HYDROPOWER IN NEW ENGLAND

An Introduction

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This first article in the small hydropower symposium will provide a brief overview of hydroelectric power in New England. The objectives of this article are (1) to put some perspective on the role hydro could play in meeting electricity demand in New England and (2) to discuss the many potential conflicts and implications to river management that a significant return to hydropower would bring.

A few introductory concepts and definitions will prove helpful. The natural fall of water from a higher to a lower elevation converts potential energy into kinetic energy. The difference in this elevation is commonly referred to as head. A turbine connected to a generator is driven by this kinetic energy to produce electricity. Many of the very small dams in New England are based solely on this simple principle. These run-of-river dams rely entirely on the natural flow of the river to produce power. They do not have the capacity to store water and consequently do not provide a constant or predictable source of power. Therefore, this kind of power, based on natural flow, can contribute only minimally to meeting electrical demand served by fossil fuel plants in New England.

A predictable and reliable source of power that can be managed to meet specific loads is needed to displace oil fired generation. Hydropower can meet this requirement only if impoundments to store and regulate natural river flow are created. These impoundments are usually classified as either low head or high head facilities. Low head facilities usually range in head from a few feet to about sixty feet. Dams designed for low head installations usually include large spillways which pass all river flow exceeding turbine capacity. The powerhouse, which houses turbines and genera-

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tors, typically forms part of the dam. Low head dams offer only modest storage capacity which can be used for daily or weekly peak load operations. Daily or weekly storage is often referred to as pondage, signifying the relatively modest storage capacity available at the dam. Federal energy policy emphasizes the rapid development or restoration of low head hydro capacity.[1] This policy stems in part from the assumption that low head facilities involve only modest impacts on streams.

High head facilities, on the other hand, can produce as much as 5,000 feet of head. In high head systems the powerhouse is usually detached and is often situated well downstream from the dam to capture additional natural fall in elevation. The river flow is conveyed to the powerhouse through penstocks. High head facilities generally create large storage areas which can be used for baseload or daily, weekly, or even seasonal peak operations. Examples of such installations are the Tennessee Valley Authority System and the Bonneville and Grand Coulee Dams.

The basic low head hydropower system has some potential as an energy source in New England. As development occurs, water management problems, river use conflicts, and environmental impacts associated with hydropower will appear with greater frequency. These impacts on a river system will create social consequences which must be considered in the development of hydro facilities.

I. Hydropower Potential in New England

Expansion of New England's hydro capacity may take two different forms—redevelopment of existing sites and the construction of new sites. The New England River Basins Commission (NERBC), in conjunction with the New England states and the Army Corps of Engineers, is currently conducting a hydropower study.[2] Two elements have been completed.

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1. White House Rural Development Initiatives, Energy for Rural America 2 (May 1979).

2. New England River Basins Commission, Potential for Hydropower Development at Existing Dams in New England (January 1980) (Vols. 1-8) [hereinafter referred to as NERBC].

An inventory of existing dams in New England was the starting point of the hydropower study. NERBC has determined that nearly 11,000 dams currently exist in New England. The inventory process involved site investigations to determine the current use and conditions of dams. The inventory revealed, in part, that:

- 363 dams are currently used to generate electricity;
- 53 dams were built by the Corps of Engineers exclusively for flood control; and
- 1,445 of the dams are wholly or partially breached.

A more complete profile of existing dams is available in the following table:

TABLE I[a]
TYPE OF EXISTING DAM BY STATE

	Existing Dams Not Currently Generating Electric Power	Breached Dams.	Hydro Dams Currently Generating Electric Power	Dams Built by Corps of Engineers	Other[4]	Total
Connecticut	1,441	34	21	12	1	1,509
Maine	1,005	246	98	1	68	1,418
Massachusetts	2,286	131	52	14	29	2,512
New Hampshire	2,301	845	125	14	47	3,332
Rhode Island	738	120	2	1	39	900
Vermont	436	69	65	11	418	999
Total	8,207	1,445	363	53	602	10,670

In the analytic element of the study, each dam was evaluated to determine the practicality of producing power at each of two plant factors.[5] A 40% plant factor is typical of peaking/intermediate power generation. A 70% plant factor is representative of baseload operations.

To be included in the evaluation of production practicality, a

3. *Id.*, vol. 1 at 13.

4. Primarily small dams for which insufficient information was collected to perform generating capacity calculations.

5. Plant factor refers to the ratio of the average load to the installed capacity of a plant, expressed as an annual percentage.

dam must have had greater than five feet of head and capability to generate fifty kilowatts (kW) or more. At a 40% plant factor, 1,748 dams met these criteria; and at a 70% plant factor, 1,154 dams qualified.[6] About 1,000 megawatts (MW) of installed capacity would result if all 1,748 dams at a 40% plant factor were developed. This installed capacity would equal about seven per cent of the New England winter peak load.[7] This estimated production represents the maximum potential contribution of redeveloping all of the existing dams that meet the practicality criteria. This maximum potential could, of course, be increased or decreased out of consideration of economic, environmental, and social concerns.

TABLE II[8]
MAXIMUM POWER POTENTIAL[9] AND OIL SAVINGS AT EXISTING DAMS

	# 40% Plant Factor	Capacity (kW)	Oil Savings (BBC)	# 70% Plant Factor	Capacity (kW)	Oil Savings (BBC)
Connecticut	202	87,172	432,453	116	35,296	305,797
Maine	465	367,852	1,809,140	312	154,440	1,328,810
Massachusetts	295	114,922	565,537	188	46,472	401,241
New Hampshire	535	260,495	1,292,364	353	107,812	930,098
Rhode Island	99	38,321	190,142	70	16,190	137,036
Vermont	152	134,081	664,110	115	58,873	498,005
Total	1,748	1,002,843 (1002.8 MW)	4,953,746	1,154	419,083 (419.1 MW)	3,600,987

Each dam which passed the initial engineering screening criteria was subjected to a detailed economic analysis to determine the feasibility of its redevelopment. As might be expected, economic feasibility is very sensitive to the cost of money and the market value of the energy produced. For example, as can be seen in Table III, at a 40% plant factor, an interest rate of 14%, and a market

6. See Table II accompanying note 8 *infra*.

7. 1 NERBC, *supra* note 2, at 17.

8. *Id.* at 14-16.

9. This potential includes all sites with a minimum of five feet and a minimum power generating capacity of 50 kW. It does not include any economic, environmental or social constraints.

value of 45 mills[10] per kilowatt hour, only 82 out of 1,748 sites in New England would break even.[11] These 82 dams would have a combined capacity of only 164.8 MW. The entire table is informative.

TABLE III[12]
REDEVELOPMENT SENSITIVITY TO CHANGING FINANCIAL CONSTRAINTS

	14% Interest 45 Mills CREC[13]		6⅞% Interest 45 Mills CREC			14% Interest 67 Mills CREC		
	Number of Sites	Capacity (kW)	#	Capacity (kW)		#	Capacity (kW)	
Connecticut	16	29,589	32	51,639		23	40,957	
Maine	14	52,420	45	270,034		32	121,355	
Massachusetts	15	21,342	39	47,369		25	34,511	
New Hampshire	14	20,496	41	87,258		29	48,455	
Rhode Island	6	6,432	15	15,472		9	8,851	
Vermont	17	34,607	37	94,846		30	79,459	
Total	82	164,886	209	466,418	(sic)[14]	148	333,568	(sic)[15]

As the interest rate is reduced or a higher purchase price applied, however, many more dams would become feasible. For example, of all dams at 6⅞% interest and 45 mills per kilowatt hour, 209 dams with 566 MW of capacity are economically attractive. In comparison, at 14% interest and at a higher price per kilowatt hour—67 mills—about 40 dams with 333 megawatts appear feasible. Thus, hydro development at existing dams will not provide a significant offset to conventional thermal or nuclear generation. Nonetheless, rising electricity costs from these conventional sources, financial incentives through the Public Utility Regulatory Policies Act (PURPA)[16] and tax credits included in the windfall

10. Ten mills are equivalent to one cent. Forty-five mills per kW hour is the rate currently set by New Hampshire Public Utilities Commission for power generated at small-scale hydro facilities.

11. That is, have an annual return that would at least equal annual costs.

12. 1 NERBC, *supra* note 2, at 40-41.

13. Capital Energy Recovery Cost.

14. The total should be 566,618.

15. The total should be 333,588.

16. 16 U.S.C. §§ 2601-2645 (1978).

profits bill,[17] and hydro development at undeveloped sites may offer profitable opportunities to entrepreneurs and utilities.

II. Impacts of Hydropower Development

The expanded interest of utilities and entrepreneurs in hydro development has already stirred considerable controversy throughout the New England region. On the environmental side, the debate focuses on the effects hydro development may have on stream-flow maintenance, anadromous fisheries programs, recreation, wildlife habitats, flood control, and water supply. On the social side, the debate focuses on the proper procedure to determine the best balance between water uses.

A. *Restriction of Streamflow*

To maximize power production at a hydro facility, all of the water flowing downstream should pass through the turbines of the facility. Spillage over the top of the dam must be mimimized during periods of high flow (late winter and spring) to maintain a sufficient volume of water behind the dam to drive the turbines during periods of low flow (later summer). In general, large dams with significant storage capacity are able to capture a greater portion of the flow than smaller "run-of-river" dams[18] which can impound water only on a daily or weekly basis to build up the available flow.

Operation of most dams on New England's rivers will require some manipulation of natural streamflow to create the best conditions for efficient and economic power generation. The extent to which streamflow is manipulated may, however, have important implications downstream. For example, a downstream municipal sewage treatment plant or industrial waste discharge system requires a certain volume of water to operate effectively—there must be enough water passing the end of the discharge pipe to ensure adequate dilution of waste.[19] Lowering the streamflow may impair

17. Act of Apr. 2, 1980, Pub. L. No. 96-223, 94 Stat. 229.

18. True "run-of-river" dams are hydro dams which do not interrupt the natural streamflow at all.

19. Referred to as "waste assimilation."

this dilution process, degrade water quality, and possibly jeopardize past or proposed investments in treatment plants to improve water quality.

Manipulation of natural streamflow would also adversely affect anadromous (*e.g.* salmon, shad) and resident (*e.g.* trout) fish species. These species depend on the maintenance of certain flow-related conditions for their survival, including current velocity, water temperature, stream depth, and bottom material.

The extent to which natural streamflow may be altered in the operation of a hydroelectric dam is usually specified in permits issued by the federal government through the Federal Energy Regulatory Commission (FERC) and the states through Water Quality Certificates, with consultation from fish and wildlife agencies at both levels.[20] The minimum flow requirements may vary from dam site to dam site, and there is considerable debate as to whether an adequate level for waste assimilation will also be adequate for fish.

The matter of regulating flow goes over and beyond agency requirements, however, since the rights to river flow must first be established. New England's rich history of waterpower includes a set of "mill acts" or "flowage acts"[21] that granted upstream flowage rights to the original developers of waterpower dams. Tracking these rights is often complicated by the number of changes in ownership that have occurred over time. The rights remain in effect, however, and will have to be sorted out in conjunction with the FERC licensing process.[22]

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20. *See* Scotch, *Small Hydropower Development and the Environment: A Survey of State and Federal Law*, 5 VT. L. REV. 251 (1980).

21. *See* Brion, *The Common Law of Water Power in New England*, 5 VT. L. REV. 201 (1980).

22. Establishing rights to flow is like the search for a clean title and has often been confounded by unforeseen problems. For example, the Swansville Lake Project located on the Goose River in Maine provides an example of complications that can arise in implementing a flow management scheme. This proposal called for installation of turbines in each of four successive dams with heads ranging from 6 to 31 feet and using a fifth dam upstream to regulate the flow through the four lower dams in a partial peaking operation. In purchasing the uppermost dam, the developer also acquired all riparian rights around the lake above it, giving him the legal right to control fluctuation of the lake's water level consistent with his operational objectives. Residents around the lake, however, reacted violently to this

B. *Conflicts with Anadromous Fishery Restoration*

Anadromous fish spend most of their adult life in salt water but return to fresh water to spawn. Atlantic Salmon and American Shad were once prominent sport and commercial species in New England. The damming of the region's rivers for hydroelectric power and other uses has, over the years, severely restricted runs of shad and all but eliminated runs of salmon. Consequently, both the federal government and several of the New England states, with substantial support from sport fishing interests, are now engaged in major efforts to restore these species to their earlier prominence. Programs sponsored by the U.S. Fish and Wildlife Service, the Atlantic Salmon Restoration Program, and several of the New England states aim to provide facilities for the passage of migrating fish around existing dams. These agencies are also engaged in the raising and release of young fish in the upper reaches of certain rivers to which they should eventually return to spawn and breed future generations.

FERC is empowered to require dam developers to install fish passage facilities.[23] Unfortunately, the cost of such facilities is high—$4,000 to $10,000 per foot of dam height—and in some cases represents ten percent or more of the total costs that must be borne by the developer. As more dams are proposed, questions will be raised concerning the merits of requiring these expenditures, the potential effectiveness of the facilities and restoration programs as a whole, as well as the equities involved in assigning responsibility for their costs to the dam developers.

C. *Impacts on Recreation*

Hydro development raises obvious conflicts with recreation activities dependent on the free-flowing qualities of streams, such as white-water canoeing, kayaking, or rafting. Periodic impounding of

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proposal fearing the loss of their recreational asset. In response to the controversy, FERC suggested that a compromise plan be developed through mediation. After considerable delay, a fluctuation compromise was in fact agreed to, and the developer has succeeded in securing his FERC license.

23. *See* 16 U.S.C. § 2705(c) (Supp. II 1978).

upstream waters to optimize power generation may either fully eliminate white-water reaches by inundation or reduce flow to the extent that canoeing or rafting becomes impossible. On the positive side, it may be possible to regulate the release of water from impoundments behind hydroelectric dams so that flow conditions are actually enhanced during periods of peak white-water activity. Such regulation has helped a booming white-water rafting business on the Kennebec River in an area reputed to challenge the thrills on the more famed white-water rivers in the west. Further, in areas where there is substantial demand for increased flatwater recreation—swimming, boating, or water skiing—losses in white-water may be offset by the creation of new flatwater opportunities on reservoirs. Residents of urban areas will benefit the most from these pools since flatwater demand is great and there is a shortage of lakes or manmade impoundments in urban areas.

The Heritage Conservation and Recreation Service (HCRS), a division within the Department of Interior, has developed an inventory of Wild and Scenic Rivers in New England and is now completing an inventory of rivers with significant recreational assets. The inventories are the first step toward consideration of the rivers for eventual inclusion in the national Wild, Scenic and Recreational Rivers System.[24] Such classification of any river would preclude new hydropower development since a basic requirement is that the river be kept essentially free flowing and barrier-free.[25] Seventy-seven rivers or river reaches in New England, many of which may be prime candidates for economically attractive hydroelectric development, were included in the inventory.

D. *Compatibility with Flood Control*

In New England approximately fifty-three dams have been constructed by the Corps of Engineers for flood control.[26] Some of these may have potential for power generation as well as for continued use in storing and regulating flood waters. If the full poten-

24. *See* 16 U.S.C. §§ 1271-1276 (1976).
25. *Id.* § 1273(b).
26. *See* Table I, accompanying note 2 *supra*.

tial of twenty-three of these dams were developed, the power produced would be about 20% of the power that could be economically produced from all of New England's existing dams.[27] Most of these dams, however, were designed and are operated with the single purpose of flood control in mind. If developed for hydropower generation, therefore, these flood protection capabilities will have to be maintained.

E. *Social Consequences*

Whether a proposed hydro facility involves construction of a major new dam or the retrofitting of a small scale existing structure, there will always be those who support its construction and those who oppose it. Some conflicts will be site-specific and will be resolved on an individual basis as hydro proposals are made. Others will be common to many sites and will require consideration in the context of their cumulative impact on an entire basin or region.

Finally, as with any water resource development project, upstream uses, even those apparently insignificant, may have major consequences downstream. For example, installation of a costly fish ladder downstream would be impractical if construction of new facilities upstream will reduce flow to a level insufficient to support migrating species or their young between the structures.

Conclusion

Hydropower at existing dams will not be a panacea for New England's energy problems. Development of the 200 most favorable existing dam sites would only provide savings of about 2.7 million barrels of oil per year.[28] This saving is minimal when compared to the 75 million barrels of oil consumed in 1978[29] to produce electricity in New England. Even the most optimistic estimates indicate that development of New England's maximum hydropower potential would provide only about 1,000 MW of capac-

27. NERBC, *supra* note 2, at 8-9.
28. New England River Basins Commission, New England Hydro 6 (June 1980).
29. *Id.*

ity or seven percent of the region's 1978 winter peak load.[30]

From a developer's viewpoint the more attractive hydro sites are those with some storage capability to increase reliability. Storage capability will mean manipulation of natural streamflows which will increase the incidence of conflict with other competing water interests and users. Restriction of flow on a seasonal, weekly, or even daily basis in conjunction with a small scale low head project may have several effects: (1) degradation of water quality due to diminished downstream waste assimilative capacity, (2) decreased volume and quality of the water needed to support both resident and migratory fish species, (3) reduction in the availability of water supplies to downstream users such as municipalities or manufacturing industries, (4) reduced or eliminated recreation opportunities dependent on the free flowing qualities of streams, and (5) increased fluctuations in lake levels. These problems will be compounded by development of a number of hydro sites over the length of a single basin creating significant cumulative effects.

One goal of proper hydro development is to optimize the power benefits that can be achieved and still ensure that other water uses are maintained or even enhanced. Optimum water use in a particular basin will require comprehensive management of streamflow throughout the entire basin. New England currently lacks well developed comprehensive flow management for any of its major basins. Implementation of such management will first require development of a data base to define both natural flow conditions and competing demands. The use of computer models[31] would help develop this data base by suggesting the optimum river flow to accommodate the variety of users over the length of the basin.

Furthermore, development of an effective flow management system will require evaluation of existing institutional mechanisms. Such a system must provide for the sustained and coordinated involvement of all competing interests.

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30. NERBC, *supra* note 2, at 17.

31. Lynch, *Fundamental Economic Issues in the Development of Small Scale Hydropower*, 5 VT. L. REV. 295 (1980).

If hydropower is to be developed in New England, sites with economic potential must be identified and willing buyers found. Increased hydropower development is now forcing the issue of river regulation upon New England for the first time, and development must occur as part of a system of overall regulation of rivers and river systems. In summary, the following policies should be developed to balance the various uses of the rivers:

1. A framework for negotiating instream flow requirements;
2. A process for identifying which recreational and pristine river segments should be included in the federal or state Wild, Scenic and Recreational Rivers Systems;
3. An examination of anadromous fish restoration plans to evaluate the costs and restraints placed on overall hydro development. This evaluation should include consideration of hydropower benefits in addition to fishery benefits in developing the list of rivers to be restored;
4. A study of existing flood control structures to determine the tradeoffs between protection, flooding, and hydro generation that are feasible and acceptable.

Hydropower may once again contribute a share of New England's energy in harmony with other users of precious water resources.