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United States Department of the Interior
National Park Service

National Register of Historic Places Multiple Property Documentation Form

This form is used for documenting multiple property groups relating to one or several historic contexts. See instructions in *How to Complete the Multiple Property Documentation Form* (National Register Bulletin 16B). Complete each item by entering the requested information. For additional space, use continuation sheets (Form 10-900-a). Use a typewriter, word processor, or computer to complete all items.

X New Submission ___ Amended Submission

A. Name of Multiple Property Listing

HYDROELECTRIC GENERATING FACILITIES IN VERMONT

B. Associated Historic Contexts

(Name each associated historic context, identifying theme, geographical area, and chronological period for each.)

HYDROELECTRIC POWER IN VERMONT, 1882-1941

C. Form Prepared by

name/title Martha H. Bowers, Senior Architectural Historian

organization Louis Berger & Associates, Inc. date May 1992

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city or town Waltham state MA zip code 02154

D. Certification

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for the listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in 36 CFR Part 60 and the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation. (☐ See continuation sheet for additional comments.)

Suzanne C. Jamele National Register Specialist 8-3-04
Signature and title of certifying official Date

Vermont State Historic Preservation Office
State or Federal agency and bureau

I hereby certify that this multiple property documentation form has been approved by the National Register as a basis for evaluating related properties for listing in the National Register.

Edson H. Beall for 9.15.2004
Signature of the Keeper Date of Action

Name of Multiple Property Listing: Hydroelectric Generating Facilities in Vermont

State: Vermont

Table of Contents for Written Narrative

Provide the following information on continuation sheets. Cite the letter and the title before each section of the narrative. Assign page numbers according to the instructions for continuation sheets in *How to Complete the Multiple Property Documentation Form* (National Register Bulletin 16B). Fill in page numbers for each section in the space below.

E. STATEMENT OF HISTORIC CONTEXT

Note: References in this document to specific hydroelectric facilities are for illustrative purposes only, and do not constitute judgements about eligibility for the National Register.

Introduction

Vermont's waterways have been utilized for mechanical power since the earliest settlement by people of European descent. Sawmills and gristmills were the first of the state's water-powered industries. Introduction of Merino sheep from Portugal in the early nineteenth century helped foster development of woolen mills, which used water in the manufacturing process as well as to power machinery. Other major water-powered industries during the nineteenth century were cotton mills, carding mills and producers of machine tools, scales, paper, and pulp (Tucker 1986:40-41). In this continuum, hydroelectric developments can be viewed as possibly the last in a series of uses of hydraulic systems on Vermont's rivers and streams.

The availability of electricity, like development of the automobile, wrought profound changes in life and work in the Green Mountain State prior to World War II. Electric railways and interurban lines augmented existing transportation systems, within major cities such as Burlington and Rutland, and to a lesser extent between communities and to parks and resorts. In the home, electric refrigerators brought an end to unreliable and often messy "iceboxes," and electric washing machines and irons lifted some of the burden from laundry chores. For dairy farmers, electrically-operated milking, pasteurization and refrigeration equipment were crucial to increased and more efficient production and to meeting increasingly stringent requirements imposed by public health officials on the production and sale of milk. Electric power also freed industry from the need to locate at a water power site, or to bear the costs of building, maintaining and importing coal for steam power plants. Furthermore, manufacturing machinery was liberated from the line shafts and belting which had heretofore dictated the spatial arrangement of equipment and processes.

As was noted in the Vermont Bureau of Publicity's Industrial Vermont (1914:176), "the state...is peculiarly favored by nature with an abundance of natural water powers...the Green Mountain range...condenses the moisture and keeps the whole region well watered...While Vermont has not been favored with any deposits of anthracite or bituminous coal, nature has been lavish in supplying Vermont with an inexhaustible amount of 'white coal'." The availability of water power for production of electricty was seen by both state agencies and local communities as a real opportunity to increase Vermont's industrial base by advertising the "great natural advantage" of this renewable resource. Industrial Vermont provided a comprehensive overview of water powers throughout the state, touting some of the more important hydroelectric projects that had been built to that time. Major sections of the publication described, stream by stream and town by town, the location and potential of developed, and potentially developable, power sites. At least 116 of these sites were, over time, developed for the production of electric power. Although not all of these were successful, their existence, however precarious, was instrumental in bringing Vermont into the "modern age." The overwhelming importance of hydropower in the state's electric power industry is reflected in the fact that as late as 1940, fully 90 percent of Vermont's needs were met by stations operating on "white coal." Since then, however, the state's energy and capacity needs have surpassed those available from developable hydroelectric resources, leading to extensive purchase of power from sources outside Vermont and to development of large-capacity fossil-fueled and nuclear generation. As of 1984, there were 52 sites in Vermont actively used for hydroelectric power generation, with a few additional, small plants having been placed in operation since then (Tucker 1986: 219).

Environmental Setting

The rivers and streams of Vermont flow into three river basins: the Connecticut, Hudson, and St. Lawrence. The largest basin is the St. Lawrence, which includes 5,230 square miles within the state. Major rivers in the Vermont portion of the basin, all emptying into Lake Champlain, are the Missisquoi, Lamoille, and Winooski, which flow generally from east to west, and Otter Creek, which flows generally north-northwest. The Connecticut River basin includes most of eastern Vermont, some 3,928 square miles. Its watershed contains a large number of Vermont streams, including the Passumpsic, White, Ottauquechee, Black, West, and Deerfield rivers. The Hudson basin incorporates the smallest area in Vermont, 451 square miles at the extreme southwest corner of the state, and contains the Battenkill, Walloomsic, and Hoosick rivers (Tucker 1986:30-32).

Annual precipitation across Vermont averages 38 inches, varying from about 30 inches around Lake Champlain to over 50 inches at Somerset. Much of Vermont's precipitation comes as snowfall, and accumulations are highly variable, ranging from about 60 inches in the lower elevations to over 120 inches in the Green Mountains. Springtime snowmelt accounts for some two-thirds of the yearly total runoff, with river flows lowest in the late summer and early fall (Tucker 1986:33-35). As a result, development of storage reservoirs has been an integral component of the year-round production of hydroelectricity in Vermont.

National Context

Previous studies of the American electric power industry (Hughes 1983:366; Edison Electric Institute 1989:i) have noted four main stages of evolution from the 1880's to World War II. During the first stage, from about 1880 to 1895, numerous small direct-current steam and/or hydroelectric stations supplied arc and incandescent lighting to limited geographical areas, utilizing rudimentary distribution systems to transmit a standard voltage from station to consumer. The second stage was initiated in the mid-1890s by two events. First was the demonstration of the "universal supply system," at the 1893 Chicago exposition, which introduced the concept of heterogeneity of both supply and demand. Through rapidly evolving technology it became possible to interconnect power plants having various kinds of generating systems, and to serve a broader range of consumers by combining alternating and direct current in a single system. The second event, occurring in 1895, was the placing on-line of the world's then-largest hydroelectric station at Niagara Falls, which vividly dramatized the enormous potential of hydroelectric power and brilliantly demonstrated the value of high-voltage alternating current in the long-distance transmission of electric power. These events stimulated the proliferation of hydroelectric generating stations and offered the technological means by which small utilities began rapidly to combine into larger subregional and regional systems, or limited-area companies.

The third stage, beginning about 1920, saw the maturation of the industry and a pronounced standardization of equipment and (to a lesser extent) design. Power generation and distribution systems continued to expand both in size and in complexity of both technological and holding/management company structures. New generating stations of the 1920s, with their ever-greater capacity, supplanted older, marginal facilities, which were abandoned or substantially reconstructed.

The Depression of the 1930s effectively brought to a halt the previous period of growth. Unwieldy corporate structures tottered into bankruptcy and receivership, and passage of the Public Utilities Holding Company Act in 1935 eventually resulted in the breakup of most of the mega-corporations into independent, more manageable (and more accountable) constituent parts. As construction by investor-owned utilities came nearly to a standstill, the Federal government emerged as a major sponsor of hydroelectric development, often on an enormous scale.

Hydroelectric Power Development in Vermont

The beginning date for this historic context, 1882, corresponds to the establishment of the first electric company in Vermont. The end date, 1941, is somewhat arbitrarily selected as conforming to the 50-year requirement of the National Register, since construction of several large-scale hydroelectric developments in the state occurred during the late 1940's into the mid-1950's. (Further research on hydroelectric facilities built after 1941 may indicate that they may possess qualities of exceptional significance that would make them eligible for the National Register under Criteria Consideration G, which governs properties less than 50 years of age. Also, the inevitable passage of time will eventually bring all these plants within the 50-year requirement for consideration.) The geographic boundaries of this historic context generally conform to the boundaries of the state of Vermont, since all contexts for the Vermont State Historic Preservation Plan have been delineated on a statewide basis. (Portions of New York, New Hampshire, and Massachusetts, however, may also be potentially included, since one hydroelectric development spans the Poultney River between Vermont and New York, a number of others extend from Vermont to New Hampshire across the Connecticut River, and the integrated system of storage and generation on the Deerfield River includes facilities in both Vermont and Massachusetts.)

The evolution of the hydroelectric power industry in Vermont from the 1880's to about 1940 generally corresponded to the national pattern. The chief departure from the pattern occurred during the 1930s, when for a variety of reasons, most of them political, the Federal government was discouraged from developing new hydroelectric facilities in the state, although it did oversee several flood-control projects (Webb 1974). Although presented in terms of periods, the national development of the hydroelectric power industry, as well as the industry's evolution in Vermont, should be understood as a continuum, rather than a set of discrete phases.

Since 1882, when Vermont's first electricity company was chartered, over 300 others have been created to produce and/or distribute electric power to the public. Some, of course, never progressed past corporate organization. Through the efforts, luck, and persistence of those companies which did survive, however, a total of 130 hydroelectric stations were built at 116 sites in Vermont (Tucker 1986:2-3, 218).

By 1890, ten Vermont communities boasted some form of electric service (Tucker 1986:57). A decade later, the number had risen to 52. Of these, at least 26 were supplied from hydroelectric stations. Another 20 received electricity from both hydroelectric and steam plants, while only five were dependent upon steam power alone (Tucker 1986:67-68). Over the next two decades, hydroelectric plants increased steadily in number, peaking at 89 by 1922. Their numbers declined somewhat thereafter, as marginal operations were abandoned and production was concentrated at fewer, but larger, installations (Tucker 1986:77-79). As of 1984, 52 sites were actively utilized for hydroelectric power generation (Tucker 1986:219). The principal hydroelectric producers were (and are) Central Vermont Public Service Company, Green Mountain Power Corporation, Citizens Utilities Company, and New England Power, a subsidiary of the New England Electric System.

Communities, industry, and investor-owned utility companies all contributed to the development of hydroelectric power in Vermont, particularly in the early decades of the industry. Remote location, lack of local capital, and/or inability to attract outside investors led a number of communities to build municipally owned and operated production and distribution systems, beginning with the village of Swanton in 1893 (Tucker 1986:63). By 1900, ten municipal systems were in operation, located primarily in the northern counties of Franklin, Lamoille, Caledonia, and Orleans (Tucker 1986:66). Hydroelectric stations associated with Vermont municipalities include Morristown's Cadys Falls plant (1895-1913), Swanton's Highgate Falls plant (1894, replaced 1913), Barton's plant in West Charleston (1895, replaced 1930), Enosburg Falls (ca. 1895), and the village of Lyndonville's Vail (1911) and Great Falls (1896) stations on the Passumpsic River in Lyndon.

Some early hydroelectric power enterprises were initiated by, or supplied through the facilities of, local industries, such as sawmills, gristmills, papermills, textile mills, and quarries. In North Troy, Bradford, Manchester, and Groton, for example, the first electric power was generated from gristmills, while sawmills provided electricity for Weston, Brattleboro, and Essex Junction (Tucker 1986:73). Long dependent upon Vermont's waterways for hydromechanical power, local industries owned many of the best power sites and had the necessary hydraulic systems already in place and in operation. To such enterprises, a generator was simply another machine which could be connected to an existing waterwheel or turbine. Electricity thereby produced was used first at the mill or factory for lighting and, gradually, to power equipment. The surplus (normally that produced during periods of low industrial demand) was sold to a local distributor or directly to local users. A few of these manufacturers acquired or built small hydroelectric stations, for example, the Dr. B.J. Kendall Company of Enosburg, maker of patent medicines, which produced electric power for its own use and a few other local customers beginning in 1902; the Lunenberg Manufacturing Company, maker of caskets; and the Gilman Paper Company (also in Lunenberg), producer of paper bags (Tucker 1986:72). Others included the Blair Veneer Company of Troy, which developed two small hydroelectric stations on the Missisquoi between 1918 and 1922; and the Woodbury Granite Company, whose Hardwick hydroelectric station was in operation by 1907 (Tucker 1986:Appendix B).

The largest "industrial" developer of hydroelectric power, however, was the Vermont Marble Company, which, in the first years of the twentieth century, decided to convert its large and growing operations from mechanical to electric power. The company's first hydroelectric generation was established at Sutherland Falls on Otter Creek, in Proctor, in 1905. Vermont Marble's Huntington (1911) and Beldens (1913) stations were located north of Middlebury in New Haven. The fourth, Center Rutland, went on line in 1914 on Otter Creek in Rutland Town (Henry 1986a; 1986b; 1988).

At least one Vermont hydroelectric plant was constructed purely for private, recreational use. In 1911, a "miniature" plant was placed in operation on a small spring-fed brook flowing into the Black River within a 600-acre private fish and game preserve in Springfield owned by one W.D. Woolson. The 3 1/2 kw generator, housed in a diminutive wood-shingled frame powerhouse, provided sufficient current to power "all kinds of electrical service, including lighting, heating, cooking, sweeping, ventilating, etc." to Woodson's remotely sited "bungalow" (Hicks 1911:1358-9).

By far the greatest developers of hydroelectric power in Vermont were investor-owned utility corporations. Some early companies were established by manufacturers who set up separate organizations to produce and distribute electricity initially as a sideline. More often, they were organized by local businessmen seeking to capitalize on the emergence of a new industry and/or to boost the images of their communities as modern, progressive places in which to live, work, and do business. The first of these local ventures was the Middlebury Electric Light and Power Company, chartered in 1882 by a group of Middlebury businessmen. The enterprise never went further than its organization, however, and the honor of having Vermont's first operating electric system went to Rutland, where the lights went on on October 3, 1885, courtesy of the Rutland Electric Light Company (Tucker 1986:52-3). Burlington was lighted within the following year, the Brush-Swan Electric Light & Power Company's two-mile circuit placed in service in July of 1886 (Tucker 1986:54). Montpelier businessmen organized the Standard Light and Power Manufacturing Company that same year, with three "dynamos" powered from "water motors" installed in city water mains (Tucker 1986:55). Other local investors were successful in Bennington, where the Bennington Electric Light and Power Company was organized in 1887, and in St. Johnsbury, where the St. Johnsbury Electric Light & Power Company organized that same year and built a small hydroelectric station on the Passumpsic River. The St. Albans Electric Light & Power Company began operation in 1888, its power first supplied by a steam plant (Tucker 1986:56, 299).

The efforts of these early entrepreneurs, and of those who followed in increasing numbers in the 1890s and into the first decade of the new century, resulted in a proliferation of small, generally self-contained production and distribution systems, each serving a limited geographical area and an equally limited number of customers. There was very little interconnection between systems, as the technology to do so was still evolving, as was the technology by which power could be efficiently transmitted over distances. The early limitations on transmission also constrained utilities' selection of power sites to those within a mile or so of potential users. Operation of early production and distribution systems was full of risk for the often precariously financed little utilities, and frequently subject to calamity. Interruptions in service were common, as utilities struggled with ice jams, mechanical failure, debris, flood, occasional fire, and the seasonally recurring problem of irregular stream flow.

Shortage of development and operating capital greatly limited the ability of many of Vermont's early utilities to acquire or develop new power sites, or to support operations. Perhaps illustrative was the development of Chittenden Reservoir in the town of Chittenden. In 1896 two Rutland businessmen financed a small dam on East Creek in the town of Pittsford, from which a short penstock conveyed water to a small hydroelectric station that powered the partners' cold storage business, surplus being sold to the local utility, Marble City Electric. In 1900, one of these entrepreneurs, backed by the Vermont Marble Company, formed the Chittenden Power Company and acquired several parcels of land at Chittenden Meadows. The ultimate object was construction of a reservoir which could store water overly abundant during spring thaw, and release it during times of low flow. The dam was begun in the summer of 1900. The following year, the venture attracted a New York investor who acquired the Chittenden Power Company along with trolley, gas, and electric properties in Rutland. Whatever the resulting infusion of capital, however, it proved insufficient and the dam project was halted. In 1906, the Rutland properties and Chittenden Power were acquired by another New York source and combined as the Rutland Railway, Light & Power Company, under which Chittenden Dam was finally completed in 1909 (Tucker 1986:88-90).

The hydroelectric plants developed by local industries and utilities in the late 19th and early 20th centuries represented a marriage of hydraulic engineering, tested and evolved at scales small and large over centuries, with fast-moving developments in the very new field of electricity. Out of this marriage were produced electric power generating facilities of great variety. They were commonly located at readily-accessible sites, often among, or near, mills and other industries that already utilized hydraulic power for manufacturing purposes. Dams were constructed of stone or of rock-filled timber cribs, and if the generators were not simply connected to existing hydraulic turbines in manufacturing plants and mills, they were housed in small powerhouses, many of which were of wood. By the turn of the century, as the potential promise of the new electric industry drew investors, utilities had begun to acquire desirable water power sites and to develop, or redevelop, them with as much sophistication as financial resources would allow. To increase operating head, old dams were replaced (increasingly with concrete gravity structures) or "refurbished" through capping with concrete, reshaping of spillways for installation of flashboards, and construction of new intake structures. These structures were for the most part fitted with the kinds of standardized equipment found at other types of hydraulic developments during the late 19th and early 20th centuries. They usually contained vertical gates, whose manually-operated rack or screw hoists were protected from the elements within simple wooden gatehouses with gable roofs, clapboard or shingle exteriors and a sash window or two. The materials of which powerhouses themselves were constructed also exhibited variety. While a concrete substructure was of fundamental importance, the superstructure might be built of wood, concrete, or, increasingly, brick. Traditions grounded in 19th century mill construction were carried over to the erection of early powerhouses, in the form of pitched (usually gabled) roofs and solid masonry walls pierced at regular intervals with openings (segmental, straight-headed, or round-arched) fitted with double-hung or hinged sash window elements. Turbines were usually mounted on the main floor of the powerhouse, enclosed in cylindrical, riveted plate casings, or in cast spiral cases. At some plants, belt or rope-drives similar to those utilized in mills and other manufactories connected turbine to generator, while other plants employed direct-connected turbine-generator units. Transformers and associated apparatus, which stepped up the voltage for efficient transmission over distances, were commonly contained within a section of the powerhouse, or in a separate building nearby.

By the first decade of the twentieth century, rapid improvements in the technology of generation, transmission, and interconnection offered increasing opportunities for economies of scale through the expansion of service areas, increase in load diversity, and the coupling of power plants into regional systems of generation and distribution. By the 1910's, those utilities with sufficient generating capacity and/or financial backing were exploiting these opportunities by forming limited-area companies, which expanded their range through acquisition of or merger with utilities serving adjacent or nearby areas, and were achieving increasingly greater production capacity through the development, or redevelopment, of under- or un-utilized power sites. One such limited-area company was the Colonial Light and Power Company, formed in 1913 under control of Eastern Power & Light, a holding company based in Virginia. Colonial combined the Rutland Railway, Light & Power Company, Clarendon Power Company, and Western Vermont Power & Light Company with properties in Springfield, Manchester, and Claremont, New Hampshire. In addition to providing more effective service, and obtaining improved load distribution, Colonial Light and Power sought to increase production through hydroelectric development on Mill River in the southern part of the Otter Creek basin, and on East Creek. While plans to develop property of the Clarendon Power

Company on Mill River were never realized, Colonial (reorganized as the Vermont Hydro-Electric Company in 1919) did oversee further development of the East Creek system which had been initiated by construction of Chittenden Reservoir. To the existing production from the Mendon Plant, built by the Rutland Railway, Light & Power Company in 1905-06, was added production from the Pittsford Power Company's 1914 plant in Chittenden, the Glen Station (Rutland, 1920) and Patch (Rutland, 1921), acquired from the F.R. Patch Manufacturing Company in the early 1930s (Tucker 1986:103-108; Engineering Record 1905; Fraher 1915).

Another of Vermont's limited-area companies was Hortonia Power, incorporated in 1914. The company's initial venture, a hydroelectric station at Hortonville (Hubbardton), was spectacularly unsuccessful, as it drew too much water from Lake Hortonia and with it the ire of property owners around the lake, leading to its closure after only about six years of intermittent operation. In the meantime, however, Hortonia Power had been acquiring a variety of electric properties and water-power sites in the area, in particular former mill sites on the Otter Creek in Salisbury, Middlebury, and Weybridge. In 1916, Hortonia completed its Silver Lake project in Salisbury, which had a capacity of 2200 kw and operated at the highest head in the eastern United States -- 676 feet. A second station was constructed downstream at Salisbury in the following year, and a third, now known as Lower Middlebury, was placed in operation in Middlebury in 1918. Hortonia continued to expand its territory during these years, acquiring the assets and distribution systems of the Neshobe Electric Company (based in Brandon), Lake Dunmore Power & Traction Company of Bristol, White River Electric Company of Randolph, Royalton Light & Power, and Gaysville Light & Power (Tucker 1986:109-11; Connor 1917).

In the Winooski River basin region, the Consolidated Lighting Company had been operating successfully since 1885, serving Barre, Montpelier, and Waterbury by 1900 (Tucker 1986:68). The company's major source of power was a hydroelectric station at Bolton Falls, in Duxbury, built in about 1890 and doubled both in size and generating capacity in 1906-07. During the latter year, Consolidated and another small utility, Vermont Power & Lighting (originally the J.S. Viles Electric Light Company of Middlesex), came under shared management (Electrical World 1908). Five years later, the Montpelier & Barre Light & Power Company, a Massachusetts corporation, was organized, bringing under one management Consolidated, Vermont Power & Lighting, the Corry-Deavitt-Frost Electric Company (supplier of power to a street railway between Montpelier and

Barre), and the Molly's Falls Electric Company of Marshfield. The utility also acquired a company serving Moretown and Waterbury, and by 1921 included 16 towns in its service area. In the course of these acquisitions, the Montpelier & Barre Light & Power Company obtained control of five hydroelectric stations on the Winooski River, a steam plant at Montpelier, and a combination steam and hydroelectric plant at Barre (Tucker 1986:108-109).

The St. Albans Electric Light & Power Company, which had been organized in 1888, was reorganized in 1902 as the Vermont Power & Manufacturing Company under the ownership of the American Pipe & Manufacturing Company of Philadelphia. By 1904 the utility had completed a small hydroelectric development at Fairfax Falls, in Fairfax, which included what may be Vermont's only subterranean powerhouse. In 1915, however, American Pipe went bankrupt. That year, owners of the St. Albans & Swanton Traction Company formed a new corporation called Public Electric Light Company (PELCO), and acquired the assets (including the Fairfax Falls station) of Vermont Power & Manufacturing. PELCO then commissioned Charles T. Main of Boston as consulting engineer for a second, larger capacity hydroelectric plant at Fairfax Falls, which was built in 1919 to supply power under a newly negotiated contract with the city of Burlington (Slattery 1979). With two hydroelectric plants, plus the steam station, PELCO was eventually able to provide electric service to the entire Lamoille River valley west of Cambridge, and to consumers along Lake Champlain from Burlington to Sheldon (Slattery 1979).

The St. Johnsbury Electric Light & Power Company, established in 1887, was reorganized in 1891 as the St. Johnsbury Electric Company. Its first hydroelectric station was built at the site of the present Gage station in St. Johnsbury. In 1901, the utility purchased land and water rights for a small station at Arnold Falls in St. Johnsbury, and in 1905 constructed a third powerhouse in the village of Passumpsic (town of Barnet). The company's Bay Street (St. Johnsbury) station was built in 1911. In 1913, St. Johnsbury Electric was acquired by the Twin State Gas & Electric Company, which already owned utility properties in Bennington and Brattleboro. Under Twin State (which was owned by Chicago investors (see below)), yet another hydroelectric plant was built on the Passumpsic River, at Pierce Mills north of St. Johnsbury village in the town of St. Johnsbury, in 1918. The following year, Twin State completely rebuilt the original station in the system, as the Gage plant (Slattery 1979).

The infusion of out-of-state money and the resulting "foreign" control of Vermont utilities that began within the first decade of the twentieth century, derived from utilities' need for capital dovetailing with the interests of investors and speculators in major U.S. financial centers who sought opportunities for profitable investment in the burgeoning electric power industry. By the mid-1920s, most of the state's hydroelectric production was controlled, through extremely complex operating, management, and holding company arrangements, by four organizations, the New England Public Service Company, Peoples Light and Power, Public Utilities Consumer Corporation, and the New England Power Association.

The New England Public Service Company (NEPSCO) was organized in 1925 as a subsidiary of Middle West Utilities, a holding company based in Chicago and controlled by Samuel Insull. Although the Insull interests had acquired several Vermont properties as early as 1913 (St. Johnsbury Electric and Bennington Gas Light, under the name Twin State Gas & Electric Company), their real move into the northeast occurred in 1925 with acquisition of the Central Maine Power Company. The same year, NEPSCO was created to control and manage Insull's acquisitions in New England, including the Vermont Hydro-Electric Company and its extensive Rutland and East Creek properties, the Otter Creek properties of Hortonia Power (which had gone bankrupt in 1924), and properties in Bradford, Middlebury, and Windsor (Tucker 1986:102-3, 128-30). In 1929, the Central Vermont Public Service Company was organized as a NEPSCO subsidiary, merging eight separate Vermont holdings into one company, and in addition managing the operations of Twin State Gas & Electric. It served over 100,000 people in 90 communities in Vermont, western New Hampshire, and eastern New York, and controlled 18 hydroelectric stations in Vermont with a combined capacity of nearly 20,000 kw (Tucker 1986:131-32).

The Peoples Light & Power Company was formed in 1926 as a holding company initially controlled by W.B. Foshay of Minneapolis. Under the name Peoples Hydro-Electric Vermont Company, Foshay acquired the Vergennes Electric Company, Montpelier & Barre Light & Power, and the latter's subsidiary, Green Mountain Power, which had been formed in 1925 to redevelop the hydroelectric power site at Molly's Falls in Marshfield. Sold within a year to a New York investor, G.L. Ohrstrom, the Peoples Hydro-Electric Vermont Corporation acquired still other production and distribution properties, including several in Burlington. In 1928 Peoples Hydro-Electric Vermont was reorganized as the Green Mountain Power Corporation, with virtually total control of power production in the Winooski basin.

The company operated no fewer than eight stations on the main river, facilitated by completion of a large storage reservoir, known as Molly's Falls Pond, near the headwaters in 1926. The company also operated six other stations on the Mad, Wells, and Stevens rivers, Coopers Brook and Otter Creek (Tucker 1986:118-120, 122-126).

The Peoples Utility Consolidated Corporation (PUCC) was also a Foshay creation. After sale of the Peoples Hydro-Electric Vermont Company to Ohrstrom, Foshay in 1927 set up PUCC as a holding company. He created a subsidiary, Public Utilities Vermont Corp., to acquire electric properties in northern Vermont, beginning with the Clyde River Power Company, which had been formed in 1921 to acquire properties of two small utilities, the Island Pond Electric Company and the Sweat-Comings Company. That purchase was soon followed by acquisition of the Missisquoi Light Company of Highgate Springs, the Vermont & Quebec Power Corporation of Richford, and the Newport Electric Light Company, which had operated independently since 1891, and continued to do so under Foshay's ownership. Under the management of PUCC, a small storage reservoir was constructed, called Seymour Lake, and a hydroelectric plant was built on Lubber Lake in West Charleston (town of Charleston) (Tucker 1986:119, 121-23).

The stock panic of 1929, and the depression that followed, resulted in the collapse of the speculative pyramids with which these Vermont holding companies were associated, and the passage of the Public Utilities Holding Company Act in 1935 further fostered the breakup or reorganization of utility empires. The Public Utilities Consolidated Corporation, in existence only two years, went into receivership in 1929. It was followed by Peoples Light & Power (parent company of Green Mountain Power) in 1931, and Middle West Utilities (parent company of NEPSCO and its subsidiary, CVPS) in 1932. In 1935, the Citizens Utilities Company was organized to take over a number of PUCC's former Clyde River holdings, along with the Newport Electric Company (Tucker 1986:184-5). The New England Public Service Company was purchased out of the Insull holdings, bringing with it CVPS and Twin State Gas & Electric (Tucker 1986:177). In 1941, the Securities Exchange Commission ordered NEPSCO to reorganize or dissolve. Selecting the latter, NEPSCO in 1943 relinquished control over CVPS and Twin State, which CVPS had taken over earlier that year (Tucker 1986:183-4). Green Mountain Power, the major Vermont subsidiary of Peoples Light and Power, suffered a somewhat different fate. As part of the reorganization of its parent company, GMP's common stock was put up for auction and was acquired in 1931 by the New England Power Association, Vermont's fourth major hydroelectric utility.

The three utility organizations so far discussed (New England Public Service, Peoples Light & Power, and Peoples Utility Consolidated Corp.) had developed hydroelectric power production and distribution systems that essentially generated electricity at Vermont sites and sold electricity to Vermont consumers. They grew through acquisition and merger of smaller utilities, acquiring in the process assorted hydroelectric installations which they variously operated as before, abandoned, or reworked for greater generating capacity. The New England Power Association, however, built new, expensive and highly sophisticated hydroelectric developments at carefully chosen sites on the Connecticut and Deerfield rivers, then "exported" the resulting power wholesale to industrial users and "retail" utilities in Massachusetts and Rhode Island. This enormously successful enterprise was initially conceived by Malcolm G. Chace and Henry I. Harriman of Boston, who correctly observed that while northern New England possessed great hydroelectric power potential, the region's largest markets for power were located in flatter terrain nearer the seacoasts, where most existing power sites nearby had long been developed by private industry for hydromechanical power (Tucker 1986:139ff; Nichols 1960).

Between 1906 and 1924, the Chace-Harriman program, financed and executed through a corporate structure of notable complexity due both to its speculative nature and the number of states involved, was begun on the Connecticut River (with completion of the Vernon project in 1909) and almost fully realized on the Deerfield River, with three hydroelectric stations near Shelburne Falls, Massachusetts, plus Vermont's Somerset Reservoir completed -- the Deerfield No. 5 station (Monroe and Florida, Mass.) in 1915, the Searsburg station (Searsburg) in 1922, and the Davis Bridge (Harriman) reservoir and station (Whitingham) in 1924 (Bascom 1909; Engineering Record 1913; Power Plant Engineering 1923; Power 1924; Eaton 1925). In 1926, the parent company, then called the New England Company, joined with the Northeastern Power Corporation (which included the Niagara-Mohawk utilities in New York), the engineering/management firm of Stone & Webster, and the International Paper Company (IPC) to form the New England Power Association (Nichols 1960; Tucker 1986:153-4). Among the results of this venture was the expansion of activities from an almost completely wholesale operation into the "retail" power business through acquisition of retail utility companies in the NEPA service areas in Massachusetts and Rhode Island.

The infusion of capital resulting from the venture also funded the further development of the Connecticut River (facilitated to no small degree by the fact that the sites, at Bellows Falls, Fifteen Mile Falls, and McIndoes Falls, were owned by International Paper). NEPA's Bellows Falls project (Rockingham) was completed in 1928, Comerford and McIndoes (at Fifteen Mile lower falls, in Barnet) in 1930 and 1931, respectively (Engineering News-Record 1927; Power Plant Engineering 1928; Dow 1930; Bliss 1932; Popp 1932). (It might be noted that none of New England Power's Connecticut River projects is located entirely in Vermont; each spans the river from Vermont to the New Hampshire side.)

NEPA's pursuit of retail outlets was significantly extended into Vermont with the 1931 acquisition of the Green Mountain Power Company, which added valuable service territory and at the same time provided a "home" for scattered retail utility properties at White River Junction in Hartford, Bellows Falls in Rockingham, and Vernon which NEPA had acquired in the course of its Deerfield and Connecticut river programs. NEPA was, however, forced to reorganize by the Securities Exchange Commission under provisions of the Public Utilities Holding Company Act. Under reorganization, which did not fully occur until 1947, NEPA was replaced by the New England Electric System, and control of Green Mountain Power was relinquished to its security holders as an independent company. Retained by NEES, however, were the Vermont generating systems on the Connecticut and Deerfield rivers, today operated by the NEES subsidiary, New England Power (Nichols 1960; Tucker 1986:181-83).

The "takeover" of the hydroelectric industry by out-of-state organizations in the 1910s and 1920s was not unique to Vermont by any means, as it was a phenomenon that occurred throughout the United States during the period. Despite their organizational and financial complexities, holding company structures such as those involved in Vermont provided local operating subsidiaries with needed capital. With such capital, local utilities were able to expand or upgrade their production and transmission systems, and to pay for expert design and technical assistance. The hydroelectric developments of the Connecticut and Deerfield rivers (although conceived and built under somewhat different auspices) offer the most pointed object lesson, as these works, individually and collectively, constituted some of the best hydroelectric engineering money could buy, whether in 1909, 1924, or 1930.

Access to capital and to quality engineering services also greatly facilitated the recovery of the hydroelectric industry across Vermont after the devastating flood of November 3 and 4, 1927. This event is justly infamous throughout the state (and region) for the extraordinary damage it caused to communities, industries, farmlands, roads, bridges, and hydroelectric plants. Record rainfall, coming in an already wet autumn, outstripped the capacities of reservoirs and streams. With some four billion tons of rain engulfing Vermont, at least 11 hydroelectric facilities were so extensively damaged that they were abandoned (Tucker 1986:197), and uncounted others required work ranging from lengthy cleanup to major repairs before they could be returned to service. New England Power's Deerfield River system, however, survived largely unscathed, because Harriman Reservoir was able to contain much of the floodwater on that stream.

For some utilities, the disaster offered the opportunity or incentive for major improvements. For example, both the Peoples Hydro-Electric Vermont Company and New England Public Service Corporation completely reconstructed a number of facilities, building and equipping them according to then-current standards and for greater generating capacity and efficiency. The Middlesex plant on the Winooski River in Moretown had been built in 1895 with a timber-crib dam, open canal, and large, though inefficient powerhouse with belt-connected generating equipment, the combined capacity of which was only 1200 kw. In 1928-9, Middlesex was completely transformed by Green Mountain Power (People's subsidiary), into a modern plant, designed by Charles T. Main, Inc., of Boston, featuring a new concrete dam, steel-framed brick powerhouse, two 80-foot penstocks, and two 1600 kw direct-connected vertical turbine-generator units (Fitch 1929:189-191). During the same years, Green Mountain Power built a new station (known as #18) on the south side of Winooski Gorge, in South Burlington. On the Passumpsic River, NEPSCo subsidiary Twin State Gas & Electric had operated five stations in and near St. Johnsbury. In 1919 Twin State, completely redeveloped a site (known as Gage) which proved to be one of only two that were returned to service after the flood. Soon thereafter, with design assistance from the NEPSCo engineering department, Twin State constructed new facilities out of the rubble of its old Passumpsic (Barnet) and more recent Pierce Mills (St. Johnsbury) stations, and added a third at a newly acquired site at Arnold Falls (St. Johnsbury) to replace a small station on the other side of the river. It should be noted, however, that the process of abandonment, redevelopment, and new construction of Vermont's hydroelectric "infrastructure," began well prior to the 1927 flood and continued, although to a lesser extent, into the 1930s. In many respects, the flood simply hastened the inevitable abandonment of marginal installations as well as the repairs or reconstruction of sites important enough to maintain in service.

Despite the Depression and resulting corporate upheaval, construction of new hydroelectric facilities did not cease entirely in Vermont during the 1930s. In 1926, the Public Electric Light Company (PELCO) acquired three valuable power sites on the Lamoille River in Milton from the IPC. Down to one hydroelectric station after the 1927 flood (the underground plant at Fairfax Falls was abandoned, leaving only the 1919 station on the opposite bank), PELCO built a new station at IPC's former pulp mill at Milton, just below the village, in 1929. Eight years later the second site, at Clarks Falls, was developed, including a large dam that created Lake Arrowhead (Ropes 1937b). The following year, 1938, the Milton facility was expanded through the addition of a second generating unit (Slattery 1979). (The third site, at Woods Mills in West Milton, was not developed until 1948.)

Also in northern Vermont, the Newport Electric Company, then a subsidiary of the Citizens Utilities Company, built in 1936 a completely new hydroelectric facility adjacent to its 1906 hydro plant on the Clyde River south of Newport (town of Newport). The first generating unit in the new station was installed at that time, a second added in 1940 (Ropes 1937a). The two stations were eventually joined through construction of areas for a third hydro unit and several diesel units during the 1940s. Citizens Utilities continued to expand its generating capacity during the 1950s, with construction of its Newport No. 11 facility (also in Newport).

Storage reservoirs, primarily for flood control, were built at several Vermont locations under Federal auspices during the 1930s. The site of one of these, on the Waterbury or Little River in Waterbury, was owned by Green Mountain Power. Completed in 1938, Waterbury Dam was turned over to the state of Vermont. Power rights, however, remained with Green Mountain Power, which finally built a generating station there in 1953 (Tucker 1986:213-214).

The last major hydroelectric developments in the immediate post-war period occurred on the Connecticut River. In 1950, New England Power completed its Wilder project, a large new facility at White River Falls between Hartford, Vermont and Lebanon, New Hampshire. Six years later, the company realized full development of Fifteen Mile Falls with completion of the Moore facility between

Waterford, Vermont, and Littleton, New Hampshire, upstream from the 1930 Comerford plant between Barnet, Vermont and Monroe, New Hampshire.

Hydroelectric stations built in Vermont during those eventful decades between the World Wars generally reflected the maturation of the industry nationwide. Standardized equipment became the norm, as a few large manufacturers came to dominate the production and supply of turbines (notably Allis-Chalmers, S. Morgan Smith, James Leffel & Co.), generators and other electrical equipment (Westinghouse, General Electric) and governors (Lombard, Woodward). In Vermont, where the great majority of pre-World War I installations had been built for turbine-generator units in horizontal settings, the direct-connected vertical unit was widely employed in plants constructed during the 1920's and 1930's. Outdoor substations were the rule, and fewer plants included gatehouses above the intake structures, as gates were increasingly operated by electric or hydraulic power, rather than by manual force. The flat-roofed, brick-clad steel frame emerged as the basic "block" for the great majority of powerhouses (large and small) built during these decades. The amount of wall area devoted to openings increased, both vertically and horizontally, the openings (straight-headed, segmental or round arched) filled with multiple-light steel window units. Some new powerhouses built during this period achived a high degree of sophistication as industrial architecture. Most, however, were, in terms of architectural "treatment", fairly conservative, although patterned brickwork, pilastering along walls and at corners, keystones and impost blocks of concrete or glazed terracotta, and simply molded concrete or metal cornices below corbelled parapets, were common features. Aspects of the Art Deco and Moderne styles found their way onto a number of the more visually-sophisticated powerhouses, as did the occasional Craftsman detail on several very small stations.

Hydroelectric Engineers in Vermont

To date, only a few names of engineers can be reliably associated with the design of hydroelectric projects in Vermont. Perhaps the most readily accessible sources of such information are professional publications containing articles about various plants. In Vermont, however, industry publication coverage was somewhat dominated by the large-scale projects of New England Power on the Deerfield and Connecticut Rivers, perhaps to the neglect of smaller, but not uninteresting, developments elsewhere in the state. Future research in corporate archives is likely to reveal additional names of engineers who designed hydroelectric stations in Vermont.

W.S. Barstow

W.S. Barstow, of New York, served as consulting engineer for the Pittsford Power Company's 1914 powerhouse in Chittenden (Electrical World 1915)

W. A. Brackenridge

Brackenridge, of Niagara Falls, New York, served as consulting engineer for the 1907 Cavendish station on the Black River (Drawing entitled "Claremont Power Co, Cavendish Plant, Powerhouse Superstructure, South Elevation" (1907), CVPS files).

French and Bryant

The Boston firm of French and Bryant served as consulting engineer for the initial development of Chittenden Reservoir, completed in Chittenden in 1909 (Engineering Record 1905).

George F. Hardy

Perhaps the earliest hydroelectric plant in Vermont for which an engineer has been identified is the 1904 Fairfax Falls station on the Lamoille River in Fairfax, which was designed by George F. Hardy of New York. During the 1890s, Hardy was associated with the Holyoke, Massachusetts, firm of D.H. and A.B. Tower, which, after a brief stint with International Paper, Hardy purchased and continued to manage on his own. Hardy relocated to New York in 1901, and the bulk of his subsequent career was devoted to design of paper and pulp mills, as well as hydroelectric facilities, primarily in the southeastern United States (Who Was Who in America 1950:234).

Hortonia Power Company

Hortonia was one of several utilities who apparently employed in-house engineering services in the design and construction of at least one of its stations. Hortonia's

Silver Lake project was designed by the company, with an employee, W.E. Connor, as hydraulic engineer (Connor 1917).

I.W. Jones & Co.

The Milton, New Hampshire, firm of I.W. Jones & Company provided designs for three hydroelectric projects on the Passumpsic River: the original (non-extant) Passumpsic station (1905) in Barnet; Bay Street (1911) (non-extant) and Gage (1919) in St. Johnsbury (CVPS Files, Drawings A7-5-C 1-27; A7-5-D 1-54).

J.J. Kennedy

Jeremiah Joseph Kennedy, consulting engineer for the 1913-1917 Essex (#19) hydroelectric development in Essex Junction, was born in Philadelphia in 1864. Largely self-educated due to "delicate" health as a child, Kennedy had a "wide and varied career" as a civil engineer. First employed by the Norfolk & Western railroad, in 1882, he later worked for the Grubb Iron Works of Blue Ridge, VA, constructing railway extensions and operating mines. Between 1892 and 1894, Kennedy was primarily engaged in the design and construction of gasworks and gas-holders, and from 1894 to 1901 served as Chief Engineer for the J.G. White Company of New York. In the latter year, he established his own practice as a consulting engineer, which he pursued until his death in 1932 (Hammer 1933: 1565-6).

Kennedy's consulting career involved him with steel plants, railways, pneumatic mail-tube systems and even the fledgling motion picture industry, the latter through investment in the Biograph Company. Within this wide range of projects were included a number of hydraulic-power developments for manufacturers and transportation companies, plus several projects for electric utilities. His "Memoir" (published in the Transactions of the American Society of Civil Engineers) cited for the latter one at Phoenixville, PA; and a second (1903) at Lynchburg, VA. The "Memoir" also includes hydroelectric development "for the American Gas Company at Winooski and Essex Junction" in Vermont, which apparently refers not only to the design of the new plant at Essex Junction but perhaps to some form of improvements to the 1893 plant (now Essex #17) at Winooski Gorge in Colchester (Hammer 1933: 1566).

Charles T. Main, Inc.

A major designer of hydroelectric projects in Vermont was Charles T. Main, Inc., of Boston, which was responsible for at least six stations in addition to the firm's work for New England Power. Main was a mechanical engineer who graduated from the Massachusetts Institute of Technology in 1876, and from 1881 to 1891 worked for the Lower Pacific Mills in Lawrence, Massachusetts. In 1891, Main opened a consulting partnership with Francis Winthrop Dean, and in 1907 established his own practice, incorporated as Charles T. Main, Inc., in 1924. Author of Notes on Mill Construction (1886), Main also began to publish articles on water and steam power in the 1890s. Some 80 hydroelectric facilities were designed by Main's firm prior to his death in 1943 (James 1973: 500-501). In Vermont, C.T. Main, Inc., served as consulting engineer to PELCO for three Lamoille River hydroelectric plants prior to 1940: Fairfax Falls (1919), Milton (1929), and Clarks Falls (1937). The firm was also retained by Green Mountain Power for the redevelopment of Molly's Falls (1926) (in association with Charles H. Tenney & Co., Engineers, of Boston) and Middlesex (1928), and may also have been responsible for the Gorge (#18) plant built about the same time as Middlesex. C.T. Main, Inc. also served as consulting engineer for the Newport Electric Company's redevelopment of its Clyde River station in 1936. The firm was long associated with the New England Power Association's multi-component Deerfield River project, and with that utility's McIndoes and Comerford projects.

New England Public Service Company

The New England Public Service's Engineering Department provided design services to the Twin State Gas & Electric Company for its 1920's construction of the Passumpsic, Arnold Falls and Pierce Mills stations on the Passumpsic River following the 1927 flood. In the 1940's, under the name NEPSCO Services, Inc., it also prepared designs for the new powerhouse at the Weybridge station, built in 1950.

Major Collaborative Efforts

The enormous scale of NEPA's hydroelectric development activity involved the participation of numerous consulting engineers and contractors besides C.T. Main, to the extent that credit for the successful design and construction of those facilities cannot be assigned to any one individual or firm. J.G. White & Company of New York contributed significantly to design efforts associated with the both the Connecticut and Deerfield River programs, beginning with Vernon in 1909. Also crucial to the conceptualizing and design efforts for the multi-component Deerfield River hydroelectric project was H.K. Barrows, a long-time professor of hydraulic engineering at M.I.T. and author of a standard text in his field (Barrows 1927). Frederick P. Stearns, retained by New England Power as consulting engineer on "storage reservoir problems" associated with the Deerfield project, was a noted hydraulic engineer and "architect" of the Boston metropolitan water supply system. The New England Power Construction Company was created by NEPA to supply in-house design and construction services for the Deerfield developments. This company later designed the Bellows Falls project and, as New England Power Engineering and Service Corporation, joined with Charles T. Main and Albert Crane of New York in the realization of the McIndoes and Comerford projects.

F. ASSOCIATED PROPERTY TYPES

I. Name of Property Type: Hydroelectric Power Generating Facility

II. Description

Note: This property type discussion has been derived in large measure from documentary research. The principal sources of information for this discussion are textbooks on hydroelectric engineering published prior to 1930, articles published in engineering periodicals, the Edison Electric Institute's 1989 draft report on American hydroelectric development, Vermont Historic Sites and Structures Inventory Forms for a limited number of plants, and selected data from the corporate archives of Central Vermont Public Service, New England Power, Green Mountain Power, and Citizens Utilities Co. Additional information has been drawn from the author's personal observation of approximately a dozen hydroelectric stations in Vermont as well as stations in other states built prior to 1940. Additional documentary research in corporate archives, coupled with comprehensive field survey, may in the future provide further information about the character of original construction, nature and extent of modifications, and present condition of hydroelectric installations in Vermont. Such investigations may ultimately mandate some revision to the property type discussion presented below.

A. Physical Characteristics

A hydroelectric development is a system, the purpose of which is the production of electricity by hydraulic power. The basic source of hydraulic power is the stream, large or small, across which a dam is constructed to create a reliable operating head. When power is to be generated, water from behind the dam is obtained by opening one or more gates which are contained within an intake. Trash racks on the upstream side of the intake prevent debris from entering the system. The water flows, either directly or through some form of open or closed conduit (penstock, canal) to the powerhouse. Within the powerhouse is the water wheel, or turbine. The force of the water against the blades of the turbine runner cause the runner to rotate. The speed of the rotation varies with the velocity and angle at which the water encounters the blades. The governor provides this control, through hydraulic or electronic manipulation of pivoting vanes, or wickets, arranged in a ring around the runner. Having passed through the turbine, water is discharged through a draft tube in the powerhouse substructure into the tailrace on the downstream side of the powerhouse.

The rotation of the turbine wheel is conveyed, by means of a shaft, to the generator. A generator's basic components are a field, or assembly of magnets, arranged to produce a magnetic flux, and an armature or assembly of electric conductors arranged across the path of the magnetic flux. The field and armature are arranged in such a manner that when the field is rotated (by action of the shaft), an electromotive force, or current, is produced. The magnetic field of this alternating-current generator is energized by an exciter, a smaller generator which produces direct current. The alternating current produced in the powerhouse is carried on circuits to transformers which increase, or step-up, the voltage for more efficient transmission on high-tension lines to points of distribution. Transformers and transmission apparatus, as well as some switching equipment, are commonly located outside the powerhouse at a substation. Switchboards, located inside the powerhouse, contain the control, metering and sometimes the switching equipment of the power station.

The design, construction, and subsequent physical history of any given hydroelectric facility are conditioned by many factors, such as character of the site (soils, geology, topography, presence of "re-usable" infrastructure); character of the stream; available construction and equipment technology; and how much power the facility is intended to produce. Another, very important, factor is the amount of money available to do the work, since financial considerations limit (or enhance) the size of the development, the materials of which it is built, and the kinds of equipment installed. The character and features of a hydroelectric facility may also be affected by events subsequent to construction, such as floods, and by management decisions leading to expansion, reconstruction, or abandonment. As a result, each hydroelectric power generating facility is unique. At the same time, each is a product of the nationwide evolution of hydroelectric engineering practice, technology, and construction methods over the past century.

Physical Arrangement and Principal Structural Features

The physical arrangement of hydroelectric installations can be characterized as either concentrated fall or divided fall (Barrows 1927:249-51). In a plant utilizing concentrated fall, the dam creates pondage at the point where the water is to be used, and the distance between the dam and the turbines is quite short. Such installations often position the powerhouse at one end of the dam. Plants with divided fall, on the other hand, are characterized by a dam with an intake at the headwater, through which water is conveyed, depending upon the topography along the river bank, along an open channel and/or through an enclosed pressure conduit (tunnel or penstock), from the dam to the powerhouse located some distance (from under a hundred feet to several miles) downstream.

Nearly all of Vermont's hydroelectric installations are of the divided fall type, which typically consists of a dam, intake, gatehouse (optional), canal and/or penstock, surge tank (optional), powerhouse, and substation. Concentrated fall facilities, on the other hand, normally consist simply of a dam and powerhouse, with an intake structurally integral to the latter. Arnold Falls and Gage in St. Johnsbury, Gorge # 17 in Colchester, Vernon, McIndoes Falls, Patch in Rutland, and Bethel (no longer extant) are among the limited number of known examples of concentrated fall facilities in Vermont.

In addition to these basic structures, hydroelectric stations may contain a variety of other features. On-site maintenance structures shelter vehicles, machinery, and equipment used in the normal course of facility operation. Housing for plant operators was often provided by utilities for plants at remote locations and/or when plant operation required the 24-hour presence of one or more plant personnel. Since many of Vermont's hydroelectric installations were built at sites where water power had been harnessed for decades, or even centuries, remains of old dams, hydraulic systems, and industrial buildings are often present on the property of the hydroelectric station or along the river banks up- or downstream. (Such features, unless they constitute remains of earlier hydroelectric facilities, are not encompassed by this historic context, but might be included in other contexts, such as water-powered industry.)

Dams

Hydroelectric facilities in Vermont have operated at a wide variety of heads, from under 20 feet (Arnold Falls, in St. Johnsbury, and Passumpsic, in Barnet, for example) to over 400 feet (Pittsford in Chittenden) and even over 600 feet (Silver Lake in Salisbury). The distinctions among low, medium, and high heads are, on one level, somewhat relative, as a "medium" head may be very high in a region of low-head operations, and considered low in a region where operating heads are generally quite high. Roughly speaking, however, low heads are generally those under about 40 feet, while high heads begin at about 200 feet. Of hydroelectric installations in Vermont, at least five stations have operated at heads over 200 feet, thirteen between 100 and 200 feet, and the great majority between 30 and 100 feet (Tucker 1986: Appendix A).

Although the purpose of the dam is primarily to create a head of water, it also serves to create pondage or storage. According to Barrows (1927:150), pondage is defined as the holding and subsequent releasing of water to equalize daily or weekly fluctuations in flow, or to compensate for fluctuations in the demand for electricity. The term storage is most properly used to describe relatively large reservoirs which are usually distinct from power facilities, and which serve to equalize monthly, seasonal, and/or yearly fluctuations in flow for the benefit of power installations downstream. In Vermont, the great majority of hydroelectric dams were built to create pondage. Examples of storage reservoirs in Vermont include Chittenden, near the head of East Creek; Somerset and Harriman on the Deerfield; Mollys Falls Pond on the Winooski; and Seymour Lake, on a tributary to the Clyde. In general, ponds and storage reservoirs are, except for their ultimate purpose, indistinguishable from impoundments associated with other uses, such as manufacturing, recreation or flood control, nor do they possess, apart from the dams that create them, obvious characteristics that would visually distinguish them from natural bodies of water. (Since hydroelectric ponds and reservoirs extend for some distance upriver from the dam, and since utilities often acquired only flowage rights, rather than large tracts of real estate, from riverside landowners, the banks of such water bodies may contain buildings and structures unrelated to hydroelectricity or to operation of hydroelectric facilities, such as vacation camps, residences, or industrial buildings, and may be crossed by bridges. Such buildings and structures are not included in this historic context, but may be included under other historic contexts, such as recreation or metal truss, masonry and concrete bridges in Vermont.)

Wood and stone being abundant in Vermont, many of the state's early hydroelectric installations featured dams constructed of stone masonry or, more commonly, rock-filled timber cribs, both dam types also associated with Vermont's 19th century industrial history. A sizeable number of timber dams associated with hydroelectric developments appear to have persisted into the 1920s, until washed out or extensively damaged by the 1927 flood, or replaced during modernization of the facility. Sometimes-substantial portions of old timber dams can be found submerged behind later, concrete, structures. Those that remain in active use are often capped with concrete, or their spillways re-shaped with concrete to improve flowage over the crest.

By the first decade of the 20th century, concrete gravity dams (first built in California in 1887) were being employed at Vermont hydroelectric developments, and remained standard throughout the period of this context. Commonly, concrete gravity dams consist largely, or entirely, of spillway, or overflow, sections, arranged, in terms of plan, in linear fashion across the river or in curves or V's. Many of these dams have wooden flashboards ranging from 6 inches to 6 feet high mounted along the crest to permit regulation of the water level above the dam. These flashboards are set in steel stanchions and are designed to wash away in periods of high water. Steel "bridges" or walkways, or cableways suspended from towers, may extend above the spillway, from which plant personnel can replace the flashboards. Where such features are lacking, flashboard replacement does not occur until the water level has fallen sufficiently below the level of the spillway crest. An alternative to "replaceable" flashboards is a hinged system in which sets of boards can be lowered against the crest when water reaches a prescribed level behind the dam, then raised as the water level recedes. In addition, to reduce the number of occasions when flashboards must be released and then replaced, many dams are built with sluice gates which can release water through a passage at the base of the dam. Such gates are similar to those used in intakes (see below) and are operated in much the same manner. At a very few installations, from the 1920's or later, the need to accommodate, however occasionally, extremely large flows, is met by radial Taintor gates or roller gates, each gate electrically or hydraulically operated and mounted between concrete piers along a section of the spillway.

A number of dams combine spillway and "non-overflow" sections, the latter constructed of earth with a core wall, or of hydraulic or semi-hydraulic fill. Examples of such combinations include Clarks Falls dam on the Lamoille, Searsburg and Somerset dams on the Deerfield, and Chittenden on East Creek. Vermont's most unusual spillway is located behind the Harriman Dam on the Deerfield. There, a concrete structure, shaped like an inverted horn, or "morning glory," 160 feet in diameter, serves as the mouth of a vertical shaft leading to a diversion tunnel which extends beneath the dam to empty into the river below the reservoir.

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Harriman Dam, although later modified, was, at 200 feet, the highest semi-hydraulic earth-fill dam in the world at the time of its completion in 1924.

Intake

The intake is a concrete or masonry structure, sometimes topped with a gatehouse, which contains gates to admit water from behind the dam either directly to the powerhouse or into a canal, tunnel, or penstock. At installations of the concentrated fall type, the intake does not constitute a separate structure, but is instead built into the upstream side of the powerhouse substructure. At divided fall installations, however, the intake structure is commonly positioned at one end of the spillway. In either case, an intake commonly consists of one or more timber stoplogs or steel gates which are raised and lowered on stems by geared or screw hoists, or by electrically operated cranes. The hoisting mechanisms are positioned on a concrete deck immediately above the gates. Early photographs of intake structures at divided fall plants indicate that many in Vermont were capped with small gatehouses, to shield the hoisting equipment from the elements. These buildings were usually of wood (although brick and/or concrete might also be employed), consisting of a single room beneath a gabled or hipped roof. Many have entrances from both the river bank and the adjacent spillway, and are provided with natural illumination from one or more moveable- or fixed-sash windows. As hydroelectric plants increasingly employed electric motors, hydraulic systems, or cranes to operate the gates, the need for gatehouses declined. As a result, existing gatehouses were sometimes removed, and plant builders included them less frequently in the construction of facilities.

At earth dams which constitute "primary" structures (rather than wings or extensions to masonry spillways), the intake of water is often achieved in a somewhat different manner. At such dams, water may enter a tunnel or penstock laid through the base of the dam. The gate controls are positioned near or at the crest of the dam, sometimes in small gatehouses. Alternatively, the intake structure may be built in the form of a "tower" placed in the reservoir or pond at some point upstream from the dam. The tower forms the entrance to the penstock or power tunnel, and contains gates or valves to control flow into the conduit.

Water Conveyance

Topographic conditions (such as insufficient space along riverbanks) along Vermont's waterways have generally prevented or discouraged use of open canals to convey water from hydroelectric dams to powerhouses. Among exceptions are the Gorge (#18) plant on the Winooski River, which employs a rock cut channel, and the Bellows Falls station on the Connecticut River, which utilizes a canal originally opened in 1802 for navigation purposes and later utilized for hydromechanical power to paper and other industries. A few power developments have employed tunnels, including the original Fairfax Falls station on the Lamoille and the Harriman (Davis Bridge) project on the Deerfield. Most of Vermont's hydroelectric developments feature some form of penstock -- a pipe or pipes extending from the intake at the dam to the powerhouse. Penstocks vary from under 100 feet to several miles in length. They may include sections laid in cut, sections carried in low timber or concrete cradles, and sections elevated on piers, trestles, or bridge-like truss spans. Wood stave penstocks were built at Vermont hydroelectric installations well into the 1920's; a number are still extant, or have been repaired or replaced with like materials. The Searsburg development on the Deerfield River features a wood stave penstock. Other common materials for penstocks, sometimes used in combination with wood stave construction, are riveted, welded, or lockbar steel pipe, and reinforced concrete. Among numerous examples of use of steel penstock are the Clark's Falls station on the Lamoille River, the Newport #1,2,3 station on the Clyde River, and the Huntington Falls station on Otter Creek. The Sherman facility, extending from Vermont to Massachusetts along the Deerfield River, includes a section of concrete pipe in the Massachusetts portion of the project.

Common on many penstocks is the surge tank, which aids control of water hammer and facilitates regulation of pressure within the penstock; it may also supply or store up water during a change of load. Surge tanks are vertical cylinders which may be of wood stave, concrete, or steel. In Vermont, they are sometimes cased against frost or freezing. They may be set directly on the ground or elevated on high steel pylons. Among many examples are those at Milton, West Charleston, Newport #1,2,3, Harriman and Chittenden.

Powerhouse and Equipment

The powerhouse serves as a protective cover for the hydraulic and electrical equipment. The basic plan and dimensions of powerhouses are based primarily on the type and number of generating units to be employed at the development. As "enclosures" for a manufacturing process, powerhouses are broadly reflective of the evolving practices of American industrial architecture from the late 19th century until around World War II. By and large, the extent to which powerhouses were given "architectural treatment" depended upon the inclinations of the designing engineer, the aesthetic or promotional wishes of the utility, and/or the extent to which the latter was willing (or able) to spend money on decorative finishes or features. Simple, rectilinear forms and regularly-spaced bays lended a somewhat "classical" effect to many powerhouses, while high round arches and brick corbelling suggested the lingering influence of Victorian styles on industrial architecture. The Art Deco/Moderne idiom lent itself well to the embellishment of powerhouses in the 1920's and 1930's, as did, to a lesser degree the Craftsman style.

By the late nineteenth century, many water-powered industries utilized turbines with vertical shafts. Power from such turbines was transferred to horizontal line shafts by bevel gears or twisted belting. Some early hydroelectric plants in Vermont may have employed this configuration, as most generators of the period were built with horizontal shafts. In the years prior to World War I, direct-connected units were made possible through development of large-capacity thrust bearings, improvement of vertical turbines, and introduction of vertical "umbrella"-type generators. Such units were soon widely employed at new plants planned for vertical settings, although bevel gearing and belting remained in use at older plants.

Turbines operating at very low heads were installed in open "pit" or "flume" settings. (It might be noted here that at plants employing these settings, water is introducted to the turbines either from an open channel or from an intake on the upstream side of the powerhouse, not from a penstock.) The original vertical units at Vernon (1909) were so installed, in that instance with three turbines on each shaft. Two operated under normal flow conditions, the third during periods of high floodwater (Bascom 1909:513-4). Other (single turbine) examples include Patch, on East Creek, and Passumpsic and Gage stations on the Passumpsic River. More commonly in Vermont, vertical turbines were enclosed in volute or spiral casings of cast or plate steel, or, particularly after World War I, in concrete casings cast into the substructure of the powerhouse. Among many known examples are Highgate Falls in Swanton (1915), Middlesex (1929), Fairfax Falls (1919), Searsburg (1922), Harriman (1924), and Bellows Falls (1929). Propeller-type turbines came into use during the 1920s, and were installed in plants such as Gorge (#18) (1928), Arnold Falls (1928), and McIndoes (1930). McIndoes is also credited with the first use in New England of the Kaplan adjustable-blade propeller turbine (Popp 1932).

In general, however, horizontal turbine-generator installations were most widely used in Vermont, being employed from the early years of the hydroelectric industry in the state well into the 1920's. Among the earliest for which information is presently available were the Vermont Electric Company's Gorge station (now Green Mountain Power #17, no longer in operation), and the original Middlesex station (no longer extant), both dating to the 1890s, at which horizontal turbines were connected to generators by means of belting and clutch pulleys, much as manufacturing machinery had been run by hydraulic power (Adams 1903:147-18; Fitch 1929:189). The most common installation, however, was that in which horizontal turbines, enclosed either in cylindrical "boilerplate" cases or in rather more expensive spiral cast- or plate-steel casings, were direct-connected to generators. The original (1904) Fairfax Falls station was equipped in this manner, as were the Vermont Marble Company's Center Rutland (1914), Huntington Falls (1910-11), and Beldens (1913-14) plants; Essex #19 (1917), West Danville (1915-16), Vergennes #9 (1912), Silver Lake (1916), and Pittsford (1914).

Powerhouses basically consist of a substructure and a superstructure. Uniformly, foundations and substructures of Vermont powerhouses were of concrete (mass or reinforced, or a combination of the two), unless, as at Vermont Marble's Center Rutland plant, the powerhouse utilized portions of an earlier structure. The design of the substructure was based upon the type of turbine setting employed. For example, a plant employing vertical turbines in open pits would have a substructure divided into one or more "rooms", with a turbine set in each space to discharge through a draft tube into the tailwater below. Vertical turbines in "closed" settings were contained within spiral scroll cases, either of steel or cast into the fabric of the substructure. Cased horizontal turbines, however, were placed on the main floor of the powerhouse, and the substructure contained only the draft tubes. In all cases, the point of discharge from each turbine into the tailrace below the powerhouse was marked by an arched opening in the downstream face of the substructure.

Brick was by far the most common material for powerhouse superstructures. It was employed first in load-bearing masonry walls but by the 1920's was almost always used as cladding over a steel frame. Wood frame superstructures, with shingled or clapboard exteriors, were not unknown, particularly in the early decades of the industry in Vermont. Examples include the former Woodbury Granite Company plant (ca. 1895, now owned by the village of Hardwick), Bennington's 1887 steam-hydro plant (non-extant), and West Danville (GMP #15) (1916). The 1892 Bristol station, also of wood frame construction, is clad with a pressed metal facing that resembles coursed masonry. At least one small station, Patch (1921), was built with hollow clay tile. Concrete was employed at Swanton's station in Highgate (1915), Gage (1919), Colchester Gorge #18 (1928), Hydeville (Lake Bomoseen in Castleton) (1921), and the original Weybridge (1921). Vermont Marble, rather logically, built its powerhouses with marble.

Powerhouses were built with gable roofs, flat roofs edged with low parapets, and occasionally hipped roofs. Gable and hipped roofs could be shingled with wood, slate, metal or asphalt. Flat roofs were often constructed of reinforced concrete, then covered with tarred felt and gravel. Such roofs were commonly hidden behind low parapets. Exterior walls were commonly divided into equally sized bays. Wall openings could be rectangular, round-arched, or segmental-arched. Into the 1910's, these openings commonly contained wooden double-hung or hinged sash, much like window elements found in late 19th and early 20th century factory buildings. By the 1920's, however, most powerhouses were built with openings of considerably larger dimensions, made possible by the steel structural frame, which in some instances filled the entire space between piers. These openings were fitted with multiple-light steel window units, often with wire glass, containing sections moveable on hinges or pivots for ventilation.

The exterior walls of brick and concrete powerhouses were often pilastered, primarily for structural reasons but also as a simple, yet effective, form of ornamentation. Corbel tables were commonly run from the top of one pilaster to another, to frame window bays in brick walls. Corbel tables were also used on gable-roofed powerhouses to create a "pediment" effect. Window arches were often picked out with corbelled voussoirs, or with concrete or tile keystones and impost blocks. Cornices, of concrete, corbelled brick or metal, were occasionally embellished with dentils or modillion blocks at the frieze. Other exterior details could include panels of patterned brick, tile or terracotta, concrete plaques containing dates (or more rarely, the name of the plant or of the utility), and wall-mounted globe or sconce lighting to either side of the main entrance. This entrance, twelve feet wide or more, and at least as high, was large enough to accommodate the most massive pieces of equipment. Sometimes capped with a round-arched transom, the entrance could be fitted with double leaf wooden or metal doors, or with an overhead roll door. Either type of door often featured one or more windows, and wooden doors were commonly paneled.

The principal space within the powerhouse superstructure is the generating floor. In smaller installations, this was the only room, sometimes almost completely filled by the generating unit. A partial subdivision into levels might be achieved by concrete or steel platforms along one or more of the interior walls. In earlier powerhouses of size, transformers and associated apparatus were contained in bays that were often located in a multi-level projection off the main block of the building. Powerhouse interiors commonly featured concrete floors, walls of painted or glazed brick or plainly painted concrete, and exposed wood or steel roof trusses or beams. Natural light from the many windows was supplemented by simple suspended bulb fixtures with metal shades. Generators or turbine-generator sets were regularly spaced along the main (generating) floor. Governors, which regulate turbine speed, were positioned next to their respective units. Exciters (small direct-current generators used to energize the magnetic fields of the main, alternating current generators) could be positioned nearby, grouped between pairs of main generators, or grouped at one end of the generating room. Exciter units mounted atop vertical generators were employed at some 1920s and 1930s installations. Controls were centralized, but could be located at one end of the generating room, along one of the long walls at floor level, or on a raised platform or mezzanine. In larger plants, controls were often enclosed in a partitioned-off space on the main floor or mezzanine. Some plants were also equipped with small wooden telephone booths. Powerhouses were normally equipped with at least one travelling crane of a size and height above the floor sufficient to lift any of the equipment or machinery (the clearance required to do so was the determining factor in the height of the superstructure). The crane moved along I-beam crane rails carried on brick or steel piers set between window bays of the upstream and downstream walls.

Substations

A common feature of nearly all hydroelectric stations is the substation, comprising transformers and other high-volgate equipments, such as circuit breakers, buses, and lighting arresters. Transformers at the plant step up the voltage at which power is generated to a higher voltage that is more efficiently transmitted over distances, at which point it is stepped back down for distribution. Prior to World War I, transforming apparatus was enclosed, either in a separate section of the powerhouse, or in a nearby building constructed for that purpose. With development of transformers and apparatus able to withstand the natural elements, the "outdoor" substation became the rule. Such substations consist simply of equipment mounted on a concrete slab near the powerhouse, or in some instances on the powerhouse roof. For safety reasons, outdoor substations are normally enclosed within high metal fencing.

On-Site Maintenance Structures.

Garages and storage buildings exist at many facilities to shelter vehicles, machinery, equipment, and tools employed in day-to-day operation, maintenance activities, and repairs. Where present, they are utilitarian buildings of wood frame, brick, or concrete construction. Very occasionally they may display some of the stylistic attributes of the powerhouse. Modern versions of these buildings often simply employ wood or steel frames with sheet- or corrugated-metal cladding.

Operator's Housing.

Until perfection of automatic and semi-automatic power station and substation controls in the 1920s, the operations of hydroelectric plants were manually controlled. Round-the-clock operations thus required round-the-clock presence of one or more plant personnel. For plants at locations remote from the homes of employees, utilities might rent, purchase, or build housing on or near plant premises. (The definition of "remote" would of course change with time, due to improved roads and to increased use of automobiles and motor trucks.) Today, such housing may be distinguishable only through documentary sources (such as deeds, leases, and utility records) or by continued physical presence on utility company land. Physically, operator's housing was indistinguishable from the domestic architectural fabric of Vermont prior to World War II.

Construction Camps.

The great majority of Vermont's hydroelectric plants were constructed with local labor, with a limited number of engineers and other specialists brought in for the duration and provided with accommodations in local hotels or rooming houses. This arrangement was possible due to the relatively small scale of the construction efforts, and to the fact that many plants were developed somewhat incrementally out of existing infrastructure, and to the proximity of the hydroelectric power site to sources of labor and supplies. Very large-scale projects, however, such as New England Power's Deerfield and Connecticut River developments, required work forces which outstripped the availability (and sometimes skills) of local labor as well as the availability of housing. In these instances, utilities or their contractors imported large numbers of men and housed them in hastily-built camps.

Temporary by nature and intent, construction camps would have been dismantled as the need for them came to an end. Buildings might be sold to, or simply expropriated by, local parties, or dismantled and the materials sold, or retained for use elsewhere. Physical remains of camps thus are likely to be limited to scattered stone or concrete footings, and to an occasional building now serving anonymous duty elsewhere in the village or town.

B. Associative Characteristics

Hydroelectric power generating facilities in Vermont may possess a variety of associative characteristics. Most facilities, by virtue of their origins and use, may be broadly associated with the process of the development of the investor-owned electric utility industry in the state. Some installations, built by and for a manufacturing or processing concern, may, on the other hand, be associated with developments within that industry or that particular firm. Others, built by and for municipalities, may be associated with broader late 19th and early 20th century movements toward community ownership of certain kinds of infrastructure and services, such as lighting, sewage, and water supply. Still others illustrate the efforts of private individuals to obtain electricity for their own uses in advance of municipal or commercial systems. Hydroelectric facilities may also be associated with important events in the history of the electric industry in Vermont, such as the development of storage reservoirs; efforts to increase operating head; systematic, large-scale development of major power sites; or the demonstration of new or innovative technologies or equipment, such as the Kaplan turbine or automatic operation.

C. Geographical/Locational Information

Hydroelectric facilities in Vermont occur on waterways large and small. They may be located in village, town or city centers, within manufacturing complexes, or in rural or mountainous areas. Over the period of this context, the most intensively-developed river basins for hydroelectric power generation in Vermont were the Otter Creek (18 sites), Winooski (15 sites), Passumpsic (11 sites), and Lamoille (10 sites), plus the Connecticut River (9 sites) (Tucker 1986: 218). In addition, river basins which have had at least four hydroelectric developments include the Missisquoi, Clyde, White, Black, West and Wells. As of 1984, the Otter Creek basin still had the most power sites in active use, with 12, followed by the Connecticut River (8), and the Passumpsic and Lamoille River basins (7 each) (Tucker 1986: 219). That portion of the Deerfield River within Vermont includes the state's two largest hydropower storage reservoirs; the entire Deerfield project (encompassing Massachusetts as well as Vermont locations) is among the most important hydroelectric developments in the region.

D. Boundaries

The boundaries of a hydroelectric facility as a historic property should be sufficient to contain the basic structural components (as outlined in Section A of "Physical Characteristics" above) and any functionally-associated ancillary structures. Under other historic contexts, a hydroelectric facility may also be contained within a larger boundary, such as that of a historic village center or manufacturing complex, or of a water power site which contains significant evidence of historic industrial usage apart from that represented by the hydroelectric plant.

E. Condition

The condition of hydroelectric power generating facilities depends primarily upon whether the installations have been abandoned, and for how long, or whether they remain operational. Abandoned facilities will have experienced physical deterioration due to lack of repair and maintenance, and are particularly (though not exclusively) subject to vandalism as well. Abandoned facilities generally still possess dams and powerhouses, since these are massive structures and difficult (or expensive) to remove. Penstocks and surge tanks, however, are more likely to have been dismantled, or if present are in poor repair. Powerhouse equipment (except, perhaps, for turbines) may have been salvaged from abandoned plants, either by the utility or by vandals seeking salable materials. Nonetheless, while abandoned plants may be in poor condition, they may still display basic characteristics of design and method of operation.

Operational facilities benefit from continued maintenance, and as such will be in fair to excellent condition, depending to some extent upon their age and to a greater extent upon their importance within a utility's production system. Plants built from the 1920's onward are most likely to possess a high level of integrity, not only because they are more recent but because they often incorporated state-of-the-art design, construction and equipment that have proved both durable and efficient over intervening years. It thus follows, with regard to earlier plants, that sophistication of original design, construction and equipment will have a major bearing on the extent to which they will have been upgraded for continued use.

The two basic reasons why hydroelectric stations are modified are to increase generating capacity and to increase operating efficiency. However, such modifications do not necessarily alter either the basic structural components of the facility or the ways in which the components are operated. The major exceptions to this occurred in the 1920's, when damage from the 1927 flood prompted the complete replacement of earlier installations (Pierce Mills and Passumpsic on the Passumpsic River, Middlesex on the Winooski River), and the reconstruction of the Molly's Falls plant on the Winooski River prior to the flood. Since that time, few major replacement efforts have occurred. One example is the new powerhouse and intake at Bolton Falls on the Winooski, which replaced structures removed in 1938. Occasionally, generating capacity has been increased by construction of an addition to an existing powerhouse and installing new generating units therein. Known examples include the Taftsville station in Woodstock and the Cadys Falls station in Morristown. In several instances, utilities have chosen to build new powerhouses as separate structures, but at the same time retain the old. This is seen at Fairfax Falls on the Lamoille River, the Newport #1,2,3 plant on the Clyde River, the Weybridge on Otter Creek, and the Gorge stations on the Winooski. Of these, however, only the Newport facility has both powerhouses in active use.

Hydroelectric dams are diligently maintained, for both operational and safety reasons, and are thus in generally good to excellent condition. One of the most common alterations to timber or stone dams is capping, or completely facing, the structure with concrete, sometimes resulting in altered profiles. The general purpose of capping is to improve flowage or to facilitate maintenance through decreasing the need for repairs due to damage from ice or debris. Less often, concrete spillways may be reconfigured or lengthened to increase flowage capability. In recent years, Federal requirements for stabilization have resulted in the insertion of post-tensioned steel rods through both stone and concrete spillways, as well as addition of concrete sections along the toes. Wooden flashboards, by their very nature, are replaced at intervals, and the stanchions or needle beams holding them in place are likely to have been replaced more than once. Timber gates are subject to deterioration, and thus are likely to have been replaced as well, either with new wooden elements or with steel leaves. While most gate hoists are now electrically or hydraulically operated, conversion from manual operation generally has involved addition of equipment (e.g. electric motors), rather than removal of original hoist mechanisms.

Penstocks are often replaced in sections, as deterioration or leakage at various points over time dictates. They may be replaced with like materials, or with another material (the choices being wood stave, steel pipe, or concrete pipe). A completely new penstock, however, will probably be of a diameter similar to the old, and will be at the same location (since its beginning and end points (the intake and the powerhouse) remain fixed). The same generally holds true for surge tanks, which in addition may have been "wrapped" with wood or other material as a frost deterrent. Surge tanks are also subject to complete collapse (as has occurred at Newport #1,2,3, for example), and as a result, to complete replacement.

In the Edison Electric Institute's listing of 40 operating hydroelectric stations in Vermont built prior to 1940, nearly all are still operating with pre-World War II (1910's to early 1930's) equipment (EEI 1989). The manner in which electricity is generated with hydraulic power, which is visibly reflected in the turbine-generator setting, almost invariably remains constant over time, since changing to a different setting is either unnecessary or would require almost complete reconstruction of the powerhouse substructure. In general, alterations to powerhouse interiors and their equipment tend to be additive, rather than subtractive. Turbines and generators themselves are seldom "altered", although turbine blades, wicket gates, and occasionally entire runners may be replaced (in kind, of necessity), and the wire coils of many generators have been rewound for increased capacity. Modern (and increasingly computerized) equipment for control and monitoring is a common feature in active stations, but its installation does not necessarily result in complete removal of original switchboards and apparatus. The functions of hydraulic exciter units have been, in many cases, supplanted by electric motors or solid-state exciters, but the earlier exciters usually remain in place. Oil-pressure governors commonly exhibit certain modifications. For example, if the oil pumps were originally belt-driven, they are now more commonly operated by electric motor. Another common modification, which began in the 1930's, was the installation of heads manufactured by Woodward on earlier governors manufactured by Lombard or Allis-Chalmers (EEI 1989: 95). Some plants may be equipped with cabinet-type electric governors; these, introduced in the 1930's, may represent either original equipment or replacements. Stations which originally contained major transforming apparatus will have established outdoor substations, sometimes by the 1920's. Substation equipment is likely to have been updated periodically over the history of the facility, as technological developments make available more efficient transmission apparatus. The transformer bays and switching galleries within the powerhouse will, however, remain as structural features, although largely denuded of their equipment.

Diesel generating units, used for backup, may be found at a number of hydroelectric facilities. Some are located within the powerhouse proper. In other cases, they have been installed in wood, brick or concrete block additions. The presence of diesel units is a post-World War II phenomenon, occasioned by the widespread availability during the late 1940's of cheap, reliable internal-combustion engines which had been produced by the millions during the war, and by an enormous surplus of extremely inexpensive fuel. At the Essex #19 station, the diesels were placed within the powerhouse, while at the Village of Barton's Clyde Falls station in Charleston they are located in an addition. At the Newport #1,2,3 station, the first diesels were installed in space originally occupied by a steam plant, with later units placed in a connection between the old and new powerhouses.

Powerhouse exteriors generally experience few alterations over time. Original double-leaf doors on some entrance bays may have been replaced with overhead roll doors, and exterior lighting fixtures may have been removed or replaced due to deterioration or for greater illumination. Window elements are subject to replacement for various reasons, including simple deterioration or for greater thermal efficiency. Vandalism is also the cause of window replacement, particularly since more and more stations are automatically controlled and personnel are no longer present round the clock, or even daily. However, it is seldom the case that window openings are completely sealed (for example with brick or concrete block), and the shapes of the openings remain unchanged.

III. Significance

Criterion A

Under Criterion A, hydroelectric power generating facilities are the most tangible manifestations of an important late 19th and 20th century industry in Vermont that, like its predecessors (such as grist mills, saw mills, textile and paper mills) utilized the state's abundant water power resources. From the establishment of the earliest hydroelectric stations in the 1880's and 1890's, to at least 1940, hydropower produced nearly all the electricity consumed in Vermont. This was the case when small utilities, and individual entrepreneurs supplied power within the confines of a village or town. It continued to be the case throughout subsequent decades during which many of these local enterprises were gradually integrated into larger regional systems, today reflected in the operations and service areas of Green Mountain Power, Central Vermont Public Service, and Citizens Utilities Company. Hydroelectric power generated at stations located wholly or partly within Vermont also benefitted consumers in Massachusetts and Rhode Island, through the Connecticut and Deerfield River development programs of the New England Power Association, now operated by the New England Power Company. Once a plant was interconnected with other generation and distribution systems, its service was no longer limited to a specific community, and the community no longer depended on a particular plant at a particular location for its electricity. The major exceptions were hydroelectric stations built and operated by municipalities, which continued to provide distinctly local service, and those built by certain manufacturers, such as the Vermont Marble Company, primarily for their own use.

Thus, as the principal source of electric power in the state, Vermont hydroelectric stations have materially contributed to 20th century patterns of social, industrial and economic development, and in some cases have made possible, or enhanced, the development of historically important industries or commercial endeavors. Hydroelectric stations have also been the basis for the establishment and maturity of electric utilities that ultimately dominated the electric industry in the state.

A hydroelectric facility is therefore significant under Criterion A for its contribution to the broad pattern of Vermont's industrial, economic or social history if it:

1. played a significant role in the development of the hydroelectric power industry; and/or

2. played a significant role in the industrial, social, or economic development of Vermont, of a region or community within Vermont, or of an important industry in Vermont; and/or

3. was important in the development and/or maintenance of an electric utility in Vermont.

Criterion B

In a limited number of instances, a hydroelectric facility may be significant for its association with an individual (usually the original developer) who achieved importance for contributions to local, regional or statewide development of the electric power industry, or whose associations with the electric power industry materially contributed to industrial or economic development. (See National Register Bulletin 32, Guidelines for Evaluating and Documenting Properties Associated with Significant Persons.)

A hydroelectric facility is therefore significant under Criterion B if:

1. it is directly associated with a person or persons who are important for contributions to the hydroelectric power industry, or are important in industrial or economic history through activities involving hydroelectric power; and

2. the facility clearly illustrates or represents those contributions.

Criterion C

Under Criterion C, Vermont's hydroelectric facilities constitute works of engineering and architecture designed and built for a specific purpose. Each site offered a new opportunity to design and build an efficient, cost-effective and up-to-date facility while contending with site constraints, occasional financial problems, idiosyncratic stream characteristics and fast-moving technological developments. The characteristics and features of Vermont's hydroelectric facilities combine aspects of hydraulic engineering, civil engineering, electrical engineering and industrial architecture as these disciplines were employed and evolved over six decades, from the 1880's to World War II. Hydroelectric facilities thus represent the work of numerous engineers and engineering firms (and possibly of a number of architects), some of whom achieved national prominence.

A hydroelectric facility is therefore significant under Criterion C if it:

1. embodies the distinctive characteristics of a type, period, or method of hydroelectric facility engineering or architectural design or construction; and/or

2. constitutes a significant engineering or architectural development in hydroelectric facility, structural, and/or technical design or construction; and/or

3. represents a successful or notable solution to challenging site conditions; and/ or

4. is representative of the work of a significant hydroelectric engineer or architect; and/or

5. embodies a rare form of hydroelectric engineering in Vermont; and/or

6. contributes to the significance of a larger entity, e.g., a conceptually and/or functionally interrelated series of plants along a particular waterway which are collectively significant under one or more National Register criteria.

In addition, major components of the property type "hydroelectric power generating facilities" (e.g. dams, intake/water conveyance systems, powerhouses) may, in certain circumstances, be significant in the areas of engineering or architecture under Criterion C as individual resources. A dam, intake/water conveyance system or powerhouse may be significant if it is a singularly important example of design, construction, or use of materials characteristic of a particular period in the history of dam, intake/water conveyance, or powerhouse design, construction or technology.

Criterion D

Under Criterion D, in certain instances hydroelectric facilities, individual components, or the remains of either of these, may have the potential to yield information which would enhance understanding or interpretation of industrial or technological developments of a particular time and/or place. However, unless these developments pertain to hydroelectricity, such facilities would be significant under some other historic context.

A hydroelectric plant, a plant component, or remains of either is therefore significant under Criterion D if:

1. it demonstrates the potential to yield information important to understanding or interpretation of one or more themes in the context of hydroelectricity and

2. the information cannot be obtained from other sources, or the information will materially supplement similar kinds of data from other sources.

IV. Registration Requirements

A hydroelectric station, or one or more of its individual components, may be eligible for the National Register for reasons unrelated to hydroelectricity. The registration requirements listed below apply only to the evaluation of properties within the historic context of "Hydroelectric Power in Vermont, 1882-1941".

General Registration Requirements for Hydroelectric Facilities

For all Criteria: The facility must have been built during the period of significance for this historic context, 1882-1941.

Criteria A and B: A hydroelectric facility significant for its historical association is eligible if it retains the essential physical features that made up its character during the period of its association with the important event, historical pattern of development, or person(s).

Criterion A:

1. The significance of the event or historical pattern with which the facility is associated must be clearly identifiable.

2. The direct association of the facility with the event or historical pattern must be clearly demonstrated.

3. The facility must possess integrity of design, materials, location, setting and association.

Criterion B:

1. The significance of the individual, his or her important contributions or activities, and the association of the hydroelectric facility must be substantiated through accepted methods of historical research and analysis.

2. The facility must possess integrity of location, setting, design, materials and association from the period with which it was associated with the individual.

Criterion C:

1. A hydroelectric facility significant for its ability to represent or illustrate, as a work of hydroelectric engineering and/or of architecture, a type, period, design or construction method must clearly demonstrate those characteristics, features and functions for which it is considered significant.

2. A hydroelectric facility significant as the work of an important hydroelectric engineer or architect must be representative of, or of particular importance within, the overall body of the engineer's or architect's work. The significance of the engineer or architect must be substantiated through accepted methods of historical research and analysis.

3. The hydroelectric facility, and the majority of its principal components, must possess integrity of location, design, materials, and workmanship.

4. A hydroelectric facility that contributes to the significance of a larger entity (e.g. historic district) must possess integrity of location, setting, association, and design.

Criterion D:

1. The importance of the information which the site of a hydroelectric facility has potential to yield must be explicitly demonstrated.

2. It must be demonstrated either that the information is not obtainable through other means, such as examination of extant hydroelectric facilities of the same type or period, or through research in sources such as technological publications and utility files of photographs, drawings, and other records; or that the information obtained from the site will materially supplement information available from other sources.

Requirements for Integrity of Design

1. The historic spatial and functional (operational) relationships among the principal components of the hydroelectric facility (dam, intake/water conveyance, powerhouse) must be readily discernable. It must be possible to determine the manner in which water historically flowed through the facility, from the dam to the powerhouse, through the powerhouse, and into the tailrace.

2. A dam possess integrity of design if:

a. the spillway, crest control, and reservoir outlet have not been altered since their construction; or

b. if subsequent replacement, alteration or repair has not resulted in loss of qualities or features for which the dam, as a component of the facility, is considered significant.

3. A dam has lost its integrity of design if:

a. the original spillway, crest control, or outlets have been replaced with systems that are incompatible with the historic character of the dam; or

b. the overall shape, form, elevation, or massing of a dam has been altered by reconstruction, repairs, or improvements that have resulted in loss of qualities or features for which the dam, as a component of the facility, is considered significant.

4. An intake/water conveyance system possesses integrity of design if the majority of its various features (headrace, intake gates, flowlines, surge tanks, and/or penstocks) possess integrity of design.

a. A headrace has lost integrity of design if it has been eliminated or greatly altered in size.

b. Intake gates/control structures have lost integrity of design if they have been replaced by systems that are not in keeping with their overall historic fabric or historic method of operation.

c. Flowlines, surge tanks, and/or penstocks have lost integrity of design if they have been relocated (above- or below-ground) or changed in size by 50 percent or more.

5. A powerhouse possesses integrity of architectural design if it retains those characteristics, such as exterior form, scale, massing, pattern of fenestration (wall openings), and principal aesthetic features, for which, as a component of the hydroelectric facility, it is considered significant.

6. A powerhouse does not possess integrity of architectural design if:

a. additions or modifications have been made to the exterior which are incompatible with historic aspects of the structure's form, massing, and scale; or

b. the historic form, massing, or scale of the powerhouse has been substantially altered by partial demolition, or by reconstruction; or

c. the pattern of fenestration has been substantially altered by enlarging or decreasing the size of the wall openings, or by reconfiguring the pattern of wall openings.

7. The architectural design of a powerhouse may be diminished if architectural or aesthetic features (applied ornamentation, or decorative masonrywork, for example) which figured prominently in the historic architectural design and character of the powerhouse have been removed. The extent to which this constitutes loss of integrity is dependent upon whether the powerhouse is significant for architectural qualities or for qualities of association or engineering.

8. A powerhouse possesses integrity of engineering design if it retains a majority of the principal items of generating equipment (turbines, governors, generators, exciters, transformers) for which the powerhouse was designed and built. Although some of this equipment may have been subsequently modified or replaced, integrity of engineering design may still be present if the overall character and configuration of the generating system remains clearly evident.

9. A powerhouse lacks integrity of engineering design if the majority of power generating equipment for which the powerhouse was designed and built has been removed, or replaced with elements substantially different, or of a different technological configuration.

Requirements for Integrity of Materials

1. A component of a hydroelectric facility (dam, intake/conveyance, powerhouse) possesses integrity of materials if:

a. the existing materials are original construction; or

b. subsequent replacements or repairs employ the same types of materials as those originally present; or

c. different materials have been employed in a manner that does not significantly alter the basic characteristics for which the component or facility is considered significant.

To determine integrity of materials, inprovements made during the historic period of this context must be evaluated in terms of the applicable National Register criterion or criteria, and also in terms of the specific reason or reasons the component and/or facility are considered significant.

Requirements for Integrity of Workmanship

The physical scale of a hydroelectric facility, and of its major components, is generally quite large. Integrity of workmanship (i.e., the manner or techniques employed in the manipulation of materials to achieve a desired functional purpose or aesthetic treatment) thus depends upon the extent to which changes in workmanship, or removal of evidence of workmanship, are readily perceivable, and to the extent to which such changes or removals alter the overall historic character of the facility or the historic character of a particular component.

Requirements for Integrity of Location, Setting, Feeling and Association

If a hydroelectric facility or component exists at all, it has integrity of location. The most important aspect of location for a hydroelectric plant is its spatial relationship to a water body. Because individual components of a facility are immobile, or their location is fixed by immobile components, integrity of location is generally always present at hydroelectric facilities. Overall integrity of design, materials and workmanship are prerequisite to integrity of association and feeling. Integrity of setting and feeling are not present if materials, structural equipment or outbuildings, out of keeping with the historic character of the facility, physically and/or visually dominate remaining historical components.

Integrity Requirements for Sites of Hydroelectric Facilities Significant in the Area of Industry under Criterion D

Four types of integrity are relevant to the eligibility of industrial properties under this criterion: location (in-situ remains), association (identifiable temporal and functional dimensions), design (functionally or culturally determined spatial distribution of remains), and materials (identifiable artifacts attributable to specific industrial processes through time). The actual degree to which these must be present cannot be determined outside the context of specific research designs. However, certain general rules can be established.

Integrity of location is essential to research designs which focus on the study of industrial processes, such as the application of specific technological solutions to the economic goals of specific public, corporate, or individual entities. Design integrity is also essential for a site having the potential to demonstrate the adaptation of process to a particular location and/or when the design being studied incorporates adaptations of a process not common during the historic period of the site's operation or use. Integrity of association is essential to the study of any industrial process. If a given site cannot be related to a particular time period, it lacks the ability to provide comparative information to sites of similar or different time periods. Integrity of materials is also essential to research designs focusing on the study of industrial process, as materials evidence the specific application of technology during a period in the historical use of the property.

G. GEOGRAPHICAL DATA

The State of Vermont.

H. SUMMARY OF IDENTIFICATION AND EVALUATION METHODS

This historical study of the hydroelectric power industry in Vermont was undertaken through a contract between Stetson-Harza, of Concord, New Hampshire, and the Cultural Resource Group of Louis Berger & Associates, Inc., of Waltham, Massachusetts. The study was prepared at the request of the Vermont Division for Historic Preservation (SHPO) and jointly funded by Central Vermont Public Service Company, Citizens Utilities Company, Green Mountain Power Company, and New England Power Service Company.

"Public and Private Utilities, 1865-1940" is among a number of historical themes that has been included in Vermont's state historic preservation plan, but neither historic context statements or property type definitions had been developed sufficiently for use in evaluating or registering hydroelectric facilities. In compiling information for the historic context statement for hydroelectric power installations, Robert Tucker's 1986 master's thesis has proved to be of particular importance, as it provides a clear, thoroughly documented account of the development of the hydroelectric industry in Vermont from the 1880s to 1940. Important sources of information on the industry in a national framework were the Edison Electric Institute's 1989 draft of "Hydroelectric Power Development in the United States, 1880-1940," written by Duncan Hay; Thomas Hughes' Networks of Power (1983); and standard texts on hydroelectric practice such as those by Barrows (1927), Rushmore and Lof (1923), Koester (1911), and Von Schon (1911).

A comprehensive listing of hydroelectric plants built in Vermont from the 1880s to the 1970s, as well as a list of utilities operating in Vermont during the period, are included as appendices to the Tucker thesis. As the preparation of this multiple property documentation material did not include field investigation, and no comprehensive inventory of hydroelectric stations in Vermont has yet been undertaken, facility-specific data were compiled from a wide variety of documentary sources, including National Register and Vermont Historic Sites and Structures Survey files, records and photograph collections of the New England

Power Service Company, Central Vermont Public Service Company, Citizens Utilities Company and the Green Mountain Power Company, and from professional publications such as Engineering News, Power Plant Engineering, Engineering Record,

Power, and the Journal of the Boston Society of Civil Engineers. These data were used both in development of the historic context statement and in the property type description.

Sources utilized in development of registration requirements included the National Park Service's "How to Apply the National Register Criteria for Evaluation" (National Register Bulletin #15) and multiple property documentation forms prepared for Washington State (Soderberg 1988) and Minnesota (Hess 1989). Valuable information and suggestions were also contributed by staff of the utility companies which funded preparation of this document, in particular Mr. Gordon E. Marquis of the New England Power Service Company.

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