Hardy Hydroelectric Plant
6928 East 36th Street
Newaygo Vicinity
Newaygo County
Michigan

HAER No. MI-100

PHOTOGRAPHS

WRTTTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
United States Department of the Interior
National Park Service
Great Lakes Systems Office
1709 Jackson Street
Omaha, Nebraska 68102-2571

HISTORIC AMERICAN ENGINEERING RECORD

HARDY HYDROELECTRIC PLANT

HAER No. MI-100

Location: 6928 East 36th Street
Newaygo Vicinity
Newaygo County
Michigan

UTM: 16:610380:4815970 (NW point)
16:610990:4815480 (SE point)

Quad: Croton

Dates of Construction: 1929-1931

Engineer: Edward M. Burd, head of civil and hydraulic engineering for Consumers Power Company, Jackson, Michigan, 1921-1929

Present Owner: Consumers Energy Company (formerly Consumers Power Company), Jackson, Michigan

Present Use: Hydroelectric generating plant

Significance: Consumers Power Company built the Hardy Hydroelectric Plant in the early 1930s as a link in its system of electric power generation. In designing and building Hardy, the company found a way to erect a stable, relatively high dam on Michigan's notoriously gravelly foundations, continuing its tradition of developing solutions to the problems presented by the state's geography and geology. The design process for the dam also appears to reflect a tendency in American civil engineering to use established regional practices over technology developed elsewhere.

Project Information: This documentation was prepared by Consumers Power Company (CPCo) in conformance with its Cultural Resources Management Plan for the Muskegon River Hydroelectric Projects (July 1995). The plan stipulated the recordation of the entire Hardy Hydroelectric Plant (according to the standards of the Historic American Engineering Record). The documentation was completed in 1997 by Hess, Roise and Company of Minneapolis under contract with CPCo. Cynthia de Miranda served as Project Historian under the supervision of Principal Investigator Jeffrey A. Hess. Photographer Clayton B. Fraser of Loveland, Colorado, worked under a subcontract with Hess Roise.

OVERVIEW

The Hardy Hydroelectric Plant, built in the early 1930s on west-central Michigan's Muskegon River, stands as a monument to Consumers Power Company's (CPCo) interconnected system of electric power supply. The company had been generating electricity since the turn of the century, beginning with small hydro plants that produced power for local consumption. By the 1920s, CPCo had established a string of hydroelectric and coal-burning steam plants tied together with high-voltage, long-distance transmission lines that distributed power throughout Michigan's Lower Peninsula.

Such systems became increasingly common in the 1920s, allowing some plants to act as base suppliers while others stood ready to provide peak and emergency service. This strategy assured customers of an efficient and reliable power supply. Throughout the decade, demand for power grew faster than anyone anticipated. As power systems evolved, a variety of technical considerations made hydroelectric plants well-suited to serve as peak-supply plants.

The late 1920s found CPCo planning a peak-load hydro plant with a large storage pond for a site on the partially developed Muskegon River in west-central Michigan. The 100' head proposed for the plant exceeded by 30' any other CPCo development, a significant increase for a system comprising mostly low-head dams. All parties agreed that the project's size and location called for a conservative plan—failure would be catastrophic for the company as well as for communities downstream—but engineers argued over specifics. At its heart, the question weighed designs for small- to medium-sized earth dams built on Michigan's soft foundations against plans used in Western states for larger embankments founded on rock. The resolution of that debate appears to reflect a tendency of American civil engineers to use established regional practices over technology developed elsewhere.

SITE DESCRIPTION

Hardy's Embankment (HAER No. MI-100-A) stretches 2,600' across the Muskegon River at a point twelve miles northeast of the village of Newaygo. The 120'-high, semi-hydraulic earth-fill dam impounds a 3,900-acre lake for use in generating electric power. The upstream slope of the dam has a grade of 1:4 that flattens to 1:5 towards the bottom. A steeper downstream slope of 1:2 changes to 1:2.5 halfway down the Embankment; near the toe it flattens again to match the 1:5 grade of the upstream base. The dam's width approaches 1,000' at its base and narrows to 25' at its crest. A two-lane, paved road crosses the length of the dam along the crest.[1]

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[1] This description is based on: a site survey completed by the authors on 24 July 1995; engineering articles detailing the complex during construction; documents produced by Consumers Power Company; and an interview with Charles Smith, the plant's superintendent, conducted by Jeffrey Hess on 24 July 1995. See Edward M. Burd, "Hardy Dam Provides 40,000 Hp. for Michigan Peak Loads," *Power Plant Engineering* 36 (1 March 1932): 194-198; Burd, "Location and Design of Hardy Hydro Plant," *Au Sable News* 17 (August 1931): 3-6, 28-31; "Hardy Dam Goes on the Line," *Electrical World* 99 (27 February 1932): 412-413; *Consumers Power Company's Hardy*

A concrete corewall reinforces the Embankment; the corewall rises 120'-0" above the original streambed and is embedded 30'-6" upstream from the centerline of the dam. A short section of concrete facing, jointed to the top of the corewall, sheaths the portion of the upstream slope above the corewall and terminates in a vertical splashwall about 10' upstream from the centerline of the dam. The splashwall provides 10' to 11' of freeboard.

The Powerhouse (HAER No. MI-100-B) rests on a massive concrete foundation in the downstream toe of the dam near the river's east bank.[2] Clad in yellow brick, the building exhibits the Spanish Colonial Revival style popular in the 1920s and 1930s. A hipped roof covered with glazed green tile caps the two-story steel-framed Powerhouse, which looks out over the tailrace with a uniform row of six, full-height, round-arched windows on its downstream (south) facade. Contrasting brick surrounds and arch hoods further accent the windows. A single-story wing houses the control room; the wing protrudes from the east end of the Powerhouse on its upstream (north) side. Inside the Powerhouse, three vertical direct-connected General Electric generator units driven by I.P. Morris hydraulic turbines are capable of producing 10,000 KW of three-phase, 60-cycle, alternating current at 7,500 volts. East of the Powerhouse, a concrete staircase provides access from the roadway across the dam to the structures at the Embankment's toe.

The small yard immediately north of the Powerhouse accommodates an outdoor Substation (HAER No. MI-100-C). A transformer bank supported on a concrete slab foundation steps up the current to 140,000 volts for transmission to the system line. A concrete retaining wall borders the upstream (north) edge of the Substation yard. A smoke stack, built with the same yellow brick as the Powerhouse, stands at the northwestern corner of the yard. The stack was part of the steam heating system that warmed the generating room in winter: as a peak load plant, Hardy could not rely on its own electricity for heat. The plant currently makes use of electric heaters powered through the Substation during the winter months.

North of the Powerhouse, about 96' upstream from the centerline of the dam, the Intake Tower (HAER No. MI-100-D) emerges from the waters of Hardy's pond and serves as an emblem for the entire plant. Built of the same materials in an identical architectural style as the Powerhouse, the Intake Tower houses hoisting mechanisms for the penstocks' head gates. The foundation of the tower encases vertical water shafts as well; these merge into the horizontal penstocks at the tower's base. A two-span steel plate-girder pedestrian bridge provides access from the crest of the dam to the tower.

Dam: An Invitation to Recreation, Consumers Power Company brochure (n.d.), Hardy Dam on-site storage; and "Hardy Dam," 1933 summary of plant's features, historical files, Civil/Mechanical Engineering Projects, Engineering and Construction, Consumers Power Company, Parnall Road, Jackson, Michigan.

[2] The dam is aligned along a line running northwest to southeast; associated structures match this axis. For the sake of clarity, however, descriptions are written to reflect approximate full cardinal points.

Three steel penstock tubes connect the concrete foundations of the Intake Tower and the Powerhouse, running through concrete sleeves in the base of the Embankment to do so. In the Powerhouse foundation, each 14'-0" diameter penstock branches into two tubes: the upper tubes lead to scroll cases, which divert water to the turbines to turn the generators, while those below simply spill excess water. The spill tubes, which narrow from 14'-0" to 12'-0" in diameter, are further controlled by butterfly valves; when these valves are closed, all water passing through the penstocks is used to generate power.

The underground conduit spillway system was designed to accommodate normal flood waters in the Muskegon River. The river's steady flow translates into few floods, and Hardy's pond, the largest on the river, can absorb a great deal of flood water and excess runoff. Still, in the event of a massive flood, the company included an Emergency Spillway (HAER No. MI-100-E) in Hardy's original design. The concrete-lined overflow spillway chute on the west edge of the Embankment drains flood waters from the pond before they overtop the dam. The 600'-0" wide spillway lip on the upstream side of the road provides 2'-6" of freeboard above the normal maximum headwater elevation of 822'-2". Concrete blocks of various sizes comprise the weir; the blocks topple over individually according to the volume of spilled flood water. In this way, the weir can control the amount of water spilled, allowing the overflow to increase if the water level in the pond continues to rise. At the same time, the design prevents the amount of spilled water from exceeding the inflow to the pond. Since the Hardy Pond is meant to collect flood water, such a situation could lead to severe downstream flooding.

Two additional buildings complete the site. A small Oil House (HAER No. MI-100-F) stands just west of the Powerhouse on the Embankment and serves as a storage facility. The single-story hipped-roof brick structure shares the same yellow brick cladding and green tile roofing of the Powerhouse and Intake Tower, but the building's simple cornice and unornamented windows reflect its utilitarian function and less prominent siting.

A few hundred feet to the southwest, the Dormitory (HAER No. MI-100-G) occupies a spot in the toe of the Embankment. Another brick building with a hipped roof, the Dormitory differs in materials from Hardy's other structures. A veneer of brown brick sheathes the building, and composition shingle covers the roof. The boxy, two-story structure has evenly spaced windows on all facades. A personnel door allows entry from the east, while a cargo door opens to the west. The lower floor provides storage space, and the upper story holds dormitory rooms. The second-floor rooms are currently used for additional storage space.

HISTORY OF THE HARDY PLANT

SYSTEMS OF POWER SUPPLY

Michigan saw firsthand many of the country's early developments in the hydroelectric industry. One of the pioneering uses of hydroelectricity in the United States took place in western Michigan in 1880, when a direct-current generator turned by the water turbine of a chair factory in Grand Rapids powered sixteen electric lights. This may have been the country's first hydroelectric plant. Less than twenty years later, two brothers from Adrian, Michigan, built a power plant on the nearby Kalamazoo River and sent high-voltage current over twenty-four miles of wire to their customers. This was the first plant in the Midwest to generate power at a "remote" location and transmit the current to distant customers.[3]

Achievements such as these apparently inspired Michiganians to consider the possibility of developing rivers in sparsely populated northern Michigan to produce electricity for consumers in the southern part of the state. William Augustine (W.A.) and James Berry Foote, the brothers responsible for the 1899 plant on the Kalamazoo, were actually busy doing just that. In the early years of the twentieth century, the Foote brothers built chains of hydroelectric plants on several rivers in the northern part of Michigan's Lower Peninsula. They sent the power generated on these systems over high-voltage, long-distance transmission lines to their consumer base, or "load center," in Michigan's southern cities. Regional system-building began to spread nationally after World War I.[4]

As the industry's technology evolved, its economics changed. Plants were originally made more efficient by increasing demand for their electricity. This was particularly true with hydropower plants, which had significant installation costs but relatively low operating costs. Plants operating close to their maximum capacity were more efficient, since each unit of power produced by a plant lowered the cost of generating that unit. Electricity generated at a hydro or steam plant could not be stored, however, so plants customarily generated only enough power to meet the present demand, referred to within the industry as "load." The ratio of power produced to maximum plant capacity was known as "load factor."[5]

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[3] Duncan Hay, *Hydroelectric Development in the United States, 1880-1940* (Washington, D.C.: Edison Electric Institute, 1991), 13, 32. According to Hay, the Vulcan Street Plant in Appleton, Wisconsin, is incorrectly credited as the country's first hydro station. Hay's earliest example is the Grand Rapids plant, which first generated electricity two years before Vulcan Street.

[4] For more on the Foote brothers' early developments, see Cynthia de Miranda and Jeffrey A. Hess, "Cooke Hydroelectric Plant," HAER No. MI-98, 1996, Historic American Building Survey/Historic American Engineering Record Collection, Library of Congress, Washington, D.C. For more on regional power systems and the evolution of the industry, see Chapters 12 and 13 of Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983).

[5] Consumers Power Company explained the effect of a good load factor on electric rates in E.J. Burtt's "Load Factor and Revenue," *Au Sable News* 12 (January 1926): 4-6.

Naturally, utility companies sought to increase the load factor of their plants. One approach was to identify groups of consumers who would demand power at different times throughout a 24-hour period. Commercial and residential customers, for example, were complementary because their peak demands separated, respectively, into day and evening periods. This strategy was referred to as "diversifying load."[6]

Load continued to increase, and utility companies responded by expanding plants and building new ones. Extra generators were added to steam plants easily enough, but hydroelectric plants, reliant on river flow for fuel, often could not be expanded. Utility companies augmented fully developed hydro systems with steam plants. Hydro plants were called upon to supply the majority of a system's load, given the plants' low operating costs. Steam plants, more costly to use, supplied power only at peak times or in emergency situations. This organization dramatically increased the load factor of the hydro plants generating base supply because their maximum capacity could be correlated to the system's maximum average load, rather than to its maximum peak load.[7]

Through the development of new turbine, boiler, and fuel-handling technologies, the efficiency of coal-burning steam plants rose dramatically in the late 1910s and early 1920s. Utility companies began to reevaluate their formula for power generation. Demand for electricity continued to increase, and power companies responded by building more coal-burning steam plants. The new steam plants' improved efficiency meant lower operating costs, and they soon became the base suppliers within systems. Hydro plants were re-assigned to handle peak loads. Hydroelectric plants were actually better suited to this purpose, partly because they could generate power as soon as demand was evident, while steam plants required at least thirty minutes to warm up. In addition, hydro plants with large storage ponds were capable of providing emergency power for extended periods while steam plants, forever vulnerable to disruptions in the mining and transportation industries, could not always count on maintaining an adequate coal supply during an unexpected crisis.[8]

DEVELOPING THE MUSKEGON RIVER

The Foote brothers and their Grand Rapids-Muskegon Power Company began buying riparian rights on the Muskegon River in 1904 in anticipation of building hydro plants there. They erected the Rogers plant in 1906, followed a year later by Croton, situated seventeen

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[6] For more on both load factor and diversified loads, see Hughes, 216-222.

[7] These trends are documented in the engineering press from the period: M.H. Aylesworth, "Evolution of Interconnected Power Lines and Effect on Utility Regulation," *Electrical World* 79 (18 February 1922): 325-327; Allen M. Perry, "Operating a Fully Interconnected System," *Electrical World* 86 (26 September 1925): 657-662; Edward M. Burd, "Water Power in the Middle West," *The Michigan Engineer* 46 (September 1928): 12-21. Also see Hay, 117-119.

[8] Ibid.

miles downstream.[9] Each plant had a hydraulic head of 40'-0", which left a drop of about 100' between the two facilities. Since the Foote brothers generally built low- to medium-head embankments for their power plants, early discussions for the stretch of the river between Rogers and Croton revolved around two developments, each with a 50' head. Boring studies were made to identify two sites, but no suitable foundations were found in the study area.[10]

In 1910, the Foote brothers consolidated their many utility companies, including the Grand Rapids-Muskegon River Power Company, under the umbrella of a holding firm known as Consumers Power Company (CPCo). As the industry's economics began dictating in the 1920s that hydro plants generate power for peak periods, officials at CPCo initiated studies to explore building a single plant with a large pond near the village of Oxbow to develop the entire 100' drop between Rogers and Croton. Plants with large storage ponds were far more valuable for supplying peak power than were run-of-river plants. In addition, CPCo's work on other Michigan rivers had demonstrated that higher-head plants were more economical.[11]

At the same time, the company was also considering building a base-load steam plant in Kalamazoo to supply additional generating capacity for the system. A 1926 planning study commissioned by CPCo to consider the alternatives outlined several compelling reasons to build a hydro plant. Specifically, a hydroelectric plant would cost less and would equalize the ratio of steam to hydro plants in the CPCo system. A peak-load hydro plant would enable existing steam plants to operate at a higher load factor, therefore increasing their efficiency, and would improve the reliability of the entire system by providing emergency power. Officials further speculated that the company's image might benefit from developing more hydropower, which enjoyed popularity with the general public at the time. Finally, a 100' dam, would be a major accomplishment in Michigan, where low- to medium-head dams were the standard. According to the report, CPCo should not ignore "the prestige which would be secured for the Company by the publicity attending the building of a hydro plant of 100-foot head in Michigan."[12]

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[9] For the history of the Croton plant, see Charles K. Hyde, "Croton Hydroelectric Plant," HAER No. MI-81, 1994, Historic American Building Survey/Historic American Engineering Record Collection, Library of Congress, Washington, D.C.

[10] Edward M. Burd, Civil and Hydraulic Engineer, Commonwealth Power Corporation, Jackson, Michigan to W.E. Swift, Manager of Construction, Stevens & Wood, Inc., New York, New York, 2 August 1928, in historical files, Hydro Operations, Consumers Power Company, Cadillac, Michigan.

[11] Burd, "Location and Design," 3. During CPCo's early years, dams at hydro plants generally ranged between 27' to 42' in height. The company then began constructing larger dams: in 1918, CPCo erected a 57' dam for the Junction Plant (now known as Tippy), followed by Hodenpyl's 75' dam, built in 1925.

[12] Commonwealth Power Corporation, "Report on Advisability of Construction of Custer Steam Plant or Oxbow Dam during 1927," Report No. R-147, 27 August 1926, in historical files, Hydro Operations, Consumers

OXBOW DESIGN CONSIDERATIONS

Consumers Power Company had spent the first quarter of the twentieth century refining a standard design for its hydroelectric power plants. The company typically combined the powerhouse and intake section into a single structure flanked by earth embankments. The preferred intake was an open penstock block: essentially a large concrete room with gates at the top of the upstream wall controlling the flow of water to the turbines. In horizontally connected plants, the turbines sat inside the block, while vertically connected plants had scroll cases that directed water from the open penstock to the turbines. The height of the penstock block was determined by the plant's head.[13]

The standard earth embankment CPCo favored contained a central corewall to limit water seepage in the structure. The poured concrete wall topped a cutoff of steel sheet piling driven into the foundation. Crews employed semi-hydraulic means to construct the dams, hauling embankment material to the river channel in railroad dump cars and using high-pressure streams of water to direct fine sands to the center of the dam and progressively coarser materials to the outer layers. Civil engineers adapted the hydraulic method from techniques Western placer miners had developed for separating metals from gravel.[14]

CPCo derived its dam-building practice from that of William G. Fargo, a Jackson, Michigan, civil engineer who made the design of small- to medium-head earth dams on the soft, gravelly stream beds of Michigan his specialty. Fargo began building for the company in 1899 at the Trowbridge Plant on the Kalamazoo. As head of the Fargo Engineering Company, he designed more than twenty dams for CPCo, including those at the Croton and Rogers plants on the Muskegon River, before retiring in 1925.[15]

The 100' head proposed for the Oxbow plant challenged CPCo's standard design. "The open penstock type of construction at other plants reached its limit when extended and adapted to the 70 foot head at Hodenpyl," wrote Edward M. Burd, head of civil and hydraulic engineering at CPCo's Commonwealth Power Corporation, of the plant the company built on the Manistee River in 1926. Hodenpyl's penstock block required massive concrete walls that construction crews found difficult to build and officials deemed costly to finance. In the company's opinion, the increased bearing loads of Hodenpyl's necessarily larger combined

Power Company, Cadillac, Michigan.

[13] W.W. Tefft, "System and Operating Methods of Consumers Power Co.," *Power* 55 (4 April 1922): 526-529.

[14] Ibid.; Hay, 53.

[15] Tefft, 526-530; Hyde, 3; and Commonwealth Cultural Resources Group, "Hydroelectric Plant Historical Review" (prepared for Consumers Power Company, Jackson, Michigan, April 1991), 11. Also see articles authored by Fargo: "Earth Dams," *Au Sable News* 6 (December 1920): 8-10; and "Hydraulic Excavation and Dam Building at the Croton and Lyons Dams in Michigan," *Engineering News* 58 (24 October 1907): 429-431.

structure approached the limit that a typically soft Michigan foundation could support. The height of the dam also required that the combined powerhouse and intake structure be placed deeper in the embankment, resulting in a less attractive appearance.[16]

Another consideration entered into the design equation. The nearly 4,000-acre pond proposed for Oxbow was roughly twice that of any other on the company's system. The Muskegon River valley, although somewhat remote, was home to the village of Newaygo and to other CPCo hydro developments. More so than at existing plants, a catastrophic dam failure at Oxbow could devastate downstream settlements and facilities and ruin the company's name.[17]

DEVELOPING A NEW DESIGN

Commonwealth's engineering department understood that it needed to consider a new design for the Oxbow site. Burd, who had worked with the Fargo Engineering Company before moving to CPCo, was undoubtedly very knowledgeable about the company's standard construction methods.[18] As the Oxbow plant evolved into a larger, perhaps even "prestigious" development for CPCo, Burd began to see that safer—and more costly—construction could be an important investment for the company.

Specifically, Burd wanted to replace the customary central corewall with concrete paving on the face of the dam's upstream slope. In internal documents, he admitted that Commonwealth's engineers had for some time considered the facing method superior to a central corewall for producing a drier embankment. "That portion of the embankment upstream from the vertical corewall merely holds the wall in position, having no value for water-tightness," Burd wrote to Commonwealth's chief engineer William Wolcott Tefft in 1926. "It has always been realized that the ideal construction would place the corewall or water cut-off at the upstream slope, greatly increasing the so-called percolation distance thru [*sic*] the embankment, which is the real measure of its safety. Owing to the greater length of upstream slope and the possibility of unequal settlement, it has never before seemed either economical or advisable to lay the concrete facing on this slope in our work."[19]

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[16] Burd, "Location and Design," 4. Commonwealth Power Corporation, a CPCo subsidiary, handled the parent company's engineering work.

[17] "Hardy Dam Goes on the Line," 412; A.A. Cummins, "Hardy Dam Construction," *Au Sable News* (September 1931): 3; Burd to Swift, 2 August 1928.

[18] Winfield S. Downs, ed., *Who's Who in Engineering* (New York: Lewis Historical Publishing Company, 1931), 179.

[19] Burd to Tefft, "Oxbow Report," Commonwealth Power Corporation, Jackson, Michigan, 12 December 1926, in historical files, Hydro Operations, Consumers Power Company, Cadillac, Michigan.

The percolation distance Burd spoke of, also known as the "line of saturation," could be represented by a line sloping through the cross-section of an embankment from its upstream to its downstream end. This line was the accepted measurement of seepage in an earth embankment, and, therefore, an indication of the dam's stability, as Burd asserted. Experience had demonstrated that a relatively impervious diaphragm placed through a dam would lower the line of saturation; placement nearer to the upstream slope would logically result in a greater reduction of percolation.[20]

As Burd mentioned, the possibility of settlement did make upstream facing problematic. Settlement in the foundation or in the embankment itself could create air pockets between the dam and the lining's concrete slabs. Unsupported facing slabs were more likely to crack, permitting seepage that could erode a section of the embankment to the point where the entire dam could fail. West of the Rocky Mountains, dams with concrete facing were generally built on rock or very hard clay: foundations not likely to yield to loading. Eastern locations, in contrast, usually could not provide hard foundations.[21]

Despite Burd's contention that engineers in his department considered the facing method superior to a corewall, there was some debate in the field over which method should be favored. As a member of the American Society of Civil Engineers, Burd was probably familiar with Joel D. Justin's extensive discussion of earth dams published by the society in 1923. Justin, a Cornell-educated civil engineer, had built railroad tunnels, reservoir dams, and filtration plants. He had also gained some experience with hydroelectric structures between 1915 and 1917, when he served as resident engineer in Wisconsin for the Fargo Engineering Company. Justin's review of earth-dam construction methods included a warning: "It is generally poor practice to place much reliance on a concrete pavement for keeping water from entering the embankment. The function of such a lining, in the writer's opinion, is wave protection." [22]

Still, Burd's review of a number of faced dams left him feeling encouraged. Burd is known to have studied the Kentucky Hydro-Electric Company's 1925 Dix River Dam, a rock-fill

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[20] Joel D. Justin, "The Design of Earth Dams," *Transactions of the American Society of Civil Engineers* 49 (May 1923): 858-867.

[21] Examples of Western faced dams include Reclamation's Belle Fourche Dam in South Dakota and McKay Dam in Oregon. See O.T. Ready, "Construction of the Bell Fourche Dam," *Engineering Record* 61 (2 April 1910): 466-469; M.E. Trenam, "McKay Dam," in U.S. Dept. of Interior, Bureau of Reclamation, *Dams and Control Works* (Washington, D.C.: General Printing Office, 1938), 119-122; and Jeffrey A. Hess, "McKay Dam," HAER No. OR-18, 1991, Historic American Building Survey/Historic American Engineering Record Collection, Library of Congress, Washington, D.C.

[22] Downs, 1118; Justin, 896. Justin's article was later incorporated into *Hydro-electric Handbook* (New York: John Wiley and Sons), a standard text for the industry co-authored by Justin and William P. Creager and first published in 1927.

structure with steep slopes rising to a height of about 240'. The dam's rock-fill construction, rarely seen in the East, made it notable, but the Dix River Dam further distinguished itself as the world's largest rock-fill dam. Concrete paving, laid on the upstream slope in 48'-0" x 70'-0" rectangular panels and connected by expansion joints, was installed "to make the dam substantially watertight," according to one article.[23] The Dix River Dam did experience considerable uneven settlement in its first two years of use, but the facing, according to Burd, had not leaked. Furthermore, based on company records dating back to 1913, Burd concluded that Michigan's mudstone and glacial outwash exhibited a more predictable settlement rate than did other types of soft foundations. "That settlement is proportional to load, and proceeds as loading is applied, and then ceases, even under these conditions, has been proved at several plants of lesser head, and under dissimilar conditions," Burd later wrote of Michigan foundations.[24]

Yet another alternative to the corewall must have been known to Burd. Several practicing engineers responded to Justin's article on earth dams, including consulting engineer Gardner S. Williams of Ann Arbor, Michigan. Williams possessed a varied background and had worked in the hydroelectric field, making observations related to loss of head and designing scroll pits and draft tubes for vertical-shaft water turbines. As a professor of experimental hydraulics at Cornell University, he had run the school's hydraulics lab from 1898 through 1904. Williams then moved to the University of Michigan, where he taught civil, hydraulic, and sanitary engineering from 1904 through 1911. Beginning in 1910, he built a number of earth embankments in northern Wisconsin and Michigan and clearly was familiar with the problems of keeping such dams dry. Burd received a bachelor's degree in civil engineering from the University of Michigan in 1911 and was undoubtedly aware of Williams's work.[25]

Williams revealed that he had "found it more economical and entirely satisfactory to control the position of the line of saturation within an earthen embankment by drains, rather than by a core-wall." Williams's system employed drainage tiles laid parallel to the centerline of the embankment. Transverse lines of tile diverted seepage from the main channel to a trench outside the downstream toe of the dam. Coarse rocks and gravel covered the interior drains to prevent soil from clogging the tiles.[26]

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[23] "Design Considerations in Dix River Rock-Fill Dam," *Engineering News-Record* 94 (25 June 1925): 1058-1061.

[24] Edward M. Burd, "High Dams on Pervious Glacial Drift," *Transactions of the American Society of Civil Engineers* 59 (April 1933): 538-546; Burd, "Oxbow Prospectus," 12 December 1926, historical files, Hydro Operations, Consumers Power Company, Cadillac, Michigan.

[25] For more on Williams's career, see Downs, 1432-1433.

[26] Gardner S. Williams, "The Design of Earth Dams: Discussion," *Transactions of the American Society of Civil Engineers* 44 (August 1923): 1320-1321.

OXBOW'S FIRST PLAN

In December, 1926, apparently drawing from his recent research, Burd presented a general scheme for the Oxbow development that differed considerably from CPCo's previous standard. His design called for a hydraulic-fill earth embankment with concrete facing on the upstream side rather than CPCo's traditional protective corewall. To help carry away seepage that might penetrate the upstream facing, Burd proposed an embankment drainage system similar to that described by Gardner Williams in 1923. Several courses would extend upstream into the embankment and would intersect with a main line running parallel to the centerline of the dam. That line would discharge collected seepage into the tailrace. All drains would be of sewer tile laid in gravel.[27]

To accommodate the loading limitations of the Muskegon's gravelly riverbed, Burd deviated again from the CPCo standard and split the combined intake and powerhouse structure. His plan placed an intake tower above the pond in the upstream slope of the dam and positioned the powerhouse in the embankment's downstream toe. Burd recommended founding the structures on round wood piling, as the company had done at other plants, to reduce settlement into the site's compressible mudstone foundation. Three 14'-diameter penstock tubes built through the embankment would connect the two buildings. "The separation of intake and powerhouse by buried penstocks . . ." explained Burd, ". . . lessens and spreads out the loading and greatly simplifies both design and construction."[28] Intake towers and buried penstocks were already in use at large storage reservoirs; Burd, for example, had encountered the configuration at the Dix River Dam.[29]

Burd's understanding that the Oxbow development could be a showcase for CPCo apparently did not extend to his proposed architectural treatment. CPCo powerhouses were generally utilitarian structures displaying only modest embellishments or subtle allusions to architectural styles.[30] Burd's schematic design for Oxbow structures followed that precedent. His proposed powerhouse design was a very subdued version of the Jacobethan Revival style other CPCo plants employed. A suspension foot-bridge linked the embankment's crest to the intake tower, which, despite its prominent position, was to be another utilitarian structure

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[27] Burd, "Oxbow Prospectus," 11.

[28] For Burd's discussion of the plant's design, see Burd, "Location and Design," 4.

[29] Examples of other storage reservoirs using this design again include Reclamation's Belle Fourche and McKay dams cited earlier.

[30] Commonwealth Cultural Resources Group, 16, 23. The main Jacobethan Revival characteristics employed at CPCo's Au Sable River plants include roof parapets and windows with oversized mullions and small panes. See descriptions for the Cooke and Five Channels plants in Commonwealth's report.

with a single-story superstructure faced in brick to match the powerhouse. Burd's description even categorized the concrete tower as "similar to grain elevator bin design."[31]

OBJECTIONS TO 1926 PLAN

A. Strieff, a fellow Commonwealth engineer, who, like Burd, had worked at Fargo Engineering Company years before, harshly criticized the 1926 prospectus for the Oxbow site. Strieff cautioned that Burd's adaptation of the company's standard design violated the "ultra-conservative attitude" the high-head project demanded. Specifically, Strieff questioned the stability of the proposed concrete-faced dam and advised against Burd's plan to lay penstock tubes through the embankment.[32]

Strieff alleged that William Fargo's hydraulic construction method, adopted by CPCo, "tended to dump the coarse, pervious material in the center [of the embankment] and the finer material outside."[33] Such an arrangement was in direct opposition to standard engineering practice. Fargo, on the other hand, explained in a 1920 article that his hydraulic process "insures the proper distribution of the fine materials, that is, with the most of the fine materials at the center of the dam, and grading outward with the coarser materials at the two toes of the dam."[34] Articles in the engineering press featuring several of CPCo's plants make no mention of unusual sluicing results on Fargo's dams. Still, Strieff claimed to have discussed his concerns with Fargo at some point, stating that "Mr. Fargo fully realizes the inherent weaknesses of the constructions followed in the past."[35]

The concrete corewall, Streiff maintained, was an essential component of the company's embankments and should not be excluded from the Oxbow plan. He asserted that the stability of the proposed facing was questionable, based on uncertainty regarding upward hydraulic pressures that would be exerted on the concrete slab. Such forces could crack the

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[31] Burd, "Oxbow Prospectus," 12-13, 19.

[32] A. Streiff, "Notes on the Design of the Oxbow Dam," 1927, in Plant Investment--Hydros--Hardy Hydro Plant--Miscellaneous File 1, Hydro Operations, Consumers Power Company, Cadillac, Michigan. Strieff's report does not list his professional affiliation, but certain wording in the document and the fact that he knew details about Hardy's design while it was still in an early planning stage indicate that he was on staff at Commonwealth Power Corporation, the planning subsidiary of Consumers Power Company, at the time he authored the report. In 1917, as an employee at William G. Fargo's Fargo Engineering Company, Streiff conducted tests on the effectiveness of the newly developed conduit spillway at CPCo's Mio Hydroelectric Plant.

[33] Strieff, "Notes on Oxbow," 2.

[34] Fargo, "Earth Dams," 9.

[35] Streiff, "Notes on Oxbow," 2.

facing, allowing water from the impoundment to penetrate the embankment. "Failure of the paving with corewall omitted may conceivably lead to failure of the fill," Streiff cautioned.[36]

Streiff further claimed that Burd's plan to run the penstocks through the embankment violated "an old and established rule to avoid laying reservoir outlets in an earth fill dam."[37] Older texts did indeed advise against such an arrangement: Burr Bassell's 1904 *Earth Dams* counseled "that the only admissible outlet for a storage reservoir formed by a high earth dam is some form of tunnel through the natural formation at a safe distance from the embankment."[38] Later texts, however, amended this rule. Justin's 1923 treatise cautioned engineers about the practice, but did instruct that "conduits through an earth dam should always be placed on or below the original surface" of the streambed.[39]

Combined, these factors fueled Streiff's declaration that the plan was "a complete departure from accepted engineering standards. . . . In case of failure no Board of engineers instituted by the Governor of the State would back up the Commonwealth's engineers," Strieff warned. "The latter would receive no support from outside experts, and failure of the dam would probably mean elimination of the Commonwealth Engineering Company as well as serious crippling of the Consumers Power Company."[40]

FOUNDATION STUDY

Apparently in response to Strieff's admonitions, CPCo submitted its proposed plan to Charles Terzaghi, a visiting professor at Massachusetts Institute of Technology and founder of the school's soil mechanics program.[41] Upon surveying the site in 1928, Terzaghi reported to CPCo that "although the geological conditions which exist at the proposed site are far from ideal, I am pretty firmly convinced that a perfectly safe and satisfactory dam can be constructed at a reasonable price." However, like Streiff, he urged caution. "A rather conservative and foolproof design should be adopted. Even those risks which according to

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[36] Ibid., 3.

[37] Ibid., 4.

[38] Burr Bassell, *Earth Dams: A Study* (New York: The Engineering News Publishing Company, 1904), 7.

[39] Justin, 900-901.

[40] Strieff, "Notes on Oxbow," 1. As noted above, Commonwealth was the planning subsidiary of Consumers Power Company at that time.

[41] According to Emily McMurray's *Notable Twentieth-Century Scientists* (Detroit: Gale Research, Inc., 1995), Charles [Karl] Terzaghi "bridged the gap between geology and civil engineering by creating the field of soil mechanics" (p.1995). He became interested in combining the two fields in the early years of the twentieth century when he worked as a construction superintendent at an Austrian engineering firm. In the late 1920s, when CPCo retained him to survey the Oxbow site, Terzaghi was a visiting lecturer at MIT. He also served as chairman of the Soil Foundations Committee of the American Society of Civil Engineers before returning to Vienna in 1930.

common engineering practice are considered admissible in connection with ordinary foundation work, must be avoided in case the foundation beneath the dam is of questionable stability."[42]

Terzaghi agreed with Burd that the upstream slope could be faced with concrete to make the dam less pervious. Although Terzaghi acknowledged that inclusion of a corewall was standard practice in such circumstances, he knew that the proposed height of the dam would require the corewall to be constructed in several sections. The connecting joints within the wall, as well as its juncture with the penstocks, could constitute weak points. Given the highly compressible foundation material at the site, Terzaghi predicted that severe stresses would develop, possibly cracking the wall. CPCo would have no way of repairing an embedded concrete corewall.[43]

In contrast, Terzaghi cited the advantages of upstream facing: flexibility and accessibility. He pointed out, however, that he was not aware of any permeable dam of 100' on a compressible foundation that had used the slope-lining method. Other designers of faced dams had not relied on the concrete covering to protect the slope without taking pains to protect the facing from rupture. A critical weak point formed at the seam between the bottom of the slope lining and the top of the cutoff wall, and Terzaghi urged CPCo to "omit no precaution . . . for insuring the continuity of the watertight skin over the joints along the row of sheet piling and around the intake tower." Terzaghi recommended a design to protect that joint.[44]

Terzaghi's other suggestions related to the foundation material at Oxbow and to the possible uneven settlement of the structures to be located there. To eliminate shearing stress at the connections of the powerhouse and intake tower with the penstocks, Terzaghi proposed linking the structures with flexible joints. Rather than found the buildings on wood piles in an attempt to minimize settlement, as Burd had proposed, CPCo should allow the buildings to settle. The joints' flexibility would compensate for any settlement differences between buildings. The penstocks, in his opinion, should be supported by piles only at each end and should be installed as late as the construction schedule would allow, enabling the embankment to settle prior to their installation.[45]

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[42] Charles Terzaghi, "Report on Structural Details of the Oxbow Dam, Michigan, for the Consumers Power Company, Jackson, Michigan," 18 June 1928, historical files, Hydro Operations, Consumers Power Company, Cadillac, Michigan.

[43] Ibid., 1-3.

[44] Ibid., 2-5.

[45] Ibid., 2.

NEW DESIGN FINALIZED

Despite Burd's supporting research and Terzaghi's approval, the company ultimately eschewed slope facing and opted for its usual corewall construction. While Burd was responsible for the plant's revised design, he was apparently directed by executives in CPCo's New York office to include certain features. Specifically, the company instructed Burd to "revert back to our former standard sand dam with vertical concrete corewall slightly upstream from the center line."[46]

The final design called for semi-hydraulic fill embankment with a concrete corewall positioned, like that of Hodenpyl, 30'-6" upstream from the centerline of the dam. A short section of concrete facing would sheathe the topmost section of the upstream slope, terminating in a vertical splashwall to eliminate damage from wave action. An emergency spillway, added to the west end of the dam to supplement the service spillway, comprised an overflow weir and shallow paved channel. The concrete blocks of varied sizes that made up the weir would topple over progressively depending upon the volume of water spilled. This design provided an automatic control and ensured that spilled water never exceeded inflow to the pond.[47]

The powerhouse and intake remained separate, as in Burd's 1926 plan, with conduits laid through the base of the embankment. The design apparently relied on the corewall to combat seepage along the penstocks' concrete encasement. Power plant structures would sit on monolithic concrete foundations, as Terzaghi recommended, and flexible joints would prevent ruptures between connections.[48]

While the final design maintained Burd's original layout for the power plant structures, the buildings' architectural treatment departed from the simplicity of the 1926 plan. Rather than alluding to a particular style with an embellished cornice line or distinctive window treatment, the buildings designed for Oxbow displayed a well-articulated Spanish Colonial Revival style. That style, popular throughout the country in the 1920s, was evidenced by the buildings' tiled roofs, arcaded cornice lines, round-arched windows, contrasting window surrounds, and arch hoods.[49]

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[46] Burd to C.H. Wescott, Newaygo, Michigan, 23 September 1929, in historical files, Hydro Operations, Consumers Power Company, Cadillac, Michigan.

[47] Burd, "Location and Design, 5, 29-30; Burd, "Consumers Power Co. Adds Hodenpyl to System," *Power Plant Engineering* 30 (15 July 1926): 803. Gardner Williams, in his response to Justin's 1923 article on earth dams, described a similar overflow spillway. See Williams, 1321.

[48] This description of the final design is based on as-built drawings. See "General Plan and Section of Dam and Powerplant, Hardy Plant, Muskegon River, Figure No. 10," Hydro Operations, Consumers Power Company, Cadillac, Michigan.

[49] Marcus Whiffen, *American Architecture Since 1780* (Cambridge, MA: MIT Press, 1981), 226.

The change in the level of architectural detailing illustrates the company's view of the plant as a showpiece in its system. CPCo recognized the need to dress the plant in appropriate garb to draw attention to its achievement and to promote investment in the company. To that end, the Intake Tower (HAER No. MI-100-D) also served as a beacon for visitors and as advertisement for the company. Unlike the Powerhouse, which can only been seen from the downstream side of the plant, the Intake Tower is visible from all angles. CPCo further encouraged motorists to visit the plant by laying a highway across the dam and giving the Powerhouse (HAER No. MI-100-B) interior a polished appearance.[50]

CONDUIT SPILLWAY

The new plant also used a design developed by CPCo twenty years earlier and first tested at the Mio Hydroelectric Plant on the Au Sable River. In the 1910s, William W. Tefft was an engineer at CPCo looking for a way to reduce dam construction costs. Tefft knew the amount of concrete used in his company's solid block foundations was a major expense, so he created a design that incorporated a spillway into the foundation of the powerhouse, reducing the amount of concrete needed. Tefft's spillway consisted of tubes that diverted excess water from the penstock block through the powerhouse foundation and into the tailrace. The "conduit spillway," as it became known at CPCo, included gates or control valves to close the spillway when all water should be used to generate power. Tefft received a patent for his design in 1918.[51]

CPCo installed the conduit spillway at Mio, which was under construction in 1916. As a safety mechanism, the final design included a small, conventional overflow spillway in the event that Tefft's invention failed or the river experienced unusually heavy flooding. A study of the new design, completed after the plant had been in use for about a year, concluded that the conduit spillway was not only an effective and cost-saving design, but that it actually slightly increased the efficiency of the plant by increasing the draft head.[52]

Consumers Power Company used the conduit spillway again at the 1924 Alcona Plant on the Au Sable River, and at the 1926 Hodenpyl Plant on the Manistee River. At Alcona, six 78" conduits controlled by butterfly valves acted as the service spillway, backed by an overflow emergency spillway included on the embankment. Hodenpyl's six tubes, controlled by

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[50] Donald Mackie to C.J. Holmes, Jackson, Michigan, 13 May 1930, in Hardy correspondence files, Legal Department, Consumers Power Company, West Michigan Avenue, Jackson, Michigan.

[51] For more on Tefft's spillway conduit, see *Hydraulic Power Plant*, Specifications of Letters Patent, No. 1,281,706, filed 6 February 1915, approved 15 October 1918; A. Streiff, "Report on Tube Spillway Experiments and Inspection of Mio Dam," prepared by Fargo Engineering Co., 17 April 1918, in historical files, Civil/Mechanical Engineering Projects, Engineering and Construction, Consumers Power Company, Jackson, Michigan; W.W. Tefft, "Alcona Dam on Au Sable River," *Power* 59 (5 February 1924): 212-214; and E. M. Burd, "Consumers Power Co. Adds Hodenpyl to System," *Power Plant Engineering* 30 (15 July 1926): 803-806.

[52] Strieff, "Report on Tube Spillway," 8.

rectangular steel gates, were sufficient to pass flood water twice the volume of the maximum flow on record at the time of construction. An emergency overflow weir was also included at Hodenpyl.[53]

Oxbow's conduit spillway followed the same configuration. Each of the three 14'-0"-diameter, steel penstock tubes split in the powerhouse substructure into a pair of tubes; the upper tubes directed water to the turbines and the lower tubes, which narrowed to 12'-0" in diameter, constituted the service spillway. Butterfly valves regulated the flow through the spill tubes, but, unlike the earlier plants, the valves were engaged by push-button motor controls instead of relying on manual operation. The emergency overflow spillway on the embankment's west end was included to augment the spilling capacity of the conduits.[54]

BUILDING THE HARDY PLANT

Construction of the Hardy Hydroelectric Plant—named in honor of George Hardy, a partner in the firm that financed CPCo from 1911 through 1928—finally got under way in June, 1929. Another CPCo subsidiary, Allied Engineers, oversaw Hardy's construction. Preparatory work included establishing a construction camp on the river's east bank. The camp contained workers' cabins and bunkhouses, a carpenter's shop, machine shop, and central concrete mixing plant. Allied Engineers laid nine miles of standard gauge tracks to connect the construction site to the nearest railroad and erected a temporary trestle to extend trackage across the river.[55]

Despite Terzaghi's advice to the contrary, crews laid the concrete-encased steel penstock tubes first, providing a channel for the river during construction. Flexible joints connected

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[53] Tefft, who eventually became head of engineering at Commonwealth Power Corporation, discussed the conduit spillway in articles outlining the Alcona and Hodenpyl plants. He called the spillway "the most interesting single factor of the Alcona development. . . . This method of design not only reduces the cost of the spillway to a negligible amount, but betters construction methods and power-house design." Despite such publicity, the design does not seem to have been widely used outside CPCo's own system. For more on Alcona and Hodenpyl, see W.W. Tefft, "Alcona Dam on Au Sable River," *Power* 59 (5 February 1924): 212-214; and Burd, "Consumers Power Co. Adds Hodenpyl," 803-806.

[54] Burd, "Hardy Dam Provides 40,000 Hp.," 197; Burd, "Design and Location," 29.

[55] George Bush, *Future Builders: The Story of Michigan's Consumers Power Company* (New York: McGraw-Hill Book Company, 1973), 164-167; 257-258. Stevens and Wood, the precursor to Allied Engineers, had offices in New York as well as in Jackson, Michigan. The company changed its name to Allied Engineers in 1930. A year later, Consumers Power Company dissolved Allied and established its own engineering department. See Bush, 257-258. The construction account is based on articles, interviews, and historic views. See Burd's articles: "Hardy Dam Goes on the Line;" "Hardy Dam Provides 40,000 Hp.;" and "Location and Design of Hardy Hydro Plant." Also see A.M. Komora, "Construction of Hardy Dam Progresses," *Au Sable News* 16 (December 1930): 4-6; and A.A. Cummins, "Hardy Dam Construction," *Au Sable News* 17 (September 1931): 3-6. The historic photo collection is maintained at the site.

each 30'-0" section of tubing to allow for differences in settlement among the sections. As a safety factor, the design allowed for settlement several times the anticipated amount.

Work on the concrete corewall followed shortly: in December, 1929, crews drove a row of steel sheet piling into the streambed. They then poured 21'-high sections of the concrete corewall directly over the underground sheet-piling cutoff. Workers built trestles of milled lumber and logs on each side of the growing corewall, allowing fill for the upstream and downstream slopes to be delivered over the trestles and dumped on either side of the wall. Highly pressurized streams of water washed the fill into place. As the Embankment (HAER No. MI-100-A) rose to the height of the corewall, crews poured another section of the wall and continued the procedure.

Apparently anxious to complete construction quickly, the company ordered both day and night crews to work through the winter. Dropping temperatures required that ingredients for the concrete be heated before mixing. Jets of steam kept the poured concrete from freezing while it hardened. By February 1930, workers had begun the monolithic concrete foundations for the Powerhouse (HAER No. MI-100-B) and the Intake Tower (HAER No. MI-100-D). They completed the concrete slab of the tailrace by May and wrapped up most of the work on the penstocks at the same time.

Crews continued sluicing fill into placc for the embankment the following summer. They installed the huge butterfly valves that controlled flow through the spillway and the scroll cases that directed water to the turbines. Crowds of spectators began visiting the construction site to watch the installation of such massive equipment. Counting hundreds of visitors each day during August 1930, CPCo took full advantage of the attention. The company mounted a map of the site and a series of construction photographs. Diagrams illustrated how water power produced electricity. The company kept an employee on hand to answer questions, while posters and pamphlets urged onlookers to "be a profiting partner in this great waterpower development."[56]

Crews completed most of the concrete work by November, 1930. They continued sluicing fill for the Embankment and began the brickwork on the plant's buildings. Workers also installed the generating equipment in the Powerhouse. Again, construction continued throughout the winter as crews labored to complete the embankment and pour the concrete Emergency Spillway (HAER No. MI-100-E).

Ponding began in December 1930 and continued through the following April, taking advantage of the spring runoff for most of the volume in the pond. Using Sears and

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[56] Consumers Power Company, "Consumers Power Company and its 10,000 Shareholders Welcome you to Hardy Dam," undated brochure on display at Hardy Hydroelectric Plant.

Roebuck mail-order kits, workers built four operators houses just upstream from the dam, along the eastern bank of the pond. The pattern appears to have been the Dutch Colonial "Van Dorn": a one-and-a-half-story, three hedroom home with wood siding and brick foundation.[57]

Consumers Power Company put Hardy Hydroelectric Plant into operation on 30 April 1931. A few months later, obviously pleased with the plant's appearance and operation, CPCo dedicated the entire August issue of its in-house newsletter, the *Au Sable News,* to Hardy, outlining the plant's design, construction methods, and novel features. The company congratulated itself on building a modern plant and predicted that "the improved highway across the dam will undoubtedly bring more visitors to Hardy than to the other dams."[58] Another article proclaimed that "public relations are mightily helped when Mr. Citizen can stop his car on a highway on the top of a dam and show his family a river vista like this over the roof of a power house."[59]

In designing and building the dam for the Hardy Hydroelectric Plant, Consumers Power Company found a way to erect a stable, relatively high dam on Michigan's notoriously gravelly foundations. In doing so, the company continued its tradition of developing solutions to the problems presented by Michigan's geography and geology, enabling construction of an extensive system of electrical power supply that reached throughout the state's Lower Peninsula.

The evolution of Hardy's design, specifically the consideration and ultimate rejection of the upstream slope facing, also appears to reflect a tendency in American civil engineering to favor regional practice over technology developed elsewhere. Despite the increasing standardization in the hydroelectric field, thanks in part to texts like Justin and Creager's *Hydro-electric Handbook,* civil engineers appeared to prefer to continue local building tradition. American civil engineers seemed to live by the words of Frederick Stearns, a past president of ASCE: "Good engineering requires that in dam building, as in other work, the problem should be studied locally, and that the type of dam adopted should be that best suited to local conditions."[60]

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[57] Katherine Cole Stevenson and H. Ward Jandl, *Houses by Mail: A Guide to Houses from Sears, Roebuck and Company* (Washington, D.C.: Preservation Press, 1986): 329. The four operators houses were removed from the site at an undetermined date. Historical views of the plant show the houses, which appear to match the Van Dorn plan included in Stevenson's and Jandl's book.

[58] Burd, "Location and Design," 30.

[59] "Hardy Dam Goes on the Line," 413.

[60] Quoted in Caleb Mills Saville's response to Justin's 1923 article: Saville, "Design of Earth Dams: Discussion," *Transactions of the American Society of Civil Engineers* 49 (September 1923): 1608.

CHANGES AT THE HARDY PLANT

The Hardy Hydroelectric Plant has seen no major changes in design or operation since it went on line in 1931. A few minor alterations have, however, taken place. The spillway tubes suffered rather severe, but expected, vibrations when the butterfly valves were open at certain levels. Air vents were installed in 1946 to eliminate the vacuum that formed behind the partially open valves. This addition obviated the need to follow complicated spilling instructions that had been employed to avoid the noisy vibration.[61]

On Saturday, 17 September 1960, an explosion in the switch gear destroyed two walls of the small wing connected to the Powerhouse (HAER No. MI-100-A). The blast also blew out the glass in the windows of the upstream facade of the Powerhouse. The pressure inside the generator room was sufficient to warp the windows' frames. The wing was rebuilt according to the original plans, but the two steel sash windows on the upstream facade of the Powerhouse were infilled with brick for safety reasons. The Powerhouse interior also underwent a few changes: the switch board, which was blown out of place by the force of the explosion, has been sheltered inside a flat-roofed, metal office booth.[62]

In 1988, the crest of the Emergency Spillway (HAER No. MI-100-F) was modified to allow manual operation of the tipping blocks. Other changes to the site, made at undetermined dates, included the installation of a chain-link fence across the crest of the dam on the downstream side of the roadway, and removal of the light standards that originally illuminated the road. The four operators houses have also been removed.[63]

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[61] L.M. Day to L.L. Benedict, Consumers Power Company, Jackson, Michigan, 21 March 1946, in historical files, Hydro Operations, Consumers Power Company, Cadillac, Michigan.

[62] E.D. Schantz, Grand Rapids, Michigan, to E.H. Kaiser, Jackson, Michigan, 20 October 1960, in historical files, Hydro Operations, Consumers Power Company, Cadillac, Michigan.

[63] Ebasco Services for Consumers Power Company, "Stability Analysis: Hardy Hydroelectric Plant," 28 May 1993, in Hardy files, Hydro Operations, Consumers Power Company, Cadillac, Michigan.

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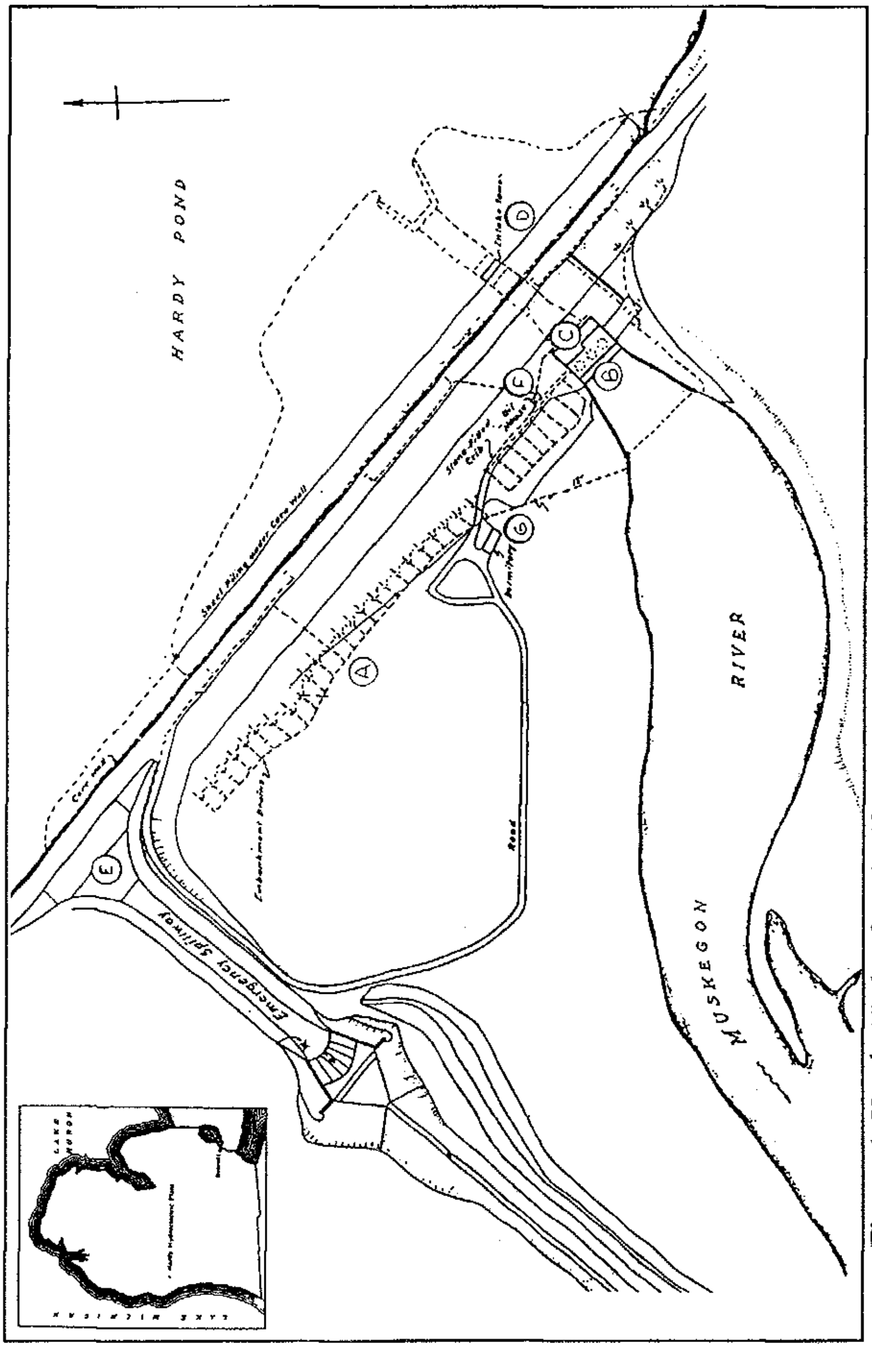

Figure 1 *Hardy Hydroelectric Plant: General Site Map and Regional Map (insert).*
Approximate scale: 1"=480'

Embankment	HAER No. MI-100-A	Emergency Spillway	HAER No. MI-100-E
Powerhouse	HAER No. MI-100-B	Oil House	HAER No. MI-100-F
Substation	HAER No. MI-100-C	Dormitory	HAER No. MI-100-G
Intake Tower	HAER No. MI-100-D		

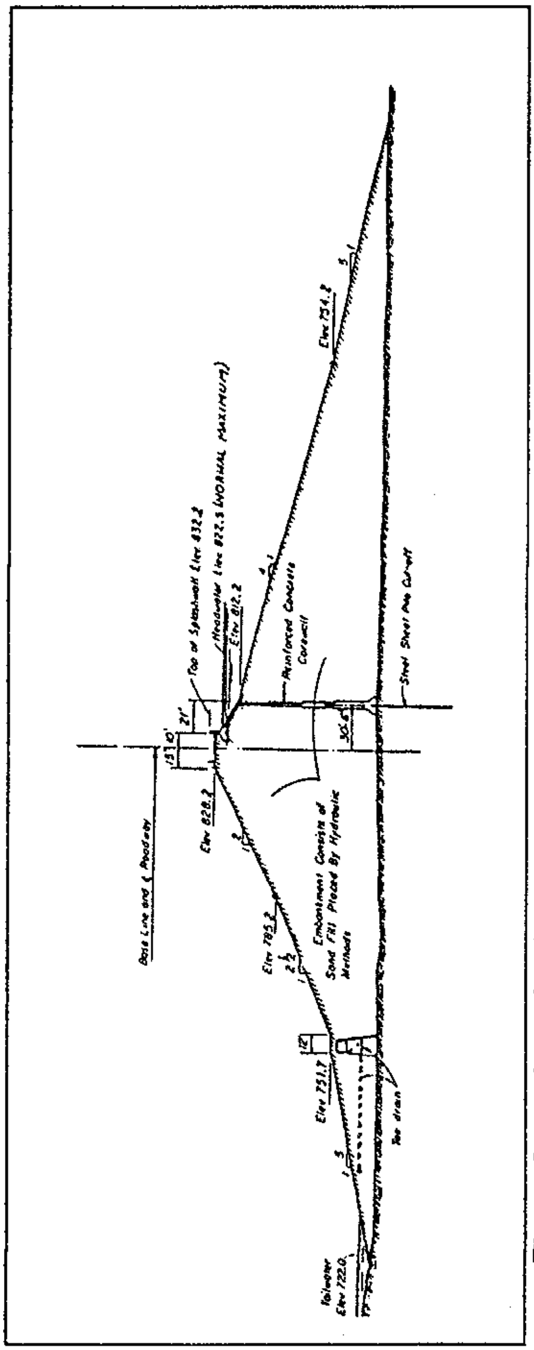

Figure 2 *Hardy Hydroelectric Plant: Embankment Section (detail from 1990 drawing by Consumers Power Company). Approximate scale: 1"=120'*

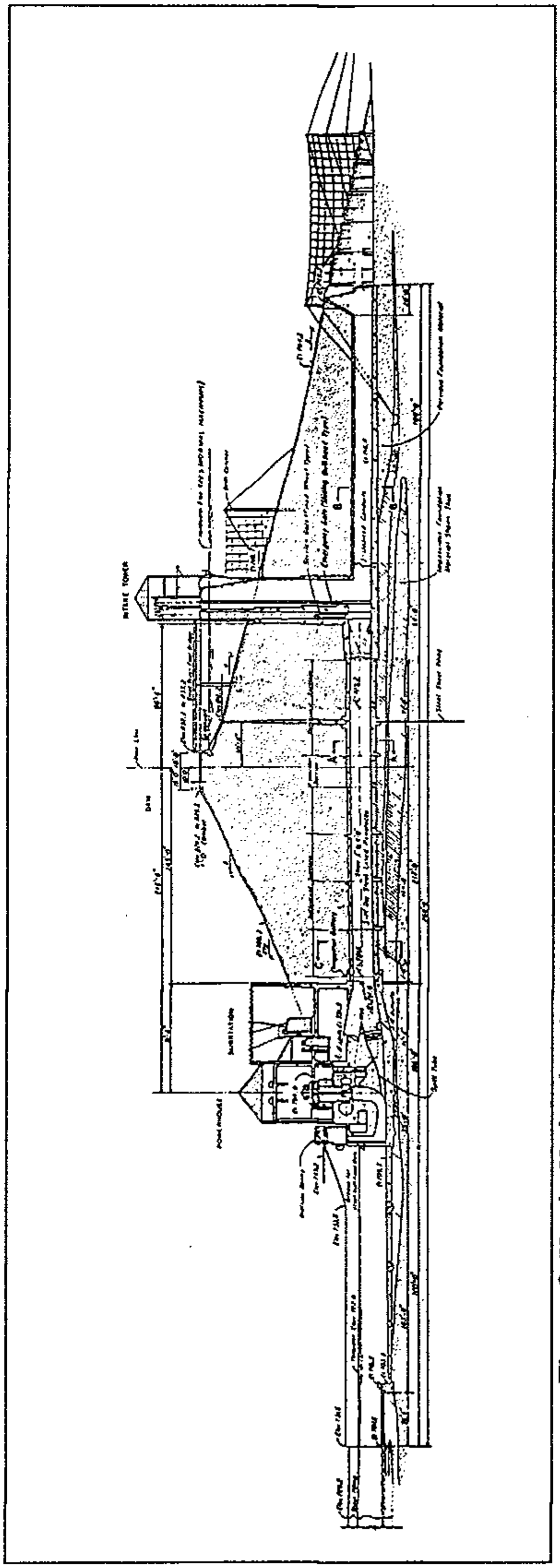

Figure 3 *Hardy Hydroelectric Plant: Dam and Powerplant Section (detail of 1990 drawing by Consumers Power Company). Approximate scale: 1"=100'*

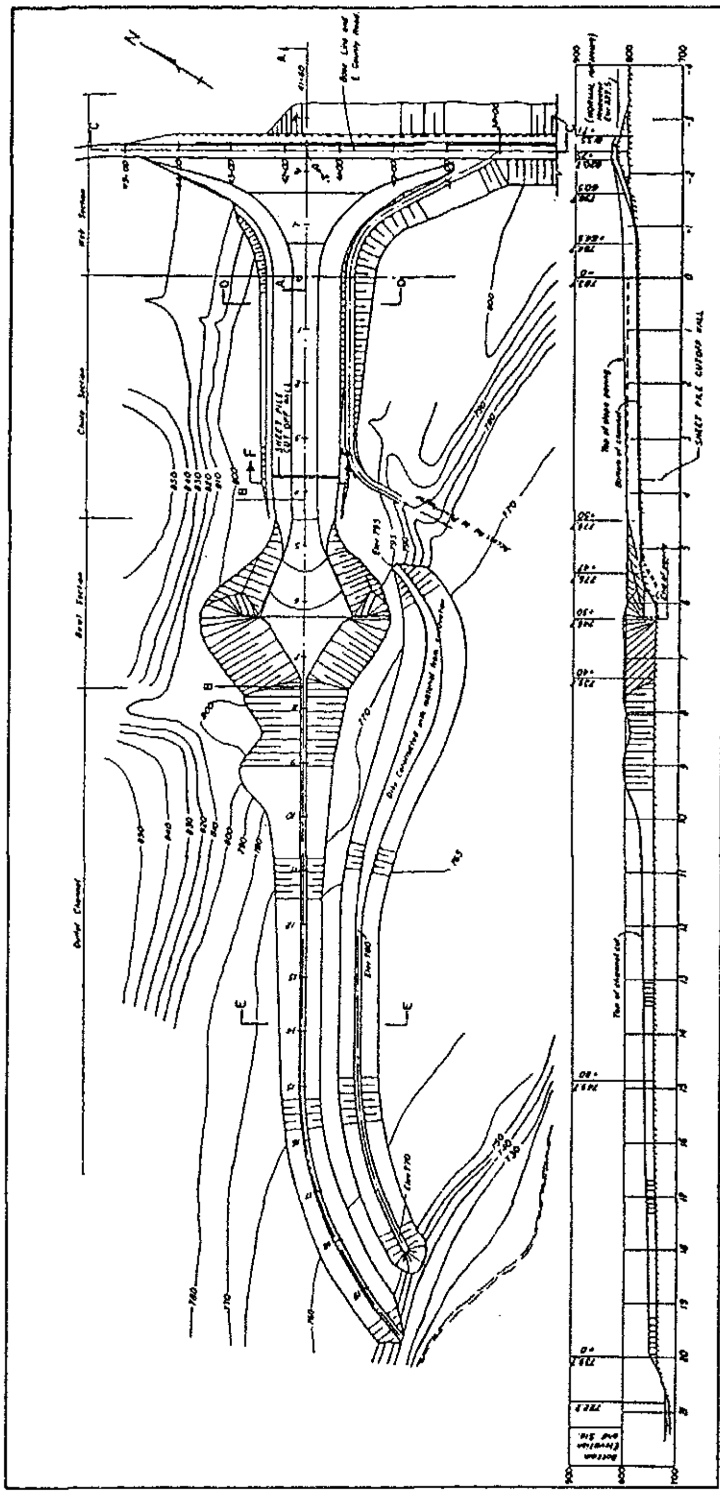

Figure 4 *Hardy Hydroelectric Plant: Plan and Profile of Emergency Spillway (detail of 1990 drawing by Consumers Power Company). Approximate scale: 1"=350'*

ADDENDUM TO:
HARDY HYDROELECTRIC PLANT
6928 East Thirty-sixth Street
Newaygo vicinity
Newaygo County
Michigan

HAER MI-100
HAER MICH,62-NEWA.V,1-

FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001