The Undeveloped Hydroelectric Potential of Vermont

Prepared for and available from:

Vermont Department of Public Service

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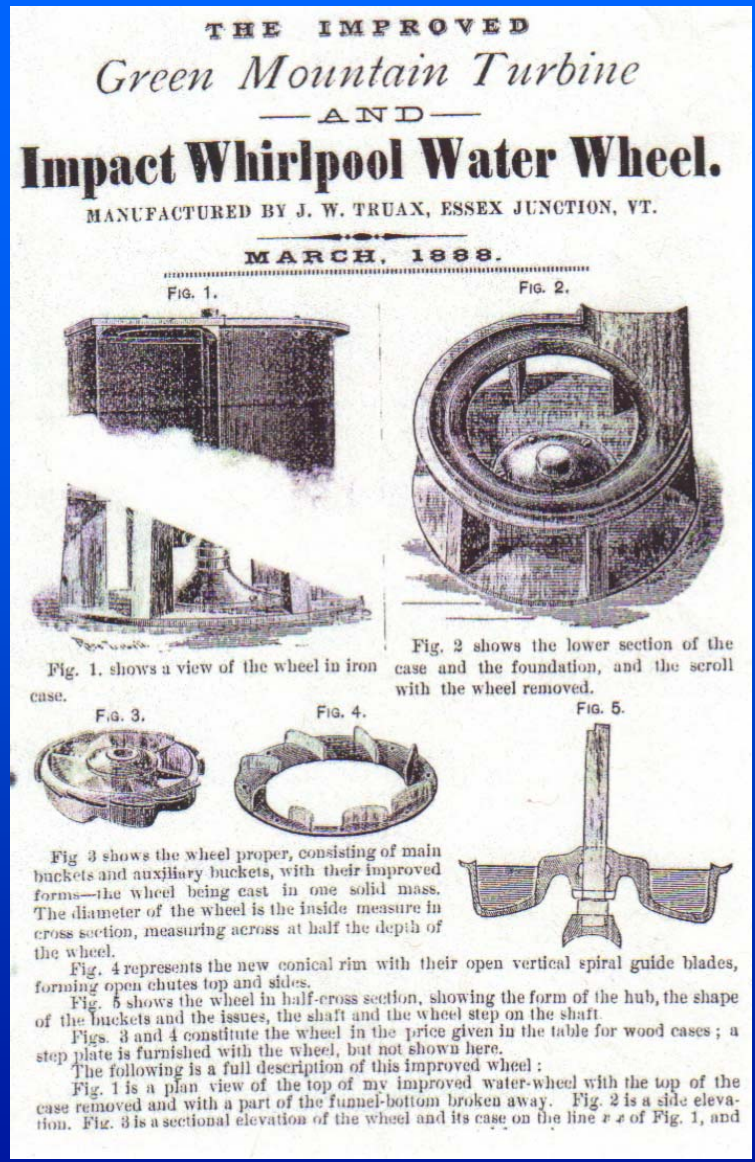
Hydro was the economic backbone of Vermont

over 2000 mills:

saw mills
grist mills
woolen mills
bobbin mills
fishing pole mills
small industry



THE IMPROVED

Green Mountain Turbine

—AND—

Impact Whirlpool Water Wheel.

MANUFACTURED BY J. W. TRUAX, ESSEX JUNCTION, VT.

MARCH, 1888.

FIG. 1.

FIG. 2.

Fig. 1. shows a view of the wheel in iron case.

Fig. 2 shows the lower section of the case and the foundation, and the scroll with the wheel removed.

FIG. 3.

FIG. 4.

FIG. 5.

Fig 3 shows the wheel proper, consisting of main buckets and auxiliary buckets, with their improved forms—the wheel being cast in one solid mass. The diameter of the wheel is the inside measure in cross section, measuring across at half the depth of the wheel.

Fig. 4 represents the new conical rim with their open vertical spiral guide blades, forming open chutes top and sides.

Fig. 5 shows the wheel in half-cross section, showing the form of the hub, the shape of the buckets and the issues, the shaft and the wheel step on the shaft.

Figs. 3 and 4 constitute the wheel in the price given in the table for wood cases; a step plate is furnished with the wheel, but not shown here.

The following is a full description of this improved wheel:

Fig. 1 is a plan view of the top of my improved water-wheel with the top of the case removed and with a part of the funnel-bottom broken away. Fig. 2 is a side elevation. Fig. 3 is a sectional elevation of the wheel and its case on the line *x x* of Fig. 1, and

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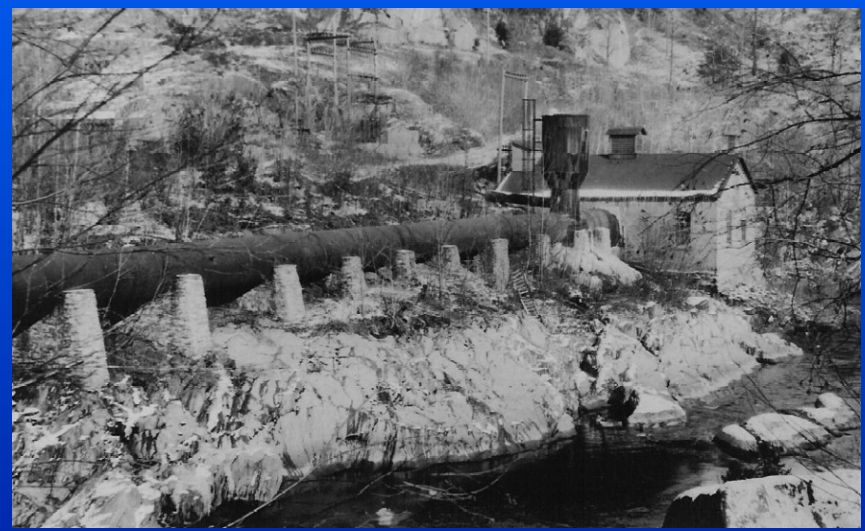
Hydro: Redevelopment – not new development

In 1898:

74,376 HP by water wheels (approx. equal to 55 MW)

24,048 HP by steam at 1552 manufacturing establishments



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Dams: earliest infrastructure in Vermont

Montpelier, 1821

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Study relied on 17 existing data sources –no new work:

(variable quality)

Excel spreadsheet was built from ANR databases.
Can be imported into GIS.

1) **Vermont Dam Inventory (VDI) – 1210 dams –170 breached.**
1) **Hydro.MDB – includes hydro without dams.**

Interestingly enough:

1914: estimate of 1492 MW (2,000,000 HP) of undeveloped hydro potential in the State (Industrial Vermont)

2006: 1022 MW of undeveloped hydro potential in the State (Department of Energy).

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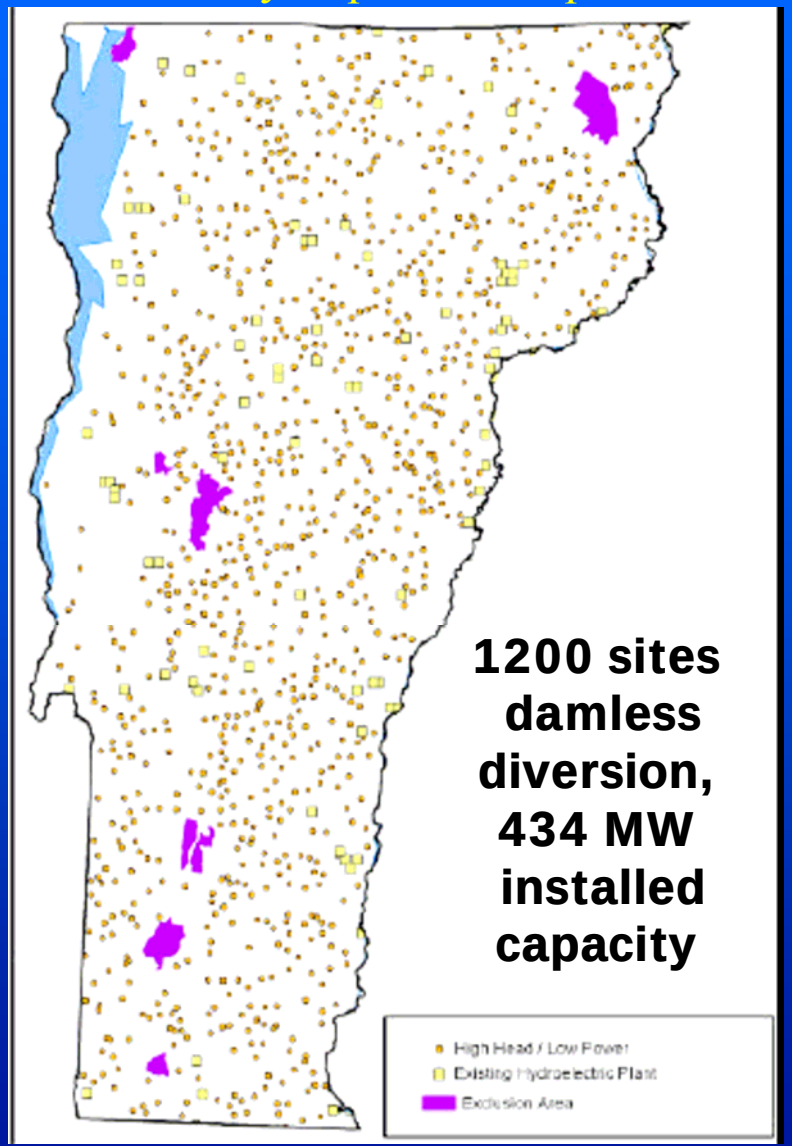
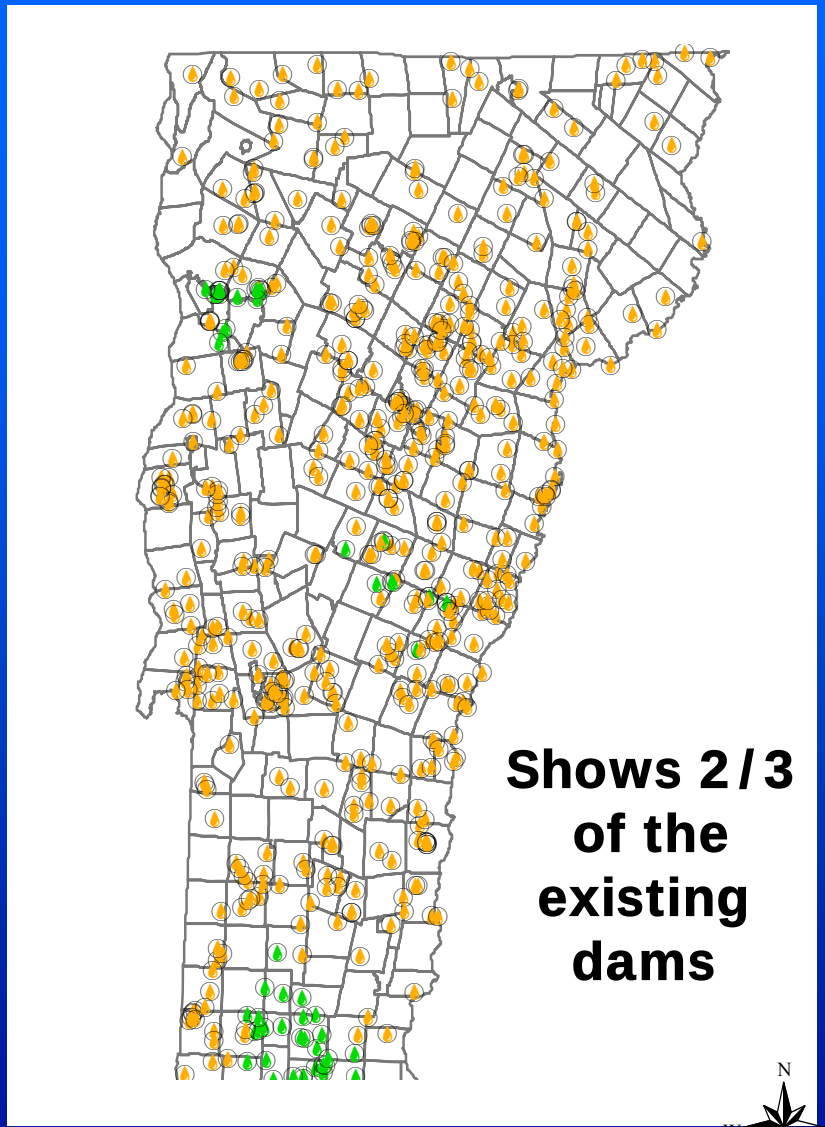
DOE, 2004
Virtual Hydropower Prospector



Vermont Dams VCGI

VCGI: 2005 - 880 of 1200 Existing dams



Potential hydro sites,
developed at natural drop in river, no dams

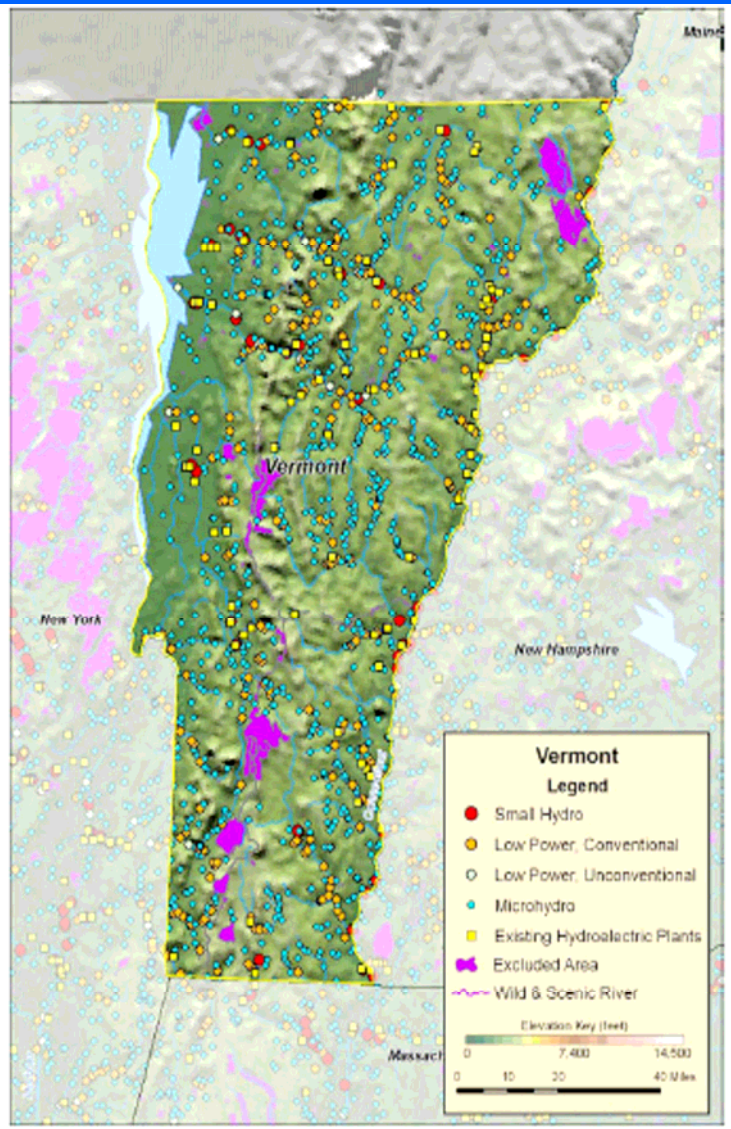


Figure B-225. Low power and small hydro feasible projects, and existing hydroelectric plants in Vermont.

Table B-92. Summary of results of feasibility assessment of water energy resources in Vermont.

Power Class	Available (MWa)	Feasible Sites (MWa)	Feasible Projects (MWa)
Total Power	1,022	812	217
Total High Power	606	552	112
Large Hydro	43	43	0
Small Hydro	564	509	112
Total Low Power	416	260	105
Conventional Turbines	373	233	65
Unconventional Systems	11	10	6
Microhydro	32	18	34

VIRTUAL HYDROPOWER PROSPECTOR

(needs ground truthing)

(On web - link through my website)

1,200 **feasible** sites - 434 MW installed capacity
Dept. of Energy, 2006

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DOE sites rely on damless diversion: near natural falls or using natural gradient –

Twinfield School (on Virtual Hydropower Prospector)

A diversion project will provide all the power for the school -$60,000 annually –90 KW.

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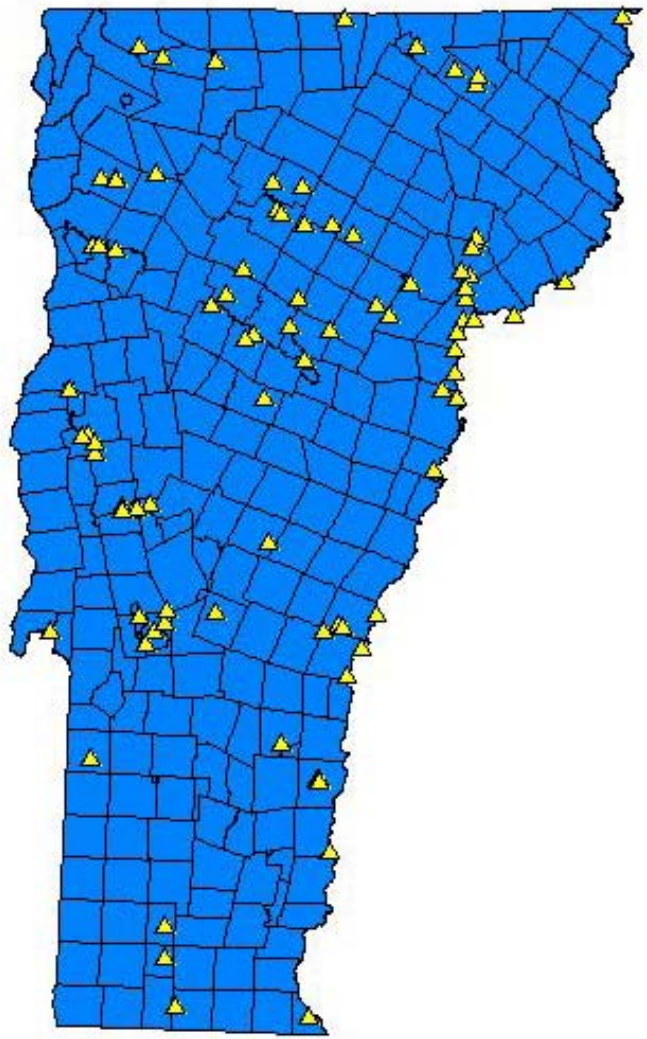
Active Hydroelectric Sites-ANR map

Jurisdictional Status Existing Vermont Hydroelectric Plant	Number of Sites
Sites with FERC licenses and 401 certificates	38
Sites with FERC licenses without 401 certificates	6
Sites with FERC exemptions and 401 certificates	14
Sites with FERC exemptions without 401 certificates	4
Sites with no FERC license and with 401 certificates	4
Sites with no FERC jurisdiction and no 401 certificate	16



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Cavendish=6,000,000 kwh/yr

CAVENDISH GORGE HYDROELECTRIC SITE

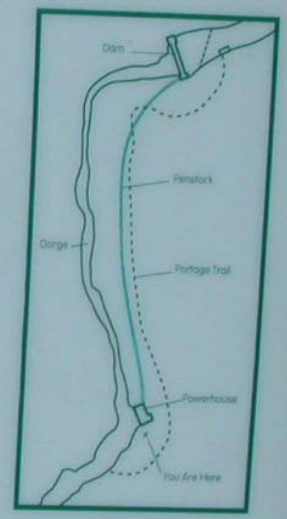
The Powerhouse

The Cavendish hydroelectric plant was built in 1907-1908 for the Claremont Power Co. from designs by W.A Brackenridge of Niagara Falls, New York. It is currently owned by Central Vermont Public Service Corp.

The generating system consists of the dam at the top of the gorge, the powerhouse at the bottom and a large underground pipe, or "penstock," running between the two. The power plant, appearing very much as it did when constructed, displays distinctive features of hydroelectric engineering and architecture from the turn of the century, when hydroelectric generation of electricity in Vermont was just beginning. Most representative of the period is the powerhouse, with its solid masonry walls, pilasters, segmental arched window openings, sweeping hipped roof and slate shingles.

Up to 226 cubic feet of water per second flow from the dam through the penstock to the powerhouse. Falling 120 feet in elevation, the water drives three horizontal shaft Francis turbines. Each is rated at 500 kilowatts, or enough electricity to light five thousand 100-watt lightbulbs. Each year, the plant generates 6 million kilowatt hours of electricity, enough to supply about 800 homes.

In 1994, the Federal Energy Regulatory Commission issued Central Vermont Public Service Corp. a new, 30-year license for the operation of the plant.



The Gorge

Cavendish Gorge is a large, beautifully sculptured gorge with large boulders, pools and cascades stretching almost 1,050 feet. Sheer rock walls stretch 50 to 80 feet in height from the waters of the Black River.

The rock is a hard quartzite schist with garnets and quartz veins of Cambrian Hoosic schist. The spray and moist conditions in the gorge promote the growth of liverworts and mosses on the rock walls. Unfortunately, most of the gorge is hidden from view. Nevertheless, please avoid the temptation to leave the trail, since the edges are dangerous.

600 kwh = 1 barrel oil=10,000 barrels oil/yr

Built in 1907.

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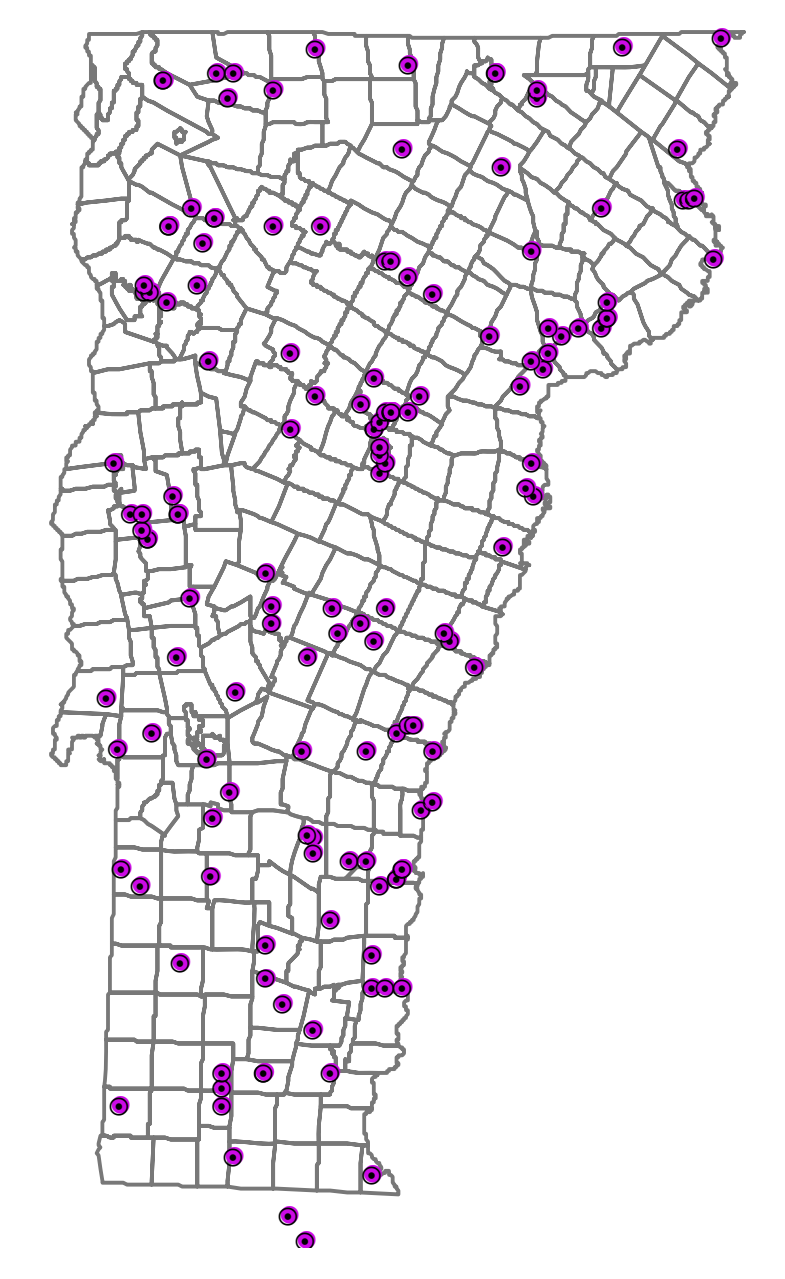

Department of Energy
-Idaho 1998
(on web: link through my website)

420 MW undeveloped hydro capacity at 149 sites. Most with dams

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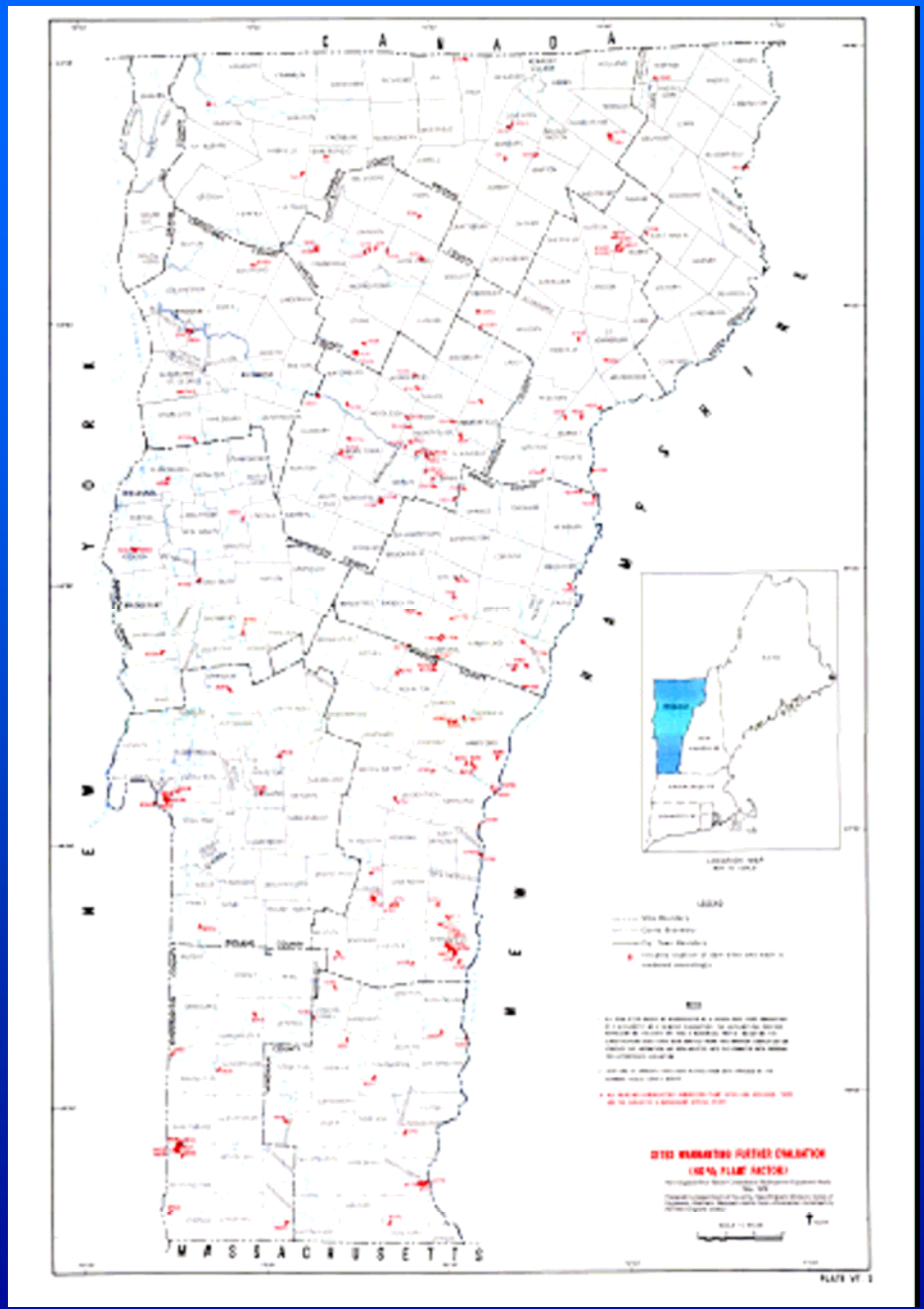

175 MW
peak
(60 MW base)
at 151 sites
40% plant factor
-NERBC
1980

(~25 MW baseload still not developed)

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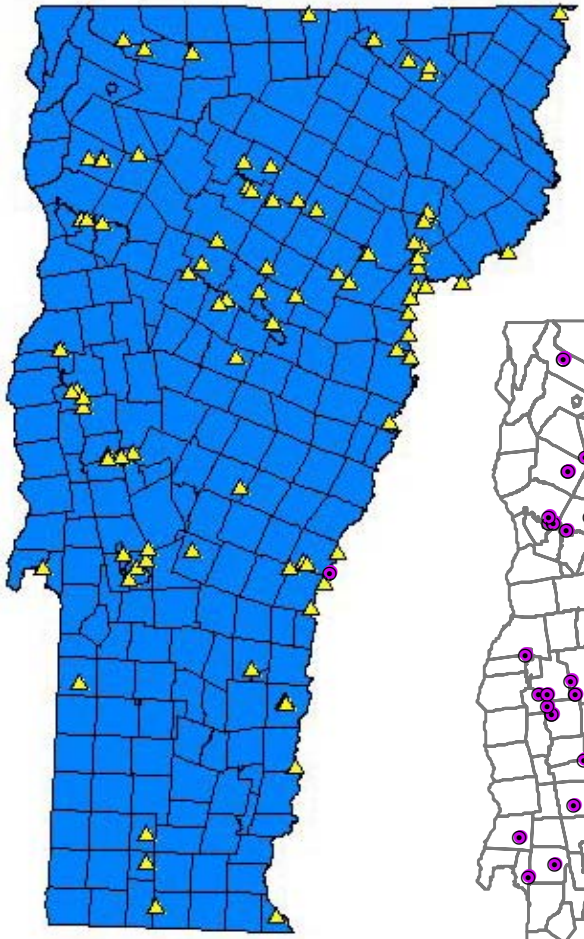
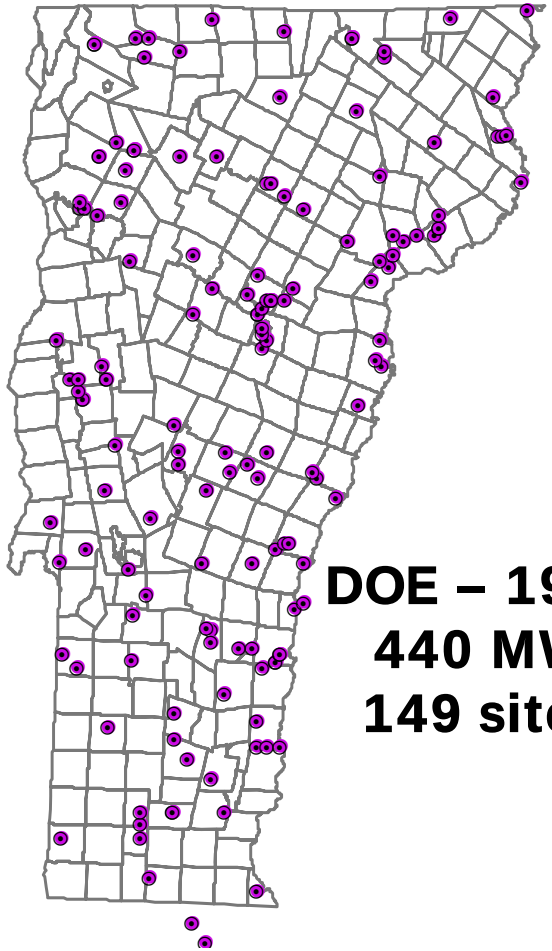
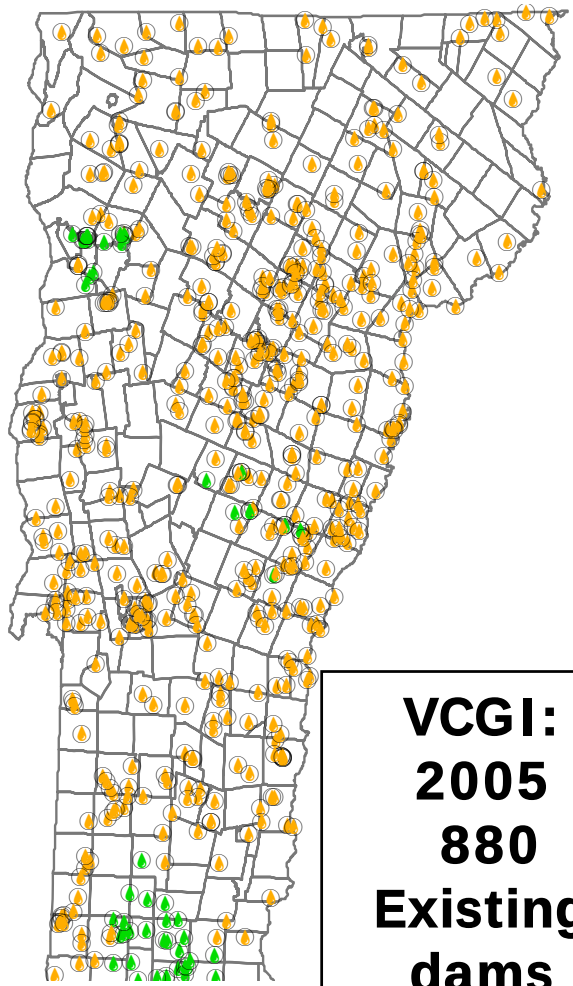
Vermont Dams-VCGI



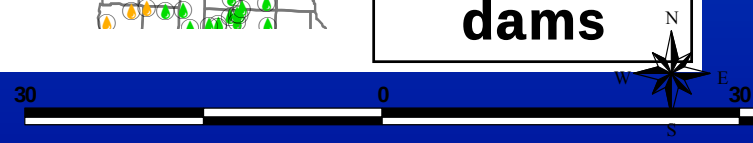
Existing Hydro -ANR



DOE – 1998
440 MW
149 sites



VCGI:
2005
880
Existing
dams



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45 Towns own 107 dams

- Barnet
- Barre
- Bennington
- Brandon
- Brattleboro
- Chester
- Danville
- Enosburg
- Essex
- Fair Haven
- Franklin
- Glover
- Hardwick
- Hartford
- Londonderry
- Ludlow
- Lyndonville
- Marlboro
- Middlebury
- Middletown Springs
- Milton
- Montpelier
- Morrisville
- Newbury
- Newport
- Northfield
- Norwich
- Pittsford
- Plainfield
- Pownal
- Proctor
- Readsboro
- Richford
- Rutland
- South Royalton
- Springfield
- St. Albans
- St. Johnsbury
- Swanton
- Thetford
- Vergennes
- Washington
- Whitingham
- Windsor
- Winooski

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Why so many dams?
Dams Have benefits

- Flood control
- Recreation
- Water supply
- Fish and Wildlife

(VTDFW owns majority of state-owned dams –no fish passage installed)

- Historic value
- Economic - Mill dams
- Keep native fish population discrete from stocked population

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Dams have liabilities

- Block fish passage-fish can't get upstream. Many fish ladders don't work.
- Fish can get entrained in turbine downstream-need screening.
- Engineered, can breach.
- Store and release hydro can change flows dramatically. Alternately drying up and flooding river.
- Backwater effects-no longer free flowing river.
- No documented dissolved oxygen, temperature problems at run of river hydro in VT or DFW owned dams.

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Costs

Water to Wire package $850 - $1,100 kW.

Approximate all installation costs $1500 - $2,500 KW(per Mike Scarzello, CVPS).

Smaller systems can be much more expensive per kW.

Big cost is permitting and protection mitigation and enhancement.

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Only renewable with extensive regulatory requirements

FERC license or exemption need OK from:

- ✓ Vt. Dept. of Environmental Conservation – Dam Safety, Water Quality Division,Hydrology, Wetlands, Lakes, River Management;
- ✓ Vt. Dept. of Fish and Wildlife - Fisheries, Wildlife, Non-game and natural heritage;
- ✓ Vt. Division for Historic Preservation (SHPO);
- ✓ Vt.Public Service Board; &.
- ✓ Vt. Dept. of Public Service.
- ✓ U.S. Fish and Wildlife Service;

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< 1 MW
high permitting costs

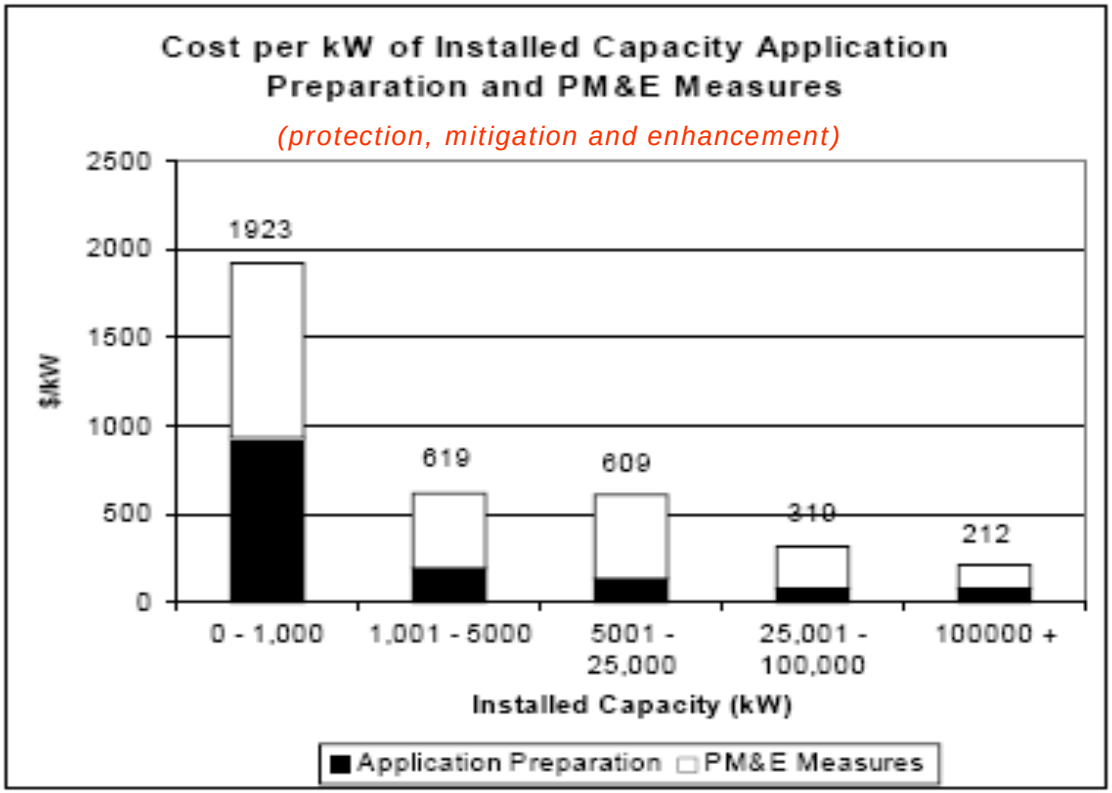

Figure 5 Cost ($ per kW of Installed Capacity) Application Preparation and PM&E Measures.

From FERC-2001 Report on Hydroelectric Licensing Policies, Procedures and Regulations Comprehensive Review and Recommendations Pursuant to Section 603 of the Energy Act of 2000

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Ideas for Incentives

1. Easier permitting. England reduces requirements for <500KW
2. England offers grants of £1.000 per kW to max of £5,000 per project.
3. Municipalities receive grants of up to 50% of project costs up to £100,000.

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What does Undeveloped Hydro look like in Vermont?

Appendix of Study has photos of over 50 sites visited

10 KW

- Flood Control
- Recreation
- Fish and Wildlife
- Water Supply
- Hydroelectric
- Historic Mill Dams

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Flood Control Dams- Townshend, 3000 KW

Ball Mtn, Townshend, Union Village, and N. Springfield could produce ~10 MW combined (NERBC)

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Union Village-Thetford-650 KW

Only N. Hartland produces power.

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Windsor-Historic Mill Dam

220 KW

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Weston –40 KW

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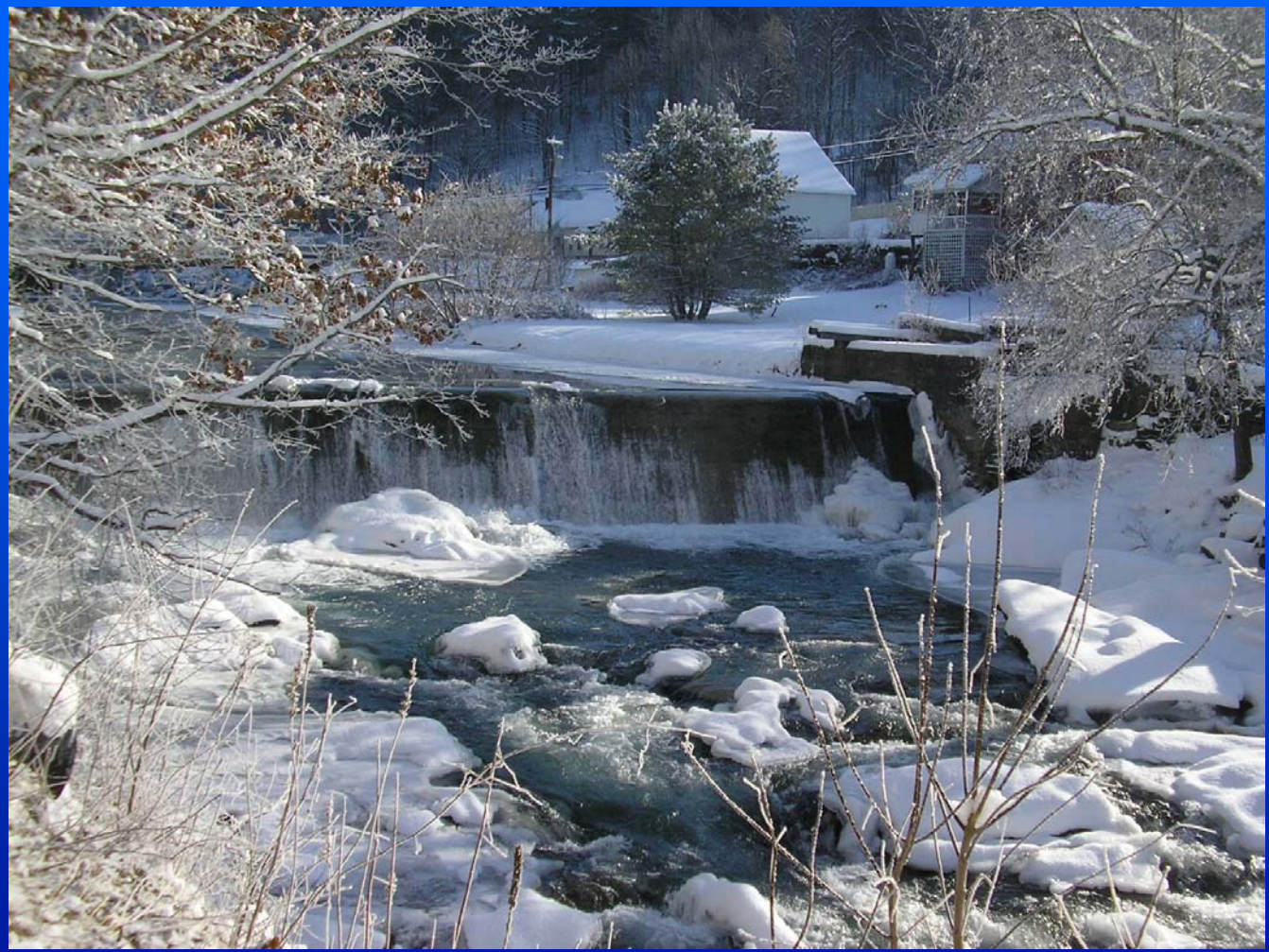
Tunbridge – 100 KW



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Fair Haven – 170 KW

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Londonderry –70 KW

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Plainfield –124 KW

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Recreation: Lake Bomoseen- 50 KW

Aesthetics?

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Crystal Lake 200 KW

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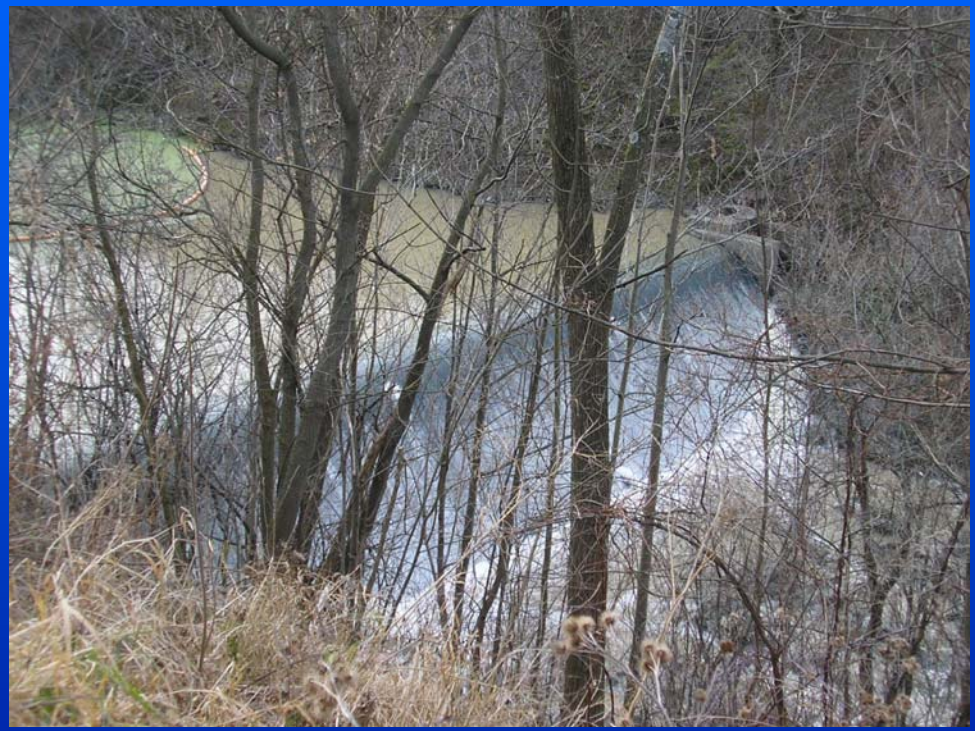
Fish and Wildlife: Shoreham 83 KW



Department of Fish and Wildlife owns 54 of the State owned dams

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Lake Hortonia – 8 KW

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Noyes Pond – 15 KW

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Water Supply Dams-Barre
58 KW

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Barre – 13 KW

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Hydro Sites
Middlebury-Frog Hollow
> 1000 KW

Photo courtesy of Anders Holm

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Swanton-850 KW

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Woodstock – 105 KW

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North Bennington – 200 KW

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Troy –750 KW

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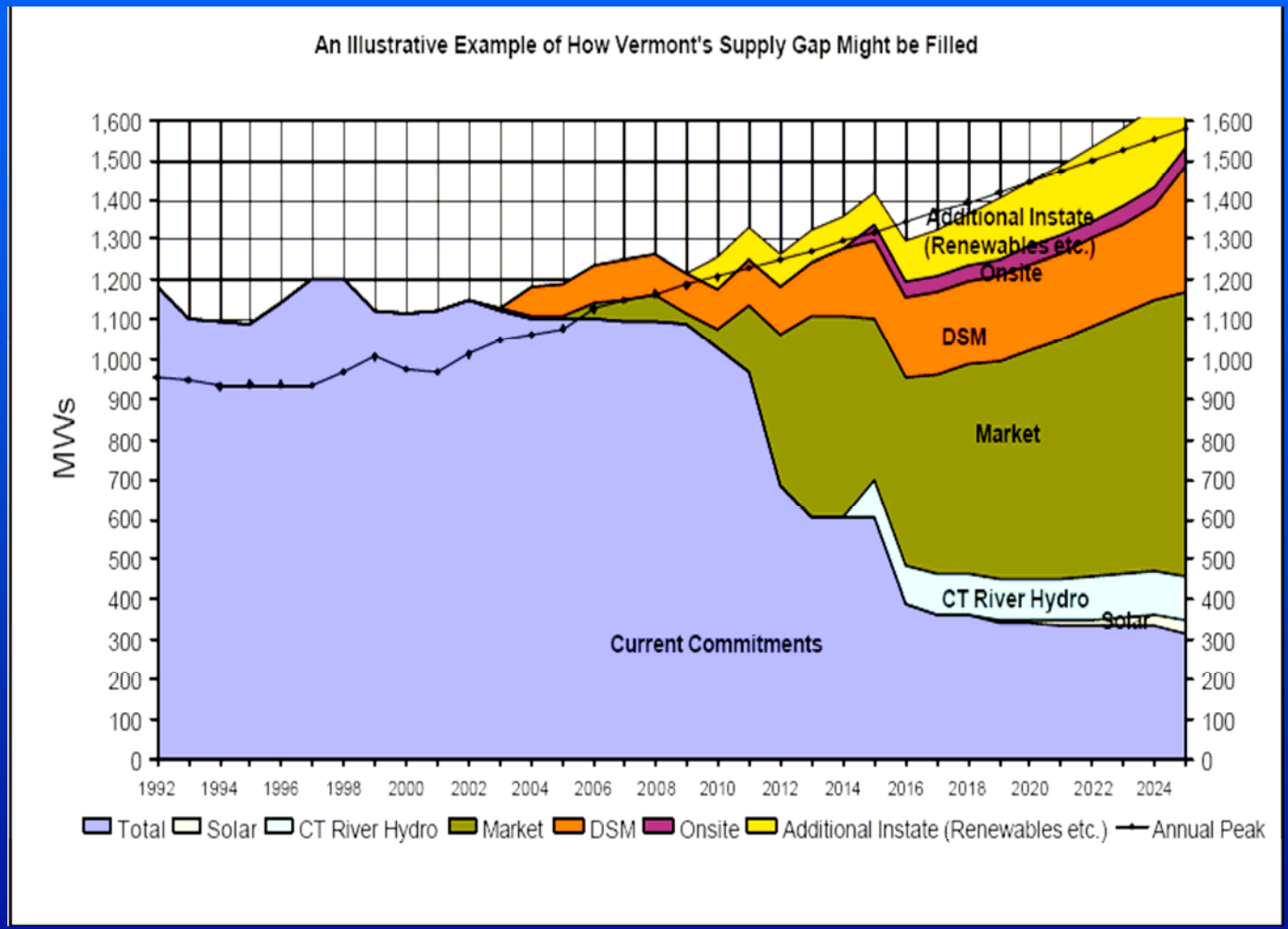
Filling the Supply Gap- DPS 2005



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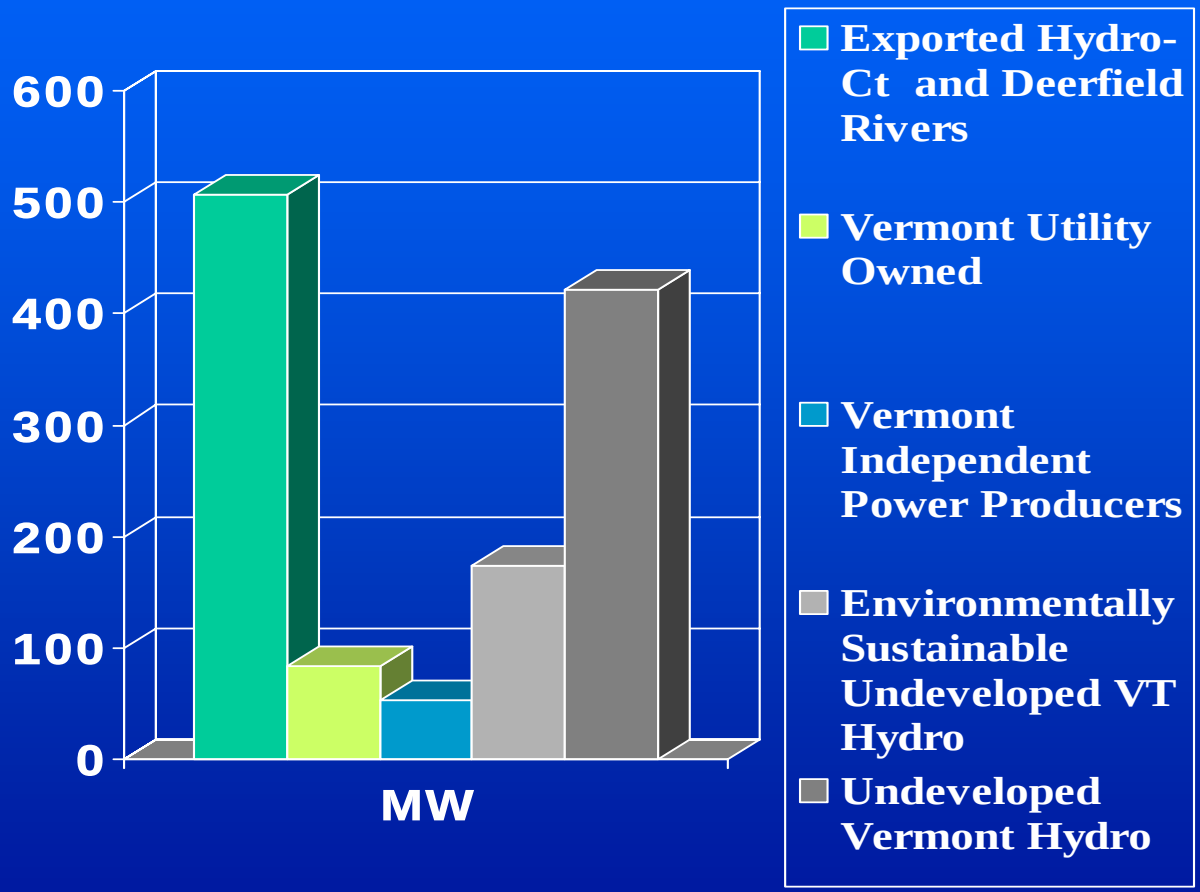
Vermont's Hydro Potential



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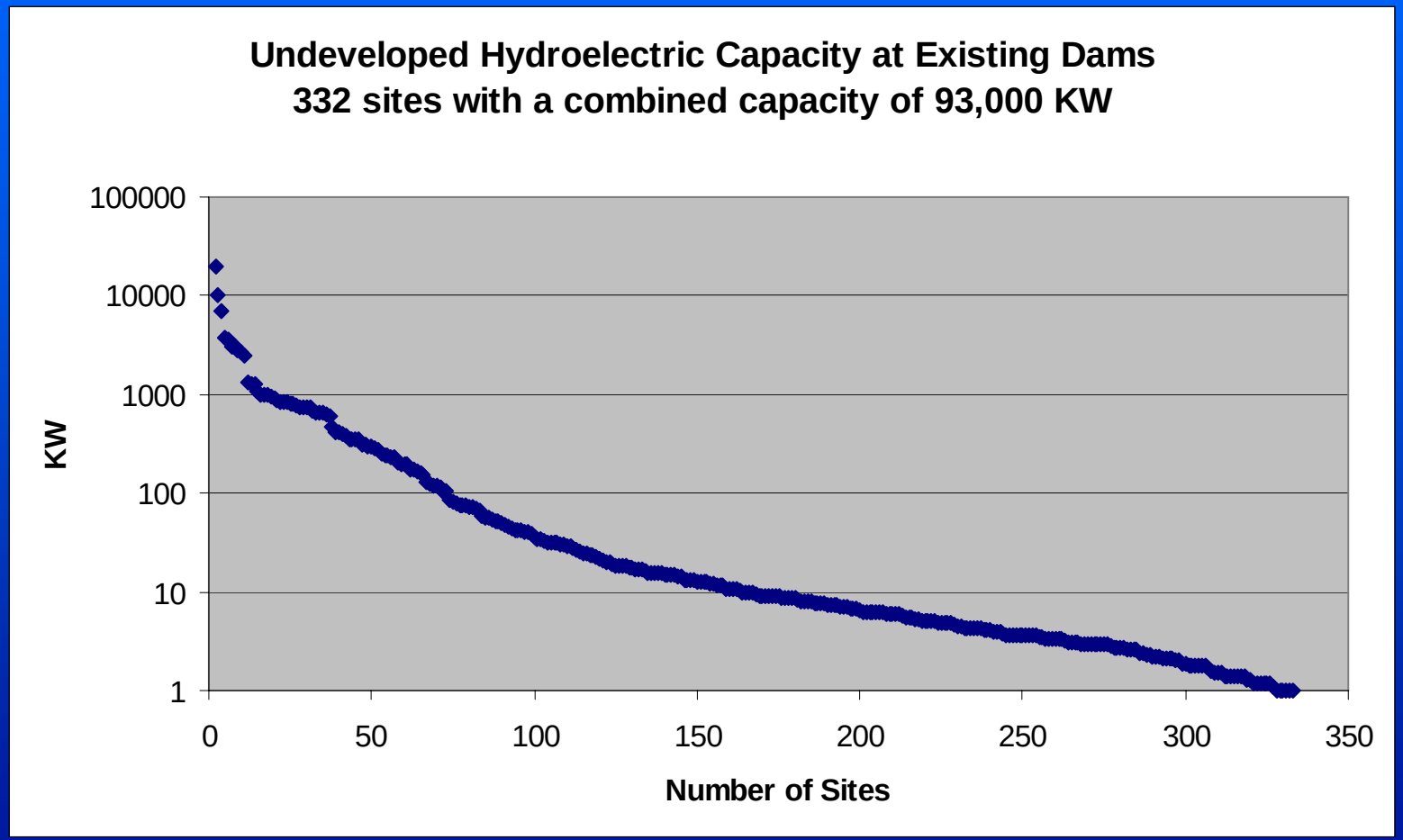
Conservative Assumptions:
332 dams with 93 MW undeveloped hydro capacity



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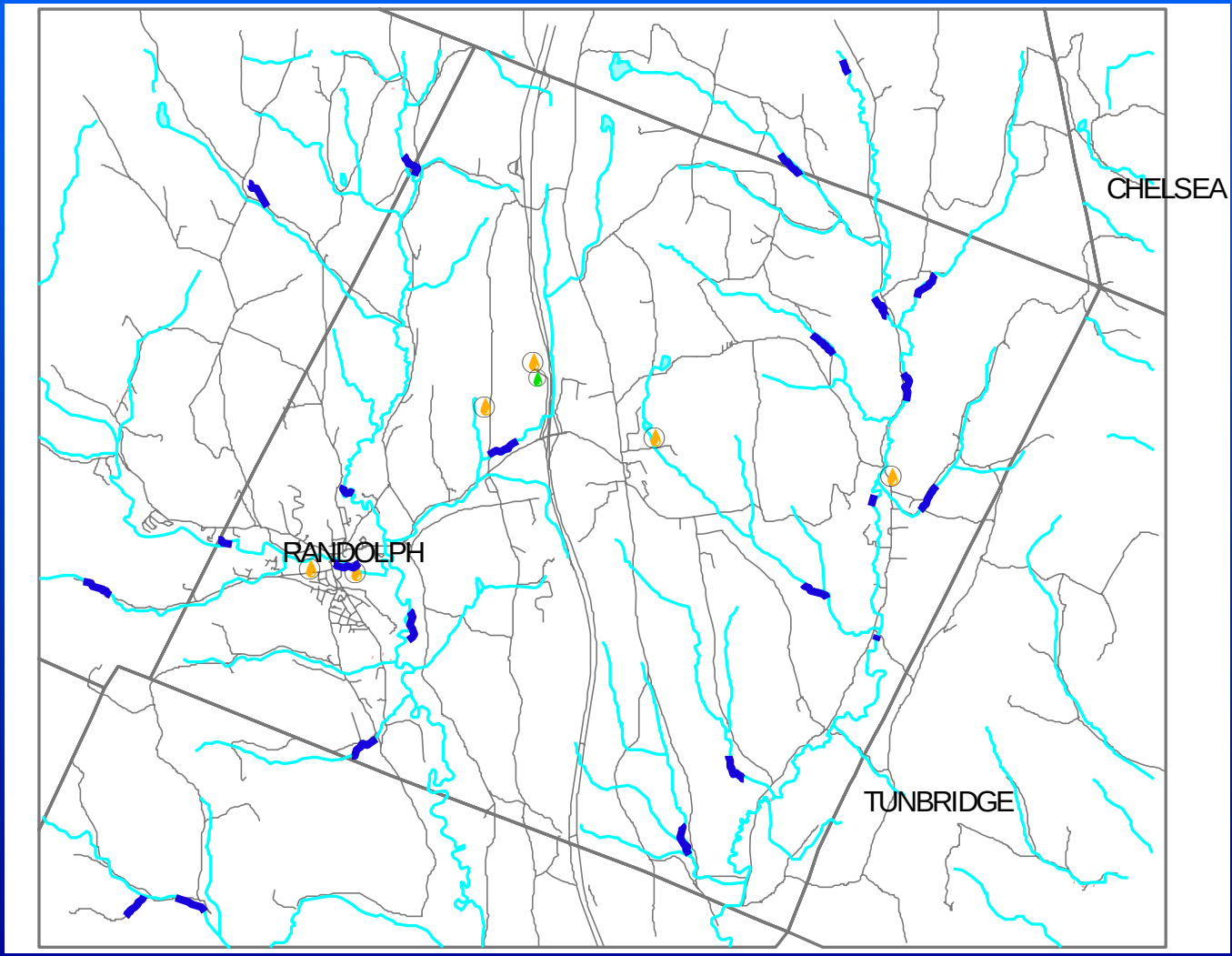
Example: Randolph-6 dams, 17 damless diversions (<100 KW)



Can combine existing dam with penstock to increase power

Data from VCGI and Virtual Hydropower Prospector

Needs field assessment

Community Hydro

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"This white coal from hydro-electric development, free from smoke, soot and cinders….are today producing power sufficient to displace the use of a million tons of black coal annually, and this power can readily be distributed to every small and large town ……and thus revive the hundreds of small factories, which were formerly the hives of industry in so many of our small villages…Again how differently, financially, for our people and state, if this $5,000,000 now paid annually to the coal producers of Pennsylvania and Ohio should be produced and kept within our borders."

Vermont Governor John A. Mead - 1912

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