points south made at least a minor reorganization of the utility necessary.

However, capital was also needed for other projects. Keswick had had some success in late 1901 and early 1902 in reducing the excess generating capacity of the Volta plant, and prospects seemed excellent that the company's excess capacity might soon be completely eliminated. For the mining industry in Shasta County 1901 had been a banner year. Production rose sharply in both mines and smelters [13], resulting in a substantial increase in actual and anticipated demands for electric power. The Bully Hill copper mine and smelter, eventually the second largest copper property in Shasta County, initiated operations in 1901, and offered Keswick the opportunity to secure a major customer. [14] With copper prices rising, a number of mining and smelting companies in the region planned to expand their plants and power loads. [15] With future market prospects bright, Noble and his associates were not satisfied with merely eliminating Volta's excess capacity. They wished to bring more capital into the enterprise and expand the company's generating capacity to meet the rising power needs of the area. In order to do this, and finance the purchase of the Red Bluff utility and the extension of lines south, a major reorganization of Keswick was required.

On March 12, 1902, the directors of the Keswick Electric Power Company incorporated the Northern California Power Company, capitalized at $2,000,000. Stockholders in the Keswick Company were offered $6.00 worth of Northern California stock for each share of stock in the original company (Keswick stock had been sold for $3.00 per share). [16] In addition, a syndicate including Noble, Edward Coleman, and Antoine Borel, offered Keswick stockholders who did not care to make the stock exchange $6.00 cash for each share of stock in the old company. There were no takers. Every share of Keswick stock was exchanged. The syndicate also offered to purchase any stock left in the treasury after Keswick stockholders had exercised their option. [17] To raise additional money, the new company immediately authorized a bond issue of $1,000,000. This entire issue was purchased by the Union Trust Company of San Francisco on June 1, 1902. [18]

The money raised by the reorganization enabled the Northern California Power Company to complete the power line linking Red Bluff to Volta via the switching station at Palo Cedro. It also provided the funds for the reconstruction of the Tehama Company's lines south of Red Bluff and the extension of these lines in the summer and fall of 1902 further south through Corning and Orland to Willows in Glenn County, where power was wholesaled to the Willows Water and Light Company. Lines were also erected in late 1902 southwest 12 miles from Redding to Horsetown, where Northern California had secured in August a contract for 300 hp to run electric motors for gold dredging operations and north 18 miles from Palo Cedro to Delamar, location of the Bully Hill mine and smelter. [19]

Northern California's plans for expansion initially centered not on Battle Creek, where the Volta plant was located, but on a much larger stream, the Pit River. In August 1902 Northern California placed surveyors on the Pit and filed claim on 250,000 inches (6250 second-feet) of water. Shortly after Noble announced plans for an immense hydroelectric plant. A large dam was to divert 4000 second-feet of water into a canal 28 miles long. This water would be used under a head of 1300 feet to generate as much as 400,000 to 500,000 hp, a capacity second only to the power being developed by the combined output of the stations around Niagara Falls. This power was to be transmitted 260 miles to San Francisco. [20]

This plan, however, was found to be impractical after further study and was probably too ambitious for the utility in any case. Northern California soon moved its small Pit River crew to another site and made some tentative plans for a much smaller project. But even this involved too great a capital outlay for the company. This mini-force was maintained on the Pit after 1902 to insure that the company's water rights were protected. But the utility transferred most of its efforts to a more realistic and less expensive expansion option in mid-1902. [21]

Before the fall of 1902 Northern California had begun to finalize plans for the construction of a much smaller power plant to back up Volta. This plant was to be located 20 miles north of Volta on the south bank of Old Cow Creek, a tributary of the Sacramento River north of Battle Creek. The property and water rights for the plant had been acquired with the purchase of the Redding utility companies in 1901. Although a contract for two generators for this new plant was awarded to Westinghouse in August 1902 and even though the design details of the new plant seem to have been largely worked out by December, work was pushed at only a very slow pace. Early plans to complete the plant by July 1903 were scrapped. [22]

The slow pace of construction on the new plant, to be named Kilarc, can probably be attributed to a sharp downturn in Northern California's prospects in late 1902 and early 1903. A labor dispute idled the company's largest customer -- Mountain Copper -- for the last month and a half of 1902 and well into 1903. In addition, world copper prices dropped sharply, causing companies in Shasta County's mining district to curtail operations and cancel or postpone plans for expansion. Production of copper in the region dropped from almost 31,000,000 pounds in 1902 to around 16,500,000 pounds in 1903. These developments "very materially" reduced Northern California's anticipated revenue and made expansion of generating capacity less urgent. [23] They also demonstrated, quite graphically, the risks involved in over-dependence on the mining industry.

In late 1902 and early 1903, in an attempt to secure a market for the excess generating capacity of Volta, and to further lessen dependence on mining, Northern California began to seek new markets "where income will be more permanent" in an aggressive manner. [24] The company initiated a campaign to actively promote the use of electric pumps for irrigation in the Sacramento River valley in the southern part of its territory. This campaign by the end of 1903 had had "some success". [25]

The utility also secured a contract to supply wholesale power to the Willowa Water and light company. [26] In addition, in March 1903, Northern California Power bought the Red Bluff Electric Light and Gas Company, giving it complete control of lighting in Red Bluff. [27]

In the spring of 1903 there were aome signs of improvement in the company's poaition. Increased agricultural use of electric power seemed a certainty. The company'a foothold in the Shasta County mining belt had steadily expanded. A contract, for instance, had been aecured with the Bully Hill mine and smelter at Delamar, requiring the extension of power lines to that point from the switching station at Palo Cedro. In addition, the Balaklàlà Copper Company was planning a 1000 hp (750 kW) smelter. Northern California hoped for the contract to supply it with power. [28]

With 2456 of Volta's 3000 hp (c. 1850 of 2250 kW) under contract, Noble recommended to atockholders in March 1903 that construction of the Kilarc plant be carried out immediately, since there were "excellent prospects" for new businesa. [29] His recommendation was accepted. In May 1903 Northern California purchased two sets of impulse wheels for Kilarc from the Pelton Water Wheel Company to go with the two generators contracted months earlier with Westinghouse. [30] Plans were made to extend power linea from the Bully Hill aubstation 20 miles to the site of the new plant. Theae lines were to serve two ends. They would provide electricity for construction work and would allow immediate connection of the new plant into Northern California's transmisaion network. [31]

Developments toward the end of 1903 seemed to demonstrate the wisdom of NCPC's decision to expand. Besides "some success" in acquiring an irrigation load, the company secured important power contracts with the Balaklala mine and smelter and with the Belle Vue Irrigation Company at Anderson. Lines were built in 1903 and early 1904 to both of these enterprises. [32] By February of 1904 Northern California Power had a transmission network of 220 miles. Thia system had 3634 connected horsepower (2710 kW) and a capacity of only 3000 hp (2250 kW). Although the actual peak load was still safely below the capacity of the system, it was steadily increasing. [33]

Work on Kilarc was thus pushed agressively through the spring, summer, and fall of 1903 and on into the winter of 1903-1904. Winter conditiona delayed construction, but by March 1904 company officials were predicting that the new plant would be operative with two weeks of good weather. [34] Their prognoatications were a little too optimistic. The ditch system for Kilarc was completed in June, but the penstock and equipment installation was not compeleted until July. Kilarc began generating power only on July 22, 1904. [35]

THE KILARC PLANT [36]

Kilarc's design was very similar to Volta's. The powerhouse was constructed of massive rubble masonry with a corrugated iron roof carried on ateel trusses [see HAER photos 172, 173]. Like Volta water was supplied to the powerhouse from a combination forebay reservoir, able to supply the plant with water for up to eight (or sixteen according to some sources) hours should problems develop with the ditch system. Like Volta, the governors had an independent water supply and the main penstock was partially wood stave and partially lap-welded steel pipe. Also, like Volta, the turbines and generators were placed along a common center line running the length of the powerhouse. The units themselves were basically similar in design to Volta's -- two-bearing Pelton impulse wheels linked to two-bearing generators by flexible rawhide coupling. Even the head at the two plants was almost identical — 1196 feet at Kilarc vs. 1204 feet at Volta.

But there were some differences. The ditch system at Kilarc was longer and more suceptible to problems than that at Volta, largely due to the more difficult nature of the terrain. Cow Creek runs through a steep rocky canyon. Diverting water from the stream with a small concrete overflow dam and leading it to the top of the plateau which overlooked the powerhouse required the use of a long flume which ponderously crawled up the precipitous side of the canyon. The total length of the main Kilarc ditch was around 3.7 miles. This included 8576 feet of flume; 10,600 feet of ditch; and two tunnels totaling 324 feet. This system carried, normally, around 65 second-feet of water.

There were other differences between Volta and Kilarc. At Volta the generators, transformers, and high voltage switching gear were all contained in a single building, normal California practice at that time. At Kilarc the generators and water wheels were housed in one structure; the transformers and high voltage switching gear were placed in an adjacent building. There was a single penstock as at Volta, and it was terminated by a header running parallel to the length of the generator room, with branches to the impulse wheels. Kilarc, like Volta, had water-driven exciters linked to induction motors. But, unlike Volta, the exciters at Kilarc were supplied by branch pipes taken off the main penstock header, instead of by a completely independent water supply.

The impulse wheel units at Kilarc and Volta were dissimilar. At Volta the units had single rotors. At Kilarc each water wheel unit was composed of two Pelton rotors mounted 3 feet apart on the same shaft, covered by the same hood. The capacity of these dual rotor units was 3000 hp. One of the rotors was supplied with water by a simple deflecting nozzle. The other rotor was supplied by a deflecting needle nozzle, i.e., a nozzle equipped with a movable needle in its throat whose movement altered the volume of water allowed to flow through the unit. In normal operation the plain nozzle constantly delivered its full flow to its rotor. A water-activated Lombard "Q" governor regulated the speed of the unit by moving the needle of and/or deflecting the second nozzle.

As at Volta the Kilarc water wheel units were separately mounted on dual bearings and drove Westinghouse generators mounted on dual bearings through flexible rawhide couplings at 300 rpm. The Kilarc generators were, however, larger than those at Volta (1500 kVA vs. 750), operated at a higher voltage (2200 volts vs. 500), and were of the rotating field rather than the rotating armature variety. It would have been possible at Kilarc to have used four single rotors, each linked to a generator of the capacity used at Volta. The decision to use the double rotor units and the larger generators was undoubtedly dictated by economic considerations. It was much cheaper to purchase a double rotor impulse wheel and one large generator than two single rotor impulse wheels and two small generators. Had Kilarc been the first power station of the system, the larger number of units would have been needed to provide a reserve in case of problems. But with Volta available as backup, Northern California Power could adopt the more economical equipment installation at Kilarc.

The high voltage of the generators at Kilarc required a different wiring arrangement. The dual 2200 volt busses at Kilarc were linked at the switchboard to the primaries of the transformers through oil switches instead of simple knife switches. The transformers at Kilarc stepped the potential up from 2200 volts to 22,000 volts. Oil switches, controlled from the switchboard linked the transformer secondaries to the outgoing circuit to Delamar (Bully Hill) and later (1906) to a second circuit leading south to Volta. The Kilarc plant was one of the earliest to use remote control for high voltage switches. [37]

The addition of Kilarc to Northern California's system gave the utility, according to one author, "the most flexible plant in the State," allowing uninterrupted, reliable service. [38] With a total generating capacity of 5250 kW, Northern California Power Company had become the most important utility in the northern third of California and second only to California Gas and Electric (the forerunner of the Pacific Gas and Electric Company) in the entire northern half of the state. In California as a whole, Northern California Power Company was ranked as the fourth leading utility (behind California Gas and Electric and the Edison and Pacific Light and Power Companies of southern California). [39] The Northern California transmission system in 1904 is illustrated in the table on the following page.

EXCESS AGAIN: The Northern California Power Company, 1904-1906

Kilarc was completed in the midst of a very disappointing year (1904) for the Northern California Power Company. The hopes of the previous spring proved false. The 1000 hp (750 kW) smelter which was to have been erected by Balaklala Copper Co. was not constructed. The gold dredger at Horsetown, which at one point had 700 hp in electric motors installed, shut down.[40] Farmers adopted electric pumps for irrigation "very slow[ly]". And Mountain Copper, the major customer, had cut its power consumption by 33% as a result of a prolonged fire in its mines. [41]

Thus, once again, Noble's utility found itself with a large surplus of generating capacity. In late 1904 and early 1905 the average load on NCPC's circuits was around 1500 kW (2000 hp). The company's Battle and Cow Creek plants had an installed capacity of 5250 kW (c. 7000 hp), so around 3750 kW (5000 hp) was simply allowed to run to waste for lack of a market. [42]

Plagued with excess generating capacity, Northern California Power was forced, once more, to aggressively cultivate new power markets. Again their efforts brought some success. Late in 1904 the company signed a ten year power contract with Mammoth Copper Company, which was in the process

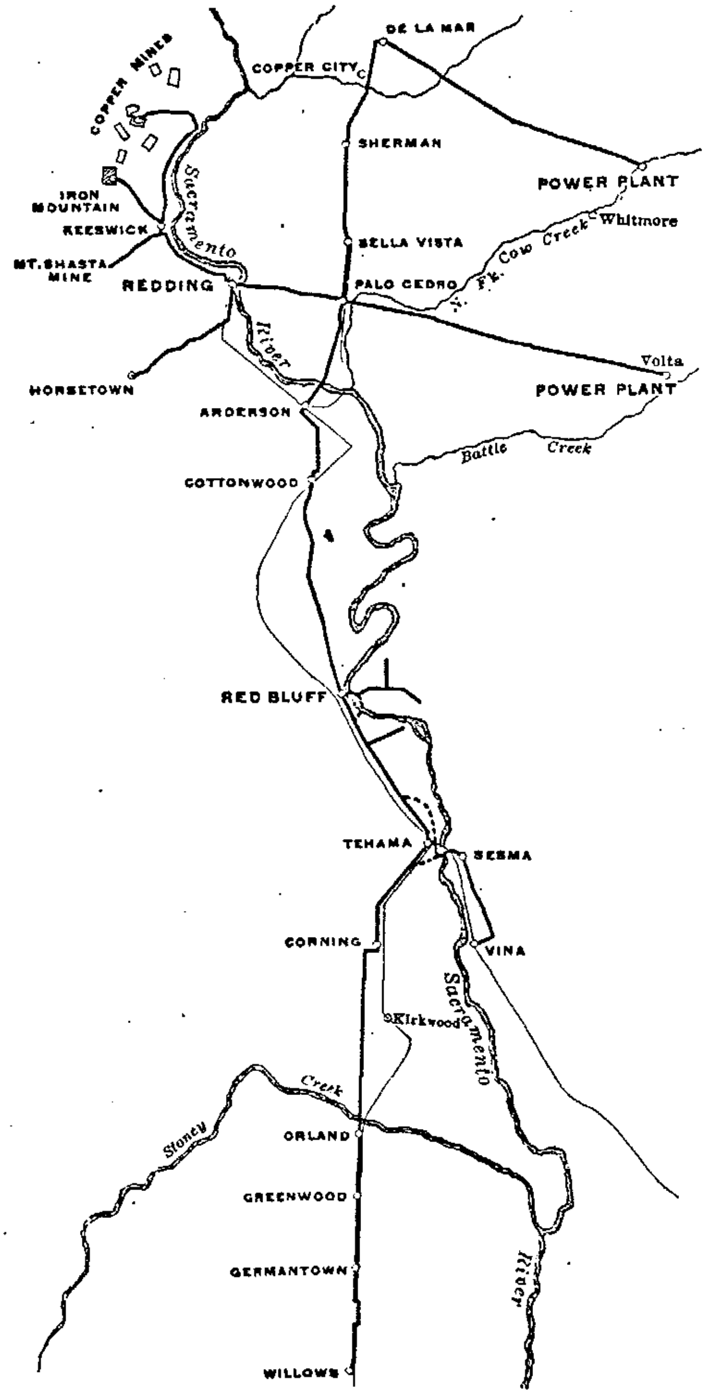


Table 8. The Northern California Power Company's Transmission System, 1904.

Source: Electrical World, v. 44 (1904) p. 503.

erecting a smelter at Kennett. Power lines were extended north a few miles from Keswick to this customer in early 1905. Another contract was signed with the Great Western Gold Company. This company was erecting a small 200 hp (150 kW) smelter at Ingot, between Delamar and Kilarc. To link this smelter and Great Western's "Afterthought Mine" into the transmission system a line was run from Delamar to Ingot, where a substation was established. Lines were extended in 1905 westward into Trinity County to the gold mining area around French Gulch and from Kennett to the mine and smelter at Balaklala. In addition, in 1904 Northern California Power purchased the Belle Vue Irrigation Company at Anderson, installed a new electrically-powered pumping plant and set out to "educate irrigationists in the use of electric power" with this facility. [43]

Another power market seriously courted by Northern California during 1904 and 1905 was railroad electrification. As early as 1901, during the construction of Volta, there had been speculation that on completion of that powerhouse another would be constructed specifically to supply power for a railroad to carry the products of Shingletown area sawmills to the Sacramento and the main line of the Southern Pacific Railroad. [44] In 1904 interest revived and local entrepreneurs, apparently with the support of Noble and other Northern California Power executives, hired surveyors to examine the territory between Shingletown and Cottonwood to determine whether a railroad was feasible. [45] Noble committed himself to the purchase of a large block of stock in any company formed to construct such a railroad provided the railroad was electrically powered and provided the railroad company signed a long term power contract with Northern California Power Company. But disputes over whether the railroad should be steam- or electrically-powered and disagreements between Noble and local entrepreneurs over financial matters and control of the enterprise led Noble to withdraw the offer in the summer of 1905. [46] Thus this market for Northern California's power failed to mature. [47]

Northern California, however, had developed alternative plans. In early 1905 active preparations were made for the extension of transmission lines down the eastern side of the Sacramento River through Chico to the gold dredging territory of the Feather River between Oroville and Marysville. Power demand was high in this area and higher electric rates prevailed than in Shasta and Tehama counties. Extension was made even more attractive because several groups were considering the erection of electric railroads in the area. Further, Northern California, in advance of actual construction, had been able to secure power contracts with several area gold dredging companies. [48]

Expansion south of Chico, however, meant invading the territory of another utility, the Valley Counties Power Company, a subsidiary, for all intents and purposes, of the Pacific Gas & Electric Company. Fearing that competition from Northern California Power might lead to a ruinous rate war, PG&E offered to purchase wholesale up to 5000 hp (c. 3750 kW) from Noble's company. [49] Since sales of this magnitude would substantially accomplish the goal sought by Northern California — reduction of excess generating capacity — the offer was accepted, the invasion aborted. The two companies signed a power contract in December 1905. [50] Linkage with PG&E's grid not only insured the sale of up to 5000 hp in excess generating capacity, but also offered Northern California potential future access to the rapidly growing power market in the Bay Area. As the Red Bluff Daily News jubilantly proclaimed: "The trolleys on Market Street [San Francisco] may be operated by power generated in Shasta County". [51]

The contract with PG&E (through its subsidiaries Valley Counties Power Company and Bay Counties Power Company), however, required Northern California to construct a 66 kV transmission line from Volta to Chico, where the grids of the two companies were to link. [52] Due to the purchase of land and water rights in the Battle Creek area, the cost of constructing Kilarc, and the steady expansion of transmission lines between 1902 and 1906, the utility had exhausted both its capitalization and the proceeds of the bonds it had issued in 1902.

To circumvent this dilemma and to carry out the construction of the Chico transmission line and to make other improvements under consideration Northern California officials in March of 1905 formed the Battle Creek Power Company. Capital for the undertakings planned was secured in 1906 by selling $430,000 in Battle Creek Power Company bonds. Northern California received all of the capital stock of the new company (making it a subsidiary corporation) in exchange for guaranteeing the bond issue with its assets. [53]

With these funds Northern California completed a line between Volta and Kilarc[54],and work began quickly on the linkup with Pacific Gas and Electric. To protect the transformers (three, 1250 kW, oil insulated, water cooled,Westinghouse units) necessary to step up the potential of the main Northern California transmission system from 22 kV to the 66 kV of the Volta-Chico line, as well as the high voltage switching gear necessary to operate the new line, Northern California erected a switch house at Volta. Work began on the structure in April 1906 and was competed before the end of the summer. Located approximately 20 feet north of the Volta powerhouse, the new 43 foot by 76 foot structure was architecturally similar to those previously erected by the utility at Volta and at Kilarc. [55] [See HAER photos 3-4, 6, 9, 16, 34-35]

The 70 mile long Volta-Chico 66 kV transmission line was completed in July of 1906. At the time it operated at a potential among the highest of any regularly used commercial transmission line in the world. [56] In addition, the transmission grid formed by the combined Northern California and PG&E systems was the "longest continuous transmission system in the world". The extreme ends of the system, Kilarc powerhouse and San Francisco, were 351.9 miles apart by wire. [57]

At about the period Northern California was linking its grid to the PG&E network, the company began to enjoy additional success in expanding its load in the agricultural regions along the upper Sacramento River valley. Beginning in 1904, and perhaps even earlier, Northern California had encouraged the development of irrigated sugar beet farming on lands near Tehama. These efforts were rewarded when a sugar refinery to process the beets and an alfalfa mill, as well, were constructed in the area. Transmission lines to serve these industries were strung from Orland on the Red Bluff-Willows line 12 miles east to Hamilton City in 1906.[58] In addition, Northern California also obtained a contract to supply electricity to the Central Canal Company, a large agricultural irrigation enterprise in Glenn County. [59]

The PG&E contract and the company's growing agricultural load had virtually eliminated the excess generating capacity problem by 1906 or 1907. Noble announced in March 1906 that sale of 1500 hp (1125 kW) more than installed capacity was "in view". [60] Hopes for continued success in the agricultural area, the PG&E contract, and similar portents of prosperity encouraged NCPC in early 1906 to develop new hydroelectric power once again. The most economical of several alternatives wss expansion at Volta. Access roads and power for construction were readily available there. Moreover, Keswick and Northern California had considerable water rights in the area, having purchased or appropriated more water than was necessary for the initial 2250 kVA capacity of the plant.

VOLTA: The First Expansion [61] [See HAER drawings 3-7 of 20]

In late 1906 the western end of the Volts powerhouse was extended approximately 27 feet to house a new generating unit. The north wall of this addition matched the north wall of the original structure, but because the new unit was larger than the earlier units, the south wall of the new section of the powerhouse extended 6.5 feet beyond the original wall. Although the addition was basically constructed in the same manner as the original structure, there were some minor differences. Mortar joints were pointed rather than unpointed and stone arches rsther than lentils were used over the windows. Moreover, the galvanized iron roof for the new section was carried on wood rather than iron trusses.

Construction of this extension began in June 1906. [62] The new 56,000 pound, 2000 kVA Westinghouse generator arrived in November, having been hauled by two steam-powered traction engines from the railroad siding at Anderson. [63] The impulse wheel being fabricated for the powerhouse was destroyed by the San Francisco earthquake and fire in April 1906. Thus the generator, although installed before the end of 1906, remained inoperative until a replacement wheel could be delivered and installed in April 1907. [64]

The expansion of Volta involved more than merely extending the powerhouse to accomodate a new generating unit. An entirely new water system had to be constructed. To supply water to the new unit NCPC erected a new forebay reservoir and a new penstock. It would perhaps have been cheaper to enlarge the existing reservoir — Lake Nora -- and install a second penstock from it. But installing a completely separate system had significant advantages. Enlarging Nora would have put Volta out of operation during construction. By building a completely independent system for the new unit, Volta was able to continue generating power (and hence revenue) throughout the construction process.

The new forebay reservoir was located about a half mile northwest of Lake Nora, the original forebay reservoir. Named Lake Grace, for Noble's second daugher, it, too, was formed by throwing a long embankment around the lower margin of a mountain meadow. The dam was 1688 feet long, 67 feet thick at the base, and 16 feet high. It flooded an area of around 8.5 acres (vs. 3.5 for Lake Nora) and had a largar storage capacity (25 acre-feet vs. 15 acre-feet for Nora). [65] Construction of the lake was begun in mid-1906. It was completed before the end of the year. [66]

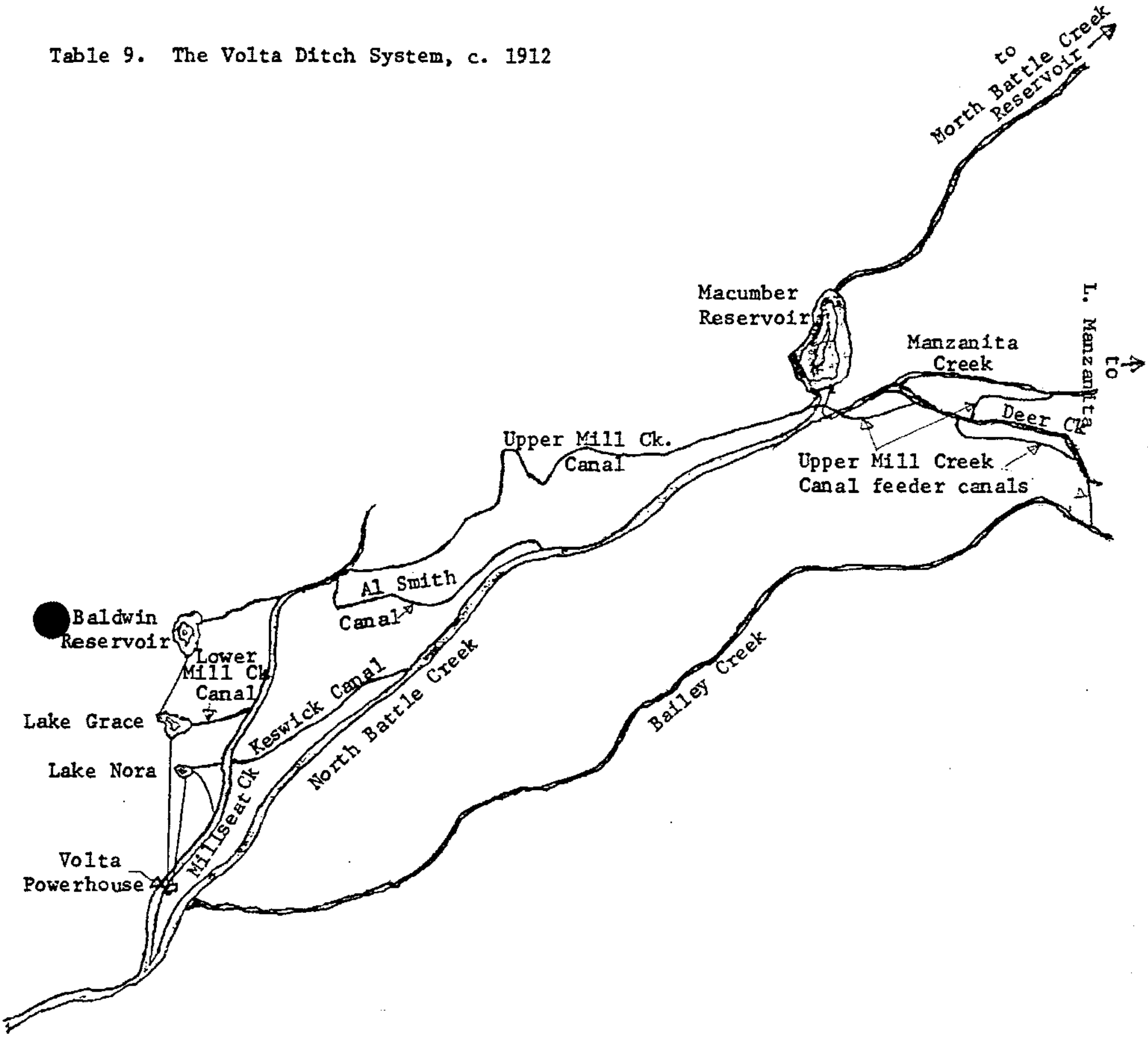
Water for this new reservoir was provided by a new ditch system arected, like the reservoir, in 1906. The main supply was taken from the west bank of North Battle Creek, near the point where it was joined by Deer Creek, about 5 miles upstream from the intake of the Keswick ditch which supplied Lake Nora. Additional water was brought to the intake site from Bailey, Deer, and Manzanita Creeks on the opposite side of Battle Creek. A series of ditches and flumes diverted water from Bailey Creek and Manzanita Creek into Deer Creek. A flume picked up this water, plus some Deer Creek water, carried it across Battle Creek, and added it to the supply available from North Battle Creek near the intake site. This system of ditches and flumes was slightly over 3 miles in length.

The water from Manzanita, Deer, and Bailey Creeks, plus water diverted from North Battle Creek was carried towards Volta by the Upper Mill Creek Canal. It was almost 7 miles long and included 30,562 feet of ditch and 5651 feet of flume. Its capacity was nearly 2000 inches (50 second-feet). The Upper Mill Creek Canal eventually deposited its water into Millseat Creek. This water was diverted from Millseat Creek several miles downstream into the Lower Mill Creek Canal, which carried it 4109 feet to Lake Grace. [67] (See the tables on the following pages for the Volta ditch system c. 1912)

Linking Lake Grace to the new generating unit was a penstock similar in design to the Lake Nora penstock, but longer (around 8900 feet vs. 6800 ft.). Wood stave pipe 48 inches in diameter took the water, screened by grizzlies, from a wooden intake crib located near the center of Grace and carried it for approximately 3000 feet until the terrain began to fall off sharply. For the remaining 6000 feet to the powerhouse the penstock was approximately half lap-riveted steel pipe, half lap-welded steel pipe. It decreased in diameter from 36 to 24 inches. The static head on the new pipeline was some 50 feet higher than the maximum static head on the old line -- 1254 feet. [68] [see HAER photo 123]

The three original generating units at Volta were Pelton impulse wheels and 750 kW, 500 V Westinghouse generators, each mounted independently on dual bearings with extended shafts linked by flexible rawhide couplings. The new generating unit was much larger. The generator was a Westinghouse 2200 V, 2000 kVA unit with the by-now standard rotating field arrangement. This generator was mounted on a shaft with two bearings. The impulse wheel which powered the generator was manufactured by the Abner Doble Company of San Francisco, chief rival of the Pelton Water Wheel Company in the impulse wheel field. The Doble wheel had an 86-inch diameter rotor and was rated at 3500 hp. It was mounted, without independent support, on an extension of the generator shaft which overhung one of the besrings. [see HAER photos 25, 26, 27 for views of this unit]. This arrangement, described as "single overhung" had been introduced by the Abner Doble Company at the Blue Lakes, California, plant in 1897. [69] It was a highly efficient means of transmitting mechanical power from the wheel to the generator and eliminated the

Table 9. The Volta Ditch System, c. 1912



THE VOLTA WATER SYSTEM, c. 1912.

Name (route)	length (ft)	length (mi)	capacity (second-feet)	approximate dimensions (width x depth)
Upper Mill Creek Canal Feeders				
1. Loomis Mill Canal (Bailey Ck-Deer Ck)	3693	0.70	10	3.5 x 2
2. Armstrong #1 (Deer Ck-Deer Ck)	2703	0.51	10	3.5 x 2
3. Manzanita Ck. Canal (Manzanita Ck-Deer Ck)	4003	0.76	10	3.5 x 2
4. Armstrong #2 (Deer Ck-Upper Mill Ck. Canal)	5506	1.04	10	3.5 x 2
Battle Creek to Volta Forebay Ditches				
5. Upper Mill Creek Canal (No. Battle Ck.-Millseat Ck.)	36229	6.86	30	7 x 3
6. Al Smith Canal/No. Battle Ck. Canal Co. Canal (No. Battle Ck.-Millseat Ck.)	18020	3.41	45	7 x 3.5
7. Lower Mill Creek Canal (Millseat Ck-Lake Grace)	4109	0.78	45	6 x 3
8. Keswick Canal (No. Battle Ck-Lake Nora)	22137	4.19	45	6 x 3
9. Baldwin-Lake Grace Canal (Baldwin-Lake Grace)	5360	1.02	2	2.3 x 2.2
10. Baldwin-Millseat Ck. Canal (Millseat Ck-Baldwin)	6472	1.22	5	
11. Shingle Ck. Canal (Eagle Ck.-Baldwin)	2851	0.54	3	
12. Misc. Small Canals (governor ditch; exciter water ditch; Lake Grace to Lake Nora seepage ditch, etc.)	5987	1.13	2.5	

Sources: The data on the dimensions, length, and carrying capacity of the ditches in the Battle Creek system in the 1900-1920 period are given variously by different authorities. Thus none of the above figures are necessarily precisely accurate, but they can be regarded as good approximations. Primary resources used were: Folwer, Hydroelectric Systems of California; the Field Books of the valuation surveys carried out by the Northern California Power Company and now in the PG&E Rates and Valuation Department storage collection; the "Report" on the Northern California Power Company by the J.G. White & Co.; the 1924 and 1930 applications of PG&E to the Federal Power Commission for the Battle Creek plants; and the articles published in various engineering periodicals dealing specifically with the Northern California Power Company's plants (see bibliography).

problem of shaft alignment which had required the use of flexible linkages.

The single Doble wheel was supplied with water from a fixed needle nozzle 6.5 inches in diameter, instead of the deflecting nozzles used to power the earlier Volta units. Deflecting nozzles, while adequate for small units, were expensive and difficult to handle in larger units like the 2000 kVA Volta #4. The increased volumes of water and pressures encountered with larger power units placed severe stresses on the seals in the ball-and-socket joints of the deflecting nozzle. Moreover, the amount of power required to move a deflecting nozzle was considerable with larger units. Because it required less power to move the needle of a needle nozzle than to move an entire nozzle, the needle nozzle also had cost advantages. The entire governing system, including the governor itself, could be made lighter and hence cheaper when speed was regulated by altering the volume of flow through the nozzle with a needle, instead of deflecting a portion of a jet off the wheel by moving the entire nozzle. [70] The needle nozzle had the additional advantage of being more efficient than straight nozzles under partial flow.

The primary difficulties encountered in early needle nozzle systems involved sudden increases in penstock pressure due to a sudden drop in load and the subsequent reduction of flow through the nozzle by the governor-activated needle. To avoid this problem a by-pass system was used to maintain flow volume through the penstock. The fourth unit at Volta thus had not only a 6.5 inch diameter fixed needle nozzle, but also a 4.5 inch by-pass needle nozzle. As the main needle nozzle, activated by a Lombard "Q" governor, reduced flow to slow down the wheel, the lower by-pass needle nozzle (which jetted water below the wheel and out into the tailrace) was opened, insuring that a constant volume of water would continue to flow through the penstock, avoiding pressure surges. [71] Although the needle nozzle/by-pass nozzle system was designed to allow the governor to act quickly on the needle, the speed regulation of Volta #4 was not "wholly satisfactory". [72] Problems with this arrangement here and alsewhere made the combination needle nozzle/jet deflector system more popular.

The decision to buy the new generating unit from Doble instead of Pelton, the manufacturer of all the earlier Northern California units at both Volta and Kilarc, may have been the result of a visit made by Noble to the Louisiana Purchase Centennial Exposition at St. Louis in 1904. [73] The Abner Doble Company's single overhung impulse wheel exhibit won a Grand Prize at the Exposition, the only Grand Prize awarded to any machinery manufacturer west of St. Louis. [74] This achievement may well have led Noble to consider switching manufacturers when plans were being laid for expansion at Volta. Doble equipment was certainly competitive in quality with Pelton's, and the Doble company had pioneered in the introduction of not only the singla overhung arrangement, but also the needle nozzle and the elliptical bucket. [75]

To provide excitation to the field coils of the new generating unit a new exciter set was installed. It was similar to the earlier Volta sets in output (45 kW), though it was powered by a small (36 inch) Doble impulse wheel, instead of by a Pelton impulse wheel. This unit was not coupled with an induction motor as the earlier units. Also its water supply was taken off the new penstock. It did not have an independent supply like the exciters in the older section of the powerhouse.

Because the new generator operated at 2200 volts and older generators operated at 500, they could not be linked to the same bus bars and the new unit had to be operated from a completely independent switchboard. The higher voltage also made it necessary to use remote controlled oil switches (located above and to the rear of the switchboard) to connect the new generator to its transformers (three, single phase 875 kW General Electric models which raised the voltage from 2200 to 66,000) which were located in the extended section of the transformer room. High voltage Kelman oil switches linked the secondaries of the transformers to outgoing transmission lines. Kelman switches were among the first commercially successful high voltage switches. The pantograph movement which broke the circuit horizontally in a tank of oil worked quite well in the 40 to 75 kV range and made Kelman switches very popular in California practice early in the twentieth century. [76]

In expanding Volta in 1907-1907 the Northern California Power Company could have made the new installation compatible with the old, could have installed several small generating units interchangeable with the older units, instead of a single large unit which could not be interchanged and even had to be operated from a separate switchboard. The new unit, with its independent water supply, forebay, and penstock, and with its independent switchboard and bank of transformers was, in effect, a plant by itself. Volta after 1907 was practically two hydroelectric plants operated under the same roof and was often considered as such. [77] This arrangement was rather unusual, but is explicable by cost considerations and the backup generating capacity which the company had at Kilarc. One generating unit of large capacity was cheaper than a number of smaller capacity; the larger number of units and interchangeability were no longer vital because Kilarc or the three older units could pick up the load if problems developed with the new unit. The higher operating voltage of the new generator reduced both transmission losses within the powerhouse complex and transformer costs.

Because extensive water storage reservoirs were less critical on Battle Creek than on most other California streams, Noble and his associates had neglected them in the initial construction of Volta. This reduced the capital raquired to begin operation. With an established investment and additional capital available from the bonds of the Battle Creek Power Company, Northern California officials now decided to insure full output at Volta through the dry months by adding a large storage reservoir to its water system. [78] The site selected was Macumber Flats, a large, soggy meadow on North Battle Creek around 9 miles northeast of Volta, just above the point where Deer Creek joined the main stream. The company had purchased the necessary lands for the project much earlier -- in 1903. [79]

Construction on the Macumber Reservoir began in late 1906 or early 1907, aided by imported Portuguese laborers, and was completed by June of 1907. [80] Twenty additional acres were cleared and at the downstream end of the meadows a masonry, earth, and rock dam was erected. The masonry portion of the dam was 187 feet long and 27 feet high. Placed directly above the stream bed of North Battle Creek, it contained the spillway and the gates which controlled the egress of water. The earth and rock portion of the dam consisted of embankments 2233 feet long by 12 feet high, with 12,412 cubic yards of fill. The dam created a reservoir which covered 150 acres and had a storage capacity of around 1200 acre-feet. [81] A small storage reservoir for Kilarc (Buckhorn Lake) was also erected in 1906-1907. [82]

THE STRUGGLE FOR SUPREMACY ON LOWER BATTLE CREEK, 1907-1908

The expansion of Volta and the construction of the Macumber Reservoir in 1906 and 1907 were in large part the result of PG&E's willingness to buy excess power from Northern California in order to prevent that utility from invading its northern territories and touching off a ruinous rate war. The danger of competition from invading utilities was much more serious for Northern California Power than for PG&E because its territories were much more sparsely populated and, as the company had already discovered, had scarcely sufficient business for a single power company. Yet, as early as 1904, Northern California was faced with the spectre of competition. Two companies in that year announced plans to erect hydroelectric stations to supply power to the Shasta-Tehama County area.

One of the potential competitors was the Shasta Power Company, represented by Harry L. Shannon, former General Manager of the Keswick Power Company. Shannon had resigned as General Manager of Keswick early in 1902 of his own volition, leaving the post to E.V.D. Johnson, Noble's son-in-law. [83] In 1904, however, he reappeared in northern California and filed claim to the waters of Bear and Hat Creeks, the former a tributary of the Sacramento between Battle and Cow Creeks, the latter a tributary of the Pit River. [84] Soon after Shannon began erecting a hydroelectric plant using these waters and located on Snow Creek, a tributary of Bear Creek. Work on this plant proceeded very slowly, hampered by labor, capital, and materials shortages. [85] But the threat to Northern California was clear, for Shannon declared in 1906:

> We do not, now, intend to confine our operations to supplying power to Redding patrons. From Palo Cedro we will run a line south to Red Bluff and further, and get right into the enemy's territory. From Redding another branch will go to Kennett. The Shasta Power Company means business . . . [86]

When the Shasta Power Company finally began stringing its transmission lines towards Redding in 1906 and 1907 across Northern California lines already in place, Northern California sought injunctions to prohibit Shasta from beginning operation and from crossing NCPC right-of-way. The courts refused to grant the injunction but supervised a settlement which permitted Northern California lines to have the superior (i.e., higher) position at crossings and charged the younger company with the costs of raising Northern California's wires so it could pass under. [87] The Snow Creek plant of the Shasta Power Company went on line finally in the summer of 1907, but with an output of only 1200 kW.

A second company which emerged to challenge Northern California was the Northern Light and Power Company, incorporated in February 1907. This company erected a 1500 kW plant on South Cow Creek which went on line in the spring of 1908. Like the Shasta Power Company, it extended its lines to Redding and began to compete with Northern California for lighting business. [88]

Because the output of the Shasta and Northern plants was small and because, initially, they only challenged Northern California in the Redding area, the early effects of this competition were small. Only a small proportion of Northern California's revenues came from lighting and from Redding. The major company load was north of Redding where Northern California supplied power for the motors of mines and smelters, and Northern California was not immediately challenged here by the new companies.

A third competitor posed potentially a much more serious threat. In 1904 the Mt. Lassen Water and Power Company had been organized. This company announced plans to convey water from North Battle Creek and two Battle Creek tributaries, Baldwin and Darrah Creeks, to a site on the "Horseshoe Bend" of Battle Creek, a few miles downstream from the junction of the north and south forks. There the company hoped to erect a powerhouse to generate 10,000 hp (c. 7500 kW) under a 450 foot head. [89] These plans never came to fruition. In 1906, however, J.A. Whitehead, a local entrepreneur representing unnamed "English capitalists", began buying options to lands with Battle Creek water rights in the same area. [90] In December 1906 Whitehead formed the Pacific Power Company, opened an office in Red Bluff, announced that his company had purchased the Battle Creek assets formerly owned by the Mt. Lassen Water and Power Company, and unveiled tentative plans for a large hydroelectric plant. Pacific Power's plant was to be built along much the same lines as the plant earlier proposed by Mt. Lassen. Water would be diverted from both north and south forks of Battle Creek, plus Baldwin and Darrah Creeks, to a point a short distance west of the junction of North and South Battle Creeks where a 500 foot fall was obtainable. The new plant was to have an output of around 12,000 hp (c. 8000 kW). [91]

The directors of the Pacific Power Company attempted to reassure the management of NCPC that they did not intend to enter into direct competition. They claimed their primary market would be irrigation pumping and electric lighting, not mining and metallurgical operations, the heart of Northern California's revenues. [92] And the Redding Courier Free Press commented: "It is not probable that the future operations of the newly incorporated Pacific Power will directly effect the business of any of the existing power companies". [93]

The Northern California Power Company, however, viewed things differently. Pacific Power's plant, unlike those being planned or constructed by Northern Light and Power and Shasta Power, would have an output sufficiently large to threaten Northern California throughout its territories, territories which had insufficient business for two companies. Even if Pacific Power did confine its activities to agriculture and lighting, as promised, the new company was unacceptable to Northern California management. Northern California had struggled for years to encourage electrification in the agricultural regions around the Sacramento River and did not wish to see another company harvest the benefits of its labor. Moreover, Northern California probably viewed Battle Creek as its own private preserve, off limits to other utility companies. Thus Northern California quickly engaged this interloper in a life and death struggle.

Following Pacific Power's announcement of its intention to erect a plant on lower Battle Creek, Northern California altered its expansion plans. Originally Noble and his associates had considered increasing their system's generating capacity on North Battle Creek, upstream from Volta, where they possessed secure water rights. [94] To counter Pacific Power's plans, Northern California Power now announced that it intended to construct a large hydroelectric plant just downstream from the Pacific Power Company's powerhouse site. [95] Northern California had purchased the necessary land earlier from the Southern Pacific Railroad and in 1905 had filed for an appropriation of water at the site.

Northern California's new Battle Creek plant was to be radically different from their earlier efforts at Volta and Kilarc. Previously, to economize on capital, Northern California had avoided the use of massive dams to develop high heads. Instead it had relied on small diversion dams and long ditches which were much cheaper to construct. However, for lower Battle Creek Northern California now planned a massive masonry dam. It was to be located just below the confluence of the north and south forks of the stream and a short distance below the site of the projected Pacific Power Company plant. The dam was to be 90 feet thick at base, 133 feet (later 154 feet) high, and 700 feet long. It was to be one of the highest dams in the United States and the only dam of its type of sucb magnitude in the world. [96] A heavy timber "false dam" was to be erected on the site first, diverting water around the foundations while the permanent structure was built. The powerhouse was to be located on the north side of Battle Creek, near "Horseshoe Bend", 6 miles below the dam. The 368 foot fall which could be developed here would be sufficient to generate 15,000 hp (c. 11,250 kW). Two 6000 hp (c. 4500 kW) and one 3000 hp (c. 2250 kW) generating units were to be installed. Estimated costs for tbe project were far bigher than with either of the earlier plants — $1,500,000. The real beauty of the plan, however, lay in the fact that the Northern California dam would flood the site of the Pacific Power Company's powerhouse. [97]

Once the decision was made to contest Pacific Power on lower Battle Creek, Nortbern California moved quickly. Before tbe end of January 1907 a crew of fifty men was working on the dam site, clearing ground and constructing camp buildings. Plans were to increase the force to 250 men as weather permitted. [98] In March 1907 the engineer in charge of construction at the site, E.W. Sutcliffe, travelled to San Francisco to contract for water wheels and generators for the powerhouse and to purchase air compressors, air drills, electric hoists, derricks, and electric railroad equipment to speed up excavation and construction. [99] A power line was strung from Volta to provide current for the drills, hoists, compressors, and the railway. [100] Electric lights from this line were used to illuminate the work sites, allowing construction to proceed twenty-four hours a day. [101]

The work was impeded first by harsh winter weather, then by spring flooding and adverse political decisions. In March, for instance, Northern California's temporary wooden dam, only partially completed, was swept away by high water. [102] And in April the Tehama County Board of Supervisors denied the power company permission to use steam traction engines for hauling equipment and supplies from Red Bluff to the dam site. This forced the company to use slower horse-drawn wagons which caused less damage to the roads with their lighter loads. [103]

The Pacific Power Company also commenced work at its site upstream. Although its resources were inferior to Northern California's, Pacific Power officials were convinced they had nothing to fear. They believed they had controlling water rights in the region, for Whitehead had purchased not only the water claims of the older Mt. Lassen Water and Power Company, but a large number of private water rights as well (many in exchange for Pacific Power stock). [104]

The waters claimed by the Pacific Power Company were not, however, as secure as the company's management led potential investors to believe. Under California law parties filing a claim on (appropriating) water must begin to erect works to utilize that water within sixty days of filing. Moreover, work associated with preparations to use claimed water must be pursued with "reasonable diligence". In cases of conflicting claims to the same water the basic maxim followed by the courts was that "the [actual] use of the water alone fixes the right" and validates the claim. [105] There were circumstances which made it questionable whether Pacific Power (through Mt. Lassen Water and Power) or Northern California had worked with "reasonable diligence" to make use of waters they had filed appropriation claims on earlier on lower Battle Creek.

The Mt. Lassen Company had, some years earlier, appropriated a certain volume of water on lower Battle Creek. But, unable to develop it immediately because of lack of capital, the company had set one man to work breaking trail, piling stones, and in other ways attempting to carry out the appropriation of water with the "reasonable diligence" required by law. When this man left the site for a longer period than normally allowed by law, Northern California agents had jumped the claim with a man of their own, pursuing the same tactics. When this man left briefly, Pacific Power Company, having purchased Mt. Lassen's claims, moved in and set thirty-five men to work digging ditches. Northern California, as we have seen, responded by setting crews to work slightly downstream, on the properties they had purchased from the Southern Pacific Railroad, claiming the same water rights. [106] The cloudiness of both companies' claims made it very likely that the courts would recognize the appropriations of the company which first actually began to use the water to generate power.

Recognizing this the chief enginer for the Pacific Power Company, J.H. Strutt, planned to build his power plant in two stages. Strutt planned to install a 500 hp (c. 375 kW) generating unit in a small structure within eight months, adding additional units at a later date in a larger building. [107] He hoped this would enable Pacific Power to begin generating current before Northern California's dam inundated the site and, due to earlier use of appropriated water, provide grounds for an injunction which would prohibit Northern California from completing its dam and flooding the site. [108]

Through 1907 and on into 1908 the two power companies fought each other in and out of court. Pacific Power, confident of the validity of its claims to Battle Creek waters, sued Northern California for damages from the flooding that would result when the Northern California dam was completed. [109] Northern California, believing its 1905 appropriation was legal and that it had pursued work at the site with "reasonable diligence", sued to condemn the land and water rights claimed by Pacific Power. [110] Meanwhile ditch laborers for the two companies actually engaged in combat, as both sides continued to rush their construction efforts. [111]

The Pacific Power Company began to falter early in the summer of 1907. In June, troubled by lack of capital, allegations of financial chicanery, and the disappearance of its president, Pacific Power suspended work on Battle Creek and discharged its labor force. [112] Rumors that Northern California had absorbed Pacific Power were denied as stockholders attempted through the summer months to raise the $65,000 needed to complete the small powerhouse designed by Strutt and construct a transmission line to Red Bluff. [113] These efforts failed. The decisive blow came in 1908. In March the courts ruled that Northern California possessed a valid claim to the waters of lower Battle Creek and, upon payment of damages totalling $32,500, could condemn the land and water rights held by Pacific Power. Northern California's directors balked at the amount of the judgment and both companies appealed for a new trial, delaying resolution of the issue for some months. [114] With this decision the Pacific Power Company collapsed, and Northern California's rights in the area were confirmed.

When Pacific Power's construction efforts lapsed in June 1907, Northern California also reduced its work force in the area, indefinitely laying off 200 workmen. [115] Northern California's decision to halt construction was, no doubt, partially influenced by the collapse of Pacific Power's immediate threat and the need to avoid further expenses until the courts had definitively settled the issue of water rights. But other factors contributed. Northern California had been unable to sell an additional $500,000 in Battle Creek Power Company bonds to finance construction at "Horseshoe Bend". [116] This put the company in financial straits. Even though $90,000 had already been spent on the dam, at least twice that amount was required to compete the dam alone and much more for the power canal and powerhouse. [117] Thus the "Horseshoe Bend" project was indefinitely postponed and the partially completed Battle Creek dam was abandoned.

Another factor which had an important influence on Northern California's decision to temporarily abandon the "Horseshoe Bend" plant was a shift in the focus of its expansion plans. In 1907 Northern California survey crews had located several sites on South Battle Creek where power could be developed at a lower cost. [118] Company engineers like H.A. Tedford subsequently filed appropriation claims on South Battle Creek waters, while the company purchased large tracts of land and water rights to supplement these claims. [119]

NOTES

[1] Daniel W. Mead, Water Power Engineering (New York, 2nd ed., 1915) p. 719.

[2] Redding Searchlight, August 24, 1901.

[3] Fowler, Hydroelectric Systems of California, p. 30; San Francisco Call, June 1, 1902.

[4] Fowler, Hydroelectric Systems of California, p. 35.

[5] Redding Free Press, July 9, 1901; Redding Searchlight, March 13, 1901; Red Bluff Daily Peoples' Cause, March 13, 1901; Jensen, "Liquid Gold," p. 6; "Deed of Trust: Northern California Power Company," June 1, 1902, p. 13(PG&E, Secretary's Office, document 2257-a).

[6] "Certificate of Proceedings Autborizing the Creation of Bonded Indebtedness of Keswick Electric Power Company," March 5, 1901 (PG&E, Secretary's Office, document 1569-b); "Deed of Trust: Keswick Electric Power Company to Mercantile Trust Co. of San Francisco, Trustee," June 1, 1901 (PG&E, Secretary's Office, document 1569-c); San Francisco Call, June 11, 1901.

[7] Redding Free Press, February 14, 1902.

[8] Red Bluff News, February 7, 1902; Red Bluff Daily News, February 4, 1902; Redding Free Press, February 17 and February 18, 1902.

[9] Redding Free Press, February 19 and March 6, 1902.

[10] Red Bluff News, February 21 and April 25, 1902; Red Bluff Daily News, March 30 and April 22, 1902; and Redding Free Press, February 19, 1902, contain articles dealing with the construction of the line to Red Bluff.

[11] Red Bluff Daily News, July 4, 1902.

[12] Fowler, Hydroelectric Systems of California, p. 126; CRRC, Decisions, v. 11 (1916) p. 41.

[13] For copper production records see, CSMB, 14th Report of the State Mineralogist (1913-1914) pp. 750-751.

[14] On Bully Hill see CSMB, Bulletin 23 (1902) pp. 9, 48. The contract between Bully Hill and NCPC is noted by Fowler, Hydroelectric Systems of California, p. 127, and CRRC, Decisions, v. 11 (1916) p. 41.

[15] For prevailing prices of copper see United States, Bureau of the Census, Historical Statistics of the United States: Colonial Times to 1970, pt. 1 (Washington, 1975) p. 208.

[16] Redding Free Press, March 6, 1902; Red Bluff Daily News, May 2, 1902; "Northern California Power Company: Bylaws " (PG&E, Secretary's Office, document 2134-c).

[17] CRRC,"General Order 38 Report of the Northern California Power Company, Consolidated, 1914-1917 " (CSA); Fowler, Hydroelectric Systems of California, p. 127.

[18] Redding Free Press, March 6, 1902; "Northern California Power Company: Certificate of Creation of Bonded Indebtedness," May 26, 1902 (PG&E, Secretary's Office, document 2134-b); "Deed of Trust: Northern California Power Company," June 1, 1902 (PG&E, Secretary's Office, document 2257-a).

[19] Red Bluff News, August 29, 1902; NCPC, 1st Annual Report (1902-1903); for a detailed description of the dredger at Horsetown see "The Northern California Power Company's Systems -- IV. The Mammoth Suction Dredge of Horsetown," Electrical World, v. 44 (1904) pp. 559-561.

[20] San Francisco Call, September 6, 1902; San Francisco Chronicle, September 6, 1902.

[21] J.G. White & Co., "Report," pp. 89-91.

[22] Plans for the projected powerhouse at Kilarc were described in "Northern California's Transmission," pp. 237-238, in the December 1902 issue of the Journal of Electricity and a completion date of July 1903 was mentioned. A note that a contract had been awared to Westinghouse for the generators of the new plant appeared in Red Bluff News, August 8, 1902.

[23] NCPC, 1st Annual Report (1902-1903); for copper production stastics see CSMB, 14th Report, pp. 750-751; for copper prices see Bureau of the Census, Historical Statistics, p. 208.

[24] NCPC, 1st Annual Report (1902-1903).

[25] NCPC, 2nd Annual Report (1903-1904).

[26] CRRC, Decisions, v. 11 (1916) p. 42. The Willows Water and Light Company was purchased by NCPC in 1907.

[27] NCPC, 1st Annual Report (1902-1903); Red Bluff News, March 6, 1903.

[28] NCPC, 1st Annual Report (1902-1903) and 3rd Annual Report (1904-1905); CRRC, Decisions, v. 11 (1916) p. 42; Fowler, Hydroelectric Systems of California, p. 127.

[29] NCPC, 1st Annual Report (1902-1903). The peak load, however, was only 1589 hp at maximum and average peak load was only 1173 hp.

[30] "New and Important Pelton Installationa," JE, v. 13 (May 1903) p. 234.

[31] NCPC, 2nd Annual Report (1903-1904); CRRC, Decisions, v. 11 (1916) p. 42.

[32] NCPC, 2nd Annual Report (1903-1904); CRRC, Decisions, v. 11 (1916) p. 42.

[33] NCPC, 2nd Annual Report (1903-1904).

[34] Ibid.

[35] Red Bluff Daily News, May 15 and June 5, 1904; San Francisco Chronicle, July 23,1904.

[36] Data on the design and layout of the Kilarc plant was drawn largely from the following sources: "The Northern California Power Company's Systems — II. Kilarc Hydroelectric System," Electrical World, v. 44 (1904) pp. 455-460; Fowler, Hydroelectric Systems of California, pp. 246-251; Van Norden, "Northern California Power Company," pp. 124-127; and NCPC-C, Valuation Survey Field Books 10 (H-7), 11 (H-5), and 12 (H-6) [R/V].

[37] "Northern California Systems — II," p. 459.

[38] "Northern California's Transmission," p. 238.

[39] "Northern California Systems — I," p. 407. The transmission system of NCPC in 1904 is reviewed in "The Northern California Power Company's Systems.—III. High-Tension Transmission System," Electrical World, v. 44 (1904) pp. 503-506.

[40] See the article on the Horsetown dredger cited in note [19] above.

[41] NCPC, 3rd Annual Report (1904-1905).

[42] NCPC, 4th Annual Report (1905-1906).

[43] NCPC, 3rd Annual Report (1904-1905); CRRC, Decisions, v. 11 (1916) p. 42.

[44] Red Bluff Daily News, October 9, 1901.

[45] Red Bluff Daily News, November 16 and November 23, 1904, and also August 18, 1905.

[46] Red Bluff Daily News, August 26, August 27, and August 30, 1905.

[47] There was talk of constructing electric railroads between Red Bluff and Redding or Red Bluff and Chico in 1906, and Northern California Power obtained a "very favorable" twenty-five year contract to supply current to a projected Redding and Red Bluff Railway Company. But these roads were never built. See Red Bluff Daily News, June 26, 1906, and NCPC, 4th Annual Report (1905-1906).

[48] NCPC, 3rd Annual Report (1904-1905).

[49] CRRC, Decisions, v. 11 (1916) p. 42.

[50] NCPC, 4th Annual Report (1905-1906); Red Bluff Weekly Sentinel, December 29, 1905.

[51] Red Bluff Daily News, May 16, 1906.

[52] Red Bluff Weekly Sentinel, December 29, 1905; Redding Free Press, January 26, 1906; NCPC, 4th Annual Report (1905-1906); JE, v. 16 (Jan. 1906) p. xxiv.

[53] NCPC, 4th Annual Report (1905-1906); CRRC, Transcripts [of Hearings], cases 675, 676, 677, 711, v. 3 (February 2, 1916) pp. 116-120 (CSA); CRRC, Decisions, v. 11 (1916) p. 41; Fowler, Hydroelectric Systems of California, p. 127; Redding Free Press, February 21, 1906; Red Bluff Daily News, February 14, 1906.

[54] NCPC, 5th Annual Report (1906-1907).

[55] For information on the switch house at Volta see Red Bluff Daily News, April 18, 1906; Redding Free Press, April 17, 1906; J.G. White & Co., "Report," p. 54; and NCPC-C, Valuation Survey Field Book 1 (H-1), esp. pp. 66-70.

[56] Red Bluff Daily News, January 26, 1906; Redding Courier Free Press, August 9, 1906.

[57] Blanchfield's Western Electrical and Gas Directory, 1910 (San Francisco, c. 1910) p. 154 [Copy in the California State Library, Sacramento].

[58] Red Bluff Daily News, June 25, 1904, and January 26, 1906; NCPC, 4th Annual Report (1905-1906); CRRC, Decisions, v. 11 (1916) p. 43.

[59] NCPC, 5th Annual Report (1906-1907); CRRC, Decisions, v. 11 (1916) p. 43.

[60] NCPC, 4th Annual Report (1905-1906).

[61] The data on the alterations made at Volta and the machinery installed in 1906-1907 is largely drawn from: Van Norden, "Northern California Power Company," pp. 112-118, passum; Fowler, Hydroelectric Systems of California, pp. 227-233, passum; NCPC-C, Valuation Survey, Field Book 1 (H-1) pp. 1-8, and Field Book 4 (H-28) passum; and PG&E drawing 63725.

[62] Red Bluff Daily News, June 6 and June 15, 1906.

[63] Redding Courier Free Press, November 23, 1906.

[64] Redding Courier Free Press, April 20, 1907; NCPC, 5th Annual Report (1906-1907).

[65] The data on Lake Grace are drawn from: Fowler, Hydroelectric Systems of California, pp. 229-230; FPC-1924, "Exhibit L"; Valuation Detail Folder no. 5, pp. 15-16, 20-21, 36-37 (R/V).

[66] Red Bluff Daily Newa, April 2,1907; Redding Courier Free Press, December 17, 1906.

[67] Fowler, Hydroelectric Systems of California, p. 228; PG&E drawing 63579; J.G. White & Co., "Report," pp. 32-37; plus scattered information in the items cited in note [61] above, and Valuation Survey Field Book 16 (H-35). Upper Mill Creek Canal is reviewed on pp. 16-20, 47-80 of the Field Book.

[68] For data on the new penstock line see, in particular, Fowler, Hydroelectric Systems of California, p. 230, and Van Norden, "Northern California Power Company," p. 113.

[69] H.H. Homberger, "The Development of the Tangential Water Wheel," JE, v. 14 (1904) p. 49.

[70] See, for example, the comments of George J. Henry, "Some Recent Tangential and Turbine Water Wheel Practice," JE, v. 22 (1909) p. 236.

[71] The 1907 water wheel unit is beat described in NCPC-C, Valuation Survey Field Book 4 (H-28) pp. 68, 74-75. See also J.G. White & Co., "Report," pp. 42-43, and PG&E drawings 63733 and 68002.

[72] J.G. White & Co., "Report," p. 43. This may have been because by-pass nozzles frequently caused pressure waves in the penstocks, making good regulation difficult.

[73] Red Bluff Daily News, June 25, 1904.

[74] Abner Doble Company, "Doble Tangential Water Wheels," Bulletin no. 7 (1906) [San Francisco, California, 1905] p. 8.

[75] For the emergence of Doble as a rival to the Pelton Water Wheel Company see Durand, "Pelton Water Wheel," pp. 513-517.

[76] My primary sources for the electric system at Volta in 1906-1907 were, Fowler, Hydroelectric Systems of California, pp. 232-233; J.G. White & Co., "Report," pp. 53-54; and Van Norden, "Northern California Power Company," pp. 115-118.

[77] For instance, JE, v. 19 (October 26, 1907) p. 370, and v. 22 (January 2, 1909) p. 17.

[78] Redding Courier Free Press, February 27, 1907; NCPC, 5th Annual Report (1906-1907); JE, v. 18 (February 23, 1907) p. 234.

[79] NCPC, 2nd Annual Report (1903-1904).

[80] JE, v. 18 (April 20, 1907) p. 310; Red Bluff Daily News, February 28, 1907;"NCPC Scrapbook,"p. 4. The "NCPC Scrapbook" is a book of newspaper clippings relating to the Northern California Power Company located in the PG&E Library. The clippings date from between 1906 and 1912. Many of the clippings are undated and practically none of the clippings are referenced to the newspaper(s) they were drawn from.

[81] Data on the Macumber Reservoir was drawn largely from: Fowler, Hydroelectric Systems of California, pp. 226-227; FPC-1924, "Exhibit L"; Computation Folder no. 48, pp. 1, 4 (R/V); NCPC-C, Valuation Survey Field Book 16 (H-35) pp. 6-15; also Computation Folder no. 555 (R/V).

[82] Fowler, Hydroelectric Systems of California, p. 247; NCPC, 5th Annual Report (1906-1907).

[83] Redding Free Press, January 20 and February 6, 1902.

[84] San Francisco Chronicle, July 13, 1904;"NCPC Scrapbook", p. 42.

[85] Redding Courier Free Press, March 6 and April 12, 1906.

[86] Redding Courier Free Press, March 6, 1906.

[87] Redding Courier Free Press, October 31 and December 17, 1906; Redding Searchlight, December 1, 1906; JE, v. 18 (May 25, 1907) p. 411.

[88] Redding Courier Free Press, April 8, 1907, and February 6, 1908; Electrical World, v. 49 (February 1907) p. 234;"NCPC Scrapbook," p. 2 ("Northern Light and Power Company, February 2").

[89] San Francisco Chronicle, June 3, 1904; Red Bluff Daily News, June 4, 1904.

[90] Red Bluff Daily News, August 23 and December 28, 1906.

[91] Redding Courier Free Press, December 17, December 22, and December 26, 1906; Red Bluff Daily News, January 6 and January 27, 1907.

[92] Red Bluff Daily News, December 28, 1906, and January 6, 1907.

[93] Redding Courier Free Press, December 26, 1906.

[94] Red Bluff Daily News, November 9, 1901; Redding Searchlight, October 11, 1901.

[95] Redding Courier Free Press, December 27, 1906.

[96] J.G. White & Co., "Report," pp. 47-50.

[97] Details on the large dam planned by the NCPC in 1906-1907 for lower Battle Creek can be found in: Red Bluff Daily News, January 4, 1907; JE, v. 18 (January 19, 1907) p. 66; (February 16, 1907) p. 137; (April 6, 1907) p. 270; J.G. White & Co., "Report," pp. 46-50; and "NCPC Scrapbook," p. 5.

[98] Redding Courier Free Press, January 16, 1907; Red Bluff Daily News, January 3, 1907; JE, v. 18 (January 19, 1907) p. 66.

[99] Red Bluff Daily News, March 6, 1907. The NCPC, 5th Annual Report (1906-1907) reported that contracts for generators and water wheels had been let.

[100] Red Bluff Daily News, March 6, 1907; "NCPC Scrapbook," p. 5 ("Battle Creek Power Company, 3-15-07").

[101] Redding Courier Free Press, January 16, 1907.

[102] Redding Courier Free Press, March 27, 1907. Other notices of weather impeding work at the site include Red Bluff Daily News, January 27 and March 21, 1907, and JE, v. 18 (February 16, 1907) p. 137.

[103] Redding Courier Free Press, April 4, 1907; Red Bluff Daily News, April 3, April 11, and May 7, 1907; "NCPC Scrapbook," p. 20 ("Traction Engine Not Liked in Tehama, Red Bluff, April 11").

[104] Redding Courier Free Press, December 29, 1906, and January 30, 1907; Redding Searchlight, January 31 and February 13, 1907. Whitehead declared at one point: "I am now the possessor of the controlling water rights for the development of hydraulic power on Battle Creek." (Redding Searchlight, January 31, 1907).

[105] For California water laws see note [8] of Chapter I, especially Chandler, "Western Laws," pp. 294, 380, and Fowler, Hydroelectric Systems of California, pp. 46-47. See also JE, v. 18 (February 16,1907) p. 137.

[106] "Battle Creek Power Litigation," JE, v. 20 (1908) p. 69.

[107] Red Bluff Daily News, February 19 and March 12, 1907; "NCPC Scrapbook," p. 5.

[108] Red Bluff Daily News, January 30, 1907; "NCPC Scrapbook," p. 52 ("Pacific Power Controls Water").

[109] Redding Searchlight, February 14, 1909.

[110] Red Bluff Daily News, February 26, 1908; Redding Courier Free Press, May 31 and September 13, 1907; JE, v. 20 (February 1, 1908) p. 69.

[111] Redding Courier Free Press, May 14, 1907.

[112] Red Bluff Daily News, June 11 and July 16, 1907.

[113] Red Bluff Sentinel, August 7, 1907; Red Bluff Daily News, July 4, 1907.

[114] Red Bluff Daily News, March 4, 1908; Redding Courier Free Press, March 5, 1908; Redding Semi-Weekly Searchlight, March 6, 1908; "NCPC Scrapbook," p. 65 ("Motion Filed for New Trial").

[115] Red Bluff Daily News, June 28, 1907. The reports of layoffs were initially denied by NCPC, see JE, v. 19 (July 27, 1907) p. 81.

[116] NCPC, 6th Annual Report (1907-1908).

[117] J.G. White & Co., "Report," pp. 47 ($70,000 spent), 96 ($90,000 spent).

[118] CRRC, Transcripts [of Hearings], cases 675, 676, 677, 711, v. 3 (February 2, 1916) p. 123 (CSA).

[119] NCPC, 6th Annual Report (1907-1908); JE, v. 19 (September 28, 1907) p. 285; (October 26, 1907) p. 370; (November 9, 1907) p. 415; Red Bluff Daily News, October 11, 1907; H.A. Tedford to E.V.D. Johnson, November 4, 1907, in Jeffcoat Letter Book, pp. 14-15. The Jeffcoat Letter Book contains copies of letters dating between August 13, 1906, and July 31, 1910. It was apparently kept at the Volta powerhouse. Most of the letters are simply instructions to order or ship materials needed for maintenance, construction, or repair.

CHAPTER V

SOUTH AND INSKIP:

The Enlargement of the Battle Creek System (1908-1910)

The future looked bright for Northern California Power Company at the end of 1907 and early in 1908. The small rival utilities which were installing or had installed plants on Snow Creek (Shasta Power Company) and South Cow Creek (Northern Light and Power Company) seemed to pose no immediate threat. The most dangerous of the potential rivals -- the Pacific Power Company -- had been completely crushed in its attempt to occupy Battle Creek. NCPC's hold on Battle Creek had subsequently been strengthened by court decisions, additional water appropriations, and large purchases of area land. In addition, the prospects seemed very good for significant increases in power sales in the near future.

Copper prices, which had declined sharply in 1902, began to revive in 1903 and had climbed steadily upwards between 1903 and 1907. This had brought increased mine production in Shasta County [1] and, as a result, a steady expansion of the electric power market. For example, Mammoth Copper increased its power purchases from the Northern California system by 2700 hp (c. 2000 kW) between 1906 and 1907, and Balaklala in the same period installed motors drawing an additional 1375 hp (c. 1000 kW). [2] All over the mining belt new mines were being opened and already established customers were expanding their electrical plant. Optimism abounded. [3] Further increases in electric demand in Shasta's mining area seemed assured, encouraging Northern California Power to again consider a major expansion of generating capacity.

Another factor encouraging expansion was some seemingly promising work being carried out by Noble in smelting iron ore with the aid of electricity. As early as 1902 Noble had conceived the idea of using cheap hydroelectric power to smelt the iron ores of Shasta County, readily accessible but long unexploited because there was no coal in the area. This vision was one of the motivations behind Noble's early plans to harness the Pit River. But the highly experimental nature of the electric reduction of iron ores made power sales to the Bay Area market a more realistic plan at that time. [4]

In 1907, however, using his own financial resources, Noble began experimenting on the electrical reduction of iron ores. He located his smelter near the confluence of the Pit and McCloud Rivers and named the site Heroult, in honor of Paul Heroult, the French metallurgist who had developed an electric furnace which had successfully reduced iron ore on a laboratory scale. Local papers were enthusiastic about the venture. They closely monitored its progress and a Redding paper informed its readers that Noble's success would transform their city into the "Pittsburg of the

West", that Shasta County would "someday control the iron and steel industry of the world". [5] Noble reported to Northern California Power stockholders in early 1907 that if his experimental plant were successful the company formed to exploit the process on a commercial basis would "become a very large consumer of power". [6]

Noble's engineers, with direction from Paul Heroult, erected a 1500 kW, three phase experimental smelter with a capacity of 20 tons per day. [7] This smelter was started on July 4, 1907, and successfully produced small amounts of pig iron. Noble jubilantly pronounced the experiment a "commercial success," incorporating the Noble Electric Steel Company to raise capital for the construction of a commercial electric iron smelter which would have a capacity of 2000 tons per day. [8] Further, Noble reported in early 1908 to Northern California stockholders that he and his associates in the iron producing venture would be expanding the Heroult smelter as "fast as we [the Northern California Power Company] can guarantee them power". The Heroult smelter, Noble declared, would soon consume more power than "all the rest of our system". The growth of the venture would be limited only by "the amount of power we can furnish them". [9]

Despite the fact that previous expansions had led to problems with excess generating capacity and compelled the utility to aggressively seek out new power markets, Northern California's management decided in late 1907 and early 1908 to undertake yet another expansion program. Copper mining was flourishing and would probably continue to flourish, increasing the need for power. Noble's steel plant at Heroult needed large amounts of power and, potentially, could consume any amount of power the company could possibly deliver. Expansion would also serve to discourage competition in the area, by preventing any gap from developing between regional power demands and regional power supply. Finally, the construction of new plants on Battle Creek would forestall rival companies from developing some very favorable sites still available on that stream.

The expansion plan developed by Northern California management in 1907 and 1908 was very ambitious. In the summer and fall of 1907 as the Pacific Power Company was collapsing, Northern California had initiated extensive surveys on the south fork of Battle Creek. These surveys had located two additional hydroelectric sites (besides the already existing plant at Volta and the projected plant at "Horseshoe Bend"). [10] Shortly after the company began to purchase lands and water rights on South Battle Creek and in the area around Manton, just south of Volta, between the north and south forks of Battle Creek. For instance, in late 1907 Northern California bought the Hazen properties, which included 2380 acres of land and 4000 inches (100 second-feet) of water from Ripley Creek, a tributary of the south fork of Battle Creek. [11]

The system envisioned by Northern California for Battle Creek by this time included four powerhouses. The existing station at Volta would head up the system. Volta's water plus additional water from South Battle Creek would be conducted to a second power house to be erected on the old Hazen properties, 5 miles south of Volta on the south fork where a head of 516 feet could be developed. Water from this plant would then be carried 5 miles further downstresm, combined with additional water diverted from North Battle Creek, and, under a head of 378 feet, used to provide power for a third powerhouse. This wster, discharged, once again, into the south fork of Battle Creek, would be diverted and used yet another time at the temporarily abandoned "Horseshoe Bend" site on the main trunk of Battle Creek. Construction there was to be delayed pending the final outcome of the litigation with Pacific Power Company and the other property owners in that region. [12]

This ambitious expansion program required a major infusion of new capital into the company. The $430,000 gained from the sale of Battle Creek Company bonds had been exhausted in the 1906-1907 expansion of Volta, in the construction of the high voltage line to Chico and the Macumber Reservoir, and in the struggle with Pacific Power at "Horseshoe Bend". An attempt to sell an additional $500,000 in Battle Creek Power Company bonds to finance construction at "Horseshoe Bend" in 1907 had failed when the anticipated purchaser backed down. This had placed Northern California in severe straits. In order to continue operations at "Horseshoe Bend" and in order to purchase the properties and water rights in the Battle Creek basin necessary for any expansion program, the company had had to suspend dividend payments (begun in 1904) and increase its short-term borrowing. These loans had enabled NCPC to continue its operations at "Horseshoe Bend" until the collapse of Pacific Power and permitted the purchase of the Willows Water and Light Company. [13]

Further expansion required the consolidation of Northern California Power Company's growing debts with long term financing and the infusion of new capital. To accomplish this, the company's directors created a new company, the Northern California Power Company, Consolidated, incorporated on August 24, 1908. The new company issued $10,000,000 in stock (vs. $2,000,000 for NCPC) in 100,000 shares, valued st $100 apiece. [14] Northern Cslifornia, Consolidated, absorbed the $990,000 bonded indebtedness of its predecessors (Northern California Power Company and its subsidiary, Battle Creek Power Company) and acquired its stock at $20 per share, using stock of the new company as payment. [15] To consolidate debts and to finance an expansion program, the board of directors of the new company (substantially the same ss the board of the old company) authorized the issuance of up to $10,000,000 in bonds. [16] These infusions of capital permitted the expansion program to begin.

VOLTA: The Second Expansion [17]

The first step in the Northern California expansion program was the installation of yet another generating unit at Volta. The west end of the powerhouse was extended an sdditional 30.5 feet in the spring and summer of 1908 and another 2000 kVA generator was installed in November or December, increasing Volta's capacity from 4250 kVA to 6250 kVA. [18]

The water supply for this new unit came from water rights which had been acquired piecemeal by the company over a number of years. The company had, for instance, acquired 50% ownership of the waters of an irrigation ditch, called the Battle Creek Canal Company ditch or the Al Smith ditch. The main trunk of this ditch, with a capacity of around 35 to 45 second-feet, was 3.41 miles long and linked North Battle Creek with Millseat Creek. [19] In 1906-1907 Northern California had purchased the Schooling property, which included 160 acres and half interest in the Schooling irrigation ditch. [20] In addition, Northern California had acquired part of the flow from a number of other small ditches. [21] Water from all of theae ditches was diverted into either Lake Nora or Lake Grace by the Keswick or Lower Mill Creek ditches.

The new unit (#5) drew its water aupply from both the Lake Grace and Lake Nora penstocks. A branch was taken off the newer Lake Grace penstock above the powerhouse and carried over to the new unit. This hranch was joined by a "Y" connection to a branch which led from the older Lake Nora penstock. Although the maximum atatic head on the Lake Grace penstock was 50 feet higher than that on the Nora penstock, the two equalized well hecause of the higher friction losses on the longer Grace penstock.

The new generating unit was basically similar to the unit added in 1906-1907. It was a dual bearing, single overhung unit. The General Electric 2000 kVA, 2200 volt generator was powered by a Pelton impulse wheel with a 76 inch diameter rotor, rated at 4000 hp. [see HAER photo 28] Water was directed on the wheel through a 6-inch deflecting needle nozzle, a system which attempted to combine the advantages of both the needle and the deflecting system. When the wheel's speed needed to be reduced, the governor (a Replogle mechanical governor driven off the shaft of the generating unit) would deflect the nozzle. The volume of water flowing through the nozzle could then be reduced by slowly closing the hand-operated needle valve. This was intended to combine fast speed regulation with economy of water. Excitation was furnished by a new 45 kW unit powered by a 90 hp impulse wheel with a 24.5 inch rotor. Water was provided this unit through a needle nozzle by a branch of the Lake Grace penstock. The control board for the new unit was similar to and placed adjacent to the board of the 1906-1907 unit. [22] [for Volta's interior after the second expansion see HAER photos 18, 20; for later views of both interior and exterior see HAER photos 1-17 (exterior) and 22, 29-30 (interior)]

Volta's enlargement, however, was just the first atage of the Northern California expansion program. As construction crews worked on Volta final plana were being made for a new plant, designated "South", and preliminary plans were being made for another, designated "Inskip".

SOUTH: Conatruction

During the winter of 1907-1908 the head of Northern California's engineering corpa, H.A. Tedford, began the preparation of specifications and construction plans for the second of the Battle Creek powerhouses -- South. [23] He was joined in this task in 1907 by J.H. Strutt, formerly chief engineer for the Pacific Power Company, but now employed by the Northern California Company. [24] By the summer of 1908 plans were complete for South and nearly complete for Inskip.

Actual construction work on the South powerhouse site began in October 1908, work on the ditch system a month later. Even earlier, however, Tedford had organized Northern California's construction forces and set them to work. These crews constructed a 10 mile long access road from Manton to South and from South along the route of the ditch which would eventually connect it to the second powerhouse at Inskip. Construction camps were laid out along the roads and at both the South and Inskip powerhouse locations. [25] Power lines were strung from Volta to compressor plants established along the route to provide power for air drills. [26]

The ditch system for South traversed rocky and rugged terrain and included long secions where flumes and tunnels were necessary. This precluded the use of steam shovels. Hence most of the excavation work on the South ditch system was carried out by hand. Workmen used only Burley (or Burleigh) air drills, dynamite, picks, and shovels. Tripod-mounted Burley compressed air drills drove the holes required for blasting the rock with dynamite. Derricks lifted the blasted rock and dirt out of the cut and hand-held drills cleaned up the ditches and excavated the stone used in building the powerhouse and the occasional rubble masonry retaining walls used at canal intakes, diversion dams, and waste weirs. [27] The rocky terrain covered by the ditches required blasting with dynamite almost every inch of the way. Northern California ordered dynamite in loads of 10 tons and blasting caps in hatches of 10,000. [28] As one local paper noted: "The booming of dynamite" became "the most familiar sound to be heard in the Manton country". [29]

To shorten ditches and reduce excavation Northern California was compelled to drive a number of tunnels on the South ditch system. All passed through solid lava rock. Laborers drove the tunnels from portals only; the shallow rock ceilings prevented the use of shafts even on the longer ones. The dimensions were the minimum necessary for construction -- about 8 feet wide by a maximum of 8 feet high (the roofs were arched). These relatively small dimensions and the absence of shafts caused some ventilation problems on some of the longer tunnels. Tedford had to bring in electric blowers to increase air circulation, noting in April 1909: "We have to get air in each of the tunnels as soon as possible". [30] In spite of round-the-clock excavation, tunnel work advanced at an average rate of only around 15 feet per day. [31]

At previous plants, Northern California had purchased prefabricated penstock sections and had these shipped to the site. At South and Inskip, however, Northern California erected pipe fabricating plants on the grounds and purchased flange-steel sheets, punched, sheared, and scarfed for fabrication into penstock pipe. When the sheets were delivered company crews rolled them into pipe and riveted them. [32]

Penstock steel and generating equipment for both the South and Inskip plants began arriving in Red Bluff, 46 miles away, in March 1909. By July over 400 tons of equipment was sitting in the yards awaiting shipment to the powerhouse sites. To move this material Northern California purchased a 50 hp, 60 ton capacity Best steam traction engine [see HAER photo 157]. Through the summer and fall of 1909 this machine hauled most of the heavy materials needed at the construction sites, including hundreds of tons of plate steel for the penstocks (155 tons for Inskip's penstock alone) and the large base plates for the generators (the two base plates for the Inskip generators weighted 34 tons each). In addition to the large equipment, thousands of pounds of smaller items were shipped in. [33] In March 1909 in preparation for the upcoming construction season, for instance, Tedford ordered 51,200 rivets, 13 tons of rivet coal and coke, 20 tons of nails for flume construction, 10,000 blasting caps, and thousands of feet of hard drill steel, along with miles of 2-inch, 3-inch, and 4-inch pipe for distributing compressed air. [34]

The peak of construction activity came in the summer of 1909. At this time the Northern California work force, a diverse mixture of Anglo-Saxons, Irish, Greeks, Mexicans, Portuguese, and Italians, totalled 1067 men with a monthly payroll of $67,000. [35] This force was much larger than that used earlier at Volta due to the much more difficult nature of the terrain and the larger ditches necessary for the larger volume of water to be used at South. Skilled labor, such as the Italian stone masons, received about $3.50 for an eight hour day. Helpers and laborers earned between $2.00 and $2.50. [36] Most of the labor force lived in one of the ten or more Northern California labor camps set up in the area. These camps were little more than a "street of large tents" with a central dining hall for meals. [37] After a visit to camp #4, in the wilds along South Battle Creek, the Manton correspondent of the Red Bluff Daily News wryly remarked: "There are no wild animals around this camp. They had all been killed off by the biscuits". [38]

Because of the large work force and the dangers of construction when dynamite was in heavy use, the Consolidated Company converted the city hall of the tiny hamlet of Manton into a hospital, staffed by a company doctor and nurse. [39] The doctor reported treating up to 400 patients per month in the summer of 1909, but as of October listed only two fatalities. [40] Although the number of deaths incurred in constructing South and Inskip is not certain, at least three more were killed by dynamite blasts or rock slides before the job was completed. [41]

The heavy construction around South powerhouse dramatically altered life in nearby Manton, previously a "quiet and sparsely settled" orchard town. As the Redding paper noted:

> The development work now in progress by the Northern California Power Company, Consolidated bas changed things completely at Manton. Men of all trades and many professions are there and for many miles around the town the hills and canyons teem with laborers. They are sleeping in barns, under trees and in out-buildings, wherever they can find room to spread their blankets. The hotels are filled up, new stores have sprung up, and every citizen has felt the new impulse and finds many easy that a few months ago was awfully sby. The teamster, the blacksmith, the landlord and bartender too are working overtime to handle the business. [42]

The checks issued by Northern California were made payable to J.L. Barham's general store at Manton. [43] This store transacted over $250,000 in business in 1909. [44] The frenzy of activity in the Manton area began to slow down only late in 1909 as South approached completion.

SOUTH: Layout and Design [45] [see HAER drawings, sheets 8-11 of 20]

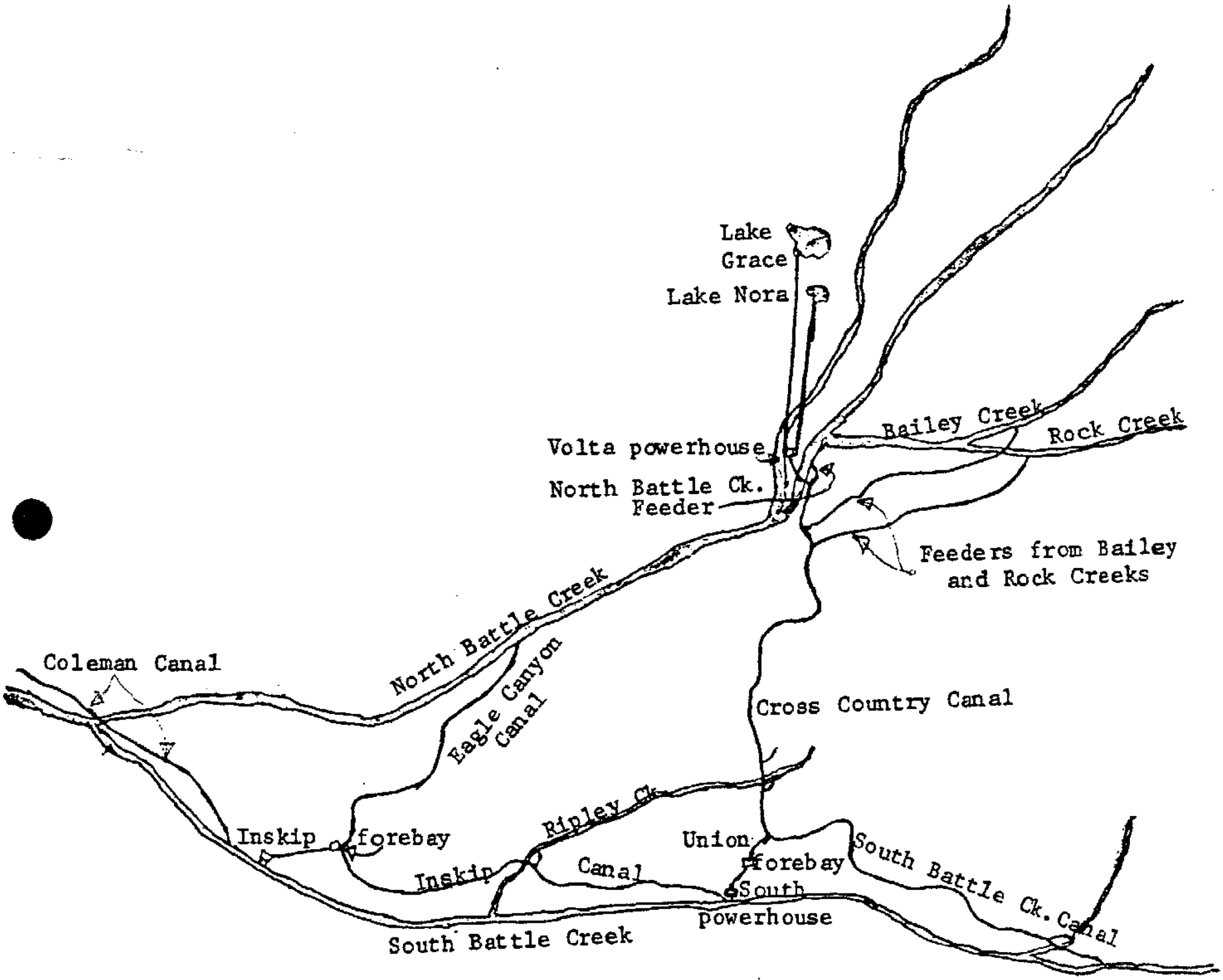
The water for the powerhouse at South was drawn from two distinct and independent sources — (1) Volta's tailrace (and North Battle Creek) and (2) South Battle Creek — in roughly equal amounts. The water brought in from Volta was carried by the Cross County Canal; that from South Battle Creek in the South Battle Creek Canal.

The Cross Country Canal began at the Volta tailrace where it picked up part of the discharge from Volta and carried it by flume across North Battle creek where it was joined by a feeder from that stream. Northern California was unable to divert all of North Battle Creek's and Volta's water because of unowned water rights which compelled the company to release slightly over 20 second-feet of water during irrigation season to downstream users. [46] The Cross Country Canal, with the combined flow from the Volta tailrace and the Battle Creek feeder, followed the south side of the canyon formed by Battle reek until it reached the top of a plateau, almost a mile south of Volta. Continuing generally southward the canal picked up additional water from Bailey and Rock and Digger Creeks and from several small irrigation ditches.

Northern California had largely avoided the use of expensive siphon, tunnel, and flume construction in its earlier plants. But the terrain along the routes of the South ditch system was much more severe than in previous projects. They could not be avoided if the ditch system was to be kept a reasonable length. In late 1907 Tedford estimated that the use of two tunnels and two inverted siphons on the Cross Country route would reduce its projected length from 8.61 miles to 5.86 miles. [47] Flume, however, was used instead, accomplishing the same object. Altogether the Cross Country Canal had 24,623 feet of ditch, averaging 6 feet wide by 4 feet deep, plus 5378 feet of wood flume, carried on timber trestles with a channel averaging 5 feet wide by 4 feet deep. The capacity of the Cross Country Canal was around 4000 inches (100 second-feet). [see HAER photo 126]

The Cross Country Canal terminated about three-quarters of a mile from the South forebay where it joined the second of the major ditches bringing water to the new powerhouse — the South Battle Creek Canal. The South Battle Creek Canal secured its water supply from a small masonry diversion dam located on the south fork of Battle Creek, about 5 miles upstream from South powerhouse. This ditch was approximately the same length as the Cross Country Canal, 30,342 feet (vs. 30,001 feet). The South Battle Creek Canal, however, traversed much more difficult terrain. The Cross Country Canal had required the removal of 39,487 cubic yards of rubble, only around 33% solid rock. The South Battle Creek Canal was to require the removal of 62,313 cubic yards of rubble, 82% solid rock. In order to reduce the tha length of the South Battle Creek Canal, Tedford had considered using siphons here too. But to reduce expenses the siphons were replaced here,

Table 11. The South and Inskip Ditch Systems



THE SOUTH WATER SYSTEM, c. 1910

Name (route)	length (ft)	length (mi)	capacity (second-feet)	approximate dimensions (width x depth)
North Battle Creek Feeder (No. Battle Ck.-Cross Country Canal)	686	0.13	50	
Cross Country Canal (Volta tailrace-Union Canal)	28552	5.41	90	6 x 4
Misc. Cross Country Canal Feeders (Bailey & Rock Cks.-Cross Country Canal)	28340	5.37	3.5 to 20	
South Battle Creek Canal (So. Battle Ck.-Union Canal)	30342	5.75	100	7 x 6
Union Canal (jct. Cross Country & So. Battle Ck. Canal - South forebay)	3231	0.61	190	10.5 x 4.5

THE INSKIP WATER SYSTEM, c. 1910

Name (route)	length (ft)	length (mi)	capacity (second-feet)	approximate dimensions (width x depth)
Inskip Canal (So. Battle Ck-Inskip Forebay) [incl. Ripley Ck. feeder]	23848	4.52	200	8 x 5
Eagle Canyon Canal (No. Battle Ck.-Inskip forebay)	13950	2.64	70	7 x 4

as on the Cross Country Canal, by wooden flumes on timber trestles. [48]

When completed the South Battle Creek Canal had ten tunnels, all 7 feet wide with a maximum height of 6.5 feet and all cut through self-supporting basaltic lava. These totalled 7731 feet in length. The longest was 4258 feet, the shortest 15 feet. [see HAER photo 128] In addition, the South Battle Creek Canal had eleven sections of wood flume totalling 3127 feet in length and eighteen sections of ditch (averaging 7 feet wide at bottom and 6 feet deep) totaling 19,848 feet in length. The canal's carrying capacity was around 90 second-feet.

The Cross Country and South Battle Creek ditches were merged 3231 feet from the South forebay to form the Union Canal. This short ditch was 10.5 feet wide by 4 feet deep, had a capacity of 190 second-feet, and was equipped with a masonry waste weir just before it terminated at the South forebay. [49]

The South forebay differed significantly from those at Volta and Kilarc. It was not a storage reservoir. It was, instead, a simple header box, a rectangular masonry structure 26 feet wide by 41 feet long, admitting water from the Union Canal on one side, delivering it to the South penstock on the other. A set of timber gates operated by rack and pinion controlled the admission of water to the header box; a set of grizzlies or trash racks screened the water. The floor of the header box was divided by submerged walls into three sections, each "V" shaped and sloped. Silt and sand which settled to the bottom of the V's was periodically flushed out by gate valves which ran through the walls.

The decision not to erect a forebay reservoir at South was influenced by several factors. One was the terrain. The ridge above South did not favor the construction of a forebay like the plateau above Volta. Even a very small reservoir, like Lake Nora, would have required a large amount of excavation and embankment work, and would have significantly elevated the cost of the project. Moreover, a forebay reservoir was not as critical at South as at the earlier plants. Since South's water supply came from two distinct souces by separate ditches, one or the other of these ditches could be closed due to accident or repair without closing the plant down. It could continue to use water from the other ditch, operating on half power, until the damage was repaired or the repairs completed. Finally, because South was part of a larger system of powerhouses, a failure of its ditch system would not interrupt service. Volta and Kilarc or the link with the PG&E system at Chico could pick up the load. The simple header box used at South was not unusual in California practice. [50] Many small hydroelectric plants that were parts of larger generating and distribution networks had them.

South had a single penstock of lap-riveted steel, almost 2000 feet long. [see HAER photo 129] This pipe was tapered from 72 to 48 inches in diameter as it fell 516 feet from the forebay to the powerhouse. Laid above ground, it was underpinned with loose rock and held secure on the slope by three rubble masonry anchors. As originally constructed the South penstock had neither a stand pipe nor air valves. This arrangement could have caused serious problems from vacuum formation in cases when the headgates were closed and water drained from the penstock and was criticized by the company's engineering consultants in 1911 as "not good practice". [51]

At Volta and at Kilarc Northern California had made heavy use of prefabricated lap-welded steel penstock, probably because of its lower cost and lower friction losses. At South, however, all lap-riveted construction was used. The key to this alteration of construction policy seems to have been cost. Although prefabricated lap-welded pipe was 15 to 20% cheaper than prefabricated lap-riveted pipe, it was possible to reduce costs even further by purchasing steel sheets, already punched, sheared, and scarfed for rolling into pipes and fabricating the pipe on site. Savings came not only in purchase price, but also in transportation costs. It was much easier and cheaper to transport flat steel sheets, particularly over the rough roads of the Battle creek basin, than prefabricated pipes. Purchasing somewhat thinner steel sheets for lap-welded pipe and rolling and welding these sheets on site would, of course, have been cheaper yet. But because welding was much more difficult than riveting and hidden flaws in a poor on site welding job were difficult if not impossible to discover, this option was generally regarded as too risky. [52]

As the lap-riveted penstock approached the powerhouse it entered a cast steel "Y". This split the single 48-inch diameter pipe into two 36-inch diameter pipes which passed through gate valves and were terminated in 9-inch diameter stationary needle nozzles. These nozzles were among the largest ever constructed. [53]

The South powerhouse was very similar in appearance to the earlier Northern California plants at Volta and Kilarc. It was a rectangular structure 69 feet 3 inches long by 37 feet 5.5 inches wide (outside dimensions). Massive walls of rubble masonry 2 or more feet thick, penetrating to bedrock 9 feet below floor level, carried steel trusses and a corrugated iron roof. The workmanship was excellent: the mortar joints were tight, the corners nestly squared, dressed arches covered windows and doors. [see HAER photos 36-45]

The interior of the powerhouse was divided into two sections. The generator room was approximately 53 feet long by 32.5 feet wide and occupied the east end. On the west were four bays. Three housed transformers, the fourth the remote oil switch for the generator. Above these bays was a gallery where the high voltage switching gear was located. [54]

There was but a single generating unit at South. It was a Westinghouse 4000 kVA, 6600 volt, rotating field generator, operated at 225 rpm by two 3500 hp Doble impulse wheels with 66 inch diameter rotors. One rotor was mounted on each side of the generator where the shaft overhung its two besrings. Speed regulation was carried out by a water-activated Lombard governor, type "Q". It controlled hollow cylinders (cylindrical deflectors) through which the jets of water from the nozzles passed. To decrease the speed of the water wheels the governor tilted these cylinders, deflecting all or part of the water from the buckets of the impulse wheels. The needles of the nozzles were hand rather than governor operated and would be slowly closed when it was necessary to conserve water. Slow closure by hand insured that there were no sudden pressure buildups in the penstock line. Water for the governor came from a separate pipeline, which tapered from 4 to 2.5 inches in diameter, and ran to the governor from the forebay. This water was screened twice, once near the forebay, again near the governor. [55] [for interior views of South powerhouse see HAER photos 46-54]

To keep the large 4000 kVA generator cool through the hot summers of the Battle Creek basin, G.H. Murphy, a company employee designed a rather novel system. He erected a sheet iron casing around the generator frame. A large pipe of sheet iron led from this casing to the tailrace below. Tailrace suction drew cool air over the generator windings, into the casing, and down into the tailrace. [56] [see HAER photos 47-48, 54] This system was later installed on generators at Volta and Inskip.

The exciter which provided direct current to the field coils of the South generator differed somewhat from the exciters installed at Volta and Kilarc. Like the earlier exciters, the South exciter was water powered through a small (78 hp) impulse wheel. But unlike the exciters at Volta and Kilarc, it had no governor. Speed regulation was completely dependent on hand manipulation of the needle nozzle control valve. If the load on the generator dropped due to the opening of an oil circuit breaker, a loading resistance automatically cut into the exciter circuit to furnish an artificial load to the exciter and keep the exciter wheel's speed within safe limits until the operator closed the needle valve by hand. [57]

Another way in which the South plant differed from the earlier plants of the Consolidated Company was in its use of a single generating unit to develop all the available power. Volta had five units; Kilarc two. Good practice in a power system dependent on a single powerhouse was, as already noted, to have multiple units, so that an accident to one water wheel or generator would not close down the entire system. In multi-plant systems, however, it was good practice to install the largest size generating unit possible. [58] A single large generating unit was far cheaper than several smaller units, and the backup capabilities which a multi-plant system offered made the larger number of units unnecessary.

Electrically there was nothing radically different about the South plant. It was basically similar to hydroelectric plants throughout the West. The transformers were three, single phase, oil insulated, water cooled, General Electric 1500 kW models which stepped the voltage up from 6600 to 66,000. The air cooled transformers of the type initially installed at Volta had been superceded around 1905 by water cooled models which cost less and, due to better cooling, had a longer life. Water cooled transformers did have higher operating costs, but in areas where water was readily available this was not a major consideration.

The generator at South was linked to the bank of transformers by a Westinghouse remote control oil switch, activated from the switchboard and placed in the bay in the southwest corner of the powerhouse. The transformers were linked to outgoing transmission lines through a Kelman high voltage oil switch and a disconnecting switch placed in the gallery over the transformer and generator switch bays. After passing the Kelman switch and disconnecting switch, the lines were taken out through a window to an adjacent switchyard with the usual pole top disconnecting switches. From the switchyard a 66 kV line led to Volta. Later a line was run west to the newer plant at Inskip as well. [59]

Water flowed through the South powerhouse penstock as early as August 17, 1909. [60] But this water was drawn solely from the Cross Country ditch. The troublesome task of tunnel construction delayed completion of the South Battle Creek Canal for weeks afterwards. Only in November of 1909 was the final tunnel on that canal, the 4258 foot long tunnel, completed. [61] South was able to go on line in January of 1910, adding 4000 kVA to the existing 9250 kVA capacity of the Consolidated Company's power system.

INSKIP: Construction

As elements of the South hydroelectric system were completed, Northern California moved its men and equipment to Inskip and its ditch system, where construction had been proceeding at a slower pace. The company also attempted to beef up its crews to speed up construction. But sparsely-populated northern California had no ready supply of surplus labor. Thus an attempt in November 1909 to find "100 laborers, shovelmen, tunnelmen, muckers, and compressormen" failed, with NCPC officials complaining that men disappeared "when work steps onto the stage to meet them". [62] Nonetheless, by October 1909 the walls of the powerhouse at Inskip had been completed and crews rushed to finish the structure and move the machinery inside before the winter rains began. [63]

During the winter of 1909-1910 Northern California sharply reduced its labor force as snows made outside work impractical. In December 800 men were laid off. But a full crew was retained to finish up work on the interior of Inskip powerhouse and 180 to 200 of the "best laborers" were kept at work on the tunnels of the Inskip water system. [64] The lay offs caused some trouble in nearby towns. Dismissed workers appeared in Red Bluff, began drinking, and soon "taxed the capacity of the jail". [65] "Each day," one Red Bluff paper complained, "another installment arrives". The new arrivals "carried their blankets", appeared to be "broke", and chose to "linger about the town". [66] Other furloughed workmen stayed closer to the work site, drinking and lingering around Manton, hoping, apparently, to find work when construction activity picked up in the spring. [67]

The construction costs of South and Inskip weighed heavily on the Consolidated Company's available capital. As expenditures increased, Noble began to monitor progress closely, making daily visits to the construction site. [68] Management discontent with construction costs and progress led to a major shake up in February of 1910. The company requested and received the resignation of W.A. Smith, superintendent of ditch and tunnel excavation, and dismissed a number of foremen and dozens of laborers. A local newspaper commented: "Inskip work will heareafter be under closer supervision and under competent hands. There will be in the future less bosses and more work. This will greatly cut expenses and lessen the labor". [69] At about the same time E.V.D. Johnson, General Mansger of Northern California Power, appealed to the Tehama County Board of Supervisors to reject an application for a saloon license. The saloon was to be erected nesr the Inskip site, and the company feared thst the 1100 men they intended to have on the payroll in the spring would have their work performance impaired by having alcohol so readily available. [70]

In an attempt to further reduce labor costs and to expedite excavation work on the Inskip ditch system, Northern California decided to experiment with a more mechanized construction plant on the last 1.5 miles of the ditch linking South with Inskip. In March 1910 the utility received its first steam shovel, s Marion with a 1.5 cubic yard capacity bucket. It was put to work immediately. [71] By May the Inskip Canal was finished. [72]

INSKIP: Layout and Design [72] [see HAER drawings, sheets 3,12-17 of 20]

There are two primary ditches that provide water to Inskip: (1) the Inskip Canal and (2) the Eagle Canyon Canal. The former is the more important of the two conveyances. It originates at a 32 foot high rubble masonry overflow dam on South Bsttle Creek, a short distance downstream from South powerhouse. This dam diverted most of the available water into the ditch.

The Inskip Canal was, like the other canals of the Battle Creek system, originally unlined. It had a capacity of 125 second-feet. A typical cross section of the ditch was 5 feet deep and averaged 8 feet wide. Roughly paralleling the course of South Battle Creek, Inskip Canal was approximately 4.45 miles long and like the South Battle Creek Canal of the South system was a mixture of tunnel (eight sections), ditch (eleven sections), and flume (1 section). [for a view of a waste weir on the Inskip ditch see HAER photo 142]

To reduce construction costs the Consolidated Company should perhaps have used more flume and less tunnel on the Inskip ditch, since the cost of the latter was three times that of the former. But Northern California's construction policy was to sacrifice economy for permanency. As one observer noted:

> It has been the policy of this company to do its work in a manner to insure permanency and low cost of upkeep. With this in view, it has stesdfastly refused to use timber flume for carrying large amounts of water, if it were possible to obviate its use. It has even gone so far as to drive crescent shaped tunnels where timber flume might easily hsve been employed at one third of the initial cost. [73]

The eight sections of tunnel on the Inskip ditch totalled 5013 feet in length. The longest was 1787 feet, the shortest 96 feet. They were the same size as the tunnels on the South Battle Creek Canal — 8 feet wide with a maximum height of 8 feet. And, like the earlier tunnel work carried out by the company, all tunnels were unlined and driven entirely with hand labor.

The eleven sections of ditch on the Inskip Canal totalled 18,640 feet. Of this total around 63% or 11,768 feet were excavated by hand. The remaining portion was excavated with the aid of the steam shovel. This gave the Consolidated Company an opportunity to compare the costs of the two systems. Final estimates indicated that the portion of the canal excavated by hand had cost the company around $4.00 per linear foot. The section excavated with the aid of the steam shovel had cost only $2.04, approximately 49% less, convincing the power company of the advantages of mechanical excavation. [74]

The water brought from South Battle Creek through the Inskip Canal was supplemented by additional water, approximately 70 second-feet, diverted from North Battle Creek through the Eagle Canyon Canal. This canal originated at a 12 foot high, 72 foot long rubble overflow diversion dam on North Battle Creek near the point it entered Eagle Canyon. Flume work carried the water from North Battle Creek up the south wall of Eagle Canyon on timber bents spaced 3 feet apart set on a bench cut into the side of the south wall of the canyon. After reaching the top of Eagle Canyon the canal travelled in a generally southwesterly direction towards the Inskip forebay.

The Eagle Canyon Canal was 13,807 feet long and contained six tunnels, six sections of flume, and one long section of ditch. The six tunnels totalled 1280 feet in length and were smaller than the tunnels on the South Battle Creek and Inskip Canals. The six sections of flume totalled 3696 feet in length. The longest section was 2938 feet long and was the section which carried the water up the side of Eagle Canyon. [see HAER photos 130, 132-139] The 8831 feet of ditch on this canal were all excavated by hand. [75]

The Inskip Canal was completed first. The last of its tunnels was driven through in March 1910 and ditch excavation was completed by May. [76] Inskip went on line on June 10, 1910, operating with water from this canal only. Work on the Eagle Canyon bench and flume delayed the completion of the Eagle Canyon Canal through the summer of 1910. Its waters joined those of the Inskip Canal only in October 1919. [77]

The Inskip and Eagle Canyon canals met at the Inskip forebay. As at South, this forebay had no storage capacity. It was simply a masonry header box, 12 feet deep by 52 feet long by 36 feet deep. The box was divided into three sections, each approximately 16 feet wide and 36 feet long. The first two sections were opposite rack-and-pinion operated entry gates, had sloping floors, and were separated by a submerged concrete barrier. Valves in the forebay wall here, as at South, allowed the sand and grit deposited in the bottom to be periodically flushed out. The third forebay compartment was separated from the other two by trash racks which screened floating debris from the water and contained the 72-inch diameter penstock entrance. [see HAER photo 140]

The Inskip penstock was a mixture of redwood stave pipe and lap-riveted steel pipe. For the first 2150 feet the slope from the Inskip forebay was gentle and redwood atave pipe was used. When the slope dropped off aharply towards South Battle Creek and the powerhouse, riveted steel pipe, around 1050 feet, was used. The redwood stave pipe was fabricated out of timber cut and finished in a mill owned and operated by Northern California, using only the beat red fir from the heart of the tree. The lap-riveted steel pipe was fabricated from steel plate at a company pipe ship at the Inakip powerhouse site. [aee HAER photos 151, 156, 158 for fabrication work at Inskip] The usual precautinna were taken to prevent pressure buildups in the pipe. There was a stand pipe and two automatic preasure relief valves. [see HAER photoa 13, 144 for views of the Inskip penstock]

The 3200 foot long penstock, after falling 378 feet, was terminated in a receiver embedded in concrete lying alongside and parallel to the length of the powerhouse. The first section of this receiver was the same diameter of the incoming penstock, 6 feet, and had three 27-inch feeder pipes taken off at right angles to one of the generating units in the adjacent powerhouse. The receiver was then tapered to 42 inches diameter and three more feeder pipes, 21 inches in diameter, were taken off at right anglea. Near the end of the receiver a 12 inch tap was taken off for the exciter wheels. [78]

In most California hydroelectric plants, and in hydroelectric plants generally, the incoming penstock reaches the powerhouse along a line perpendicular to the longest side and to the center line of the axles of the generating units (if impulse wheels are used). This arrangement reduces loases in hydraulic efficiency due to sudden changes in the direction of flow. The Inskip penstock with its perpendicular feeders violated this basic practice largely because of the terrain in the area. The extensive amount of excavation and levelling work which would have been required to reposition the powerhouse perpendicular to the penstock made the more usual and more efficient option too costly.

The Inskip powerhouse was very similar to South in design. The walls of 2 foot 3 inch and 2 foot 6 inch thick rubble masonry were carried down to bedrock. Steel trusses carried a corrugated iron roof on steel trusses over the aheil. Windows and doors had dressed stone arches. The structure was rectangular, 125 feet long by 37.5 feet wide and, like South, was divided tranaversely into two aections -- a large room contained the generating machinery; a amaller two atory section housed the transformers and high voltage switching apparatus. [79] [aee HAER photos 55-65 for the exterior of Inskip; 67-82 for the interior]

The most unusual feature of the Inakip hydroelectric plant was its generating units. There were two, placed on a common center line which ran the length of the building and paralleled the penstock and ita receiver. The upstream unit had an output of 4000 kVA; the downstream unit 2000 kVA. Both units had three rotors 48 inches in diameter. [see HAER photo 66] The three wheels of the larger unit were aupplIad with water from three 27-inch diameter pipes tapped off the upstream portion of the receiver and led through 27-inch hydraulic gate valves; the wheels of the amaller unit were supplied with water from three 21-inch diameter pipes equipped with 21-inch hydraulic gate valves. The generator and the triple rotors of both units were mounted on the same shaft. There were three water-cooled bearings, one on either end of the shaft and one between the generator and the housing for the triple rotors.

The larger of the two triple rotor units had two 6-inch diameter nozzles for each rotor. The rear or upper nozzle was a fixed needle nozzle; the needle was operated by screw and hand wheel. The forward and lower nozzle had a plain tip. The small generating unit had only one nozzle (a 6-inch diameter needle nozzle) per rotor. The speed of these units was governed by a water-activated Lombard governor, type "Q", which controlled a set of U-shaped hood deflectors. The water supply for the governors was tapped off the penstock near the forebay, led to a governor water storage tank, where the water was screened with 1/2 inch wire mesh, and then into the governor feeder pipe. This pipe, 3.5 inches in diameter near the storage tank, reduced to 2.5 inches as it neared the powerhouse, paralleled the penstock. If the water wheels began to rotate too fast, the governors, through a rocking arm, tilted the deflecting hoods (one for each nozzle) so that they intercepted the jets and deflected them wholly or partially from the impulse wheels. [80]

The "somewhat novel" triple rotor units were used at Inskip because of the relatively low head at the site (378 feet) and economic considerations. Under a head of 378 feet the velocity of the water jets and hence the velocity of the impulse wheels (half that of the water jets for maximum efficiency) would he relatively low. This made it difficult to install a single large unit like at South. For medium-to high-power generators (5000 to 10,000 kVA's in 1910) the most desirable speeds were 360, 400, or 514 rpm. [81] Above these speeds the cost of generators went up very steeply; below these speeds the cost of generators was also higher, though it was possible to purchase lower power units operating at 150, 180, 225, 240, or 300 rpm. This presented Northern California's engineers with a dilemma. A single overhung unit like Volta units 4 and 5, in order to operate at 400 rpm, would have had to use a rotor with a small diameter and this unit, with only a 378 foot fall, would have been able to deliver less than 1000 kVA. To make use of the 6000 kVA available at the Inskip site, eight to ten single overhung units would have been required, along with associated equipment (gate valves, nozzles, governors, switchboards, etc.), a considerable expense, especially since the powerhouse necessary to house that number of units would bave been quite large.

On the other hand, in order to operate a single large generator, Northern California would have had to use a rotor with a very large diameter to develop the necessary power. The larger rotor, because its peripheral speed was fixed in relation to the speed of the water jets, would have had a much lower shaft speed. The low shaft speed would have compelled the company to use a very low speed generator. And low speed generators were not only more expensive than generators with speeds of from 300 to 500 rpm, hut much larger (= higher transportation costs) and less efficient. [82]

The generating arrangement adopted at Inskip was a compromise between these two extremes. There were two ways to increase the output of impulse wheel units where speed requirements were fixed. One way was to install multiple nozzles. This would bring more water against a single wheel. Two jets striking against the buckets of an impulse wheel in two different locations would double the power of the wheel without altering shaft speed. The other way was to install additional rotors of the same diameter (and hence the same peripheral speed) on the same shaft, as, for example, had been done at South with the double overhung arrangement. At Inskip Northern California engineers adopted both of these options. This allowed them to reduce the number of generating units necessary to tap the 6000 kVA of power available under the 378 foot fall to only two and also permitted them to use a reasonably high generator shaft speed (225 rpm), thus avoiding the more expensive, less efficient slower speed generators.

How successful the triple rotor units were at Inskip is open to some question. Their efficiency was low. Tests carried out in 1910 on the larger unit indicated that its maximum efficiency was 80%, obtained at about half gate, but dropped off very sharply beyond three-quarters gate to only around 60% at full gate. The smaller unit with the single nozzles performed better. Its peak efficiency was around 87% and dropped only to 82% at full gate. [83] Interference in the form of splashing and spray between the dual nozzles on the larger units and, possibly, differing jet velocities between the two nozzles were probable causes. Low efficiency was not the only problem with the triple rotor, dual nozzle design. Later critics noted that this arrangement also complicated the governing of water wheel speed. Regulation problems and low efficiency led, in the second decade of the twentieth century, to the demise of the triple rotor/double nozzle unit. [84] However, since first cost was more important than efficiency to the Northern California Power Company, plagued as it often was by excess generating capacity, the shortcomings of the larger Inskip unit were probably not too severe from a strictly practical point of view.

It is, nonetheless, quite possible that Northern California engineers erred in adopting impulse wheels at Inskip. There was an option besides triple rotor units which might have allowed them to avoid the dual hazards of multiple units and slow-speed generators -- the Francis turbine. Because Francis turbines deliver optimum efficiency when their peripheral velocity is 75 to 100% that of the incoming water, instead of 50% as in an impulse wheel, they have a higher rotational velocity for the same power output. In addition, because water acts over the entire circumference of a turbine, instead of on only a portion of the circumference as in an impulse wheel, turbines can handle larger quantities of water and hence deliver larger power for equivalent size. Thus, the Francis turbine might have enabled Northern California to utilize the 6000 kVA of power available at Inskip in a single unit, without the necessity of having to utilize a slow speed generator.

Why, then, was a Francis turbine not selected for Inskip? In part it was due to tradition. The Francis turbine was developed and initially manufactured in the eastern part of the United States where falls were low (usually under 50 feet) and flows were large. The stock turbines long offered by most eastern manufacturers were simply not designed to handle the high water velocities and low volumes used in California hydroelectric plants. When Francis wheels were first applied to high head conditions, the grit, sand, and silt carried with the water at high velocities had an abrasive effect on the closely spaced buckets and quickly pitted the runners, sharply decreasing the efficiency of the units after a few weeks of operation. Because the runners of a turbine fit tightly within the draft case, turbines were easily clogged and runners further damaged by roots, leaves, sticks, and other trash which entered the penstock. The pitting problem and damage caused by debris entering the wheel made the replacement of entire runners a too frequent occurrence and made operating costs for turbine installations high. In addition, vortices created by the flow of water at high velocity through the turbine runners and down their draft tubes early caused major problems with vibrations. [85]

The impulse wheel was largely immune to these problems. Its simple rugged construction and free discharge operation made it much less susceptible to damage from dirt, grit, roots, and leaves. It had as good or better efficiency than the early high head Francis turbines, especially at part gate. And repairs were much simpler and cheaper -- usually involving the replacement of a single bucket instead of an entire runner. Moreover, impulse wheels had evolved specifically to meet high head conditions and were thus the dominant tradition in California.

Francis turbines were only slowly adapted to California and the high head conditions found there. Some of the early experiments with them were failures. For instance, in 1906 a 1500 kW generator was installed at the Bishop Creek No. 5 plant powered by a turbine operating under a head of 407 feet. The runner quickly wore out. [86] Thus, as late as 1906 Francis turbines were regarded as an unknown quantity in California for heads of greater than 400 feet. [87] The first successful medium head Francis turbine installation in California came only in 1907 at the Centerville plant of the Pacific Gas and Electric Company. [88]

Thus, when Inskip was on the drawing board in late 1907 and early 1908, Francis turbines had yet to prove themselves under medium heads and were generally regarded as fit only for much lower heads. As late as 1915 one writer warned that the lower efficiency and greater complexity of the dual nozzle/triple rotor arrangement was a lesser evil in some cases than a Francis turbine which required frequent runner replacement. [89]

The electrical plant at Inskip presented no really unusual features and was basically similar to that at South. There were two sets of generator bus bars and four sets of remote control generator oil switches (located in a fire proof compartment in a corner of the generator room). The generator switches were operated from the switchboard and were arranged so that either of the Inskip generators could be thrown on either bus. There were two banks of three single phase, oil insulated, water cooled transformers. These were in bays placed on either side of a passageway which linked the front entrance of Inskip to the generator room. The General Electric 1500 kW transformers stepped up the voltage from the 6600 of the generators to 66,000. Linking the secondaries of the generators to the outgoing transmission lines were two Kelman high voltage oil circuit breakers. These were located in a gallery above the transformer cells. From the Kelman switches the lines passed through disconnecting switches and through a window to a switchyard with pole top disconnecting switches outside. [90]

When Inskip went on line in 1910 Northern California possessed four hydroelectric plants, three on Bsttle Creek (Volta, South, Inskip) plus Kilarc on Old Cow Creek. The company's generating capacity had doubled in less than two yearrs from 9250 kVA to 19,250 kVA. Carrying power from these plants was a system of transmission lines 480 miles long and serving an area roughly 95 miles long from north to south and 40 miles wide (see the tables on the following pages). The load on this network was regulated at the Volta switch house, supplemented by the central switching station at Palo Cedro. Transmission loops or parallel lines insured that most of the major substations were reached by at least two transmission lines, a factor which made the system "extremely flexible". [91] The transmission lines were generally well constructed, and the substations, while leaving something to be desired in the way of refinements and first class high voltage switching gear, were at least adequate. Making the system even more efficient was its "remarkably high" load factor, something noted by just above everyone who closely investigated the Northern California system [92] In the last half of 1909 the system's load factor had varied from a low of 83.2% to a high of 95%. [93] Most utilities had load factors no higher than 30 to 60% (see table 15).

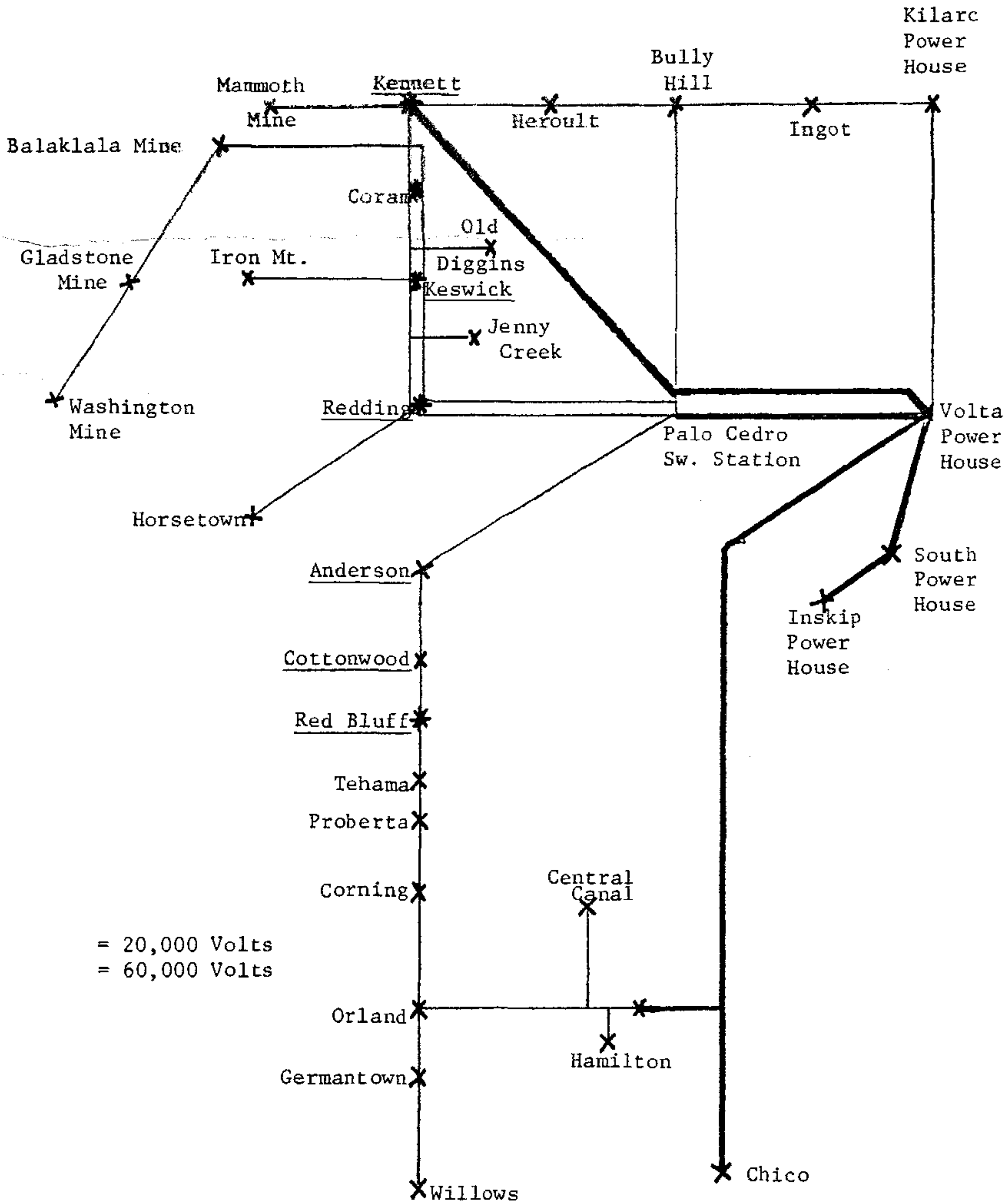


Table 13.
The High Voltage Transmission Lines and Substation of the Northern California Power Company, Consolidated, as of January 10, 1910 (Not drawn to scale)

[Source: J.G. White & Co., "Report," facing p. 17]

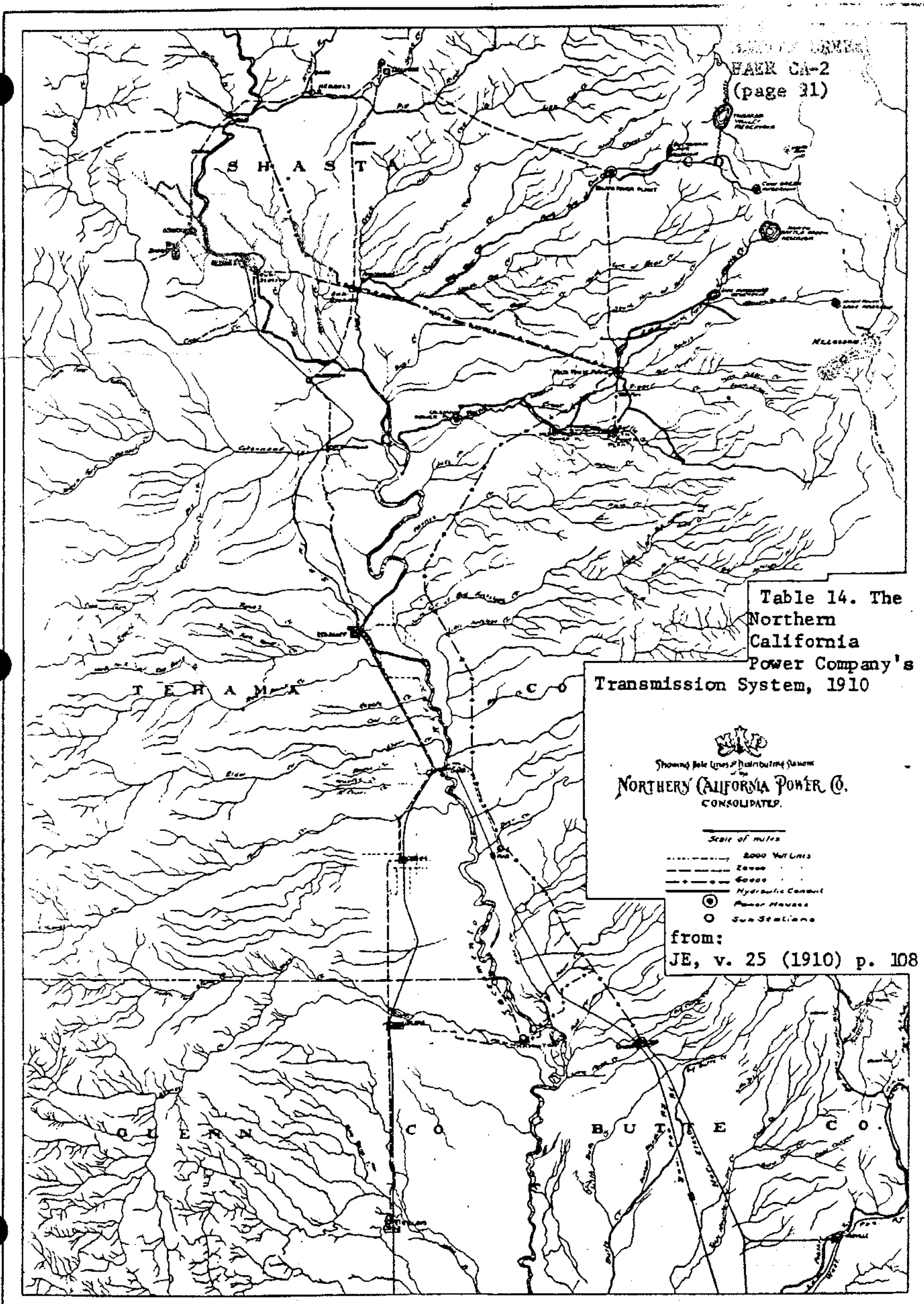


Table 14. The Northern California Power Company's Transmission System, 1910

from:
JE, v. 25 (1910) p. 108

Table 15.

Load Factors of Various Eastern and Western Utility Companies in the Early Twentieth Century

Company	Load Factor
Eastern:	
Niagara Falls Power Company	81.0
Commonwealth Edison, Chicago	40.0
New York Edison	34.7
Philadelphia Electric	34.4
Boston Edison	32.5
Western:	
Pacific Gas and Electric	59.0
Great Western Power	70.0
Sierra & San Francisco Power	50.0
Pacific Light & Power	47.8
Los Angeles Gas & Electric	40.0
NORTHERN CALIFORNIA POWER COMPANY	80.0

Source: P.M. Downing, "Report of Sub-Committee on Water Power Development on the Pacific Coast, National Electric Light Association, 38th Convention (1915), Proceedings, [v. 3] p.592, for all companies except Northern California Power Company. Fowler, Hydroelectric Systems of California, plate XX, following p. 142, for NCPC.

NOTES

[1] For increased mine production see CSMB, 14th Report (1913-1914) pp. 750-751, or 20th Report (1924) p. 208; on copper prices see Bureau of the Census, Historical Statistics, p. 208; for NCPC's increased revenues see NCPC, 5th Annual Report (1906-1907) [Gross income rose 17% from 1904-1905 to 1905-1906].

[2] NCPC, 5th Annual Report (1906-1907); Redding Courier Free Press, March 14, 1907; JE, v. 18 (April 13, 1907) p. 293; "NCPC Scrapbook," p. 3 ("Northern California Power Company, March 25, 1907")

[3] For instance, the Redding Courier Free Press seconded Mining World's assertion: "The outlook for 1908 is better and brighter than for many many years." (Redding Courier Free Press, January 30, 1908).

[4] San Francisco Chronicle, September 6, 1902.

[5] For instance, Redding Courier Free Press, March 7, 1907. For local reports on the progress of work at Heroult see: Redding Courier Free Press, June 26, July 3, July 13, July 16, and August 16, 1907.

[6] NCPC, 5th Annual Report (1906-1907).

[7] Redding Courier Free Press, July 11, 1907; Redding Searchlight, January 27, 1907; Alfred Stansfield, The Electric Furnace for Iron and Steel (New York, 1923) pp. 116-117.

[8] Redding Courier Free Press, August 15, 1907.

[9] NCPC, 6th Annual Report (1907-1908).

[10] NCPC, 6th Annual Report (1907-1908); JE, v. 19 (September 28, 1907) p. 285; Tedford to Johnson, November 4, 1907, in Jeffcoat Letter Book, pp. 14-15.

[11] NCPC, 6th Annual Report (1907-1908); NCPC-C, 1st Annual Report (1908-1909); Red Bluff Daily News, October 11, 1907; JE, v. 19 (August 28, 1907) p. 285; (November 9, 1907) p. 415; (November 26, 1907) p. 370; and "NCPC Scrapbook," p. 28 ("Northern California Power Plants" 9-18-07) and p. 31 ("Many Power Sites Are Filed On").

[12] NCPC-C, 1st Annual Report (1908-1909). NCPC apparently initially planned to construct only one powerhouse on South Battle Creek. It was to be located just south of Inskip Butte and 1 mile above the crossing of the Manton to Red Bluff Road (Red Bluff Daily News, October 11, 1907). But extensive purchases of Battle Creek properties and water rights allowed the company to redesign the system to include two South Battle Creek powerhouses (NCPC-C, 1st Annual Report [1908-1909]).

[13] NCPC, 6th Annual Report (1907-1908); Redding Courier Free Press, October 31, 1907; Red Bluff Daily News, October 31, 1907.

[14] CRRC, Transcripts [of Hearings], cases 675, 676, 677, 711, v. 3 (February 2, 1916) p. 120 [testimony of Edward Whaley, Company Secretary] (CSA); "Articles of Incorporation of Northern California Power Company, Consolidated," August 24, 1908 (PG&E, Secretary's Office, document 2092-j).

[15] "Preamble and Resolutiona of Northern California Power Company, Consolidated," September 12, 1908 (PG&E, Secretary's Office, document 2257); Red Bluff Daily Newa, October 17, 1908.

[16] "Crestion of Bonded Indebtedness of Northern California Power Company, Conaolidated," November 18, 1908 (PG&E, Secretary's Office, document 2092-k).

[17] For the second expansion of Volta the basic sources are: Fowler, Hydroelectric Systems of Californis, pp. 227-233 psssum; Van Norden, "Northern California Power Company," pp. 112-118 psssum; J.G. White & Co., "Report," pp. 32-37, 42-43, 52-54; and scattered remarks in the Valuation Survey Field Books relating to Volta.

[18] Redding Courier Free Preas, December 17, 1908; JE, v. 21 (December 19, 1908) p. 423; H.A. Tedford to Edward Whaley, July 12, 1908, in Jeffcoat Letter Book, p. 20.

[19] J.G. White & Co., "Report," p. 35; NCPC-C, Computation Folder no. 36, supporting Valuation Folder no. 5 ("Al Smith Ditch").

[20] NCPC, 5th Annual Report (1906-1907).

[21] For a diacussion of the various irrigation ditches, some partly owned by NCPC, in the Battle Creek srea see: J.G. White & Co., "Report," pp. 34-36, and Redding Courier Free Press, February 26, 1910.

[22] For data on Volts unit #5 see: J.G. White & Co., "Report," pp. 42, 53-54; Fowler, Hydroelectric Systems of California, pp. 231-233 passum; Van Norden, "Northern California Power Compsny," pp. 113-115 passum; PG&E drawing 63740; and NCPC-C, Valuation Survey Field Book 4 (H-28) esp. psges 57-59, 66, 76-79.

[23] Tedford to Johnson, November 4, 1907, in Jeffcoat Letter Book, pp. 14-15.

[24] For example, Tedford to Noble, October 20, 1908, notes some of the work Strutt was doring with Tedford on stream flow measurements (Jeffcoat Letter Book, p. 30).

[25] Red Bluff Daily News, August 14, October 28, and November 15, 1908; JE, v. 21 (November 28, 1908) p. 375.

[26] Red Bluff Daily Newa, August 14, 1908; JE, v. 21 (December 19, 1908) p. 423.

[27] Tedford to Whaley, March 25, 1909, in Jeffcoat Letter Book, p. 55; Van Norden, "The Coleman Plant," JE, v. 27 (1911) p. 414, for descriptions of canal construction.

[28] Red Bluff News, August 14, 1909; Red Bluff Daily Peoples' Cause, April 2, 1910.

[29] Red Bluff Daily News, August 14, 1909.

[30] Tedford to Whaley, April 13, 1909, in Jeffcoat Letter Book, p. 66.

[31] Red Bluff News, August 14 and August 15, 1909.

[32] Red Bluff Daily News, November 15, 1908, and August 14, 1909; Red Bluff Weekly Peoples' Cause, March 20, 1909; Redding Courier Free Press, December 17, 1908.

[33] For the transportation of supplies to the plants see: Red Bluff Weekly Peoples' Cause, March 20, March 27, April 3, and April 26, 1909; Redding Courier Free Press, July 9, 1909; Jeffcoat Letter Book, p. 114 (entry: "Repair List for Best Engine #250,"March 8, 1910.

[34] Computed from requisitions in the Jeffcoat Letter Book, pp. 34, 39, 52, 53, 66, 71, 79, 80, 82, 97, 102 (Tedford to Whaley).

[35] Red Bluff Daily News, August 11, 1909; Redding Courier Free Press, August 19, 1909.

[36] NCPC-C, Valuation Survey Field Book 1 (H-1) p. 67.

[37] Red Bluff Daily News, October 23, 1909.

[38] Ibid.

[39] Redding Courier Free Press, August 14, 1909; Red Bluff Daily News, March 29 and August 14, 1909.

[40] Red Bluff Daily News, October 30, 1909.

[41] Red Bluff Daily News, October 28, 1909, and August 4 and August 5, 1910; Redding Courier Free Press, October 28, 1909, and August 4, 1910; Red Bluff Weekly Peoples' Cause, October 30, 1909.

[42] Redding Courier Free Press, August 14, 1909.

[43] Ibid.

[44] "NCPC Scrapbook," p. 51.

[45] Basic data on the South powerhouse and its ditch system are provided by: Fowler, Hydroelectric Systems of California, pp. 233-236; Van Norden, "Northern California Power Company," pp. 118-120; J.G. White & Co., "Report," pp. 37-39, 43-44, 57; NCPC-C, Valucation Survey Field Books, especially 6 (H-27) and 5 (H-26); PG&E drawings

39613, 44808, 63683; and on site inspection.

[46] J.G. White & Co., "Report," p. 37.

[47] Tedford to Johnson, November 4, 1907, in Jeffcoat Letter Book, pp. 14-15; also Tedford to Noble, October 20, 1908, ibid., pp. 30-32.

[48] Tedford to Noble, October 20, 1908, in Jeffcoat Letter Book, pp. 30-32.

[49] In addition to the material on the water system found in the items in note [45] see: NCPC-C, Valuation Survey Field Books 3 (H-11), 5 (H-18), 6 (H-13), 7 (H-10), 14 (H-12), and Computation Folders 16 through 20 (R/V).

[50] Fowler, Hydroelectric Systems of California, p. 716.

[51] Carl J. Rhodin to J.G. White & Co., July 6, 1911, in Carl J. Rhodin Papers, California Water Resources Library, Berkeley, California. For descriptions of the South forebay and penstock see Fowler, Hydroelectric Systems of California, pp. 234-235; Van Norden, "Northern California Power Company," p. 118; and NCPC-C, Valuation Survey Field Book 6 (H-27) pp. 1-15.

[52] Galloway, "Hydro-Electric Plants in California," p. 317, for example. Galloway stated that he did not know of a single lap-welded pipe which had not been patched and banded and strongly condemned its use.

[53] Ibid., p. 362 (comment by H. Homberger).

[54] Fowler, Hydroelectric Systems of California, p. 235; Van Norden, "Northern California Power Company," pp. 118-119; NCPC-C, Valuation Survey Field Book 5 (H-26) esp. pp. 1-4.

[55] Fowler, Hydroelectric Systems of California, pp. 235-236; NCPC-C, Valuation Survey Field Book 6 (H-27) pp. 16-44 passum; Van Norden, "Northern California Power Company," p. 119.

[56] Van Norden, "Northern California Power Company," p. 120.

[57] Fowler, Hydroelectric Systems of California, p. 236; NCPC-C, Valuation Survey Field Book 6 (H-27) pp. 35-36; Crellin and Maryatt to Milford, July 9, 1930 (in PG&E, Engineering Central Files, no. 430:"South").

[58] See, for instance, Galloway, "Design of Hydro-Electric Plants," pp. 1022, 1040 (comment of E. Newman).

[59] Fowler, Hydroelectric Systems of California, p. 236; Van Norden "Northern California Power Company," pp. 119-120; J.G. White & Co., "Report," pp. 56-57; NCPC-C, Valuation Survey Field Book 6 (H-27) pp. 44-55.

[60] Redding Courier Free Press, August 17, 1909; Red Bluff Weekly Peoples' Cause, August 21, 1909.

[61] Red Bluff News, November 25,1909.

[62] Red Bluff Daily News, November 7, 1909.

[63] Red Bluff Weekly Peoples' Cause, December 18, 1909.

[64] Redding Courier Free Press, December 9 and December 22, 1909; Red Bluff Daily News, December 10, December 18, and December 21, 1909; Red Bluff Weekly Peoples' Cause, December 18, 1909; JE, v. 24 (February 5, 1910) p. 133.

[65] Red Bluff Daily News, August 21, 1909.

[66] Red Bluff Weekly Peoples' Cause, December 18, 1909.

[67] Red Bluff Daily News, December 30, 1909.

[68] Red Bluff Daily News, December 5, 1909.

[69] Red Bluff Daily News, February 27, 1910.

[70] Red Bluff Daily News, December 21, 1909; Redding Courier Free Press, December 22, 1909.

[71] Red Bluff Daily News, April 7, 1910; Redding Courier Free Press, March 22, 1910; Red Bluff Daily Peoples' Cause, March 21, 1910; Van Norden, "Northern California Power Company," p. 121.

[72] For basic data on Inskip see: Fowler, Hydroelectric Systems of California, pp. 236-240; Van Norden, "Northern California Power Company," pp. 120-124; J.G. White & Co., "Report," pp. 39-40, 45-46, 58; NCPC-C, Valuation Survey Field Books 7 (H-7), 8 (H-31), and 17 (H-30).

[73] Van Norden, "Northern California Power Company," p. 121.

[74] Ibid., p. 118; NCPC-C Combination Folder no. 24, supporting Valuation Folder no. 2 (R/V).

[75] For the Inskip canal system see NCPC-C, Valuation Survey Field Books 7 (H-10) and 8 (H-23), plus Computation Folders no. 22 and 24, supporting Valuation Folder no. 2, plus the items in note [72] above.

[76] Red Bluff Daily News, March 24, 1910; JE, v. 24 (May 7, 1910) p. 445.

[77] JE, v. 25 (July 2, 1910) p. 19; NCPC-C, Valuation Survey Field Book 7 (H-7) p. 1; "NCPC Scrapbook," p. 2.

[78] For the Inskip forebay and penstock see Fowler and Van Norden [note [72] above, and, in particular NCPC-C, Valuation Survey Field Book 8 (H-31) pp. 15-35 passum.

[79] For the powerhouse at Inskip see the items in note [72] above, in particular Valuation Survey Field Book 7 (H-7) pp. 1-9.

[80] The Inskip generating units are briefly described by Fowler, Hydroelectric Systems of California, p. 239, and Van Norden, "Northern California Power Company," p. 123. See also J.G. White & Co., "Report," pp. 45-46; NCPC-C, Valuation Survey Field Book 17 (H-30) pp. 11-19; and PG&E drawings 63766, 63767, and 63770.

[81] Jollyman, "Practice in High-Head Hydraulic Plants," p. 463; Galloway, "Design of Hydro-Electric Plants," p. 1032.

[82] Galloway, "Design of Hydro-Electric Plants," p. 1030; Alton Adams, Electrical Transmission of Water Power (New York, 1906) p. 105.

[83] Heinrich Homberger, "Efficiency Test, Units No. 1 & 2, Inskip Power House, December 1st and 2nd, 1910," with attached letters dating from 1912 (PG&E, Engineering Central Files #430).

[84] Galloway, "Hydro-Electric Developments on the Pacific Coast," American Society of Civil Engineers, Proceedings, v. 48 (1922) p. 1848, notes the difficulty of governing the multiple rotor, multiple nozzle units. On the abandonment of the design see Galloway, ibid., p. 1848, and Galloway, "Design of Hydro-Electric Plants," pp. 1001, 1030.

[85] Mead, Water Power Engineering, pp. 245-246; Pelton Water Wheel Company, Pelton Water Wheel, pp. 11-12.

[86] Galloway, "Hydro-Electric Plants in California," p. 318.

[87] "Up to about 1905, the reaction turbine was not considered as suitable for heads above 300 feet": Mead, Water Power Engineering, p. 245; "Successful Francis turbines for operating heads exceeding 400 feet were an unknown quantity prior to 1906": Arnold Pfau, "High-Head Francis Turbines and Their Operating Records," JE, v. 40 (1918) p. 158.

[88] Fowler, Hydroelectric Systems of California, pp. 116, 217.

[89] Comment by H. Homberger in Galloway, "Design of Hydro-Electric Plants," p. 1046.

[90] Fowler, Hydroelectric Systems of California ,p. 240; Van Norden, "Northern California Power Company," pp. 123-124; NCPC-C, Valuation Survey Field Book 17 (H-30) pp. 24-39.

[91] J.G. White & Co., "Report," pp. 15-20; Van Norden, "Northern California Power Company," pp. 108, 127-128.

[92] CRRC, Transcripts [of Hearings], application no. 62, v. 1 (June 24, 1912) p. 164; J.G. White & Co., "Report," p. 21.

[93] J.G. White & Co., "Report," p. 21.

CHAPTER VI

COLEMAN:

Completion of the Battle Creek Hydroelectric System (1910-1912)

With the completion of Inskip, Noble and his associates were faced with the choice of continuing their expansion program by developing the abandoned "Horseshoe Bend" site on lower Battle Creek or awaiting further developments. A number of factors encouraged the Northern California management in 1910 to continue the expansion policy they had initiated st Volta in 1908 and continued with the construction of South and Inskip in 1909 and 1910.

One encouraging factor was the continued growth of the copper industry. Copper production skyrocketed between 1907 and 1909, rising from almost 28,000,000 pounds to almost 60,000,000 pounds. [1] Northern California's revenues from her copper customers reflected this growth, increasing from $134,100 in 1908 to $167,700 in 1909. [2] The Mammoth Copper Company in 1909 was using an average of 2000 hp [c. 1500 kW] continuously. The same company had 4560 hp (c. 3400 kW) of motors connected to the Northern California system and was considering the installation of an sdditional 1000 hp (c. 750 kW). [3]

Another encouraging factor was the "very friendly" relations between the Northern California Power Company and Pacific Gas and Electric Company. The sale of power from the NCPC grid to the PG&E grid initiated in 1906 had worked out so well for both companies that in December of 1908 they signed a new twenty-five year contract. This contract committed Northern California to deliver a minimum of 5000 hp (c. 3750 kW) continuously to the PG&E grid at Chico and permitted Northern California, at its own discretion (but at a lower price), to deliver up to 5000 additional horsepower. [4] Revenues from PG&E sales had risen from $39,100 in 1908 to $60,600 in 1909, and had the potential of going higher. [5]

Further encouragement for expansion came from Noble's experimental iron smelter at Heroult. Noble's furnace, erected in 1907 and powered by three phase current, had produced a small amount of pig iron, but later proved unable to operate successfully when beefed up to commercial scale. The major problems with the unit were clogging of the shafts or chutes which fed raw materials into the furnace and the rapid oxidation of electrodes. Thus Noble's early proclamations of commercial success proved premature. Noble, however, persisted. In 1908 Dorsey Lyon of Stanford designed for Noble a single phase experimental electric furnace which used 160 kW and had a different configuration than the earlier furnaces. It produced 1 ton of pig iron per day. In 1909 this experimental furnace was enlarged to consume 1500 kW of power. Despite some difficulties in securing sufficient electric power to keep this furnace operative through the summer of 1909, it smelted enough iron to convince Noble, once again, that the process was on the verge of commercial success. Plans were made in late 1909 to expand production facilities at Heroult-on-the-Pit. [6] In early 1910 the old smelter was shut down and construction began on four new furnaces with a potential power consumption of at least 10,000 hp (c. 7500 kW). [7] Noble informed stockholders of the Northern California Power Company of the planned plant expansion at Heroult in November 1909. He noted that his steel company would soon begin consuming "a great deal of power", perhaps as much as 10,000 hp (c. 7500 kW), [8] more than the entire output of Volta, then the largest of the Northern California hydroelectric plants.

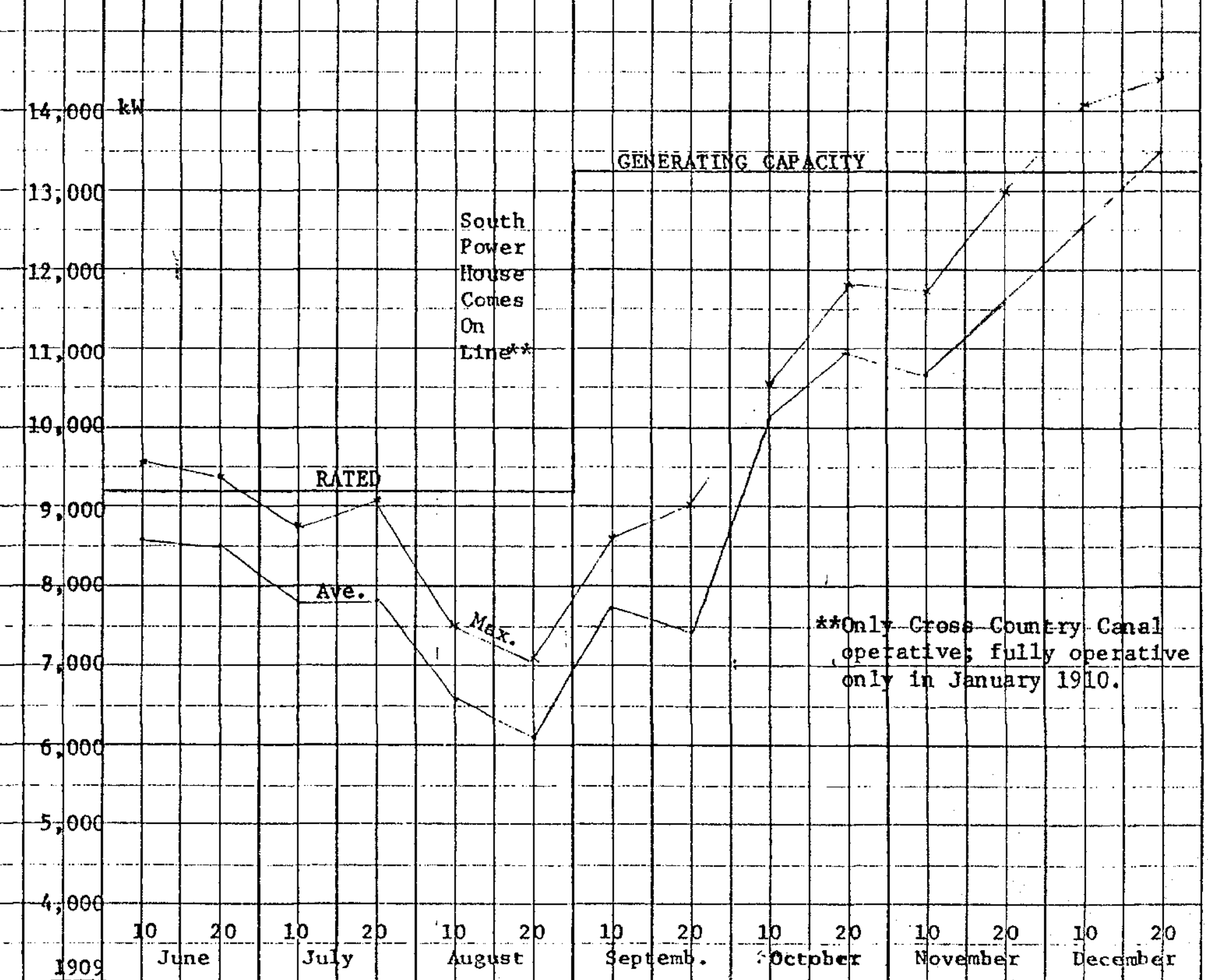
If an additional incentive were needed for expansion, it was provided by the summer of 1909. For the first time in its history, the demand for power in Northern California's territory was greater than the utility's ability to supply it. The heavy seasonal demands of irrigation customers and the growing demand for power from copper mines and smelters had forced the company to curtail the power available to the experimental smelter at Heroult [9] and to repurchase some power from the PG&E system. Through late 1909 the demand for power exceeded the company's capacity to deliver it. And even when South and Inskip came on line in 1910 the company had little excess generating capacity. Through 1910 and on into 1911 the Consolidated Company's installed generating capacity was around 19,750 kVA. The average demand on the system was around 13,000 to 14,000 kVA. [10] Since 25% was a logical reserve to have on hand to insure uninterrupted service during peak loading conditions, Northern California had little unnecessary capacity.

With Noble planning on expanding his iron smelters at Heroult, with the copper industry thriving, and with peak summer loading overtaxing the existing system, the erection of yet another plant on Battle Creek seemed to be almost a necessity. The decision was apparently finalized in late 1909 or early 1910. Noble, coordinating his activities at Heroult with his activities on Battle Creek, timed the completion of the new iron furnaces to coincide with the opening of the new hydroelectric plant. [11] In November of 1910 Noble informed Northern California stockholders that he had "no hesitancy" in saying that within three months of completion the entire 21,000 hp of the planned new plant would be sold. [12]

Once the decision was made to erect another plant on Battle Creek, there remained the question of where. The obvious location was the "Horseshoe Bend" area of lower Battle Creek, the site of the 1907 confrontation with the Pacific Power Company. Plans had originally called for a tall masonry dam across Battle Creek to develop 150 feet of head, which would be further increased by a ditch system leading water diverted by the dam to a powerhouse 6 miles further downstream on the bend itself where 11,250 kW could be developed. Neglect and spring floods had damaged much of the work which had been done at the dam site, but the company had already put $90,000 into the structure and some of the 1907 masonry work was still viable. Moreover, a 1910 engineering review of the 1907 plans concluded that the dam site itself was "well chosen and satisfactory". [13]

Table 16: Maximum and Average Load on the Northern California Power System, June-December 1909

(J.G. White & Co, "Report," facing page 21)



The same engineering study, however, had urged the Consolidated Company to consider other options, especially since it would require at least an additional $200,000 to repair and complete the 1907 dam. [14] One such option involved abandoning the massive masonry dam and obtaining the 150 feet of head it had provided by extending a canal an appropriate distance upstream. In 1907 this option had not been feasible because the lands and water rights required were not in company hands. [15] But this situation had changed by 1910. In February of 1909 the Northern California Power Company had reached an out-of-court settlement with the Asbury Estate, the largest and most desired property on lower Battle Creek. Under the settlement the utility purchased 1625 acres of Battle Creek property, including all the land needed for a right-of-way for conveying water from Inskip powerhouse. The purchase also permitted the utility to divert additional water from two tributaries of Battle Creek, Darrah and Baldwin Creeks. [16]

After reviewing the options Northern California engineers decided to abandon the Battle Creek dam. The 150 foot head it was to create was secured by extending the intake for the power canal of the new plant all the way upstream to Inskip. The company also decided to move the location of the powerhouse 1 mile downstream from the original "Horseshoe Bend" site, gaining an additional 110 feet of fall. The new locations of the powerhouse and intake, along with additional water rights secured by the company since 1907, permitted NCPC to design the new hydroelectric plant for a generating capacity of 15,000 kVA, instead of the 11,250 kVA (15,000 hp) of the 1907 plans. [17]

The new plant was named "Coleman", after Edward C. Coleman, former proprietor of the Sierra Lumber Company and one of the directors of the Northern California Power Company. [18] Perhaps because Coleman was to have more than twice the capacity of any previous Northern California hydroelectric plant, the company turned to outside consultants to design much of the new plant, instead of relying on its own engineers. J.H. Strutt, the former Pacific Power Company engineer who had assisted H.A. Tedford in the design of the water systems for South and Inskip, was retained to work on the water system for Coleman. But Tedford, who had supervised the construction of both South and Inskip, was given little role in the design or construction of the new plant. He was assigned, instead, to supervising the operation of the existing plants of the Northern California system. The design of the Coleman powerhouse and the selection of its equipment was entrusted to the San Francisco consulting engineer Rudolph W. Van Norden. [19]

Van Norden was a prominent west coast engineer. An 1896 graduate of Stanford, he had joined the Central California Electric Company, a Sacramento based firm, and had risen to the position of chief engineer by the early 1900's. When PG&E acquired the Central Company in 1905, Van Norden became a division superintendent. He remained with PG&E for only a year, moving to San Francisco in 1906 to set up private practice as a consulting engineer. The design of Coleman was a minor benchmark in his long and distinguished career. In the 1930's he served as technical adviser to the U.S. Secretary of the Interior on the construction of Boulder (Hoover) Dam. Altogether in his lifetime Van Norden designed thirty hydroelectric plants and fifty high dams. [20]

COLEMAN: Construction

Construction work began on Coleman in July 1910, just as Inskip went on line. [21] The success of the steam shovels in excavation along the last portion of the Inskip ditch encouraged Northern California to expand its mechanical plant in order to speed up construction of Coleman and reduce labor costs. Thus a second steam traction engine and a second steam shovel were added in the summer of 1910. [22] Two additional steam shovels were added in 1911. Two derricks powered by compressed air, and six electric derricks were used to remove rubble from the ditches after the steam shovels had passed. In addition, Northern California made extensive use of compressed air and electric drills. [23] [see HAER photo 155 for construction work on the Coleman Canal]

The steam shovels used by Northern California in the construction of the Inskip and Coleman ditch systems were not actually powered by steam. Compressed air fed into the steam shovel's boiler system was used instead. Because current used to power the compressors was surplus electricity, the compressed air cost the company "practically nothing". Coal to produce steam, on the other hand, would have had to be imported at considerable expense. [24]

To provide compressed air for the steam shovels, for the compressed air derricks, and for the compressed air drills, Northern California erected four compressor plants along the ditch line from Inskip to Coleman. [25] To provde electric power to these plants as well as to the electric drills and derricks used in excavation a power line was run from Inskip to Coleman early during construction. Although this line was intended to operate at only 6600 volts during construction, it was designed to carry 66,000 volts so that Coleman could immediately be tapped into the Northern California system when it was started up. [26]

Northern California was able to make extensive use of a mechanized plant during Coleman's construction for two reasons. First, there were no long sections on the Inskip-Coleman canal which required labor-intensive flume and tunnel construction. Second, the terrain along the route was gently rolling and relatively accessible. It would have been much more difficult to use steam shovels in the more mountainous terrain further upstream.

Mechanization and the much reduced amount of labor-intensive flume and tunnel work in the ditch system of Coleman permitted Northern California to reduce the number of construction camps and the size of its work force. During the construction of Coleman the company employed a maximum of 730 men in four camps. [27] This force constructed the 10.5 miles of canal leading from Inskip to Coleman. Inskip had required the construction of of around 7 miles of canal of smaller capacity than the Coleman Canal, yet had required 370 more men.

The transportation of supplies for the Coleman plant was simplified because the new plant was readily accessible from Anderson, a small town on the Southern Pacific Railroad only 12.5 miles away. This town became as lively as Manton during the construction of South and Inskip. The Redding paper reported that the Coleman labor force had added greatly to Anderson's commerce, filling up not only the merchants' and barkeepers' cash registers, but also the town's jails. [28]

In spite of the use of a mechanized plant to reduce construction costs and the reduced transportation costs afforded by proximity to Anderson, the construction of Coleman weighed heavily on the Consolidated Company's financial resources. The proceeds form the 1908 reorganization and several subsequent bond issues had been exhausted by the costs of South and Inskip. In order to pay mounting construction costs, Northern California ceased paying dividends on March 31, 1911 (it had paid record dividends amounting to $110,000 in 1909 and $210,000 in 1910). The company shortly afterwards began to divert funds from its sinking fund and took out a number of short term loans. [29] These actions enabled Northern California to complete the powerhouse at Coleman in June 1911 [30] and to complete the water network for the plant in November [31]. The first water reached the new plant on November 19, 1911, and, after tests of the system, Coleman went on line on November 24. Northern California in July 1912, in order to pay the short-term loans taken out to complete Coleman, floated a five year bond issue for $500,000. [32]

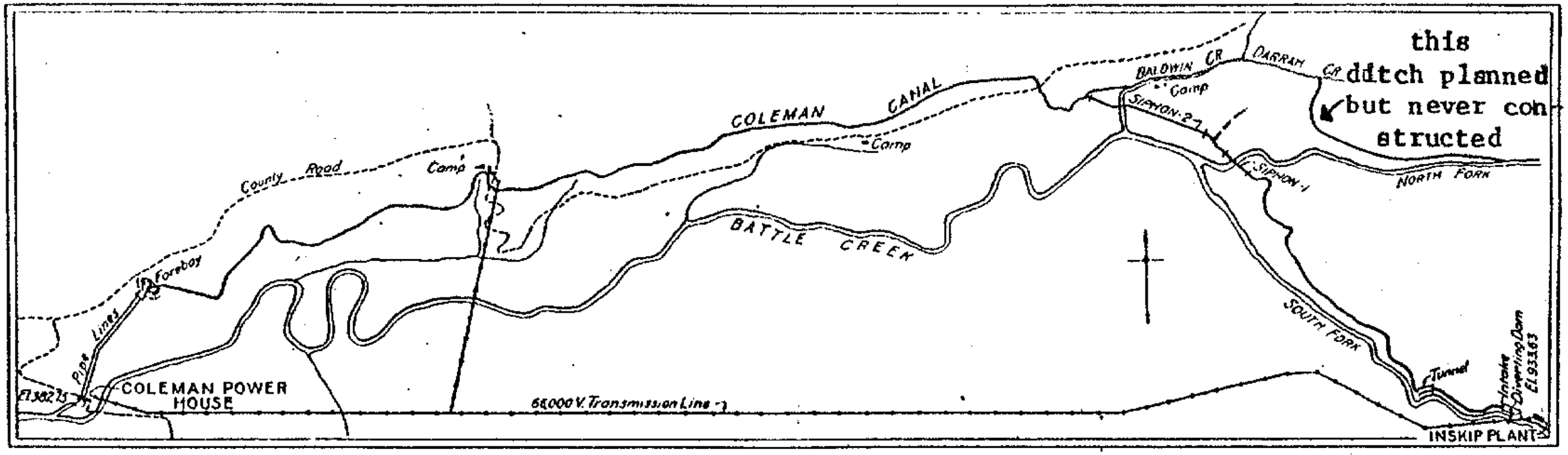
COLEMAN: Layout and Design [33] [see HAER drawings, sheets 18-20 of 20]

The ditch network which provided water to the Coleman hydroelectric plant was similar in design and construction to the systems of the other plants on the Battle Creek system. It was, however, less complex. A single main canal carried water, diverted just below the Inskip powerhouse, over 10 miles to the plateau overlooking Coleman.

The diversion dam at Inskip was larger than most of the Northern California diversion dams. Erected of rubble masonry 1/8 mile below Inskip, it was 15 feet high by 110 feet long. [see HAER photos 141, 148] Although the dam was well built, it was discovered after completion that its foundations had not been carried to bedrock as supposed. The result was some minor seepage underneath. Also, wooden flashboards were originally used in the center of the structure to hold back the water. Criticism of this design by an engineering consultant in 1911 led to the replacement of the flashboards by solid masonry construction. [34]

Because there were no conflicting water rights on the south fork of Battle Creek below the diversion dam, practically all of the available water was diverted by the dam into the Coleman Canal by a masonry retaining wall on the north side of the dam. As this wall turned into the banks of Battle Creek the flow was passed through a set of sluice gates and passed by a set of waste gates.

The Coleman Canal roughly paralleled the north side of the south fork of Battle Creek for 2 miles beyond the Inskip diversion dam. This section was largely ditch. [see HAER photos 143, 147 for views of the Coleman Canal] But it included the only tunnel of the entire Coleman water system. Located a short distance from the diversion dam, this tunnel was 12 feet wide by 9 feet high and was only 367 feet long.



Electrical World, v. 59 (1912) p. 238.

Table 17.
THE COLEMAN CANAL SYSTEM, c. 1912

Name (route)	length (ft.)	length (mi.)	capacity (second-feet)	approximate dimensions (width x depth)
Coleman Canal (So. Battle Ck.-Coleman forebay)	53328	10.10	275 to 300	11 x 5 (before siphon #1) 16 x 5.5 (after siphon #2)
Pacific Power Canal* (Darrah Ck-Coleman Canal)	840 (3580 ?)	0.16 (0.68 ?)	12.5	
Baldwin Ck. Flume & Asbury Pipe	3221	0.61	75	7 x 4

*indicated on map above by dashed line

The Coleman Canal reached the north fork of Battle Creek just above its junction with the south fork, around 2 miles east of Inskip. To cross the North Battle Creek valley Northern California engineers used an inverted siphon, a construction not found on any of the company's other water systems, although, as we have seen, it was considered for South . The 76-inch diameter riveted steel pipe used for this siphon was fabricated in sections at the Inskip penstock ship. The 1270 foot long siphon was carried across North Battle Creek's valley under a maximum head of 80 feet on rubble masonry piers. A 55 foot long Howe truss carried it across the creek bed itself.

After crossing to the north side of Battle Creek the Coleman Canal was obstructed by the valley of Baldwin Creek, a small tributary of Battle Creek. Thus approximately 1000 feet beyond the exit of the first siphon, the Coleman Canal entered a second. This siphon was 3557 feet long and operated under a maximum head of 115 feet. The first portion of this siphon was 1815 feet long and constructed of reinforced concrete pipe. The second section was 1742 feet long and was constructed of riveted steel pipe. The two sections were joined in a 10 foot by 10 foot by 12 foot block of concrete which enclosed an expansion joint. The downstream or steel portion of the second siphon was of more or less conventional construction and was 86 inches in diameter. Steel girders 40 feet long and 24 inches deep carried it across Baldwin Creek [see HAER photo 145]. The upstream or reinforced concrete section was 87 inches in diameter and was rather unconventional.

Two considerations seem to have induced Northern California to experiment with reinforced concrete pipe at siphon #2. It was probably hoped that concrete pipe would have a longer life than steel pipe, since it was not susceptible to rust. The company may also have hoped that concrete pipe would be cheaper, especially since it could be laid on the ground and did not have to be elevated to avoid ground moisture like steel pipe. The concrete pipe was formed on the site. The reinforcement consisted of steel rods laid longitudinally across the top and bottom of the pipe and a cylindrical layer of wire mesh (its weight varying with the head). These were held in place during construction by wooden forms. [35] [see HAER photos 149-150] J.H. Rhodin, an engineering consultant employed by the J.G. White Engineering Company, praised the steel pipe section of the second siphon as "an excellent piece of work". [36] He also considered the concrete pipe to be a rather "remarkable" piece of work. But he felt the concrete construction was "experimental", that the reinforcement was inadequate, and that the design was "very light" and bordering on hazardous. [37]

At the entrance to the second siphon the water in the Coleman Canal was augmented by water from a ditch 3580 feet long which included remnants of the defunct Pacific Power Company's 1907 construction activities. It contributed a small volume of water, largely from springs and from Darrah Creek, a tributary of Baldwin Creek. Additional water was added to the Coleman Canal at the outlet of the siphon by a flume from Baldwin Creek. There were plans to use the Baldwin Creek flume to add some North Battle Creek water to the Coleman Canal here. This water was to be diverted by dam from North Battle Creek into a 2 mile long ditch. This ditch was to carry the North Battle Creek water to Darrah Creek. It would then flow with Darrah Creek water into Baldwin Creek where it would be picked up by the Baldwin Creek flume. But the North Battle Creek - Darrah/Baldwin Creek feeder was apparently never constructed. A canal to divert North Battle Creek water into the Coleman Canal was added to the system only in the 1920's. And this canal, called the Wildcat Canal, was located on the south side of North Battle Creek, rather than the north side, and delivered water to the Coleman Canal before it entered either of the siphons. [38]

After passing through the second siphon the Coleman Canal paralleled the main trunk of Battle Creek for the remaining 8 miles to the Coleman forebay. Due to the addition of water from Darrah and Baldwin Creeks the canal was larger here. Above the first siphon the ditch had been around 11 feet wide by 5.5 feet deep, with a carrying capacity of around 275 second-feet. Below the siphons the ditch was approximately 16 feet wide by 6.5 feet deep and had a capacity of nearly 300 second-feet. From siphon #2 to Coleman there were no tunnels, no flumes, and no siphons, only ditch. And this ditch, as the other ditches in the original Battle Creek system, was unlined save for a few sections where a dry rubble rip rap was used to buttress weak canal walls. [39] It was, on completion, one of the biggest power ditches in the state. [40]

On the plateau overlooking the Coleman powerhouse the Northern California Power Company erected a forebay reservoir similar to those at Volta. The forebay reservoir was more of a necessity at Coleman because, unlike South and Inskip, there was only a single water supply canal. The reserve capacity of a forebay reservoir would allow repairs to the ditch system to be carried out. The forebay reservoir at Coleman was formed by erecting an earth and rock fill dam 2604 feet long, 69 feet wide at base, 11 feet wide at crest, and 20 feet high. This dam flooded 11.7 acres and provided a storage capacity of 72.9 acre-feet, sufficient to operate the power plant for around ten hours. At the lower end a masonry header directed water into the penstock entrances. [see HAER photo 146] The grizzlies for screening the water supply were not placed immediately in front of the penstocks like at the other plants, but in the canal where it entered the forebay. [41]

The Coleman plant had two penstocks over 3700 feet long, with a vertical fall of 482 feet. These penstocks, like those of South and Inskip, were of lap-riveted steel, fabricated from sheet steel in the company's own shops. The pipes were 72 inches in diameter on leaving the forebay and were tapered to 60 inches as they travelled down the slope, and each was equipped with two air valves. At Coleman, as at South and Inskip, the penstocks were not buried but ballasted with boulders and anchored in concrete blocks. However, in order to avoid an abrupt hump in the terrain as they approached the powerhouse, both were led through short tunnels.

There were three generating units at Coleman. It was therefore necessary to convert the two penstock lines into three before they entered the powerhouse. This was done by installing a "saddle" connection on each of the penstock lines. A 60-inch diameter continuation of each of the penstock lines, tapered to 48 inches just above the powerhouse, provided water to two of the units. Two branch lines of 48-inch diameter taken from the "saddles" of the two main lines were combined by a "Y" connection to create a single 48-inch diameter line for the third unit. Just outside the powerhouse four hydraulicly-operated gate valves were installed, one for each of the main pipes and one for each of the branches on the "Y" connection.

The water supply for the two water-driven exciters used in the Coleman plant was taken off of the two converging branches of the "Y" connection by means of saddles and 12-inch diameter pipe. These two pipelines were united by a "T" connection, carried into the powerhouse and divided again by a "Y" connection, the branches of the "Y" leading to the two exciter wheels. Although this made the exciter piping system a little complex, it also gave the system flexibility, since both exciter wheels could be operated off of either penstock. [42]

In designing the powerhouse at Coleman, van Nörden set for himself the task of creating "an installation entirely modern in electrical and mechanical equipment and so arranged as to afford the highest operating efficiency, both from the point of operating costs, low depreciation and high grade service at absolutely the minimum cost of installation". [43]

In keeping with this philosophy he located the powerhouse 300 feet north of Battle Creek and linked it with that stream by an artificial canal. There were two factors behind this decision. The location selected shortened the length of penstock necessary to reach the powerhouse. It also permitted Northern California to create a receiving pond with easily maintained levels for draft tubes. [44]

The powerhouse was a rectangular steel frame structure erected on a solid block of concrete carried to sandstone with large doors on either end for the easy installation and removal of equipment. It was architecturally very different than the other powerhouses on the Battle Creek system. Smooth cement plaster walls around 2 inches thick and reinforced with "hyrib" steel wire mesh replaced the more than 2 foot thick rubble and mortar walls used at Volta, South, and Inskip. Coleman had the usual corrugated iron roof, but it was topped by a 5 foot high monitor running around 5/7 the length of the structure. The monitor not only improved the appearance of the structure, making it less box-like, but insured adequate ventilation during the long hot summers. The Coleman powerhouse was considered by Van Norden to be more architecturally "modern" than the earlier Battle Creek structures, and in the words of a later observer was "an excellent example of modern construction", demonstrating that "architectural grace may be united to high-grade engineering designing at a very small additional expense". [45] Unlike the other powerhouses in the Battle Creek system, built of native stone, Coleman did not blend into the surrounding landscape well. But it was still an attractive structure. [see HAER photos 83-95].

The 116 foot 6 inch long by 59 foot 6 inch wide powerhouse was divided into two sections. The largest section was the generator room, around 35 feet wide, extending the length of the building. This room contained three turbine-generator units placed on a common center line parallel to the main axis of the structure. The two exciter units were located between the second and third main generating units. [see HAER photos 99-115 for views of the Coleman interior] There was a "basement" or tunnel 8 feet high by 12 feet wide which ran the length of the generator room. This permitted easy access for inspection of the Coleman piping system and contained, in addition to the pipes leading from the penstocks to the turbines and exciters, pipes to supply the transformers with oil, pipes to provide the governors with oil, the compressed air piping system, the transformer and bearing cooling water pipe systems, and by-pass valves for draining water from the lowest point of the penstock and filling the draft tubes with water.

The smaller section of the powerhouse was divided into three floors and housed the transformers, high voltage switching gear, and other auxiliary equipment. The first floor contained four transformer bays, two at each end of the powerhouse. Station auxiliary equipment — rheostats to control the current delivered to the generator field coils, the motor driven pumps for the governor system, the air compressor used for pumping transformer oil and driving tools — was located in the center between the transformer bays. The area to the rear of the transformer bays was used for storage and as a work shop.

Ten feet above the first floor of the non-generating portion of the Coleman powerhouse was a second floor. The switchboard was placed at the center of this floor. A 4 foot balcony extending outward from the switchboard over the turbine-generator floor allowed the plant operator to keep both the switchboard and all of the power generation apparatus in view. Behind the switchboard, in the space between the two-story tall transformer bays, were an office, a telephone booth linking Coleman to the other Battle Creek plants, a dressing room, and a lavatory. There was also a fire proof door which led to a long, narrow room which contained the high voltage switching apparatus — seven sets of General Electric Type K10, 66 kV, oil circuit breakers with associated disconnecting switches.

Ten feet above the second floor was a third floor. This floor formed the roof of the transformer bays and was only as wide as those bays. It contained the generator and transformer remote controlled oil circuit breakers (General Electric Type K4) with associated disconnecting switches. [see HAER photo 103] From this floor operators could view both the generator room, two stories below on one side, and the high voltage switching gear, one flight down on the opposite side. [46]

The three generating units at Coleman differed significantly from those used at the other Battle Creek plants. Francis turbines were used instead of impulse wheels. The Coleman units were horizontal-shaft models, with a single, 34-inch diameter runner. Manufactured by the Allis-Chalmers Company, each was rated for 7000 hp at 450 rpm and equipped with a draft tube and pressure relief valve. [47]

The Coleman turbines were regulated by Allis-Chalmers governors of the Escher-Wyss type. These controlled the speed of the turbines by opening or closing the wicket gates which entirely surrounded the circumference of the turbine runners. The Escher-Wyss governors operated with oil pressure provided by motor driven pumps, instead of by water pressure as the Lombard governors used at the other Battle Creek stations. If turbine speed went beyond a certain point a collar on the governor would open a valve, allowing oil under 250 psi pressure to act on a mechanism which would begin closing the wicket gate to reduce turbine speed. The closed oil pressure system had several advantages over the water-activated systems used in the earlier NCPC plants. One of the principal advantages was freedom from clogging by debris. The motor-activated system also permitted the use of higher operating pressures. This was necessary at Coleman because the force required to open and shut the large wicket gates was much greater than the force required to operate the jet deflectors or needles of an impulse wheel. One of the disadvantages of a motor-operated system was higher cost. Another was that generator speed problems were often mirrored and even made worse by the electric motors activating the governors. But this tended to be a critical problem only on small systems, where problems with one unit had major effects. The Northern California system was large enough by the time Coleman came into operation to reduce the magnitude of this problem.

The three generators of the Coleman plant were mounted on the same shaft with a Francis turbine. All three were Allis-Chalmers manufactured machines rated at 5000 kVA at 6600 volts and had rotors equipped with centrifugal fan blades for ventilation. The generator rotors were mounted between bearings. Each Francis turbine runner was placed on an extension of the generator shaft which terminated in a thrust bearing on the far side of the turbine casing. Excitation for the field coils of the generators was provided by two exciter sets. Each of these was driven by an overhung 350 hp Allis-Chalmers impulse wheel with needle nozzle, direct connected to a 225 kW Allis-Chalmers dc generator. Small oil pressure governors regulated the speed of these units.

Coleman was both the first and the only hydroelectric plant of the Battle Creek system to use Francis turbines. The primary reason behind the adoption of Francis turbines here may have been the success of the medium head Francis turbines installed at Centerville, not too far to the south, in 1907. The decision may also have been influenced by the adoption of Francis turbines by other plants between 1908 and 1910, some of which were operating under conditions very similar to those found at the Coleman site. [48]

The decisive factor behind the decision to use the Francis turbine at Coleman, however, was probably the engineer who designed the plant -- Rudolph W. Van Norden. Quite early in his career Van Norden had become an advocate of the use of turbines instead of impulse wheels under medium head conditions. In a discussion of a paper before the Electrical Transmission Association in 1904 he had urged consideration of turbines, noting, in addition to smaller space requirements, that with turbines it was possible to theoretically determine operating characteristics prior to installation and testing. With impulse wheels, he argued, it was impossible. The different sizes and operating peculiarities of nozzles, buckets, and rotors made it impossible to calculate or determine operating characteristics without on-site experiment. [49]

The electrical system installed at Coleman was somewhat more complex than the systems of the earlier Northern California stations and differed in a number of particulars. For instance, although the Coleman transformers were oil insulated and water cooled like those at South, Inskip, and Volta, they were three phase rather than single phase. Van Norden's selection of three phase transformers in place of banks of single phase transformers was contrary not only to prior Battle Creek practice, but to California practice generally. [50] Banks of three single phase transformers had long been preferred because problems with one transformer would not completely cripple the output of a generator. The load could be shifted to the other two units in the bank. [51] But three phase transformers did have some advantages over single phase banks. A three phase transformer occupied less space than a bank of three single phase transformers. It was also cheaper by a modest amount. Finally, by equipping a plant with a reserve three phase transformer (as Van Norden did at Coleman) the major disadvantage of the three phase system could be reduced, if not eliminated.

The leads from the generators at Coleman were carried in 3-inch fiber ducts through the generator floor to the low voltage switching apparatus on the third floor. After passing through a set of remote control oil circuit breakers, an equalizing bus, and another set of oil and disconnecting switches the current was delivered to the transformers. The high voltage current from the transformer secondaries was led through the back walls of the transformer bays to the high voltage switch gallery on the second floor. Here the current was passed through a high voltage oil switch and two disconnecting switches. From these switches the current was led to another set of equalizing buses . The outgoing transmission lines were tapped off of these busses, led out through another pair of disconnecting switches and a high voltage oil switch, then through 18-inch diameter wall bushings to an adjacent switchyard. From the switchyard lines eventually led to Cottonwood, Hamilton City, and Inskip. See the table on the following page for a simlified diagram of the Coleman electrical system and a comparison with Volta (1901) and Inskip.

Every effort was made to insure that the more complex electrical system at Coleman did not confuse the station's operators. The transformer circuit breakers and disconnecting switches were placed directly above their respective transformers. The transmission line circuit breakers were placed directly below the relevant lines. All disconnecting switches were placed above their oil switches and provided with horizontal rather than vertical swing to prevent accidental disconnection. [52]

When Coleman went on line in November of 1911 it was one of the larger hydroelectric stations in California with its 15,000 kVA installed generator capacity. It raised the potential output of the Northern California system from 19,250 to 34,250 kVA.

INCREASING STORAGE CAPACITY

The Northern California expansion program between 1908 and 1912 included not only the construccion of three powerhouses on Battle Creek, but also a significant increase in the system's storage capacity to maintain output during summer and fall months when natural stream flow declined.

Table 18.
Simplified Diagram of the Electrical Systems at Volta (1901), Inskip (1910) and Coleman (1911)

G: generator

T_b: bank of three single phase transformers

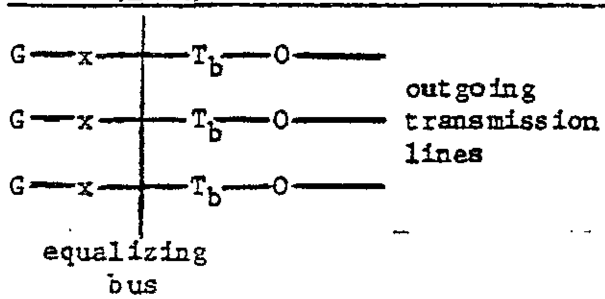
T: three phase transformer

x: knife switch or disconnecting switch

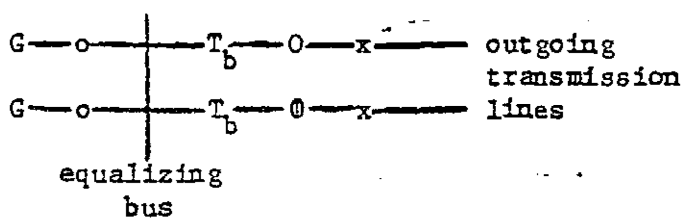
o: low voltage oil circuit breaker

O: high voltage oil circuit breaker

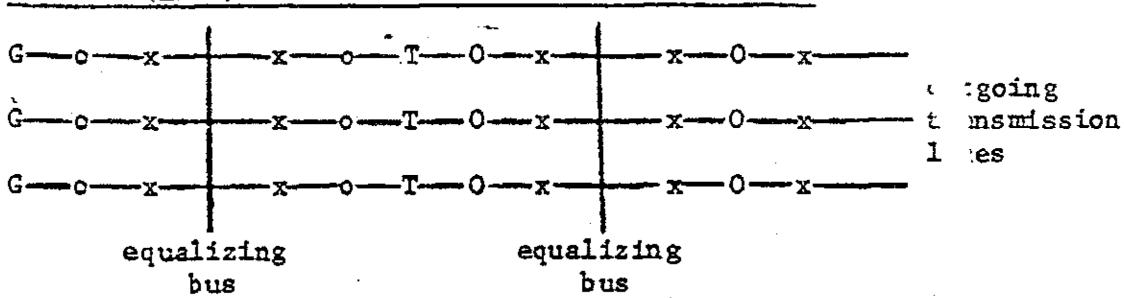
VOLTA (1901):



INSKIP (1910):



COLEMAN (1911):



Extensive reservoir building, as already noted, could be postponed on Battle Creek because its flow was relatively stable. But it still fluxuated, and a study of the Northern California system by the J.G. White Company in January 1910 had recommended that "every effort" be made to increase storage facilities. [53]

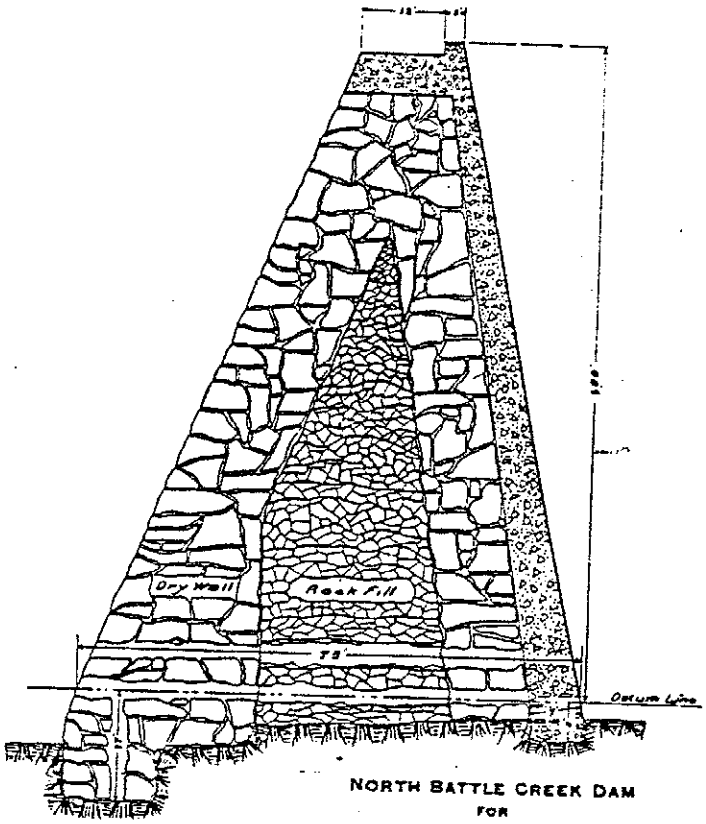
The first major storage reservoir on the Battle Creek basin, Macumber, had been constructed in 1906 and 1907. To further increase storage capabilities two additional major reservoirs were constructed: one at Manzanita Lake in 1909 and 1910; the other on North Battle Creek between 1909 and 1912.

Manzanita was a natural lake located around 9 miles due east of the Macumber Reservoir on Manzanita Creek, a tributary of Deer Creek. In 1906 Northern California had purchased 280 acres of land, including the lake and associated water rights from A.W. Smith to avoid litigation over his plans to convey water from Manzanita out of the Battle Creek watershed to the Snow Creek hydroelectric plant. The company also purchased water rights on Manzanita Creek below the lake's outlet from the Keeran Brothers, who had been using the flow to power a sawmill. [54]

In 1910 Northern California crews erected two dams on the lake. An earth dam 10 feet high at the center, 8 feet wide at the crest, and 500 feet long blocked the outlet of the lake and raised its water level by 5 feet. A second and much smaller dam or dike, only 5.5 feet high, was erected to contain the additional water within the lake. [55] In 1912 the main dam was sheeted with timber on the water face. [56] Water was tapped from the lake about 20 feet below the surface by tunnel. [57] These modifications gave Northern California a water storage capacity at Manzanita estimated at between 500 and 900 acre-feet. [58] [see HAER photo 119] The water from Manzanita was carried to Deer Creek and from there to the Upper Mill Creek Canal.

A second major new reservoir, called the North Battle Creek Reservoir, was located 6 miles upstream from Macumber where North Battle Creek passed through the narrow outlet of a gorge. The lands at the site had been purchased by Northern California between 1903 and 1906. [59] Original plans for the reservoir, made by Northern California engineer E.W. Sutcliffe, called for a large combination loose fill, dry rubble, and concrete dam 658 feet long, 75 feet thick at base, and 100 feet high, placed on a foundation of solid bedrock. (See table on following page) This structure would have formed a reservoir covering 600 acres with a storage capacity of almost 15,000 acre-feet. Flow from this reservoir was to be controlled by a conduit shaped like the letter "L". The lower or horizontal portion of the "L" was a conduit extending through the body of the dam. The upper or vertical portion of the "L" was a rectangular timber conduit. The side of the conduit towards the water was to be slotted so that boards could be added or removed as the water level rose or fell or as more or less water was needed downstream. [60]

Construction began on the dam in 1909 [see HAER photo 153] and had reached a height of 30 feet by early 1911 when the basic design of the structure was condemned by Carl Rhodin of the J.G. White Company, who had been called in to review construction plans on several company projects.



NORTH BATTLE CREEK DAM
FOR
NORTHERN CALIFORNIA POWER CO.
DESIGNED BY E. W. SUTCLIFFE.
1909

(JE, v. 25 [1910] p. 112)

Table 19. Dam Designed by Sutcliffe for the North Battle Creek Reservoir

Rhodin felt that the dam, if constructed as designed, would be "light and unstable", despite the excellent material and workmanship that had gone into the early stages of its construction, and was "almost sure to fail". He also feared that insufficient steps had been taken to insure that the dam's foundations rested on bedrock. Rhodin not only objected to the basic configuration of the dam and possible foundation deficiencies, he also objected to the "L" shaped outlet control. He considered it to be of "unique and dangerous design" and "about as insecure and dangerous as can be built". Arguing that the design adopted by the company had "many obnoxious features", Rhodin filed a "vigorous protest". [61]

Because the summer of 1910 had been rather dry, Northern California was "anxious" to lose no time in finishing the structure. [62] Rhodin was thus asked to suggest modifications to the existing structure which would make it workable. Rhodin suggested the use of more conventional pipes and gate valves to release water from the reservoir in place of the "L" conduit and the construction of additional overflow facilities. For the dam itself Rhodin suggested that a trench 5 feet deep be dug in front of the structure's existing foundation. This would insure that the dam was linked to bedrock. Using this trench as a base the dam would have its water face reinforced with a wall or layer of reinforced cyclopean concrete. To provide better resistance against horizontal pressures, Rhodin recommended, in addition, extensive back filling on the downstream side of the dam. [63]

Rhodin's modifications would have enabled Northern California to raise the structure to the planned 100 feet, but at heavy additional expense. As we have noted, the utility had begun to run into financial problems in 1911, so the funds to make these modifications were not available. Thus the existing structure was slightly modified, following some of Rhodin's suggestions, and raised only to around 45 feet. Rhodin reviewed the modified structure in December 1911 and concluded that it would probably be stable, but added that "it is not certain". [64]

When construction stopped and the North Battle Creek Dam and Reservoir were placed in operation in 1912, Sutcliffe's grand design had been stunted. The dam was only 46 feet high, although wooden flashboards were used at the crest to increase its height to 56 feet. Sutcliffe had designed the dam to be 100 feet high. It was only 465 feet long, instead of 658 feet. Moreover, the reservoir covered only 105 acres and had a storage capacity of only 1800 acre-feet. The reservoir which the Consolideted Company had origianlly considered was to have had a surface area of almost 600 acres and a storage capacity of almost 15,000 acre-feet. [65]

In addition to Manzanita and North Battle Creek, a smaller reservoir was erected in 1910 and 1911 a short distance above lakes Grace and Nora. This reservoir, called the Baldwin Reservoir, was formed by an earth fill dam 1176 feet long, 25 feet high, 7 feet wide at crest and 84 feet wide at base. Feed with water by ditches from Millseat and Eagle Creeks, the reservoir flooded 23 acres and stored almost 175 acre-feet of water. Connected to both Lake Grace and Lake Nora, Baldwin served as an equalizing reservoir. [66]

Although most of the Consolidated Company's resources were concentrated between 1908 and 1912 on improving the Battle Creek hydroelectric system, some thought was also given to increasing the generating capacity of the Kilarc plant on Old Cow Creek and to erecting a second plant on that stream. These plans involved using the water from Dry Burney Creek, a tributary of the Pit River. Northern California engineers planned to erect an earth fill and concrete core dam 900 feet long by 35 feet high at the narrow outlet of the Tamarack Valley though which Burney Creek flowed. This would create a storage reservoir of 1540 acres, 2 miles long, 1.5 miles wide, capable of holding 29,500 acre-feet. A 7000 foot long tunnel driven through a low lying natural ridge at the southwest corner of the proposed reservoir would divert the water from the Pit River watershed into Cow Creek above Kilarc. The additional water from Burney would have permitted NCPC to increase Kilarc's generating capacity from 3000 to 6000 kVA and would have enabled the utility to erect a second plant with 2000 kVA capacity further downstream. [67]

NCPC began construction work on the Tamarack Valley reservoir in 1910. But construction was suspended in mid-1910 to concentrate the company's resources on the completion of Inskip and on Coleman and to reduce expenses by obviating the need for duplicate construction equipment. [68] As the Coleman Canal neared completion in the spring of 1911 some construction activity in the Tamarack Valley was resumed. [69] But the company's monetary problems forced a suspension of work at the site in late 1911 or early 1912.

Along with its water storage facilities, Northern California expanded and improved its transmission and distribution systems between 1908 and 1912. In 1908 and 1909 60 kV lines replaced the original 20 to 22 kV lines linking Volta through Palo Cedro to Kennett.[70] In 1911 60 kV lines were extended south from Hamilton and Willows to College City in Colusa County via Maxwell, Williams, and Arbuckle. And in 1912 Northern California began delivering power to Butte City on the eastern side of the Sacramento. [71] The company's transmission network which had been only around 250 miles long in 1905, had almost doubled by 1912. The capacity of many of these lines had been increased. In 1905 all of Northern California's lines were 22 kV. By 1912 around 43% were 60 or 66 kV. [72] The system had forty-six substations, and Northern California had begun in 1908 and 1909 to install meters to replace flat rate charges on lighting. [73]

The flurry of construction activity which ended in 1912 following the completion of Coleman and the stoppage of work at the North Battle Creek reservoir substantially completed the Battle Creek hydroelectric system. By this point the system included more than fifteen storage and diversion dams, seven reservoirs, and more than 60 miles of artificial water courses. Water collected from the Battle Creek watershed and stored at Lake Manzanita, Macumber, or the North Battle Creek Reservoir was passed successively through the powerhouses at Volta, South, Inskip, and Coleman. Altogether between Lake Grace, overlooking Volta, and the tailrace at the Coleman plant there was a vertical drop of slightly over 3000 feet. The system of dams, ditches, penstocks, and powerhouses developed by the Northern California Power Company utilized around 87% of this fall or 2630 feet. It was a superb system.

As Noble triumphantly proclaimed in 1912: "At Coleman we use the water for the last time. We have taken from it all but its wetness". [74] There was not room for another plant on Battle Creek. Above Volta the flow in the available streams was too scanty and the terrain too rough to make an additional powerhouse economically attractive. Below Coleman there was insufficient fall for hydroelectric development. In between there was only the Northern California Power Company's Battle Creek hydroelectric system.

Table 20. Installation Record, Northern California Power Company, 1900-1919

Date**	Plant	Installed Capacity in kVA	System Total in KVA
November 1901	VOLTA	1500	1500
May 1902	VOLTA	750	2250
July 1904	KILARC*	3000	5250
April 1907	VOLTA	2000	7250
December 1908	VOLTA	2000	9250
January 1910	SOUTH	4000	13250
July 1910	INSKIP	6000	19250
November 1911	COLEMAN	15000	34250
February 1912	SO. COW CREEK* (purchased)	1500	
	SNOW CREEK* (purchased)	1200	36950
May 1912	SNOW CREEK* (abandoned)	-1200	35750

*not a plant in the Battle Creek hydroelectric system

**date plant went on line; not date the generator(s) was installed

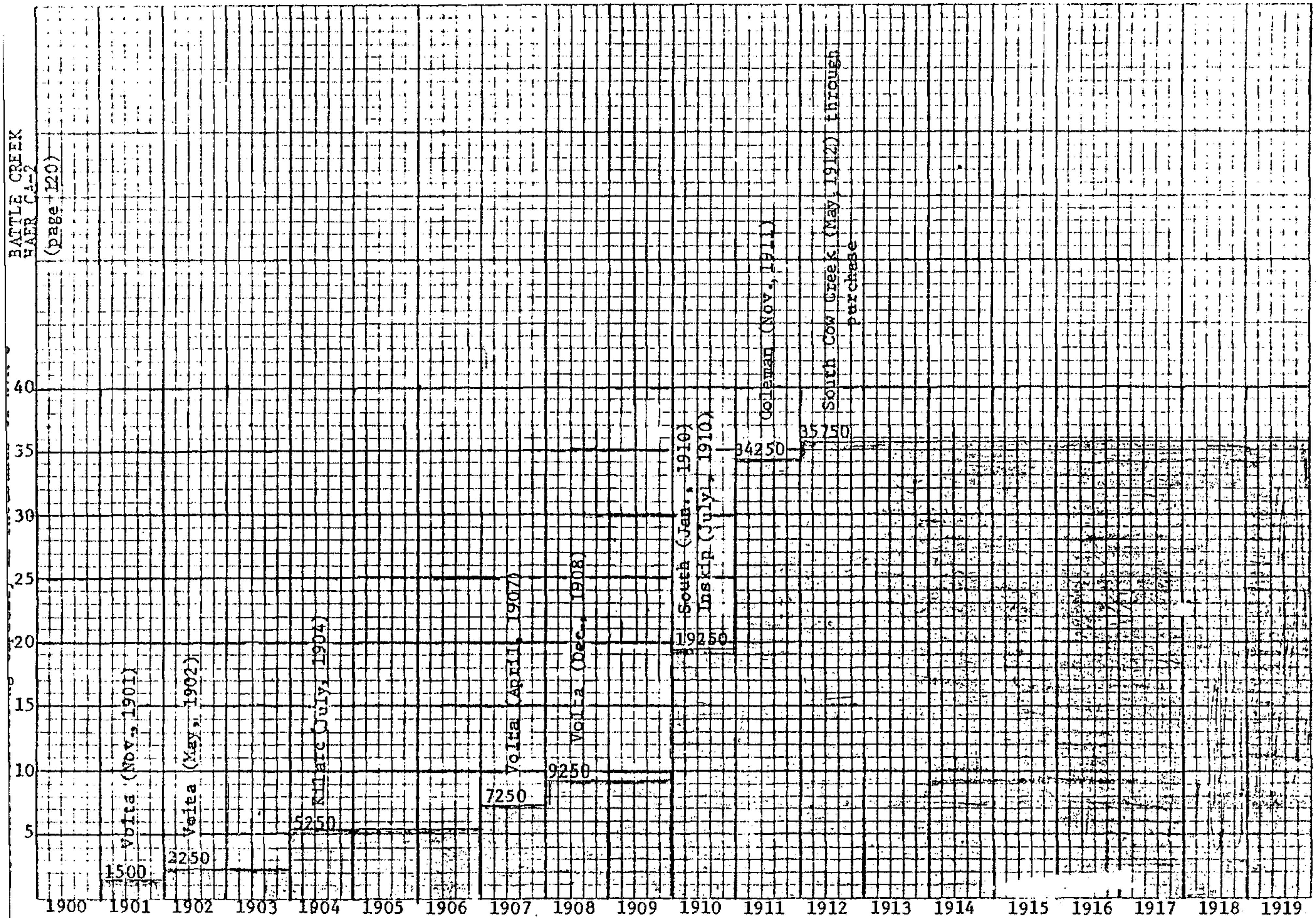


Table 21: Growth of Generating Capacity of the Northern California Power Company, 1900-1919

NOTES

[1] CSMB, 14th Report (1913-1914) pp. 750-751.

[2] NCPC, 6th Annual Report (1907-1908); NCPC-C, 1st Annual Report (1908-1909); J.G. White & Co., "Report," p. 74.

[3] J.G. White & Co., "Report," pp. ii, 3, 75.

[4] Ibid., pp. vi, 3, 76.

[5] Ibid., p. 74.

[6] Van Norden, "Electric Iron Smelter at Heroult on the Pitt," JE, v. 29 (1912) pp. 453-454; Stansfield, Electric Furnace, pp. 117-118; Redding Courier Free Press, March 26, June 4, and December 22, 1909; Redding Semi-Weekly Searchlight, March 6, 1908.

[7] NCPC-C, 2nd Annual Report (1909-1910).

[8] NCPC-C, 1st Annual Report (1908-1909); 2nd Annual Report (1909-1910).

[9] Redding Courier Free Press, July 25, December 10, and December 27, 1910.

[10] J.G. White & Co., "Report," chart facing p. 21; Fowler, Hydroelectric Systems of California, Plate XX (between pp. 142-143).

[11] Redding Courier Free Press, February 11, April 17, and September 5, 1911; NCPC-C, 2nd Annual Report (1909-1910).

[12] NCPC-C, 2nd Annual Report (1909-1910).

[13] J.G. White & Co., "Report," pp. 47, 50, 96.

[14] Ibid., pp. 50-51.

[15] Ibid., p. 48.

[16] Redding Courier Free Press, February 16, 1909; Redding Searchlight, February 14, 1909; Red Bluff Weekly Peopes' Cause, February 20, 1909; NCPC-C, 1st Annual Report (1908-1909).

[17] NCPC-C, 2nd Annual Report (1909-1910).

[18] Redding Courier Free Press, May 25, 1910.

[19] Red Bluff Daily Peoples' Cause, July 2, 1910.

[20] San Francisco Examiner, March 11, 1954 (obituary); Sacramento Bee, March 10, 1954; C.W. Taylor, Jr., Eminent Californians (Palo Alto, California, 1953) p. 309.

[21] Red Bluff Daily Peoples' Cause, July 2, 1910.

[22] Red Bluff Daily Peoples' Cause, June 14 and July 26, 1910; Red Bluff Daily News, July 27 and August 11, 1910; JE, v. 24 (June 11, 1910) p. 553.

[23] The mechanical plant used for constructing Coleman is described in Van Norden, "The Coleman Plant," JE, v. 27 (1911) pp. 414-415; see also Redding Courier Free Press, June 6, 1911. In addition to increasing the mechanical power plant to reduce construction costs, there were also some wage cuts. The Red Bluff Weekly Peoples' Cause reported on July 2, 1910, that the wages of the Burleigh drillmen were to be reduced 25%.

[24] Van Norden, "The Coleman Plant," pp. 414-415.

[25] Van Norden, "The Coleman Plant," pp. 414-415; NCPC-C, Valuation Survey Field Books 15 (H-34) p. 18, and 25 (H-25) pp. 6-7.

[26] Van Norden, "The Coleman Plant," p. 415.

[27] Redding Courier Free Press, May 16 and September 2, 1911.

[28] Redding Courier Free Press, May 16 and May 24, 1911.

[29] CRRC, Decisions, v. 11 (1916) p. 60; Transcripts [of Hearing], application no. 156 (July 24, 1912), pp. 5, 9-11. (CSA)

[30] JE, v. 26 (June 10, 1911) p. 516.

[31] San Francisco Call, November 20, 1911; Redding Courier Free Press, November 20, 1911.

[32] CRRC, Decisions, v. 1 (January 1, 1911 to December 31, 1912) pp. 407-412, and Transcripts [of Hearings], cases 675,676,677, and 711, v. 3 (1916) p. 129.

[33] Data on the Coleman plant can be found in the following materials: Van Norden, "The Coleman Plant," JE, v. 27 (1911) pp. 411-422; "The Coleman Hydroelectric Development on Battle Creek, California," Engineering Record, v. 64 (1911) pp. 700-702; Van Norden, "New Hydroelectric Plant of Northern California Power Co.," Electrical World, v. 59 (1912) pp. 237-241; Fowler, Hydroelectric Systems of California, pp. 240-246; and NCPC-C, Valuation Survey Field Books, especially Field Book 9 (H-9), 13 (H-33), and H-14.

[34] Rhodin to J.G. White & Co., July 6, 1911 (Rhodin Papers).

[35] The siphons are described by Van Norden, "Coleman Plant," p. 413; see also Fowler, Hydroelectric Systems of California, pp. 242-243 and NCPC-C, Valuation Survey Field Books 1 (H-20), 2 (H-21), and 3 (H-19).

[36] Rhodin to J.G. White & Co., August 22, 1911; Rhodin to A.S. Crane, December 6, 1911 (Rhodin Papers). Rhodin had earlier noted that siphon #1 was of a "fair class of manufacture", that the mortar work was "good", but that the associated structures showed "lack of appreciation of important principles" (Rhodin to J.G. White & Co., July 6, 1911). Some of the faults were later corrected (see the December 6, 1911, letter).

[37] Rhodin to J.G. White & Co., August 22, 1911, and December 6, 1911. (Rhodin Papers)

[38] The North Battle Creek feeder is mentioned in Van Norden, "Coleman Plant," p. 414, and "New Hydroelectric Plant," p. 238; also in "Coleman Hydroelectric Development," p. 701. But it is not mentioned in Fowler, Hydroelectric Systems of California, p. 241, nor does it appear in PG&E drawing 63579 (a 1921 map of the canals of the Battle Creek hydroelectric system) or the Valuation Survey Field Books.

[39] Van Norden, "Coleman Plant," pp. 413-414; NCPC-C, Valuation Survey Field Book 1 (H-20).

[40] Redding Courier Free Press, November 20, 1911; San Francisco Call, November 20, 1911.

[41] Data on the Coleman forebay reservoir was drawn from: Fowler, Hydroelectric Systems of California, p. 243; FPC-1924, "Exhibit L"; and NCPC-C, Valuation Survey Field Book 13 (H-33) pp. 70-73; also Van Norden, "Coleman Plant," p. 415, and "Coleman Hydroelectric Development," p. 701.

[42] For the Coleman penstocks see the items cited in note [33] above, and especially NCPC-C, Valuation Survey Field Book H-14, pp. 1-13, in addition to Fowler and Van Norden.

[43] Van Norden, "Coleman Plant," p. 412.

[44] Ibid., p. 415.

[45] Van Norden, "Northern California Power Company," p. 124; Fowler, Hydroelectric Systems of California, pp. 240-241.

[46] For a description of the layout of the Coleman powerhouse I have relied on: personal inspection; NCPC-C, Valuation Survey Field Book 9 (H-9) esp. pp. 2-11; Van Norden, "The Coleman Plant," pp. 415-418; Fowler, Hydroelectric Systems of California, pp. 244-245; and PG&E drawings 39483, 63635, 63637, and 64088.

[47] The Coleman turbines are briefly described by Van Norden, "Coleman Plant," p. 418; Fowler, Hydroelectric Systems of California, p. 245; and NCPC-C, Valuation Survey Field Book H-14, pp. 15-16. See also PG&E drawing 64642.

[48] For example, the Snow Mountain Water & Power Company was persuaded in 1908 to install a Francis turbine for their third unit. This unit, which went into operation in 1910, operated under a head of 464 feet, not much below Coleman's. See Pfau, "Francis Turbines," p. 159; Fowler, Hydroelectric Systems of California, pp. 425-426.

[49] See the discussion on the paper by E.G. De Wald, "High Pressure Water Wheels, With Particular Reference to the Girard and Francis Turbines," Pacific Coast Electrical Transmission Association, Transactions, v. 8 (1904) pp. 64-65. See also, later in the same volume, pp. 141-142, where Van Norden notes the high efficiency and the small space requirements of the Francis turbine vis à vis the tangential or impulse wheel.

[50] Fowler, Hydroelectric Systems of California, pp. 245, 371.

[51] Downing, "High-Tension Network of a Power System," Pacific Gas & Electric Magazine, v. 2 (1910-1911) p. 15.

[52] For Coleman's electrical layout and design see: Fowler, Hydroelectric Systems of California, pp. 245-246; Van Norden, "Coleman Plant,"419-421; Van Norden, "New Hydroelectric Plant," pp. 240-241; and NCPC-C, Valuation Survey Field Book H-14 passum.

[53] J.G. White & Co., "Report," p. 42.

[54] NCPC, 5th Annual Report (1906-1907); Redding Courier Free Press, November 25, 1906.

[55] NCPC-C, 2nd Annual Report (1909-1910).

[56] Fowler, Hydroelectric Systems of California, p. 227.

[57] NCPC-C, Valuation Survey Field Book 16 (H-35) pp. 42-46.

[58] Folwer, Hydroelectric Systems of California, p. 227; NCPC-C, Valuation Survey Field Book , pp. 42-46; FPC-1924, "Exhibit L".

[59] NCPC, 2nd Annual Report (1903-1904); 5th Annual Report (1906-1907).

[60] Rhodin to J.G. White & Co., July 6, 1911, and December 6, 1911. (Rhodin Papers); these letters contain a sketch of Sutcliffe's plans and Rhodin's suggested modifications.

[61] Rhodin to A.S. Crane, July 26, 1911; Rhodin to J.G. White & Co., July 6, 1911, and August 22, 1911. (Rhodin Papers)

[62] Rhodin to A.S. Crane, July 26, 1911 (Rhodin Papers); NCPC-C, 2nd Annual Report (1909-1910).

[63] Rhodin to J.G. White & Co. July 6, 1911, and August 22, 1911. (Rhodin Papers)

[64] Rhodin to J.G. White & Co., December 6, 1911. (Rhodin Papers)

[65] Fowler, Hydroelectric Systems of California, p.227; NCPC-C, 3rd Annual Report (1910-1911); NCPC-C, Valuation Survey Computation Folder no. 47, supporting Valuation Folder no. 5, pp. 1-2, 10; FPC-1924, "Exhibit L".

[66] Fowler, Hydroelectric Systems of California, p. 230; NCPC, 2nd Annual Report (1909-1910);

[67] Van Norden, "Northern California Power Company," p. 110; Redding Courier Free Press, May 25 and July 1, 1910; San Francisco Call, May 11, 1911; Red Bluff Daily News, May 27 and June 15, 1910.

[68] Redding Courier Free Press, July 1, 1910.

[69] Redding Courier Free Press, May 8, 1911; San Francisco Call, May 11, 1911.

[70] NCPC-C, 1st Annual Report (1908-1909).

[71] NCPC-C, 3rd Annual Report (1910-1911).

[72] Van Norden, "New Hydroelectric Plant," p. 237 for 1912 figures. The 1906 Volta-Chico line was the first Northern California Power Company 66 kV line.

[73] NCPC-C, 5th Annual Report (1912-1913).

[74] Redding Courier Free Press, September 2, 1911.

CHAPTER VII

DECLINE:

The Northern California Power Company in Its Lean Years (1912-1919)

With the completion of the Battle Creek system in 1911 and 1912 the future of the Northern California Power Company seemed bright. The powerhouses at South, Volta, Inskip, and Coleman gave the company more generating capacity and a greater flexibility than it had ever had before. The copper industry, on which much of its revenues depended, was thriving. Noble seemed on the verge of a breakthrough with the electric smelting of iron ore at Heroult and had promised to purchase all the power the company could deliver.

So favorable did Northern California's prospects appear that it had become by 1911 an attractive investment for holding companies attempting to build up conglomerates in the utilities field. In early 1911 the H.S. Byllesby Company of Chicago, one of the major holding companies in the utility field, solicited an option to purchase the 100,000 shares of Northern California Power stock at $80 per share. Byllesby had already merged a number of California electric utilities, including the Stockton Gas and Electric Company, San Diego Gas and Electric Company, and the American River Electric Company, into the Western States Gas and Electric Company. Western States was aggressively competing with Pacific Gas & Electric in the bay area, and Byllesby apparently felt that the addition of Northern California's generating capacity to Western States would make it an effective rival of PG&E. [1] The high load factor and favorable prospects for expansion of the Northern California system also made its acquisition attractive.

Rumors of negotiations between Byllesby and the owners of the Northern California Power Company pushed the market price of Northern California stock up from $50 to $66 per share early in 1911. [2] But on May 30, 1911, E.V.D. Johnson, General Manager of the Northern California Power Company, announced the unsuccessful termination of negotiations. [3] Byllesby's abrupt withdrawal of the offer to purchase Northern California stock seems to have been the direct result of a federal court injunction, issued on the previous day, which placed sharp restrictions on the smelting of copper in Shasta County. This injunction and the subsequent withdrawal of the Byllesby offer were but the first in a series of blows which was to cripple the Consolidated Company, transforming what had been a strong, aggressive, expanding company into a utility struggling to maintain a precarious existence.

THE FIRST BLOWS

The Northern California Power Company's decision to expand its generating capscity through the erection of three new hydroelectric plants and several new storage reservoirs had been based on two assumptions -- (1) that Shasta County copper mining and smelting would continue to expand, and (2) that Noble's electric iron smelters at Heroult would be as successful as he had predicted. The first assumption to prove false was the copper industry's continued expansion.

Copper mining and smelting in the decade and a half following 1896 had brought new prosperity to Shasta County. But this prosperity had its shortcomings. It was estimated, for instance, that the Keswick smelter of the Mountain Copper Company alone belched 1200 tons of sulphurous acid gas into the air per day. Nearby Keswick was described as "s community without lawn mowers". "Not a leaf of foliage nor a spear of grass are to be found anywhere thereabouts, and the streets are as dusty as the Hangtown crossroads . . ." [4] Since most of the population of Keswick was dependent on the copper mines and smelters for employment, these conditions raised no protests here. But the sulphur fumes also damaged vegitation in the surrounding regions [see HAER photo 170] and eventually led to a major confrontation between farmers and copper producers.

The first intimations of trouble came in 1900, even before the Keswick Electric Power Company had laid the foundations for its Battle Creek system at Volta. A group of Shasts County fruit growers sued Mountain Copper, alleging that sulphur fumes from its smelter had damaged their orchards and asking for $15,000 in damages and an injunction against further smelting unless sulphur emissions were controlled. [5] These early efforts failed, but the struggle continued. In September 1903 farmers did secure an injunction against Mountain Copper, csusing its average power draw from the Northern California system to drop from 806 to 104 hp between September 1903 and January 1906. [6] A higher court dissolved the injunction in esrly 1906 and both Mountain Copper and other smelters continued expansion.

In 1908 the United States government entered the fracas, claiming that emissions from Mountain Copper's Keswick smelter had destroyed a large tract of federal forest reserve. The U.S. Forest Service secured an injunction prohibiting Mountain Copper from open roasting copper ores. This suit forced Mountain Copper to abandon the open roasting of their ores in Shasta County. The company subsequently dismantled their Keswick smelter and re-established operations at Mprtinez, California, north of San Francisco Bay and away from federal forest lands. Mountain Copper paid the government damages and surrended a tract of company-owned woodland equivalent in size to that decimated by the sulphur fumes. [7]

The outcome of the suit against Mountain Copper initially had no direct effect on any of the other Shasta County smelters. They kept their works in operation through 1908 and the record setting year of 1909 and throughout the opening phases of Northern California's expansion program on Battle Creek. While Mountain Copper's fste may have temporarily discouraged the remaining copper producers from expanding their plants, this was offset by other developments. In 1909 and 1910 farmers and smelter operators, after long negotiations, reached a tentative agreement. The farmers withdrew suits pending against the smelter operators; the smelter operators agreed to install smoke condensing devices at their works. [8] In 1910 most Shasta County smelters briefly closed down to install or experiment with devices to desulphurize emissions, resuming operations at expanded levels afterwards. [9]

These actions defused the dispute between smelters and farmers for a few months. But the failure of most of the experimental desulphurizing systems prompted Shasta County fruit growers to return to the courts in late 1910 and early 1911 to obtain relief. [10] Following the example of Montana farmers who had successfully fought copper smelters, [11] Shasta County growers sought and obtained in May 1911 injunctions which prohibited the further operation of smelters in the county until operators installed effective smoke condensing and desulphurizing systems. [12] It was this series of injunctions which prompted the withdrawal of Byllesby's offer to purchase Northern California Power.

The injunctions against the Shasta County smelters had a deleterious affect on the copper industry. In June 1911, just at the powerhouse at Coleman was completed, Bully Hill and Balaklala, the second and third largest smelters, closed down. Mammoth Copper, which had become the county's largest copper producer after Mountain Copper had abandoned the area, continued smelting since the company had installed a relatively successful smoke condensing "bag house" in 1910. [13] But even its production was reduced and plans for expansion were curtailed. The collapse of smelting operations in Shasta County brought with it a decline in copper mining. Copper output, despite stable copper prices, plummeted almost 50% between 1909 and 1911. In 1909 production was 58,665,447 pounds; in 1911 it was only 29,539,913 pounds. [14]

The sharp reduction in mining and smelting operations naturally had a major effect on Northern California's earnings, since these industries had long been the utility's primary power market. Noble reported in 1912 that largely due to the collapse of the smelting industry in Shasta County the company's income had been reduced by around $15,000 a month. [15] Noble optimistically assured stockholders that within a few months the smelters would solve their pollution problems and resume operation at past levels. These assurances were repeated in subsequent stockholders' reports. But copper production in Shasta County declined steadily and did not begin to rise again until 1915, when demand generated by war conditions in Europe finally pushed it over the 30,000,000 pound mark again. [16] Even then, however, it was far below the record 59,000,000 pounds of 1909.

The collapse of the copper industry left Northern California in trouble. Prior to the closure of the smelters the company had been selling almost all the power it had available from the Volta, South, Inskip, and Kilarc plants. Reduced power consumption left the system with excess generating capacity and Coleman, nearly completed, scheduled to come on line with 15,000 kVA of additional power. It transformed a moderate excess generating capacity problem into a major one. It is thus not surprising that Byllesby withdrew its offer to purchase the Northern California Power Company when the copper industry began to crumble or that the price of Northern California stock began to drop. It had been priced at $66 to $80 in May 1911 during the Byllesby negotiations. By December of 1911 it was being sold at $55 and by September of 1912 had dropped to $37. [17]

Shasta's copper industry had been one of the legs on which the NCPC expansion program had been based. The other leg was Noble's iron smelter at Heroult, expected to consume up to 10,000 kW of power when it began regular commercial production of iron. But like Shasta's copper industry, Heroult proved disappointing. Originally scheduled to begin production when Coleman went on line, the Heroult smelters did not achieve a continuous production lasting as long as two months until the summer of 1912. [18] Even then only around 4500 kW was consumed in two furnaces. But these furnaces did produce 18 tons of pig iron a day. Noble was again convinced that "all difficulties have been satisfactorily overcome", and Van Norden also declared that electrical iron smelters were "an assured fact, a commercially successful machine". [19] Plans were made for four additional furnaces. [20] But new problems continued to emerge. In 1912 and 1913 the charcoal supply system for the smelters failed and Northern California Power was compelled by its financial difficulties to raise power rates at Heroult from around $12 per horsepower per year to $25. [21]

In his annual report to the stockholders of the Northern California Power Company in late 1913 Noble acknowledged difficulties but continued to be optimistic about Heroult. He reported that the substitution of imported coke for charcoal would soon permit renewed operations and that the Noble Electric Steel Company would "very materially add to the profits of our company [the Northern California Power Company]." [22] But Heroult never provided the load Northern California Power had expected of it. Electrical smelting of iron ore, even with cheap hydroelectricity, could not compete with the coke-fired blast furnace. Moreover, at the Heroult site only iron ore was cheap (especially after NCPC was compelled to raise the price of power to make a profit). Everything else was expensive since most materials had to be hauled in by rail. [23] After 1913 Heroult ceased to warrent mention in Northern California annual reports as a significant power customer or a major potential power customer. In 1914 Noble abandoned attempts to produce pig iron. The Noble Electric Steel Company continued marginal operations producing ferro-alloys. After another abortive attempt at smelting pig iron in 1918, smelter operations were terminated in March 1919. [24] By then most of the company's revenues were being generated by mining and shipping iron ore for processing to other California smelters. [25] When the company folded in 1919 it owed Noble $80,000 and the Northern California Power Company $46,882. [26]

The collapse of anticipated markets for power at Heroult and in the Shasta copper belt were major blows to the stability of Northern California Power, especially since the company had borrowed heavily to finish Coleman and was left with considerable excess generating capacity. A bad situation was made even worse when the utility was challenged for the remaining power market, a market scarcely sufficient to support a single power company, by another utility in late 1911 and early 1912.

THE RATE WAR

Northern California Power Company had been intermittently threatened with competition during the first decade of its existence. The most serious crisis, that created by the formation of the Pacific Power Company, had been staved off by rushing construction of the eventually abandoned Battle Creek dam in 1907. But contemporary with this crisis, two other power companies had emerged: Shannon's Shasta Power Company and A.W. Smith's Northern Light and Power Company. Both of these utilities were small. The combined generating capacity of Shasta's plant on Snow Creek (on line June 1907) and Northern's on Cow Creek (on line May 1908) was only 2700 kVA. With limited capital these companies had succeeded in extending their lines only to Redding. They had competed with Northern California for the lighting market there with only limited success.

In an attempt to make the companies competitive and keep them financially solvent, Shasta Power and Northern Light and Power merged in March 1909, forming the Sacramento Valley Power Company, capitalized at $800,000. [27] The new company ran its lines south from Redding to Red Bluff and Chico in an attempt to increase revenues. [28] Even these line extensions were not initially regarded as particularly threatening by Northern California. Sacramento Valley Power was hampered by lawsuits from farmers protesting the company's diversion of Lost and Hat Creek water from the Pit River watershed to the watershed of Snow Creek [29] and inadequate capital. An analysis of the threat posed by Sacramento Valley Power to Northern California Power made in 1910 by the J.G. White Company concluded that "the danger of serious competition in their [NCPC] territory is remote" and added: -

> . . . as long as the company [Sacramento Valley Power] is under present management and until they increase capacity seriously, the competition will not materially effect the revenue of Northern California Power Company. [30]

Sacramento Valley Power could , however, harass Northern California. This it did. In 1908 a group of Shingletown area farmers, including a number of Sacramento Valley Power Company stockholders (A.W. Smith, President; his son; and stockholders E.J. Smith and T.H. Benton) charged that Northern California was diverting through the Keswick ditch water that legally belonged to the Al Smith ditch and five other irrigation ditches further downstream, and E.J. Smith attempted to tear out the Keswick diversion dam. An injunction issued in September prohibited Smith and others from molesting the Keswick dam and prohibited Northern California from diverting more than the 722 inches (18 second-feet) of water that were beyond dispute. [31]

The water rights controversy which ensued was characterized as "practically a dispute between the pioneer power company [NCPC] and Sacramento Valley Power". [32] E.J. Smith was twice arrested for damaging the Keswick diversion dam, while H.A. Tedford, superintendent of the Northern California plants, was charged with stealing water. [33] Charges against both Smith and Tedford were subsequently dismissed. [34] The acrimonious water rights trial which followed lasted twenty weeks and involved over 6000 pages of testimony. [35] Feelings were so strong that at one point opposing attorneys exchanged blows in the court room. [36] The issues were extremely complicated, involving conflicting and overlapping claims of water priority, amounts actually being diverted, and ditch capacity. An additional issue was whether or not the owner of a water right could divert water needed further downstream out of the watershed. [37]

At the end of the hearings in mid-1910 the presiding judge dictated a reallocation of water only mildly detrimental to Northern California. The volume allotted to the Keswick ditch was reduced from the 1855 to 2000 inches (46 to 50 second-feet) claimed by Northern California to 1433 inches (36 second-feet). The diversion rights of the Smith or Battle Creek Ditch Company ditch, claimed to be 2600 inches (60 second-feet) by Smith,were set at 2230 inches (56 second-feet): 1640 inches (41 second-feet) permanently, 690 inches (17 second-feet) subject to sufficient flow. [38] The decision, as a Redding paper commented, was "a victory . . . for neither" [39] and both sides, equally displeased, filed for a retrial [40].

The Sacramento Valley Power Company was able only to snipe at Northern California's dominant position in the upper Sacramento Valley until 1911. But then matters changed. The decline of the mine and smelter market made Northern California more dependent on the residential and commercial light and power load of the area's urban centers. In addition, an infusion of capital made Sacramento Valley more competitive in this area. In late-1910 the Fleishhacker brothers of San Francisco purchased a 50% interest in <u>the</u> Sacramento Valley Power Company and reorganized it as <u>The</u> Sacramento Valley Power Company. [41] The Fleishhackers were experienced in the hydroelectric utility field. They had either built or operated and then sold a number of early California utility companies, including the Truckee River power plant, the American River plant at Folsom, the Stockton steam generating plant , the Central Traction Company, and the San Francisco Electric Lighting Company. [42] To secure capital for their new enterprise the Fleishhackers mortgaged Sacramento Valley Power's assets in exchange for a $2,000,000 line of credit. [43].

With new capital and new management, Sacramento Valley Power's latent threat to Northern California suddenly became a real threat. The first transfusion of cash into the utility —$900,000— provided Sacramento Valley Power with the funds to extend lines north of Redding and invade the copper mining territory around Kennett. Poles were placed and, under cover of night, wires were strung across Northern California's transmission lines. [44]

There was little Northern California could do to stop this invasion. What could be done was done. Where Sacramento Valley power lines crossed Northern California's lines and right-of-way, Johnson, Northern California's General Manager, ordered the lines severed and obtained a restraining order prohibiting the reconnection of the lines. [45] Sacramento Valley Power defiantly reconnected the lines the following night and posted guards with rifles and shotguns to protect the crossings. Sacramento Valley officials also filed for Johnson's arrest for the destruction of property. [46]

Under prodding from the courts the two utilities reluctantly negotiated an arrangement for crossing lines in September of 1911. [47]

Conditions were aggravated, however, when the Sacramento Valley Company in November of 1911 extended its lines from Redding to Chico and then through Orland to Willows, initiating a rate cutting policy in these areas designed to lure customers away from Northern California. [48] Having struggled for years to develop a market for electrical power in these agricultural communities, Northern California responded with rate cuts of its own.

The competition between Northern California Power and Sacramento Power in late 1911 and early 1912 was ruinous. Both companies had considerable excess generating capacity and were competing in a sparsely populated area with scarcely sufficient business to justify the existence of a single power company. Rates were cut drastically by both sides. Customers were permitted to make their own terms and in some cases rates were offered which were well below the actual cost of rendering service. [49] Some power was even distributed free. Northern California supplied Kennett (population 1200) and an undisclosed number of private customers without charge because the revenue did not warrent the employment of meter readers or collectors. [50] The California Railroad Commission in reviewing the rate war later concluded that for "aggressiveness and utter recklessness" it had "probably never been paralleled in the history of the state". [51]

The Sacramento Valley Power Company with its 2700 kVA generating capacity had little real hope of driving the larger, more firmly established, older utility from the field. The company's objective was apparently to use "well directed and ruthless competition" to force Northern California to "choose between financial loss or even financial ruin and the purchase of the property of the newcomer at a price far above its normal value". [52]

The tactic was successful. Noble estimated that the rate war had decreased Northern California's gross earnings around $12,000 per month between October of 1911 and January of 1912. [53] Feeling that continued competition would result in increased revenue losses and already struggling with declining revenues from the copper industry, Northern California negotiated the purchase of Sacramento Valley in February 1912. The purchase price was considered by experts to be "greatly in excess of its real value". [54] The California Railroad Commission argued later that the Sacramento Valley properties were worth around $1,250,000. Northern California paid $1,760,000. [55] To finance this purchase Northern California issued $860,000 of 6% interest Series A debentures, slated to mature in 1915, and assumed Sacramento Valley's $900,000 in bonded indebtedness. [56] This purchase put burdens on NCPC's finances that the company could ill afford. Between 1912 and 1914 sinking fund payments and the interest payments on bonds absorbed over 60% of Northern California's gross income. [57] (see Table 23 on page 138).

Northern California officials had urgent and immediate reasons for terminating the rate war with Sacramento Valley, and these probably explain the somewhat inflated purchase price they paid. In order to complete Coleman, Northern California had been forced to take out short term loans amounting to around $500,000. Declining revenues and cash flow problems, plus pressure from creditors, made it imperative for Northern California to consolidate this debt through the sale of bonds. The war with Sacramento Valley, however, had a "disastrous effect on the company's credit", making it very difficult for Northern California to secure additional short term loans and impossible to sell securities to consolidate the company's indebtedness and extend payments over a longer period. The purchase of Sacramento Valley Power eliminated the difficulties. Within five months (by July 1912) Northern California had sold $500,000 in five year Series B debentures, substantially reducing its immediate financial problems. [58]

There were other assets which Northern California secured with the absorption of Sacramento Valley which undoubtedly also had an influence on its decision to buy. Sacramento Valley had water rights on North Battle Creek amounting to 1672 inches (42 second-feet) of flow. This could be used at the company's four Battle Creek plants and was, according to Noble, trying to justify the purchase to stockholders, "absolutely necessary to the operation of installed apparatus". [59] Without this water, Noble claimed, the company would have had to construct a "vast and expensive storage reservoir". [60]

An additional bonus was that the Lost and Hat Creek water being diverted to the Sacramento Valley's Snow Creek plant could be diverted into North Battle Creek instead. Because there were four plants on Battle Creek this water could be used under a total head of 2630 feet, versus only around 900 feet at the Snow Creek plant. Northern California immediately took advantage of this . The ditch system which diverted water from Lost and Hat Creeks in the Pit River watershed and carried it across the Battle Creek watershed to Snow Creek was modified to deposit its flow into Bridge Creek, a tributary of Battle Creek above the Macumber Reservoir, and in May 1912 the Snow Creek powerhouse was abandoned. [61] This benefit, however, proved to be short lived. In 1914 the courts ruled on the long-contested suit first filed by Hat and Lost Creek farmers against the Shasta Power Company around 1908 and now inherited by Northern California. Northern California was allowed to divert water from Lost and Hat Creeks only between September 15 and May 1, the non-irrigation season. [62] Then in late 1914 and 1915 Mt. Lassen, long a dormant volcano, erupted. The lava and mud flows which ensued completely destroyed much of the Hat and Lost Creek diversions, the only water power development in the United States ever damaged by an active volcano. [63]

THE RATE WAR AFTERMATH

Elimination of competition had proven expensive to the Northern California Power Company. But the bad luck and misplaced hopes that had plagued the company in 1911 and early 1912 continued. On the conclusion of negotiations for the purchase of The Sacramento Valley Power Company, Northern California announced that it would reinstall meters throughout its territories and restore rates where possible to pre-war levels. [64] Utilities had long raised rates at their own discretion and Northern California, anxious to make up for the losses it had taken during the rate war, expected to do so again. But in 1911 the California legislature had passed the Public Utilities Act, investing rate fixing authority in the California Railroad Commission. This act took effect on March 23, 1912. Thus when the Consolidated Company unilaterally raised power rates, it was ordered by the Railroad Commission to rescend the increases until a thorough investigation established a formal rate structure based on a fixed return on invested capital. [65]

Thus Northern California was compelled to formally request the Railroad Commission to establish a uniform rate structure. Hearings were held in June 1912. When the Railroad Commission investigated Northern California, the utility encountered other problems. The Commission, seeking to establish rates based on a percentage of the utility's real value, found that there was no reliable inventory of Northern California's properties to permit determination of worth (many company records had been destroyed during the San Francisco fire and earthquake of 1906). Moreover, the Commission complained that it was impossible to determine the real income and real value of the company, since proper funds had not been set aside for depreciation. And, in addition, the companies absorbed by Northern California (Northern Light and Power and Shasta Power through the purchase of The Sacramento Valley Power Company) had kept poor records. [66] An estimate by the secretary of the Northern California Power Company that the utility's properties were worth more than $20,000,000 was apparently received with some scepticism. [67]

Because Northern California's rate system was in a "chaotic" condition and the entire company was "demoralized" as a result of the rate war, [68] the Railroad Commission decided to act quickly on the company's request for a uniform rate structure even without reliable information on its worth. On December 30, 1912, the Commission set down a uniform rate system for the Northern California system. The utility was compelled to reduce its rates to 5500 customers by amounts varying from 5 to 30%. The remainder of the utility's customers paid a higher rate than before the rate war, but a lower rate than that unilaterally imposed by the company immediately afterwards. In addition, Northern California was ordered to make some refunds. [69] Northern California agreed to give the new rates a fair trial. [70]

In July of 1912 Northern California applied to the Railroad Commission for permission to issue $500,000 in five year bonds. The money from this issue was, as noted, to be used to pay off very urgent short term debts incurred in the completion of Coleman and to consolidate the company's growing indebtedness. The Railroad Commission again complained of the difficulty of obtaining adequate information on the value of Northern California's properties and earnings, but authorized the bonds. But as a condition of the order the Railroad Commission assumed the right to require the Northern California Power Company to levy assessments against its stockholders. [71] In juatifying its position on this issue the Commission argued:

> The proper parties to bear losses of utilities as well as of any other corporations, are the stockholders. To be sure, there is a stockholders' liability which legally holds the stockholders to account, but too often in the case of utilities at least, bad financial conditions brought about by high financing are cured by exploiting the public through high rates, or by more high financing, and through reorganizing and unloading upon new stockholders and new bondholders securities that have nothing behind them except water and the desire of the promoters to reap a profit. [72]

In order to satisfy the complaints of the California Railroad Commission and to prepare for future applications to the Railroad Commission, Northern California did undertake a valuation survey in 1912 and 1913. [73] Another inventory and appraisal was carried out for the company in 1914 and 1915 by the J.G. White Company. [74] In addition, the California Railroad Commission in 1915 made a valuation survey of Northern California on its own when the rates set in 1912 were scheduled to come up for review. [75]

Although various company officials in 1912 had estimated the value of NCPC properties at between $17,000,000 and $20,000,000, [76] the valuation surveys yielded far lower figures. In setting rates for the Northern California Power Company in 1916 the California Railroad Commission valued the companies properties at slightly under $6,500,000. [77] Part of this sharp discrepancy was due to the land and water rights purchased by the Northern California Power Company. Most electric utility companies had secured water for their hydroelectric plants by appropriation. Northern California was practically unique in having secured the bulk of its water by purchase. [78] In order to secure these water rights Northern California had been compelled to buy the lands associated with the water, so that by 1910 the utility owned around 18,000 acres. [79] Northern valued these properties and associated water rights (and the franchises it had secured) as high as $8,000,000. [80] The Railroad Commission, on the other hand, viewed the lands as non-operative properties (and hence not relevant to the capital the company had invested in producing power) and valued the water rights at a very small fraction of Northern California's estimates. [81]

While the bond issue in 1912 relieved the company's most pressing debts, it was still faced with large interest payments and the need to begin retiring the $860,000 in bonds used to purchase Sacramento Valley Power and due to mature in 1915. Thus Northern California continued the dividend suspension initiated in 1911. It also, either on its own or prodded by the Railroad Commission, began to levy assessments on its stockholders to meet pressing financial demands. There were eight assessments levied between 1912 and 1915,totalling $6.00 per share. [82] To bring in additional capital the stockholders voted in July of 1914 to increase capitalization from $10,000,000 to $12,000,000, by authorizing $2,000,000 of 6% non-assessable preferred stock, $500,000 to be issued immediately. [83] In order to sell this stock the company had to apply to the Railroad Commission. The Commission in October 1914 approved the sale of $500,000 in new stock, but in keeping with the philosophy promulgated in 1912, limited the sale to existing stockholders. [84] Since most of the company's stockholders were well aware of the company's financial position and had not received any dividends in years, the issue was never sold.

Unable to bring in new capital, Northern California's financial plight steadily worsened. At the end of 1914 only $190,000 of the bonds issued to purchase the Sacramento Valley Power Company had been retired, and the remainder ($670,000) was due on February 1, 1915. Faced with a financial emergency, the utility requested, and secured, permission from the Railroad Commission to defer payment on the remaining bonds until 1920, after negotiating the delay with the bondholders. [85]

Adding to the major problems of Northern California Power were a series of minor disappointments in this era. For instance, in 1912 the Oro Electric Company agreed to purchase up to 20,000 kW of power from the Northern California system. [86] This would have significantly reduced Northern California's huge excess generating capacity. But, instead, Oro turned to the Pacific Gas & Electric system to supply their power needs, leaving Northern California with no recourse except legal action. [87] To make matters worse, an attempted merger between Oro and Northern California failed in 1914. [88]

The cumulative result of the smelter closings, Heroult's failure, the disastrous conditions under which the rate war was ended, and an assortment of minor disappointments was a rapid deterioration of Northern California's position between 1911 and 1915. For the year ending November 1, 1910, the company's earnings (surplus + dividends, if any) had been $264,888. They declined to $104,458 the following year and then dropped even further to $57,427 for 1913 and $61,754 for 1914. [89] It was out of these meager funds that payments had to be made to the company's sinking fund for bonds and for system improvement. By 1914 slighly over 48% of the utility's gross revenue was being absorbed by interest charges alone, third highest among California's ten major electrical utilities. [90] These conditions may have been responsible for W.F. Detert replacing Nohle as president of Northern California Power in 1915. [91]

When the Railroad Commission reviewed the status of the Consolidated Company in 1916 it noted that due to the "vitiating effect" of the rate war it was practically starting all over again in developing its territory and stabilizing its securities. [92] The Commission found that the Northern California syatem had an installed generating capacity of 36,150 kW. The system's peak load was only around 20,000 kW, so that even with the logical 25% reserve, Northern California Power in the middle of the 1910's had over 11,000 kW of generating capacity that was completely idle and unproductive. [93]

THE WAR YEARS

Northern California Power did not begin to recover until 1916, when the war in Europe began to affect the American economy. Copper production in Shasta County, which had averaged 27,000,000 pounds between

Table 22: Earnings of the Northern California Power Company, 1903 - 1919

Fiscal Year	Gross Revenue	Gross Income	SURPLUS* (including dividends)	Dividends
Mar. 1,1902-Feb. 28,1903	$ 85,582	$ 43,329	$ 27,829	
Mar. 1,1903-Feb. 29,1904	150,925	98,056	69,282	
Mar. 1,1904-Feb. 28,1905	178,573	123,052	79,070	$ 60,000
Mar. 1,1905-Feb. 28,1906	185,024	123,202	75,414	60,000
Mar. 1,1906-Feb. 28,1907	214,830	145,243	96,243	60,000
Mar. 1,1907-Feb. 29,1908	297,062	184,229	135,478	40,000
Mar. 1,1908-Oct. 31,1908	245,376	178,377	139,840	
Nov. 1,1908-Oct. 31,1909	432,715	282,669	174,627	110,000
Nov. 1,1909-Oct. 31,1910	578,082	406,843	304,401	210,000
Nov. 1,1910-Oct. 31,1911	639,702	423,426	264,888	100,000
Nov. 1,1911-Oct. 31,1912	706,933	415,456	104,458	
Nov. 1,1912-Dec. 31,1912				
Jan. 1,1913-Dec. 31,1913	829,036	516,454	155,730	
Jan. 1,1914-Dec. 31,1914	771,187	432,393	57,427	
Jan. 1,1915-Dec. 31,1915	782,597	428,500	61,754	
Jan. 1,1916-Dec. 31,1916	853,126	487,974	128,222	
Jan. 1,1917-Dec. 31,1917	973,240	577,727	233,928	
Jan. 1,1918-Dec. 31,1918	1,163,667	676,450	344,673	
Jan. 1,1919-Sept.30,1919	925,627	475,367	234,525	

(Fowler, Hydroelectric Systems of California, pp. 969-971)

*SURPLUS: Funds remaining from income after interest payments, uncollectable bills, and a number of other small items are subtracted; from these funds payments have to be made to the sinking fund to retire bonded indebtedness; pay maturing obligations; and made additions and betterments.

Table 23. Interest Payments of the Northern California Power Company, 1903-1919

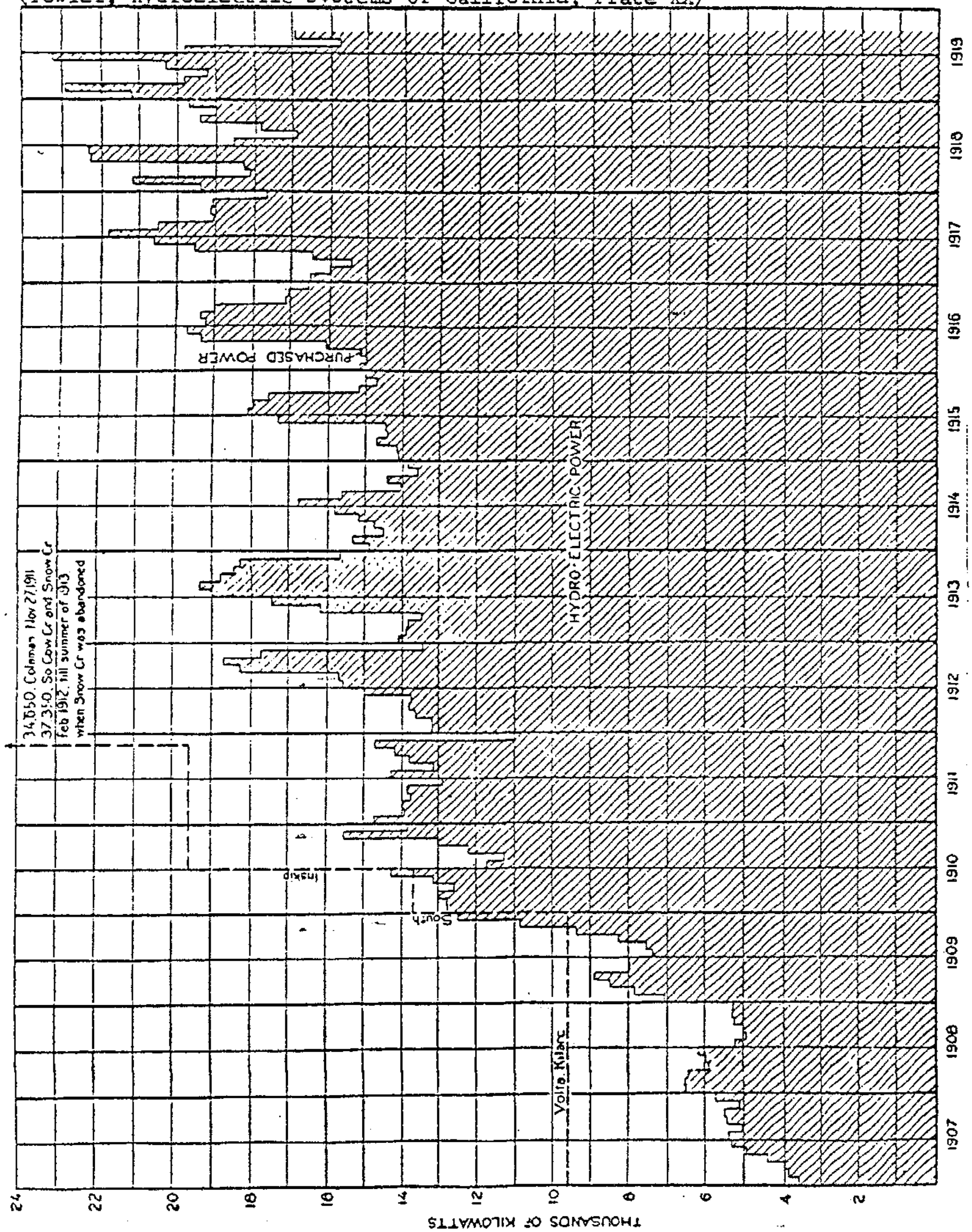
Fiscal Year	Gross Income	Interest on funded debt	% of income to interest
March 1, 1902-February 28, 1903	$43,329	$15,500	35.8%
March 1, 1903-February 29, 1904	98,056	28,774	29.3
March 1, 1904-February 28, 1905	123,052	43,982	35.7
March 1, 1905-February 28, 1906	123,202	47,788	38.8
March 1, 1906-February 28, 1907	145,243	49,000	33.7
March 1, 1907-February 29, 1908	184,229	48,750	26.5
March 1, 1908-October 31, 1908*	178,377	38,538	21.6
Nov. 1, 1908-October 31, 1909	282,669	94,654	33.5
Nov. 1, 1909-October 31, 1910	406,843	122,835	30.2
Nov. 1, 1910-October 31, 1911	423,426	156,403	36.9
Nov. 1, 1911-October 31, 1912	415,456	282,788	68.1
Nov. 1, 1912-December 31, 1912			
Jan. 1, 1913-December 31, 1913	516,454	351,586	68.1
Jan. 1, 1914-December 31, 1914	432,393	361,179	83.5
Jan. 1, 1915-December 31, 1915	428,500	359,189	83.8
Jan. 1, 1916-December 31, 1916	487,974	352,920	72.3
Jan. 1, 1917-December 31, 1917	577,727	334,626	57.9
Jan. 1, 1918-Decmeber 31, 1918	676,450	311,313	46.0
Jan. 1, 1919-September 30, 1919*	475,367	242,406	51.0

*part of a year

Source for figures: Fowler, Hydroelectric Systems of California, pp. 969-971. The exact dollar figures for interest payments, income, revenue, etc. differ somewhat between the Northern California Power Company Annual Reports, the California Railroad Commission's annual Report, and Fowler, but the deviations are not significant.

Table 24. Mean Monthly Loads on the Northern California Power Company System, 1907-1919

(Fowler, Hydroelectric Systems of California, Plate XX)



1911 and 1916 rose to 40,000,000 as the price rose from 17 to 27.5¢ per pound. Even though copper output began to slowly decline again, beginning in 1917, due to the expansion of production in Chile and the increased recovery of copper from scrap, the utility's revenues from mining and dredging operations continued to rise steadily, increasing by $86,802 between 1916 and 1917 and by $87,296 between 1917 and 1918. [94]

The one other bright spot in the company's situation was a steadily growing agricultural demand for power in the upper Sacramento River valley. Electricity had been used to power irrigation pumps in California as early as 1899, and, as we have seen, the Northern California Power Company had been aggressive in cultivating this market since 1903 when declining revenues from mining had convinced company officials that they needed a market that would "last forever". Northern California's campaign for agricultural electrification began to pay major dividends in the second decade of the twentieth century. Two extremely dry seasons (1912 and 1913) and the introduction of rice cultivation which required extensive irrigation (150 hp of pumps per 1000 acres between April and September) significantly boosted the company's revenues from agricultural load. By 1913, a decade after Northern California had initiated its campaign to encourage the use of electric pumps, irrigation customers accounted for 16.8% of the utility's yearly average load and 26.4% of the load between May and September. [95] In 1915 Northern California was serving 531 agricultural power customers with a total connected power load of 7020 hp (5265 kW). [96] The agricultural load was further increased with the introduction of rice cultivation in the Sacramento River valley. By 1915 almost 12,000 acres had been planted with rice. By 1916 the figure had increased to 16,000 and by 1917 to around 23,000 acres. [97] In 1919 new rice cultivators alone required 1500 hp and made the construction of a new substation necessary. [98] Thus annual revenues for irrigation increased by $68,608 between 1914 and 1917, and higher prices for agricultural products brought on by wartime demands led to a massive additional $116,252 increase in revenues in this field for 1918 alone. [99]

Unfortunately the steady expansion of agricultural load was not uniformly beneficial to the company. It significantly increased the expenditures the company was forced to make for new equipment. The agricultural load increase came primarily from the southern part of the company's territory. The company's hydroelectric plants were in the north. To transfer steadily larger amounts of power south and keep line losses to an acceptable level, Northern California was compelled to raise the capacity of many of its lines from 20 or 22 to 60 or 66 kV. Between 1912 and 1915, for example, the proportion of the company's lines that were operated at around 66 kV increased from 43% to 62%. [100] And this trend continued. In 1916, 51 miles of 20 kV (or 22 kV) transmission line were dismantled, while 37 miles of new 60 kV (or 66 kV) line were strung. [101] The replacement of 22 kV lines with 66 kV lines had begun even before 1910, but as power demand increased more rapidly in agriculture than anywhere else after 1912, the process was accelerated at the very time when the company needed ever dollar to help retire its huge bonded indebtedness. Raising the voltage of transmission lines from 22 to 66 kV

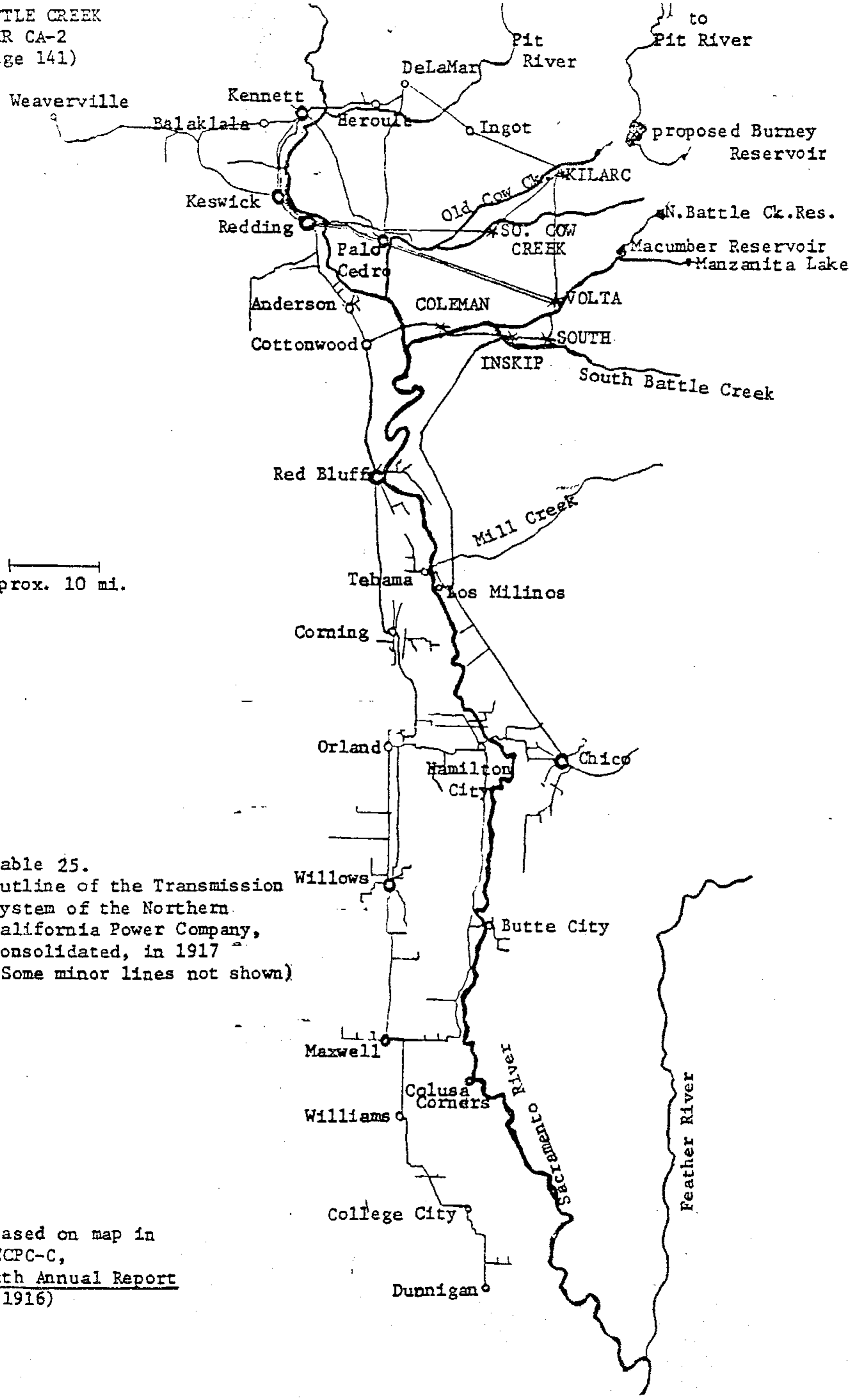


Table 25.
Outline of the Transmission System of the Northern California Power Company, Consolidated, in 1917
(Some minor lines not shown)

based on map in
NCPC-C,
<u>8th Annual Report</u>
(1916)

required not only the reconstruction of the lines themselves, but the installation of new transformers at powerhouses and substations, the purchase of new and more expensive switching apparatus to control the higher voltages, the use of better and more expensive insulators, and so on. Thus every expansion of power load in the south was partially offset by the increased expenditures which Northern California had to make to take advantage of the larger market. To a utility on a solid financial base this would not have been a serious burden. But Northern California Power was not on a solid financial base.

Nonetheless, the increased revenues from mining (after 1916) and agriculture enabled Northern California Power to stumble through the 1910's barely ahead of its creditors. Had other power markets grown to an equal extent, Northern California might have been successful in reducing its bonded indebtedness and overcoming its persistent cash flow and excess generating capacity problems. But other power markets did not grow at a corresponding rate. Revenues from commercial lighting, for instance, barely increased between 1913 and 1918 ($129,201 in 1913; $144,214 in 1918). [102] Another market which did not expand was bulk sales to other utilities, particularly PG&E with its access to the bay area. Sales to PG&E had increased steadily from 1906 to 1913, undoubtedly contributing to Northern California's decision to expand generating capacity on Battle Creek. These sales had peaked in 1913 at $243,423, accounting in that year for around 30% of NCPC's operating revenue. But 1913 had been an exceptionally dry year. The demand for power in the bay area was higher than PG&E's hydroelectric system could supply. The following year, however, was not exceptionally dry, and PG&E had completed its Drum hydroelectric plant (output 25,000 kVA). Its dependence on outside generating capacity was reduced, and Northern California's revenues from bulk sales dropped by 12% or around $30,000 for 1914. [103] Between 1914 and 1917 sales to other utilities remained almost constant, averaging only $212,000 per year, and in 1918 even dropped to $176,109. [104]

America's entrance into World War I led to increased power consumption by both the manufacturing and agricultural sectors of the economy, and this resulted in increased revenues for electric utility companies everywhere, including Northern California Power. NCPC's surplus for 1918 was over $100,000 higher than that of 1916. But this benefit was offset in part by other developments. Northern California Power Company lost nearly a third of its regular employees to the draft. [105] Wartime shortages and high wartime prices for materials made Northern California's financial problems more acute. The price of copper wire rose 180% between 1915 and 1917; cast iron pipe rose 100%. [106] In addition, wartime power demands forced Northern California to undertake line construction for which it did not have the necessary cash reserves.

Wartime production in the San Francisco Bay area in 1917 created serious power shortages. In an attempt to alleviate these shortages the California Railroad Commission had carried out a study of power consumption in California, discovering that 70% of all electric power generated in the northern part of the state was consumed within a 50 mile radius of San Francisco. [107] In order to bring more power into this area and reduce dependence on generators fired by scarce and high priced oil the Commission exerted heavy pressure on all electrical utilities in the state to interconnect their transmission networks.

This decision effected Northern California Power. One of the Commission's recommendations was that the California-Oregon Power Company, whose territory lay north of the Battle Creek area along the California-Oregon border, link its lines with those of Northern California Power north of Kennett at Delta, California. This interconnection would permit California-Oregon Power to supply 8000 kW to the northern end of NCPC's system, freeing the Consolidated Company to supply an additional 8000 kW of power to Pacific Gas and Electric for distribution in the San Francisco Bay area through a new link with the PG&E grid at Colusa Corners. [108]

The Northern California Power Company was, at the time, preparing an application for a rate increase to be submitted to the California Railroad Commission. Company officials probably felt they had little choice but to follow a recommendation made at the "urgent insistence" of the body which would rule on their request. A formal contract between the three parties (California-Oregon, PG&E, and Northern California) was signed in June 1918. Because of the acute cash flow problems of Northern California Power, arrangements were made for the California-Oregon Power Company to advance $110,000 to Northern California. This money was used to pay California-Oregon crews to construct 17 miles of new power line from Kennett to Delta, where the Northern California and California-Oregon grids were interconnected. The advance was also used to reinforce a transmission line from Hamilton City south to Colusa Corners,where the new interconnection was to be made to the PG&E grid (the 1906 interconnection had been made at Chico) and to build a new line between Coleman and Hamilton City. The advance was to be repayed out of money received by Northern California as a carrying charge on electricity transferred south for California-Oregon and out of revenues from power which NCPC would sell California-Oregon's grid during the non-irrigation season. [109]

Unfortunately the $110,000 advance proved insufficient. Lines expected to be adequate with reinforcement for the transmission of power south were found to be inadequate, perhaps due to insufficient maintenance during the financially-troubled years from 1912 to 1917. Some had to be completely rebuilt. This additional work cost the utility an additional $90,000 and, as a company official noted, was "an expenditure that the Company would not have made under any other circumstances or for any but patriotic reasons. [110]

The war years of 1917 and 1918 brought Northern California Power Company stockholders more bad news. The bonds issued in 1912 to consolidate debts incurred during the construction of Coleman matured on July 15, 1917. Attempts to negotiate a postponement on these bonds, similar to the postponement negotiated on the bonds used to purchase the Sacramento Valley Power Company, failed. Assessments totalling $200,000 were levied against Northern California stockholders, and the company secured $300,000 in short term loans to carry it over this crisis. [111]

Revenues did increase in 1917 and 1918, quite significantly. The utility's surplus after operating expenses, taxes, and interest payments were subtracted from gross income rose from $128,222 in 1916 to $344,673 in 1918. [112] But these funds were still insufficient to meet the cost of additions, improvements, maintenance, and payments due the company's sinking funds for outstanding bonds. Even though Northern California had undertaken no major capital improvements since the completion of Coleman in late 1911, and even though dividend payments had been suspended since 1911, and despite assessments which by 1918 totalled $14 per share, the company's financial situation had continued to decline and by 1919 was approaching total collapse. By June of 1919 Northern California Power Company, Consolidated, was $256,030 in arrears in payments to its sinking fund and owed $249,250 in short term notes. In addition, $370,000 of the bonds used to purchase The Sacramento Valley Power Company were still unretired. These bonds, whose payment had already been postponed five years, were due to mature on February 1, 1920. [113] Recognizing the acute nature of Northern California's financial problems, the Railroad Commission authorized a 10% surcharge on all power bills rendered by the company after May 1, 1919. [114]

THE PIT RIVER

Northern California's future was clouded not only by the company's precarious financial position, but also by developments involving the Pit River, in the extreme northern part of its territories. Very early, as we have seen, Noble and his associates had seen the Pit as a logical area for expansion of generating capacity. In 1902 Noble employed a civil engineer, R.E. Johnson to locate potential hydroelectric plant sites on the Pit, and Johnson had filed for Noble notice of appropriation of 250,000 inches (6250 second-feet) of water.

The appropriation was filed in the vicinity of the "Big Bend" of the Pit River. From the beginning of the "bend" to its termination was around 21 miles by water, but only 7 miles overland, with a vertical drop of around 1000 feet between. Northern California's plans for the area initially called for a large dam some miles upstream. This dam was to divert water into a 28 mile long canal, which would eventually cross the bend and deliver water to a hydroelectric plant under a 1300 foot head, generating as much as 500,000 hp (375,000 kW). Further studies and surveys, however, indicated that this plan was unfeasible and it was abandoned.

Johnson was next instructed to survey a site for a smaller project, a project that would reduce the length of canal by positioning the water intake somewhere on or near the "bend" itself. These surveys were completed by 1904 or 1905. This project involved a 6.33 mile long tunnel to divert 4000 second-feet of water to a powerhouse on the downstream side of the "bend", permitting operation under a head of 940 feet. [115]

Either in direct violation of instructions from Noble or because the Northern California Power Company delayed implement tion of his plans, Johnson, in conjunction with an associate, H.V. Gat , filed claim in 1906 on 150,000 inches (3750 second-feet) of water in th area of the intake he had located for Northern California. The water was claimed for use in the mining of building stone, a method sometimes used in California to reserve water rights for later development for other purposes. [116]

Although Northern California Power had neither the resources nor the need to develop Pit power in 1906, it regarded the Pit as a Northern California "preserve". [117] Thus Noble responded quickly to the threat from Johnson and Gates. In August 1906 Northern California altered its 1902 claim on 250,000 inches (6250 second-feet) of water, moving the projected intake for its plant downstream, below the point at which Gates and Johnson planned to appropriate wster. In 1907 the company began extensive surveys, started small scale construction on one of the tunnels that its new plans required, and started to acquire the necessary lands for the project. [118] In addition, in September 1906 Northern California challenged the Johnson-Gates claim. Noble's lawyers argued that this claim for the use of water for mining building stone was a subterfuge made solely to secure "a reservoir site and not for any other purpose" and that development work on the site hsd been undertaken not to mine building stone but to "find a point for an intake of a tunnel to be used in connection with a power plant". The local U.S. land office examiner concurred with Northern California'a claims and rejected the Gates-Johnson claim as filed, requiring a new application. [119] His decision was upheld in late 1910 by the Commissioner of the General Land Office in Washington, throwing the question of who had placed the first valid appropriation claim up for grabs. [120]

In the meantime Northern California had suspended work on the Pit site, transferring its crew south to Battle Creek for the expansion program there. This proved to be a wise move. In 1910 the Federal Government withdrew aeveral large blocks of public land along the Pit from development for conservation purposes. These withdrawals affected both the Johnson-Gates and Northern California projects and forced both parties to reconsider development plans. [121]

Northern California responded quickly. In 1910 the company made new surveys to avoid power site withdrawal lands, established the first stream flow measurement and permanent gauging stations on the river, altered the location of its intake, and filed a new claim on 150,000 inches (3750 aecond-feet) of water. [122] The new plans involved a ditch system around 5.25 miles long, which would include five tunnels totalling 16,697 feet in length. The Pit canal was to carry around 3000 second-feet of water. The tunnels were to be much larger than those used on the Battle Creek system (24 feet wide by 26 feet high) in order to permit the use of mechanical shovels. This system would develop a head of 464 feet and generate over 100,000 hp (75,000 kW). Northern California officials believed that the new plant would cost approximately $4,000,000 and require two years for completion. [123]

By 1911 or 1912 Northern California had completed its surveys and had begun work on the new project, having purchased or filed claim on all necessary lands and waters. Preparatory work was stepped up in late 1911 as some crews were transferred to the Pit from Coleman. [124] Noble hoped all possible preliminary work could be finished at the site so that "as soon as there is a demand for power" the project could be rushed to completion. [125]

The decline of Northern California's financial situation in 1911 and 1912 and the collapse of copper smelting and Noble's experiment at Heroult, of course, all but prohibited any major capital investment on the Pit. Northern California Power thus deferred heavy construction work there, keeping only a small crew working after 1912 to sustain its water claims.

Because the Pit offered excellent [illegible] conditions for large scale hydroelectric development, Noble's "preserve" was naturally invaded by other companies. In 1906, for example, a Pit River Power Company was formed to develop power on the stream, but collapsed, apparently due to failure to raise sufficient capital. [126] In 1909, however, the Mt. Shasta Power Company was organized, based in part on the Johnson-Gates claims. This company, backed by mining entrepreneur John Hays Hammond, planned to divert 250,000 inches (6250 second-feet) of water through a 7 mile tunnel. The projected intake of Mt. Shasta's tunnel was located 2 miles upstream from the intake planned by Northern California Power. [127] Because the Mt. Shasta project would take in water 2 miles above the Northern California intake and release the water 8 miles below, completion of the Mt. Shasta plant would have rendered Northern California's plant useless. Litigation ensued, and both projects languished. By 1917 Mt. Shasta had driven its tunnel only 1 mile. Northern California had dug only 700 feet of tunnel. [128]

In 1917, unable to develop the project on its own, the Mt. Shasta Power Company sold its rights and properties to the Pacific Gas and Electric Company, [129] a corporation with sufficient capital resources to aggressively **push** litigation involving conflicting water claims in the Big Bend area and to develop the site.

A new impetus to develop the Pit came with wartime power shortages. These shortages prompted the California Railroad Commission to review in 1917 the power potential of the Pit. It was very impressed by Northern California's plans for the "Big Bend". The Commission not only considered the plans to be feasible, but argued that of all the major power projects in the northern part of the state, the Northern California Pit River project was the one which should be developed first to alleviate present and future power demands. Costs were estimated at $9,000,000, construction time at 18 months. The Commission strongly recommended that major construction work be initiated immediately. [130]

Northern California did move a seven man crew to the site in late 1917 or early 1918, and this crew carried on the work of blasting and driving tunnels and digging exploration pits and drifts. [131] Northern California also continued to purchase land in the area. [132] But the utility was reluctant to make any additional commitment. Since litigation was pending with PG&E over water rights, Northern California did not want to invest heavily in a plant which might not have water to operate with. [133] Moreover, the company's precarious financial condition ruled out any extensive efforts.

Of the factors which limited Northern California's activities on the Pit, the company's poor financial condition was undoubtedly the most critical. In 1919 the Railroad Commission reviewed the financial position of Northern California Power in conjunction with a request for a rate increase. The Commission now estimated that it would cost the company around $6,000,000 to complete its Pit River project, if unchallenged title to the waters could be secured, but noted that it was "doubtful" whether NCPC could raise this much capital. To remain a "solvent up-to-date public utility," capable of discharging its obligations to the public, the Commission concluded, Northern California needed an influx of $6,500,000 to $7,000,000. Yet the company's current income limited any increase of its bonded indebtedness to a meager $625,000, an amount "acarcely sufficient to pay maturing obligations". [134] Thus Northern California's Pit River holdings, while potentially very valuable, were clouded by the utility's precarious financial plight and by potential litigation with PG&E.

PG&E AND THE NORTHERN CALIFORNIA SYSTEM

Despite its financial problems, the Northern California Power Company atill owned considerable asets in 1919. From a strictly technical point of view its Battle Creek hydroelectric system was one of the best medium-sized aystems in the state. In addition to the four hydroelectric plants the company had on Battle Creek and the two smaller Cow Creek plants (Kilarc plus South Cow Creek acquired with the purchase of The Sacramento Valley Power Company), it had a 584 mile long high voltage transmission network and almost 2000 miles of distribution lines. [135] Its territory covered an srea of approximately 5000 square miles (see map on the following page). Making the system even more attractive was its very high load factor. In addition, Northern California had a defensible claim to the waters of the Pit River with its immense hydroelectric potential, as well as a transmission system that could easily be linked to any plant established on tbat stream.

With these assets it is not at all surprising that a number of operating utility companies were interested in purchasing the syatem when Northern California's directors indicated in 1919 a willingness to dispose of the company to escape from its financial plight. Although negotiations were carried on with aeveral firms, [136] the best offer came from Pacific Gas and Electric. PG&E slready had two interconnections with the Northern California grid and had purchased an average of 6560 kW continuously in 1918. In previous years purchases bad been even higher (an average of 8670 kW in 1913). [137] Thus scquisition of Northern Californis would not only increase the generating capacity of the PG&E aystem by almost 20%, but would substantially reduce its dependence on otber utilities. In addition, the absorption of Northern California would leave PG&E unchallenged on the Pit, and Northern California's lines would allow any new Pit River plant to quickly and cheaply be linked to the bulk of the PG&E distribution system.

Because of the real and potential importance of Northern California's assets, Pacific Gas & Electric's offer was generous. PG&E agreed to purchase all 100,000 outstanding shares of Northern California Power Company, Conaolidated, at $34 per share and to assume payment of the company's $6,200,000 in bonded indebtedness. Northern California's board of directors unanimously voted to sccept the offer, and all but the holders of 450 shares of stock concurred with ita decision. [138]

The sale, however, had to he approved hy the California Railroad Commission, and the disaidents filed a protest with that body. They charged that the aale had been conceived and executed by individuals acting not in the interests of the Northern California Power Company but in the

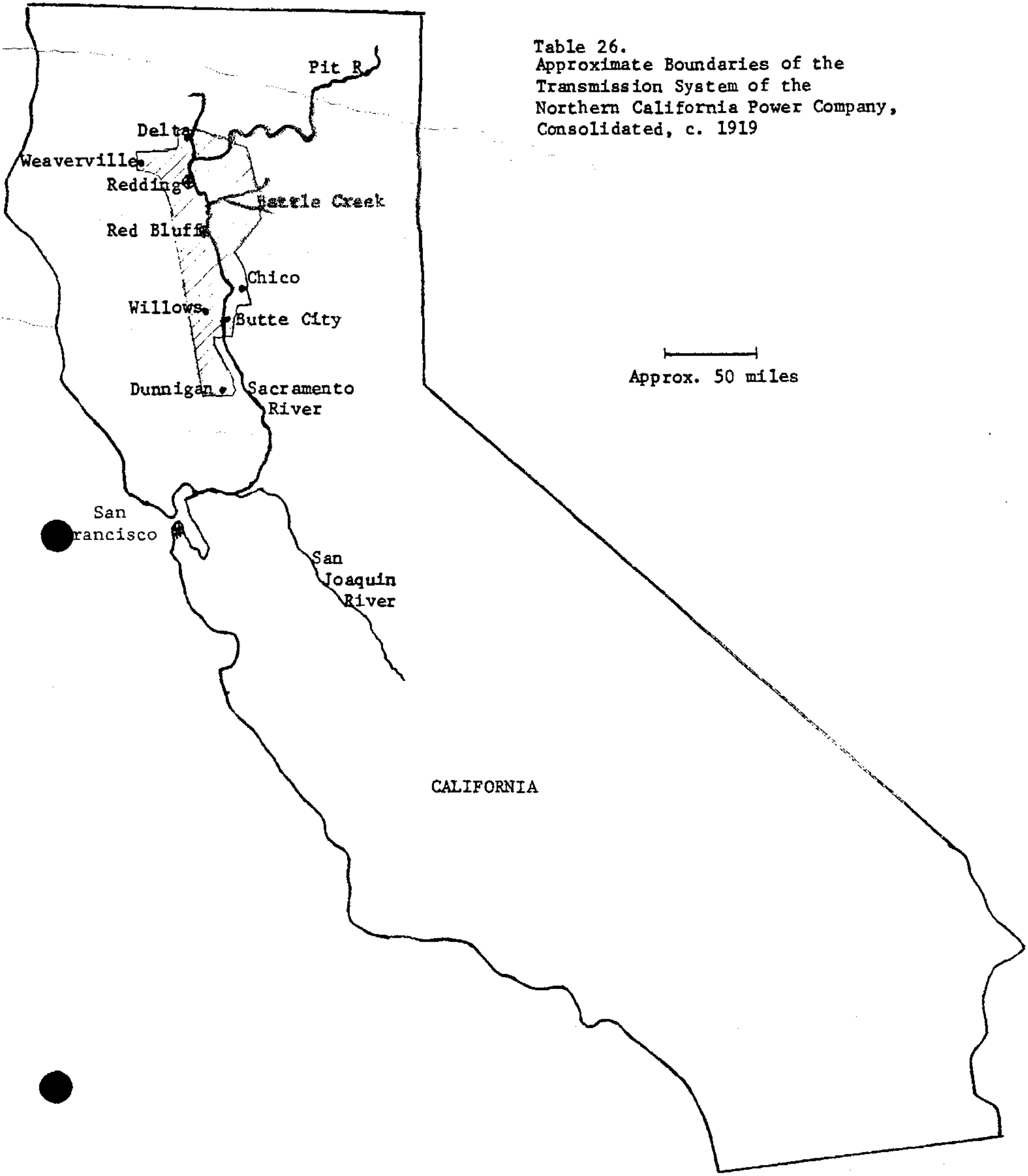


Table 26.
Approximate Boundaries of the Transmission System of the Northern California Power Company, Consolidated, c. 1919

interests of Pacific Gas and Electric Company, giving PG&E valuable water rights, franchises, and properties without proper compensation to Northern California stockholders. The protestants based their allegations on the interlocking directorships and mutual stock ownership which existed between the management of PG&E, NCPC, and the Mercantile Trust Company of San Francisco. They pointed out, for instance, that W.F. Detert, president of Northern California, was "also a large stockholder of Pacific Gas and Electric" and a director of the Mercantile Trust Company; that S. Waldo Coleman and A.F. Reis Jr., two directors of Northern California, were also PG&E stockholders; and that several high PG&E officials were also officials of the Mercantile Trust Company. The dissidents also complained that the purchase price of $34 per share did not fairly compensate them for the original cost of the shares ($20) plus the $14 in assessments levied on the shares to keep the company solvent between 1912 and 1918. [139]

The Railroad Commission, well acquainted with the precarious financial position of Northern California Power Company, Consolidated, dismissed the protest of the minority stockholders and approved the sale. [140] The Northern California Power Company with its Battle Creek system of hydroelectric plants was officially absorbed into the Pacific Gas and Electric Company on October 3, 1919. [141] The Northern California Power Company system was by far the largest and most important addition to the PG&E system since 1906, the year after PG&E had been incorporated. [142]

NOTES

[1] Redding Courier Free Press, April 28, 1911.

[2] Redding Courier Free Press, May 26, 1911; San Francisco Call, May 25 and May 26, 1911.

[3] Redding Courier Free Press, May 27, 1911.

[4] "The Northern California Power Company's Systems. - III. High-Tension Transmission System," Electrical World, v. 44 (1904) p. 505.

[5] Redding Searchlight, April 1, 1900; Red Bluff Daily News, November 15 and November 21, 1901.

[6] NCPC, 4th Annual Report (1905-1906).

[7] Redding Courier Free Press, March 4 and November 10, 1908; CSMB, Bulletin 23 (1908) p. 75.

[8] Redding Courier Free Press, October 23 and November 1, 1909; February 23, April 4, and May 12, 1910.

[9] Redding Courier Free Press, April 12, April 16, and May 2, 1910.

[10] Redding Courier Free Press, October 29 and December 12, 1910; February 4, 1911; NCPC-C, 2nd Annual Report (1909-1910).

[11] Redding Courier Free Press, May 17, 1910.

[12] Redding Courier Free Press, May 27, 1911.

[13] CSMB, 14th Report (1913-1914) p. 751; NCPC-C, 3rd Annual Report (1910-1911).

[14] CSMB, 14th Report (1913-1914) p. 750.

[15] NCPC-C, 3rd Annual Report (1910-1911). Whaley, the company's secretary, later estimated that the Northern California Power Company lost around $200,000 a year due to the closing of the three smelters (CRRC, Transcripts [of Hearings], application no. 62, v. 1 [June 24, 1912] p. 38).

[16] CSMB, 18th Report (1922) p. 698.

[17] For the declining price of NCPC-C stock see: Redding Courier Free Press, May 26, 1911; San Francisco Call, May 25, 1911; San Francisco Call, May 26, 1911; Redding Courier Free Press, December 16, 1911; and San Francisco Call, September 5, 1912. Also see CRRC, Transcripts [of Hearings], application no. 62, v. 1 (June 24, 1912) p. 43.

[18] JE, v. 29 (November 23, 1912) p. 454. The 1912 smelter is described in some detail by Van Norden in "Electric Iron Smelter at Heroult on the Pitt," JE, v. 29 (1912) pp. 453-459.

[19] JE, v. 28 (June 29, 1912) p. 647; Van Norden, "Electric Iron Smelter," p. 454.

[20] JE, v. 28 (June 29, 1912) p. 647; Redding Courier Free Press, December 27, 1910; and February 11, April 17, and May 30, 1911; NCPC-C, 4th Annual Report (1911-1912).

[21] On the failure of the charcoal system see: NCPC-C, 5th Annual Report (1912-1913); for the price increase see: CSMB, 22nd Report (1926) p. 190, and Stansfield, Electric Furnace, p. 122.

[22] NCPC-C, 5th Annual Report (1912-1913).

[23] Stansfield, Electric Furnace, p. 122.

[24] For the later history of Heroult's smelters see: Stansfield, Electric Furnace, p. 122; San Francisco Chronicle, March 7, 1919; CSMB, 22nd Report (1926) pp. 190-191.

[25] CSMB, 17th Report (1921) p. 498; 18th Report (1923) pp. 140, 353, 600, 732.

[26] "Financial Agreement between H.H. Noble and Northern California Power Company, Consolidated," August 11, 1915 (PG&E, Secretary's Office, document 2092-a); "Statement of Edward Whaley regarding debt of H.H. Noble to Northern California Power Company, Consolidated," February 25, 1919 (PG&E, Secretary's Office, docume 2092-b).

[27] Redding Courier Free Press, March 19 and March 25, 1909; Red Bluff Weekly Peoples' Cause, March 27, 1909.

[28] Red Bluff Daily News, October 10, 1909; J.G. White & Co., "Report," p. 86.

[29] Redding Courier Free Press, July 23 and July 28, 1909; J.G. White & Co., "Report," p. 87.

[30] J.G. White & Co., "Report," pp. vi-vii, 87, 95.

[31] Redding Courier Free Press, August 10, 1908.

[32] Redding Courier Free Press, May 17, 1911.

[33] Red Bluff Daily News, September 9 and September 16, 1909; Red Bluff Weekly Peoples' Cause, September 9, 1909; "NCPC Scrapbook," p. 89 ("Arrested for Tearing Out Dam on Battle Creek").

[34] Red Bluff Daily News, September 30, 1909; Red Bluff News, September 29, 1909; Red Bluff Weekly Peoples' Cause, October 2, 1909.

[35] Red Bluff Daily News, July 1, 1910; Redding Courier Free Press, June 4, 1910.

[36] Redding Courier Free Press, April 18, 1910.

[37] Redding Courier Free Press, August 6, 1909; February 26 and June 4, 1910. J.G. White & Co., "Report,"pp. 33, 35, says that Smith was planning on taking his water out of the Battle Creek watershed to hostile power plants.

[38] Redding Courier Free Press, April 15 and April 26, 1911.

[39] Redding Courier Free Press, April 3, 1911.

[40] Redding Courier Free Press, April 26, 1911.

[41] San Francisco Call, January 28, 1912.

[42] Redding Courier Free Press, December 24, 1910.

[43] "Deed of Trust: The Sacramento Valley Power Company to Anglo California Trust Company," July 1, 1911 (PG&E, Secretary's Office, document 2242).

[44] Redding Courier Free Press, September 16, 1911.

[45] Redding Courier Free Press, September 15, 1911.

[46] San Francisco Call, September 17, 1911; Redding Courier Free Press, September 18 and September 19, 1911.

[47] Redding Courier Free Press, September 22 and September 25, 1911; "NCPC Scraphook" ("Power Companies Declare Truce" 9-23-11).

[48] JE, v. 27 (November 11, 1911) p. 470; CRRC, Transcripts [of Hearings], application no. 62, v. 1 (June 24, 1912) pp. 75-76.

[49] CRRC, Tranacripts [of Hearings], cases 675, 676, 677, 711, v. 3 (February 2, 1916) pp. 126-127.

[50] CRRC, Transcripts [of Hearings], application no. 62, v. 1 (June 24, 1912) p. 76; CRRC, Decisions, v. 1 (1911-1912) p. 317; Decisions, v. 11 (1916) p. 44; Report (June 30, 1912 to June 30, 1913) p. 46.

[51] CRRC, Decisions, v. 11 (1916) p. 44.

[52] CRRC, Decisions, v. 1 (1911-1912) p. 316, and v. 11 (1916) pp. 57-58.

[53] NCPC-C, 4th Annual Report (1911-1912).

[54] CRRC, Report (June 30, 1912 to June 30, 1913) p. 47.

[55] CRRC, Decisions, v. 11 (1916) p. 57; NCPC-C, 4th Annual Report (1911-1912).

[56] CRRC, Decisions, v. 11 (1916) p. 57.

[57] CRRC, Decisions, v. 11 (1916) p. 69; NCPC-C, 4th Annual Report (1911-1912) and 5th Annual Report (1912-1913).

[58] CRRC, Transcript [of Hearing], application no. 156 (July 24, 1912) pp. 9-11; Transcripts [of Hearings], cases 675, 676, 677, 711, v. 3 (February 2, 1916) pp. 129-130; NCPC-C, 4th Annual Report (1911-1912).

[59] CRRC, Transcripts [of Hearings], cases 675, 676, 677, 711, v. 3 (February 2, 1916) p. 128. This water was apparently the water Smith was planning to carry out of the Battle Creek watershed (J.G. White & Co., "Report," pp. 33, 35).

[60] CRRC, Transcripts [of Hearings], cases 675, 676, 677, 711, v. 3 (February 2, 1916) p. 128, for a statement to this effect by Whaley, the company secretary; NCPC-C, 4th Annual Report (1911-1912) for Noble's assertion.

[61] CRRC, Transcripts [of Hearings], cases 675, 676, 677, 711, v. 3 (February 2, 1916) pp. 128-129; CRRC, Decisions, v. 11 (1916) p. 46; NCPC-C, 4th Annual Report (1911-1912).

[62] JE, v. 32 (February 14, 1914) p. 153.

[63] Fowler, Hydroelectric Systems of California, p. 224n; Mike Scott, "The History of the Hat Creek-Lost Creek Diversions, 1904-1915," typewritten MS, 18 pp. (Tehama County Library).

[64] JE, v. 28 (February 24, 1912) p. 189.

[65] JE, v. 28 (June 1, 1912) p. 565; v. 29 (July 6, 1912) p. 20.

[66] CRRC, Decisions, v. 11 (1916) pp. 63-64; see also Decisions, v. 1 (1911-1912) pp. 315-318.

[67] CRRC, Transcripts [of Hearings], application no. 62, v. 1 (June 24, 1912) p. 7 (testimony of Edward Whaley, company secretary). According to Whaley the company was worth a little more than $20,000,000, not including distribution lines, substations, and property for the same.

[68] CRRC, Report (January 1, 1911 to June 30, 1912) pp. 47-48; Report (June 30, 1912 to June 30, 1913) p. 46.

[69] CRRC, Report (June 30, 1912 to June 30, 1913) p. 47; Decisions, v. 11 (1916) pp. 39-40, 45; v. 1 (1911-1912) pp. 315-328.

[70] CRRC, Decisions, v. 11 (1916) p. 64.

[71] CRRC, Decisions, v. 1 (1911-1912) pp. 407-412 (for authorization to issue notes), 498-499 (for supplemental order regarding assessments. For strong complaint about NCPC's inability to produce adequate financial records see "Hearing before CRRC" , application no. 156 (August 14, 1912) comment of Commissioner Gordon (in "Opinions and Legal Documents," application no. 156 [CSA])

[72] CRRC, Report (June 30, 1912 to June 30, 1913) p. 310. See also CRRC, Decisions, v. 1 (1911-1912) pp. 407-412.

[73] A number of the Valuation Survey Field Books are dated 1912 and 1913.

[74] NCPC-C, 6th Annual Report (1914).

[75] CRRC, Decisions, v. 11 (1916) p. 38.

[76] In its application for increased capitalization in 1912 NCPC valued its assets at around $17,500,000 (CRRC, "Opinions and Legal Documents," application no. 156 [filed July 19, 1912]); see also Transcripts [of Hearings], application no. 62, v. 1 (June 24, 1912) p. 7, and JE, v. 29 (July 6, 1912) p. 20.

[77] CRRC, Decisions, v. 11 (1916) pp. 38, 58-62.

[78] Ibid., p. 48.

[79] NCPC-C, 1st Annual Report (1908-1909).

[80] JE, v. 29 (July 6, 1912) p. 20; CRRC, Decisions, v. 11 (1916) p. 51; CRRC, Transcripts [of Hearings], application no. 62, v. 1 (June 24, 1912) pp. 7-10.

[81] CRRC, Decisions, v. 11 (1916) pp. 58-61.

[82] CRRC, Decisions, v. 9 (January 1, 1916 to April 30, 1916) p. 130.

[83] JE, v. 33 (July 25, 1914) p. 92; "Certificate of Increase of Capital Stock of Northern California Power Company, Consolidated from $10,000,000 to $12,000,000," August 3, 1914 (PG&E, Secretary's Office, document 2092-L).

[84] NCPC, 6th Annual Report (1914); CRRC, Decisions, v. 5 (July 1, 1914 to December 31, 1914) pp. 639-644.

[85] CRRC, Decisions, v. 9 (1916) pp. 123-133; NCPC-C, 7th Annual Report (1915). As a further assist to the Consolidated Company the Railroad Commission in 1916 blocked the application of the Sierra Electric Company to construct two new hydroelectric plants on Digger Creek, a tributary of North Battle Creek. The Commission noted in rendering its decision that the existing utility [NCPC-C] had sufficient surplus capacity to supply all the demands of the territory and that there was not sufficient business to permit both the existing utility and the petitioners to earn a reasonable return (NCPC-C, 8th Annual Report [1916]).

[86] JE, v. 29 (October 26, 1912) p. 374; NCPC-C, 4th Annual Report (1911-1912); NCPC-C, 5th Annual Report (1912-1913).

[87] JE, v 32 (January 31, 1914) p. 111; NCPC, 6th Annual Report (1914); CRRC, Decisions, v. 3 (July 1, 1913 to December 31, 1913) pp. 585-586.

[88] JE, v. 32 (January 31, 1914) p. 111.

[89] Fowler, Hydroelectric Systems of California, pp. 969-971, and NCPC-C, Annual Reports from 1909 to 1914.

[90] NCPC-C, 6th Annual Report (1914) uses the term "income" instead of "revenue".

[91] In 1912 Noble was the largest stockholder in the Northern California Power Company. He owned 8500 shares, his daughters Hebe and Grace 4000 more. Detert did not even appear on a list of major stockholders. In 1919 W.J. Detert owned 14,598 shares; W.F. Detert 6795 shares, and Noble only 1200 shares (he was the 17th largest stockholder). For major stockholders in 1912 see: CRRC, "Opinions and Legal Documents," application no. 156 (filed July 19, 1912) [CSA]; for 1919 stockholders see CRRC, "Annual Report of the Northern California Power Co. to the Railroad Commission of California, for the 9 mos. ending September 30, 1919," p. 17 (CSA).

[92] CRRC, Decisions, v. 11 (1916) p. 64.

[93] CRRC, Transcripts [of Hearings], cases 675, 676, 677, 711, v. 3 (February 2, 1916) p. 116; CRRC, Decisions, v. 11 (1916) pp. 38, 49.

[94] For statistics on copper production see, CSMB, 17th Report (1921) p. 491; for NCPC-C's revenues see: NCPC-C, 9th Annual Report (1917) and 10th Annual Report (1918).

[95] CRRC, Decisions, v. 11 (1916) pp. 66-68.

[96] Ibid., p. 49.

[97] For the growth of rice cultivation in the area and its demand for electric power see C.F. Adams, "Pumping Plants for Rice Irrigation," JE, v. 37 (1916) pp. 117-119. See also, NCPC-C, 8th Annual Report (1916) and 10th Annual Report (1918).

[98] JE, v. 42 (March 15, 1919) p. 287.

[99] NCPC-C, 6th Annual Report (1914) through 10th Annual Report (1918).

[100] For 1912 figures see Van Norden, "New Hydroelectric Plant," p. 237; for 1915 figures see CRRC, Decisions, v. 11 (1916) p. 48.

[101] NCPC-C, 8th Annual Report (1916). There were also some minor line extensions in this period. In 1916, for instance, lines were extended south from College City 10 miles to Dunnigan and westward from Balaklala towards Weaverville to link up with the Western States Gas and Electric Company (ibid.).

[102] See the revelant NCPC-C Annual Reports and Fowler, Hydroelectric Systems of California, p. 972.

[103] NCPC-C, 6th Annual Report (1914).

[104] See the relevant Annual Reports, or Fowler, Hydroelectric Systems of California, p. 972.

[105] NCPC-C, 10th Annual Report (1918).

[106] Ibid., for Northern California's difficulties with higher materials prices; Pacific Gas and Electric Company, 12th Annual Report (Fiscal Year ended December 31, 1917) p. 23, for the specific price increases for copper wire and cast iron pipe.

[107] CRRC, Report (July 1, 1917 to June 3, 1918) pp. 55-56, 94; and "Hydro-Electric Power in Northern and Central California," Western Engineering, v. 9 (1918) pp. 97-99.

[108] CRRC, Report (July 1, 1917 to June 30, 1918) pp. 61-62, 67.

[109] NCPC-C, 10th Annual Report (1918). See also E.H. Steele, "The 'Pacific Service' End of the Oregon-California Chain of High-Tension Transmission Systems," Pacific Service Magazine, v. 11 (1919-1920) pp. 3-7, and Frederick S. Myrtle, "From the Mountains of Oregon to the Bay of San Francisco: By Inter-Connection of Three High-Tension Transmission Systems," Pacific Service Magazine, v. 10 (1918-1919) pp. 236-247.

[110] NCPC-C, 10th Annual Report (1918). The interconnection was not completed until early 1919, see JE, v. 42 (January 1, 1919) p. 46.

[111] NCPC-C, 9th Annual Report (1917).

[112] See the 8th Annual Report through the 10th Annual Report (1916 to 1918).

[113] CRRC, Decisions, v. 17 (June 30, 1919 to March 31, 1920) p. 284; "Railroad Commission of the State of California, Application #4789, Decision #6681," September 23, 1919 (PG&E, Secretary's Office, document 2092-e).

[114] CRRC, Decisions, v. 16 (September 1, 1918 to June 30, 1919) pp. 684-693.

[115] J.G. White & Co., "Report," p. 89.

[116] J.G. White & Co., "Report," pp. 90-91; Redding Searchlight, July 1, 1909; "Chronology of Northern California Power Co. Activities in Big Bend of Pit River - Pit 5 Project," MS, 2 pp. (PG&E Library).

[117] In the "NCPC Scrapbook" of newspaper clippings relating to the Northern California Power Company there is an item headlined: "Pit River Power", dated November 10, 1906 [p. 43 of the scrapbook], referring to the creation of a Pit River Power Company. There is a handwritten note on the clipping which reads: "H.H.N. [presumably H.H. Noble], These fellows going poaching on your preserve".

[118] J.G. White & Co., "Report," pp. 92-93; "Chronology of NCPC Activities on Pit River".

[119] Redding Courier Free Press, July 1, 1909; Redding Searchlight, July 1, 1909; J.G. White & Co., "Report," p. 91.

[120] San Francisco News Bulletin, December 9, 1910. The history of NCPC's "Big Bend" project up to 1910 is reviewed in J.G. White & Co., "Report," pp. 88-94.

[121] Redding Courier Free Press, January 4 and July 13, 1910; "Chronology of NCPC Activities on Pit River".

[122] NCPC-C, 3rd Annual Report (1910-1911); Redding Courier Free Press, November 15, 1911.

[123] NCPC-C, 3rd Annual Report (1910-1911); JE, v. 27 (October 28, 1911) p. 409; CRRC, Report (July 1, 1917 to June 30, 1918) pp. 62-63.

[124] Redding Courier Free Press, October 18, October 28, and November 15, 1911.

[125] NCPC-C, 3rd Annual Report (1910-1911).

[126] "NCPC Scrapbook," p. 43 ("Pitt River Power," 11-10-06).

[127] JE, v. 38 (May 15, 1917) p. 419; Red Bluff Daily Peoples' Cause, May 17, 1910.

[128] JE, v. 38 (May 15, 1917) p. 419.

[129] JE, v. 38 (June 1, 1917) p. 465; PG&E, 12th Annual Report (1917) p. 21.

[130] CRRC, Report (July 1, 1917 to June 30, 1918) p. 63.

[131] NCPC-C, "Pit River Construction Records," September 1917 - September 1919 (R/V). The Northern California Power Company was purchasing land along the Pit in connection with its project as late as the summer of 1919 (JE, v. 43 [July 15, 1919] p. 94).

[132] JE, v. 43 (July 15, 1919) p. 94.

[133] CRRC, Decisions, v. 17 (1919-1920) p. 285.

[134] Ibid., p. 284; "Railroad Commission of the State of California, Application #4789, Decision #6681," September 23, 1919, p. 6 (PG&E, Secretary's Office, document 2092-e).

[135] Fowler, Hydroelectric Systems of California, p.285; see CRRC, "Annual Report of the Northern California Power Co. to the Railroad Commission of California, for the 9 mos. ending September 30, 1919," 60 pp. for the holdings and status of the company at the time of the PG&E purchase.

[136] CRRC, Decisions, v. 17 (1919-1920) p. 287.

[137] Fowler, Hydroelectric Systems of California, p. 141.

[138] CRRC, Decisions, v. 17 (1919-1920) pp. 280, 286; "Offer of Pacific Gas and Electric to W.F. Detert," June 12, 1919 (PG&E, Secretary's Office, document 2092); "Resolution Duly Adopted by the Board of Directors of the Pacific Gas and Electric Company," April 19, 1920 (PG&E, Secretary's Office, document 2242-c); "Letter to 'Stockholders of the Northern California Power Company, Consolidated' explaining terms of sale to Pacific Gas and Electric Company," June 17, 1919 (PG&E, Secretary's Office, document 2092-c).

[139] CRRC, Decisions, v. 17 (1919-1920) pp. 286-289; "Protest and Objections of Stockholders of Northern California Power Company, Consolidated Before the Railroad Commission of the State of Californis," August 1919 (PG&E, Secretary's Office, document 2092-j).

[140] CRRC, Decisions, v. 17 (1919-1920) pp. 279-291.

[141] "Agreement Between Pacific Gas and Electric Company and Northern California Power Company, Consolidated," October 3, 1919 (PG&E, Secretary's Office, document 2092); PG&E, 14th Annual Report (1919) pp. 12, 17.

[142] PG&E, 14th Annual Report (1919) p. 12: "This is the most important addition to its system within recent years". See p. 13 for a year by year breakdown of the value of property acquired.

POSTSCRIPT

The Battle Creek Hydroelectric System in the PG&E Years (1919-1980)

The Battle Creek system was the heart of Northern California Power Company's system, providing almost 90% of the utility's generating capacity. It was, however, only a minor element in the much larger Pacific Gas and Electric Company's system. Hence after 1919 its relative importance was sharply diminished. Some changes were made in the system and some new elements added, but none of these were as radical as the changes made between 1900 and 1912, when Northern California Power was actively at work on Battle Creek.

The greatest of the changes which were made came at Volta. By the middle of the 1920's the equipment in the 1901 section of the powerhouse was obsolete and in need of extensive repairs. Since these repairs would entail considerable expense, Pacific Gas and Electric elected to completely re-equip the old section of the powerhouse and make it compatible with the 1906, 1907, and 1908 equipment. Thus the three original 750 kVA, 500 volt units were replaced in 1926 with a single 3000 kVA, 2200 volt unit. The higher operating voltage of the new unit made it necessary to completely rewire the older portion of the station, but made it possible to consolidate the new switchboard with the 1906 and 1908 switchboards and to operate the plant as a single powerhouse with one operator instead of as two powerhouses under the same roof with two operators. At the same time the original air-cooled transformers were replaced by larger water-cooled transformers and the last remnants of the original Northern California Power Company 22 kV transmission system were abandoned. [1]

There were several relatively significant changes in the water system. The most important addition was the Wildcat Canal, constructed in 1923. This canal diverted around 20 second-feet of water from North Battle Creek, feeding it into the Coleman Canal before it entered either of its siphons. The most significant subtraction from the system was Manzanita Lake. It was deeded to the United States Government for the Lassen Volcanic National Park in February of 1931. In addition, the Al Smith Canal replaced the Upper Mill Creek Canal as one of the major feeders for diverting water from North Battle Creek to Millseat Creek.

A number of other changes in the system resulted from the Battle Creek system's incorporation in a large, interconnected, electrical production and distribution system. The most important of these changes was the conversion of the Battle Creek plants to semi-automatic operation. This was possible because PG&E, unlike Northern California Power, could depend on the natural regulating characteristics of a large system and on a few large "live" hydro and steam units for frequency control. Conversion to semi-automatic operation involved the installation of forebay water level controls and systems to automatically shut down the plant in case of overloads. It required replacing the governors with hydraulic controllers equipped with motors to operate the needle nozzles and/or deflectors. Conversion to semi-automatic operation also entailed the installation of either motor-generator exciter units with auxiliary storage batteries or belt-driven exciters in place of the original water-driven exciters (although the latter were sometimes retained as an auxiliary method for restarting the plants). South, the most inaccessible of the Battle Creek powerhouses, was converted to semi-automatic operation in 1930. [2] The other three plants were modified in a similar manner in 1959.

By the middle of the 1960's much of the equipment installed in the Battle Creek powerhouses was approaching obsolescence and requiring increasingly more frequent repair. Thus in 1969 the Pacific Gas and Electric Company applied to the Federal Power Commission for permission to replace all four of the original Battle Creek plans with more modern facilities which could be operated at higher efficiencies and with reduced labor forces. [3]

The new powerhouses, located adjacent to the older powerhouses, are reinforced concrete structures, housing but a single generating unit and designed to be operated unattended. At Volta the three impulse wheel and generator units were replaced by a single unit with a two nozzle, horizontal impulse wheel, each nozzle independently connected to one of the two existing penstocks. At South and Inskip the impulse wheel units were replaced with single vertical-shaft Francis turbines. And at Coleman the three old horizontal-shaft Francis turbines were replaced with a single vertical-shaft Francis turbine. A single three phase transformer at Volta, South, and Inskip replaced the banks of single phase transformers previously used. These modifications, according to PG&E estimates, should increase the capacity of the Battle Creek system, beginning in 1980, by around 15%, from 30,200 kW to 34,650 kW.

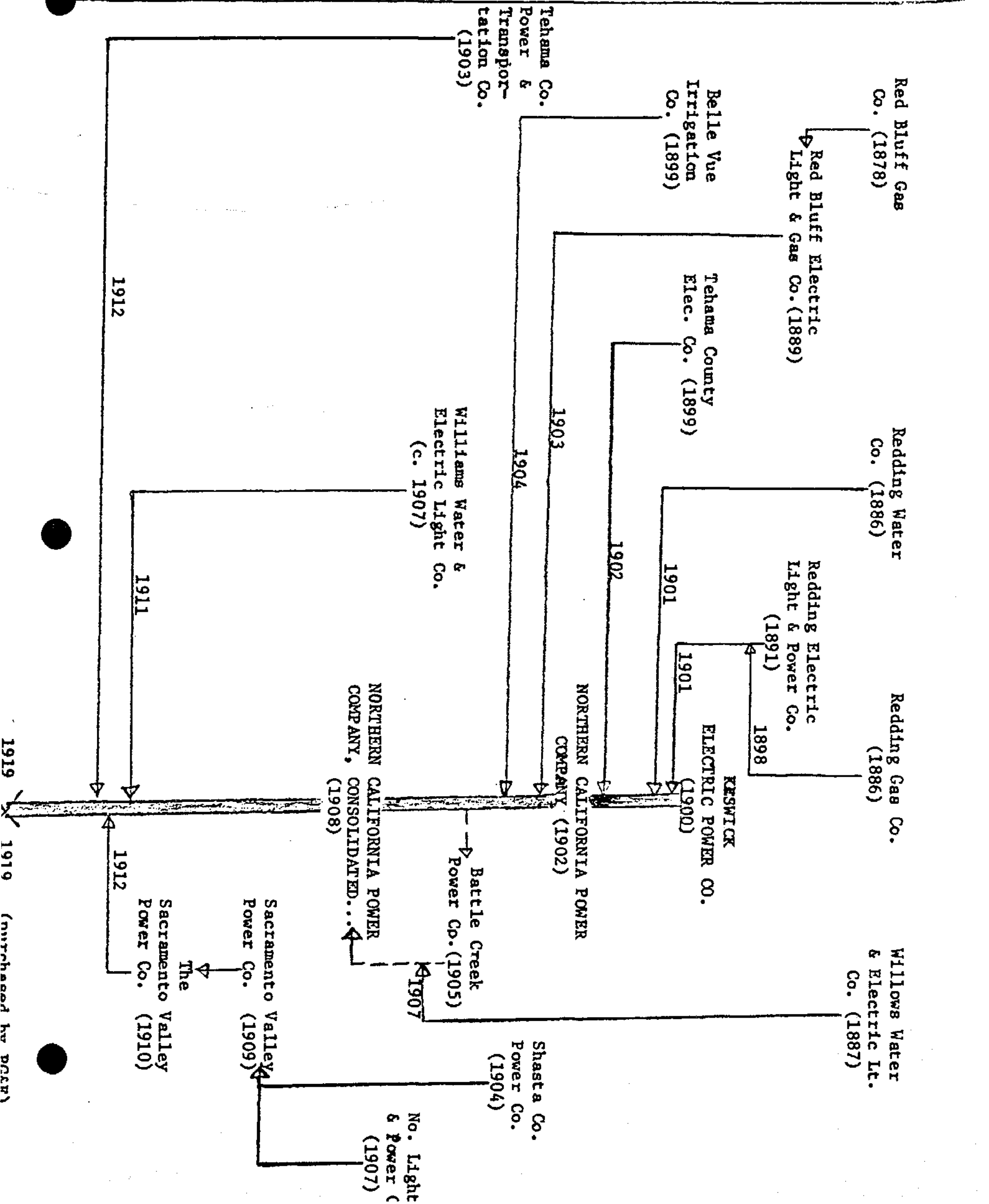
NOTES

[1] PG&E, Engineering Central File #430. This has a 1926 memorandum on alterations planned or made for Volta, plus several letters, work orders, and General Manager's Authorizations dealing with the 1926 modifications to Volta.

[2] PG&E, Engineering Central File #430, "South": There are several letters dating from 1930 and a General Manager's Authorization dating from 1929 which discuss the conversion of South to semi-automatic operation.

[3] Pacific Gas and Electric Company, "Application of Pacific Gas and Electric Company for License, before the Federal Power Commission: Battle Creek System Project 1121," October 31, 1969, reviews the system as it stood in 1969 and outlines the changes proposed by PG&E for the system. See also: "New License Sought for U.S. Plant," Water Power, v. 23 (1971) p. 193.

APPENDIX I: CORPORATE FAMILY TREE OF NORTHERN CALIFORNIA POWER COMPANY



APPENDIX II

THE BATTLE CREEK HYDROELECTRIC SYSTEM — BASIC DATA

THE STORAGE RESERVOIRS	dam type	length	height	width base	width crest	acres flooded	storage capacity (acre-feet)
Lake Nora (1901)	earth fill	1504	14	59	12	3.5	14.9
Lake Grace (1906)	earth fill	1688	16	67	10	6.5	25.1
Macumber (1906-1907)	part masonry;	187	27	26	8		
	part earth & rock fill	2233	12	59	15		
		2420				143	1213
Manzanita (1910)	earth fill						
	#1	469	14	55	15	60	500
	#2	212	5.5	18	4		
Baldwin (1910-1911)	earth fill	1176	25	84	7	23	173.6
Coleman Forebay (1911)	earth and rock fill	2604	20	69	11	11.7	72.9
North Battle Creek Reservoir (1909-1912)	masonry	439	56*	79	22	130	1827

* with flashboards 10 feet high; masonry portion is only 46 feet high

The data presented in this appendix has been gleaned from a number of sources, particularly: the 1924, 1930, and 1969 PG&E applications to the Federal Power Commission; Fowler's Hydroelectric Systems of California; Van Norden's articles on the Northern California Power Company and other articles on the company in the Journal of Electricity; and the Valuation Survey Field Books of the Northern California Power Company (R/V). These sources of information often give conflicting data. Hence the figures in this appendix must be regarded as approximate rather than exact in many cases.

THE PLANTS:

	Head (ft.)	Installed Generating Capacity in kVA's	Average Output 1911 - 1927
Volta (1901, 1907, 1908)	1204 1254	6250	4032
South (1910)	516	4000	3207
Inskip (1910)	378	6000	3611
Coleman (1911)	482	15000	5700

THE PENSTOCKS:

	length (ft)	Construction
Volta		
L. Nora	6658	Wood stave (2146'); lap-welded steel (4512')*
L. Grace	8896	Wood stave (3108'); lap-welded and lap-riveted steel (5788')**
South	1805	Lap-riveted steel
Inskip	3194	Wood stave (2145'); lap-riveted steel (1049')
Coleman		
A.	3752	Lap-riveted steel
B.	3751	Lap-riveted steel

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*The wood stave portion of the Lake Nora penstock was replaced with steel in 1912.

**The old wood stave portion of the Lake Grace penstock was replaced in 1920 by 1400 feet of new wood stave penstock and steel pipe.

WATER TURBINES

	Make	Diameter of Rotor (in.)	Output (hp)	Arrangement	Speed Control
Volta					
1-3 (1901-02)	Pelton	64	1500	self-mounted	deflecting nozzle
4 (1907)	Doble	86	3500	single overhung	needle nozzle w/bypass
5 (1908)	Pelton	76	4000	single overhung	deflecting needle nozzle
South					
1 (1910)	Doble	66	6000	double overhung (2 rotors)	needle nozzle w/cyl. deflector
Inskip					
1 (1910)	Pelton	48	6000	triple rotor dual nozzle	needle nozzle w/hood deflector
2 (1910)	Pelton	48	3500	triple rotor single nozzle	needle nozzle w/hood deflector
Coleman					
1-3 (1911)	Allis-Chalmers	34	7000	horizontal shaft "Francis" turbine (single runner, overhung)	wicket gate

THE EXCITER UNITS

	Make of Impulse Wheel	Output (hp)	speed (rpm)	Make of dc generator	Output (kW)
Volta					
1-2 (1901)	Pelton	90	850	West.	45
3 (1906-07)	Doble	92	850	West.	45
4 (1908)	Pelton	90	975	G.E.	45
South					
1 (1910)	Doble	80	350	West.	55
Inskip					
1-2 (1910)	Pelton	120	625	G.E.	60
Coleman					
1-2 (1911)	Allis-Chalm.	350	525	A-C	225

THE GENERATORS

	Make	Type (revolving-)	Voltage	Speed (rpm)	Output (kVA)
Volta					
1-3 (1901-02)	Westinghouse	armature	500	400	750
4 (1906-07)	Westinghouse	field	2200	300	2000
5 (1908)	General Elec.	field	2200	300	2000
South					
1 (1910)	Westinghouse	field	6600	225	4000
Inskip					
1 (1910)	Westinghouse	field	6600	225	4000
2 (1910)	Westinghouse	field	6600	225	2000
Coleman					
1-3 (1911)	Allis-Chal.	field	6600	450	5000

THE TRANSFORMERS

	No.	Make	Cooling	Primary/ Secondary	Phases	Capacity (kW)
Volta						
1901-02	10	Westinghouse	air	.5/22 kV	1	300
1906	3	General Elec.	water	2.2/66 kV	1	875
	4	Westinghouse	water	22/66 kV	1	1250
1908	3	General Elec.	water	2.2/66 kV	1	875
South						
1910	3	General Elec.	water	6.6/66 kV	1	1500
Inskip						
1910	6	General Elec.	water	6.6/66 kV	1	1500
Coleman						
1911	4	General Elec.	water	6.6/66 kV	3	4000

APPENDIX III

The Powerhouse Settlements of the Battle Creek Hydroelectric System

Because the Battle Creek hydroelectric plants were far from established transportation systems and urban centers, and because transportation in the early twentieth century, when few had automobiles, was slow and uncertain, housing had to be provided for the operators, foremen, and line and ditch inspectors and repairmen around each of the Battle Creek powerhouses. Typically, the operation of a medium size hydroelectric plant like those on Battle Creek required three operators, one for each eight hour shift, plus a foreman and several men to periodically run the ditch and transmission lines.

The number, arrangement, and style of the buildings which housed these men differed from plant to plant in the system. But each settlement contained at minimum a clubhouse, a barn, and several individual cottages, while most contained more. The clubhouse, generally a two-story wood structure, with four to six bedrooms, served as the residence, dining hall, and recreation center for unmarried employees at each plant. Men residing at the clubhouse purchased their meals from the company. The barn or barns were used to stable the horses used by the men who patrolled and repaired the ditches and high voltage lines. The individual cottages housed the foremen and employees with families.

All of the Battle Creek settlement structures were wood framed and provided with running water, electricity, and a fireplace for heating. The clubhouses, barns, and the majority of the cottages were erected by company carpenters during the construction of the powerhouse itself. A few of the single family cottages, however, were constructed by their occupants later, using materials supplied by the company, but with Northern California Power retaining ownership of the structure. In addition to the barns and houses, there were both private and company hen houses, meat sheds, pig pens, wagon sheds, wood sheds, vegetable gardens, and the inevitable outhouses.

Volta long had the largest settlement, since it was from Volta that the entire system was controlled. In addition to the usual domestic and animal housing common to all the settlements, Volta had a machine shop, a sawmill, and a blacksmith shop. These supplied the rest of the system with finished lumber and spare parts. Inskip's settlement (the only one substantially intact today [1979]) was nearly as large as Volta's and had a dancing platform and orchestra platform, built by the operators. [1]

The most elaborate residence in the system was H.H. Noble's home. In 1901 Noble built a massive circular stone "castle" on the ridge above Volta. [see HAER photo 169] The Noble family resided there until fire destroyed the structure in 1917. [2]

See: HAER photos 160-168 for pictures of the powerhouse settlements
HAER drawing, sheet 3 of 20, for maps showing parts of the Volta and Inskip settlements

[1] Information on the powerhouse settlements has been gleaned from the following sources: NCPC-C, Valuation Survey Field Book
2 (H-2), Volta, pp. 1-70
3 (H-3), Volta, pp. 1-72
5 (H-26), South, pp. 23-77
7 (H-7), Inskip, pp. 31-58
8 (H-31), Inskip, pp. 1-14
10 (H-10), Coleman, pp. 1-72
11, Coleman, pp. 1-72
12 (H-12), Coleman, pp. 1-74.

[2] Sacramento Bee, October 18, 1959, p. 16.

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Red Bluff Daily News (Red Bluff, California)

Red Bluff News

Red Bluff Peoples' Cause

Red Bluff Daily Peoples' Cause

Red Bluff Weekly Peoples' Cause

Red Bluff Sentinel

Redding Courier Free Press (Redding, California)

Redding Free Press

Redding Searchlight

Redding Semi-Weekly Searchlight

San Francisco Call (San Francisco, California)

II. CALIFORNIA RAILROAD COMMISSION AND CALIFORNIA STATE MINING BUREAU DOCUMENTS

A. Published Documents (page numbers refer to items on the NCPC)

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v. 2 (January 1, 1913 to June 30, 1913) pp. 761, 902-905.
v. 3 (July 1, 1913 to December 31, 1913) pp. 584-589.
v. 5 (July 1, 1914 to December 31, 1914) pp. 639-644.
v. 9 (January 1, 1916 to April 30, 1916) pp. 123-133.
v. 11 (September 1, 1916 to November 30, 1916) pp. 37-83, 546-553.
v. 12 (December 1, 1916 to June 30, 1917) pp. 630-634.
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July 1, 1916 to June 30, 1917, pp. 95, 319, 333, 347, 357, 373.
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17th Report of the State Mineralogist (1921)
18th Report of the State Mineralogist (1923)
20th Report of the State Mineralogist (1924)
22nd Report of the State Mineralogist (1926)

B. Unpublished Documents (stored in the California State Archives [CSA])
[These are arranged chronologically]

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v. 2: December 28, 1912, hearing

California Railroad Commission. "Exhibita," application no. 156, 1912. The primary item among the exhibits is: J.G. White & Co., "Report on Northern California Power Company Consolidated by J.G. White & Co. (to N. W. Halsey & Co., January 29, 1910)," 102 pp.

California Railroad Commission. "Memoranda and Correspondence," application no. 156, 1912.

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A) "Applicaton of Norther California Power Company for Order Authorizing it to Issue $500,000, 5 yr. 6% debenture notes," filed July 19, 1912.
B) Transcript [of Hearing], August 14, 1912.

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v. 1: September 14, 1915, hearing
v. 2: November 4, 1915, hearing
v. 3: February 2, 1916, hearing

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III. NORTHERN CALIFORNIA POWER COMPANY ANNUAL REPORTS (available CSA)

Northern California Power Company:
First Annual Report, for the Year Ending February 28, 1903.
Second Annual Report, for the Year Ending February 29, 1904.
Third Annual Report, for the Year Ending February 28, 1905.
Fourth Annual Report, for the Year Ending February 28, 1906.
Fifth Annual Report, for the Year Ending February 28, 1907.
Sixth Annual Report, for the Year Ending February 29, 1908.

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First Annual Report, for the Year Ending October 31, 1909.

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Fourth Annual Report, for the Year Ending October 31, 1912.
Fifth Annual Report, for the Year Ending October 31, 1913.
Sixth Annual Report, for the Year Ending December 31, 1914.
Seventh Annual Report, for the Year Ending December 31, 1915.
Eighth Annual Report, for the Year Ending December 31, 1916.
Ninth Annual Report, for the Year Ending December 31, 1917.
Tenth Annual Report, for the Year Ending December 31, 1918.

Note: All of the above can be found in the California State Archives (CSA) with the records of the California Railroad Commission. The PG&E Library has all of the reports except the First, Second Third, Fourth, and Sixth of the Northern California Power Company.

IV. PACIFIC GAS AND ELECTRIC COMPANY RECORDS

A. Pacific Gas and Electric Company Annual Reports

Pacific Gas and Electric Company:
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Thirteenth Annual Report, for the Fiscal Year Ended December 31, 1918.
Fourteenth Annual Report, for the Fiscal Year Ended Decmeber 31, 1919.

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"Articles of Incorporation of Northern California Power Company," March 14, 1902 (document 2134-a).

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"Certificate of Proceedings Authorizing the Creation of Bonded Indebtedness of Keswick Electric Power Company," March 5, 1901 (document 1569-b).

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"Deed of Trust: Keswick Electric Power Company to Mercantile Trust Co. of San Francisco, Trustee," June 1, 1901 (document 1569-c).

"Deed of Trust: Northern California Power Company," June 1, 1902 (document 2257-a).

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"Financial agreement between H.H. Noble and Northern California Power Company, Consolidated," August 11, 1915 (document 2092-a).

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"Resolution of Board of Directors of Northern California Power Company, Consolidated," July 12, 1919 (document 2092).

"Statement of Edward Whaley regarding deht of H.H. Noble to Northern California Power Company, Consolidated," February 25, 1919 (document 2092-h).

(Northern California Power Company, Consolidated, Valuation Records (now in Pacific Gas and Electric Company Rates and Valuations Department [R/V] records)

Note: The Rates and Valuations Department of PG&E has in its storage collection a large number of Valuation Survey Field Books (in pencil) dating from the period 1912 to 1916. The Field Books, apparently from several different valuation surveys, are interfiled and numbered in different ways. Most are given a number prefixed by an "H", e.g. H-12, plus a Field Book number (as Field Book 3). But some have only the "H" number; others have only a Field Book number. It proved impossible to arrange the books in any logical sequence using the numbers printed in ink on the spines or front covers. Moreover, some of the books were missing. The materials used from the PG&E Rates and Valuations records are therefore listed below by "subject".

<u>Volta and Water System Above Volta:</u>

			PG&E Rates & Valuations Records Box no.
Field Book 1	(H-1)	Volta-Buildings (powerhouse)	10952
2	(H-2)	Volta-Outbuildings	10952
3	(H-3)	Volta-Camp Buildings	10952
4	(H-8)	Volta-Factory, Strainer, Governor system, etc.	10952
4	(H-28)	Volta-Penstocks, hydraulic equip.	10953
13	(H-24)	Battle Ck. Reservoir & ditch surveys	10953
14		Ditches above Volta	10952
15	(H-16)	Ditches above Volta	10952
16	(H-35)	Macumber,Manzanita, ditches above Volta	10953
	(H-17)	Volta: Ditches, Schooling ditch	10952
17	(H-43)	Ditches above Volta	10953
	(H-18)	Volta: Equipment, Tools, Stock	10952
18	(H-15)	Macumber Reservoir and Dam	10952
20	(H-25)	North Battle Creek Res.	10952
	(H-1)	Volta: Forebay Reservoirs & Water System	10952
	(H-2)	Volta: Misc.	10952
	(H-42)	Mill Creek Ditch; Ditches above Volta	10953
Valuation Detail Folder no. 5: Volta			10946

<u>South and South Water System:</u>

Field Book 3	(H-11)	Ditches from Volta-South	10952
5	(H-18)	Ditches from Volta-South	10952
5	(H-26)	South: Powerhouse building	10953
6	(H-13)	South: ditches	10952
6	(H-27)	South: Penstocks, Forebay, etc.	10953
7	(H-10)	South Battle Creek Ditch	10952
14	(H-12)	Miscellaneous ditches	10952
Computation Folder no. 16, Supporting Valuation Folder #3 (South: Union Canal)			10944

	R/V Box
Computation Folder no. 17, Supporting Valuation Folder #3 (South: South Battle Creek Canal)	10944
Computation Folder no. 18, Supporting Valuation Folder #3 (South: Cross Country Canal)	10944
Computation Folder no. 19, Supporting Valuation Folder #3 (South: Fuller Ditch)	10944
Computation Folder no. 20, Supporting Valuation Folder #3 (South: Child's Ditch)	10944

Inskip and Inskip Water System:

Field Book 7	(H-7)	Inskip: Buildings, Powerhouse, etc.	10952
7	(H-10)	Inskip Canal	10952
8	(H-23)	Eagle Canyon-Inskip Foregay	10953
8	(H-31)	Inskip: Forebay, Penstocks, Exciter and Governor systems, etc.	10953
9	(H-14)	Inskip: Ditches	10953
17	(H-30)	Inskip: Equipment, Tools, etc.	10953
20	(H-20)	Inskip: Outside wiring, tools, etc.	10952

Computation Folder no. 22, Supporting Valuation Folder #2 (Inskip Penstock)	10945
Computation Folder no. 24, Supporting Valuation Folder #2 (Inskip Ditch)	10945
Recapitulation (Eagle Canyon Ditch)	10946

Coleman and Coleman Water System:

Field Book 1	(H-20)	Coleman Canal	10953
2	(H-21)	Coleman Canal	10953
3	(H-19)	Coleman Canal (incl. siphon #1)	10952
4	(H-22)	Coleman Forebay and Canal	10953
9	(H-9)	Coleman: Powerhouse, Buildings	10952
10	(H-10)	Coleman: Outbuildings	10952
11		Coleman: Camp and Outbuildings	10952
12	(H-12)	Coleman: Outbuildings	10952
13	(H-33)	Coleman: Temporary Buildings and Forebay	10953
14	(H-14)	Coleman: Electrical Equipment; Penstocks	10952
15	(H-34)	Coleman: Misc. tools and equip.	10952
16	(H-16)	Coleman: Misc. equipment	10953
21	(H-21)	Coleman: Ditch Apparatus	10953
22		Coleman: Ditch Apparatus	10953
23	(H-23)	Coleman: Ditch Apparatus	10953
24	(H-24)	Coleman: Ditch Apparatus	10953
25	(H-25)	Coleman: Ditch Apparatus	10953

Miscellaneous:

Field Book 4	(H-2)	Cow Creek Powerhouse	10952
10	(H-7)	Kilarc Powerhouse	10952
11	(H-5)	Kilarc Powerhouse	10952
12	(H-6)	Kilarc Powerhouse	10952

			R/V Box
Field Book	15 (H-4)	Snow Creek Powerhouse	10952
	16 (H-29)	Snow Creek Powerhouse	10952
	18	Miscellaneous #2	10952
	19	Miscellaneous #3	10952

"Pitt River Construction Records"	10946
"J.G. White Co. Valuation Survey: Power Plant Cost Data"	10946

D. Pacific Gas and Electric Company: Engineering Central File Documents

Volta (Records Center Box no. 11964)
South (Records Center Box no. 11961)
Inskip (Records Center Box no. 11721)
Coleman (Records Center Box no. 11716)

Homberger, Heinrich. "Efficiency Test Units No. 1 & 2, Inskip Power House, December 1st and 2nd, 1910," with attached letters from 1912, file #430.

Most of the data in these files are short letters which deal with alterations made to the Battle Creek powerhouses after PG&E's acquisition of the system.

E. Pacific Gas and Electric Company: Federal Power Commission Applications for the Battle Creek Hydroelectric System:

Pacific Gas and Electric Company, "Exhibits "I", "L", and "M" of [Application to Federal Power Commission relative to Battle Creek System], November 10, 1924. (Attached to J.O. Burrage to A.H. Markward, November 10, 1924, Engineering Central Files) [FPC-1924]

Pacific Gas and Electric Company. "Application of Pacific Gas and Electric Company for a License for Project No. 1121, California [Battle Creek System], filed September 12, 1930. [FPC-1930]

Pacific Gas and Electric Company. "Application of Pacific Gas and Electric Company for License before the Federal Power Commission: Battle Creek System Project 1121," October 31, 1969. [FPC-1969]

F. Miscellaneous Manuscripts in the Pacific Gas and Electric Company Library:

"Chronology of Northern California Power Co. Activites in Big Bend of Pit River: Pit 5 Project," 2 page manuscript, May 1946.

Downing, P.M. "Some Historical Aspects of the Development of Hydroelectric Power in California," 27 page manuscript. Prepared in 1940 for delivery to Newcomen Society of North America, never delivered due to World War II.

Goldsworthy, Paul A. "Hydro-Electric Development 1895-1925, Pacific Gas and Electric Company and Subsidiaries". Basically installation records of PG&E hydroelectric plants with attached bibliographies.

"Northern California Power Company Scrapbook of Newspaper Clippings". Clippings dated 1906 to 1912; source of clippings not indicated on most clippings; date not indicated on some.

V. OTHER MANUSCRIPT RECORDS

Arthur Jeffcoat Letter Copy Book. Used with the permission of the present owner Mr. Leroy Freemyers, Red Bluff, California. Letters and requisitions dating from between August 13, 1906, and July 31, 1910.

Lind, Nancy. "The Use of Manzanita Lake for Water Storage, 1910-1931," 15 page MS, 1970. (Tehama County Library, Red Bluff, California) A high achool term paper.

Carl J. Rhodin Papers, California Water Resources Library, University of California, Berkeley. Rhodin was employed by the J.G. White Co. and reviewed construction projects of the Northern California Power Company in 1911 for J.G. White. There are four letters in the Rhodin papers dealing with the Northern California Power Company's work.

Scott, Mike. "The History of the Hat Creek-Lost Creek Diversions, 1904-1915," 18 page MS, 1975. (Tehama County Library, Red Bluff, California) A high school term paper.

ADDENDUM:

Myrtle, Frederick S. "From the Mountains of Oregon to the Bay of San Francisco: By Inter-Connection of Three High-Tension Transmission Systems," Pacific Service Magazine, v. 10 (1918-1919) pp. 236-247.

Steele, E.H. "The 'Pacific Service' End of the Oregon-California Chain of High-Tension Transmission Systems," Pacific Service Magazine, v. 11 (1919-1920) pp. 3-7.

ADDENDUM TO: HAER CA-2
BATTLE CREEK HYDROELECTRIC SYSTEM *HAER CAL,52-REBLU.V,1-*
(Coleman Power House)
(Inskip Power House)
(South Power House)
(Volta Power House)
Battle Creek & Tributaries
Red Bluff vicinity
Tehama County
California

FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001