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HYDROPOWER AND FISHERIES: IMPACTS AND OPPORTUNITIES

PROCEEDINGS OF THE 1982 NORTHEASTERN DIVISION,
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TABLE 1. APPLICATIONS RECEIVED BY FERC DURING FISCAL YEARS 1977-1982[1]

Type of Application	1977	1978	1979	1980	1981	1982[2]
Licenses	33	25	33	86	98	141
Preliminary Permits	18	36	76	504	1,858	642
Exemptions from Licensing	0	0	0	7	177	249
Other	213	121	167	175	164	131
Total	264	182	276	772	2,292	1,163

1/ October 1 to September 30
2/ October 1, 1981 to April 30, 1982

TABLE 2. APPLICATIONS ACTED ON BY FERC DURING FISCAL YEARS 1977-1982[1]

Type of Application	1977	1978	1979	1980	1981	1982[2]
Licenses	37	26	45	146	96	69[3]
Preliminary Permits	7	5	38	191	1,280	834
Exemptions from Licensing	0	0	0	0	91	179[3]
Other	178	138	207	241	190	137
Total	222	169	290	578	1,657	1,219

1/October 1, to September 30
2/October 1, 1981 to April 30, 1982
3/Includes authorization of over 275 projects since 1980 that propose new generating capacity.

regulations changes we expect to implement and new legislative proposals. Figure 1 shows the various options that developers have available to obtain authorization of a project. Each of these options, at the choice of the developers, may be preceded by obtaining a preliminary permit. A preliminary permit is a study authorization that gives the permittee priority to an application for license but does not authorize any project construction. It is not a necessary prerequisite for obtaining a license. However, most developers choose to obtain a permit because it protects the investment made in feasibility studies. We view a permit in another light as it also provides a means of monitoring developer activities and ensuring that there is compliance with the conditions in a permit and the FERC regulations, most of which are related to environmental matters.

There are three basic categories of projects and regulations:

1. Projects with an installed capacity of more than 5 MW that involve new dam construction;
2. Projects with an installed capacity of more than 5 MW that use an existing dam; and
3. Projects of 5 MW or less.

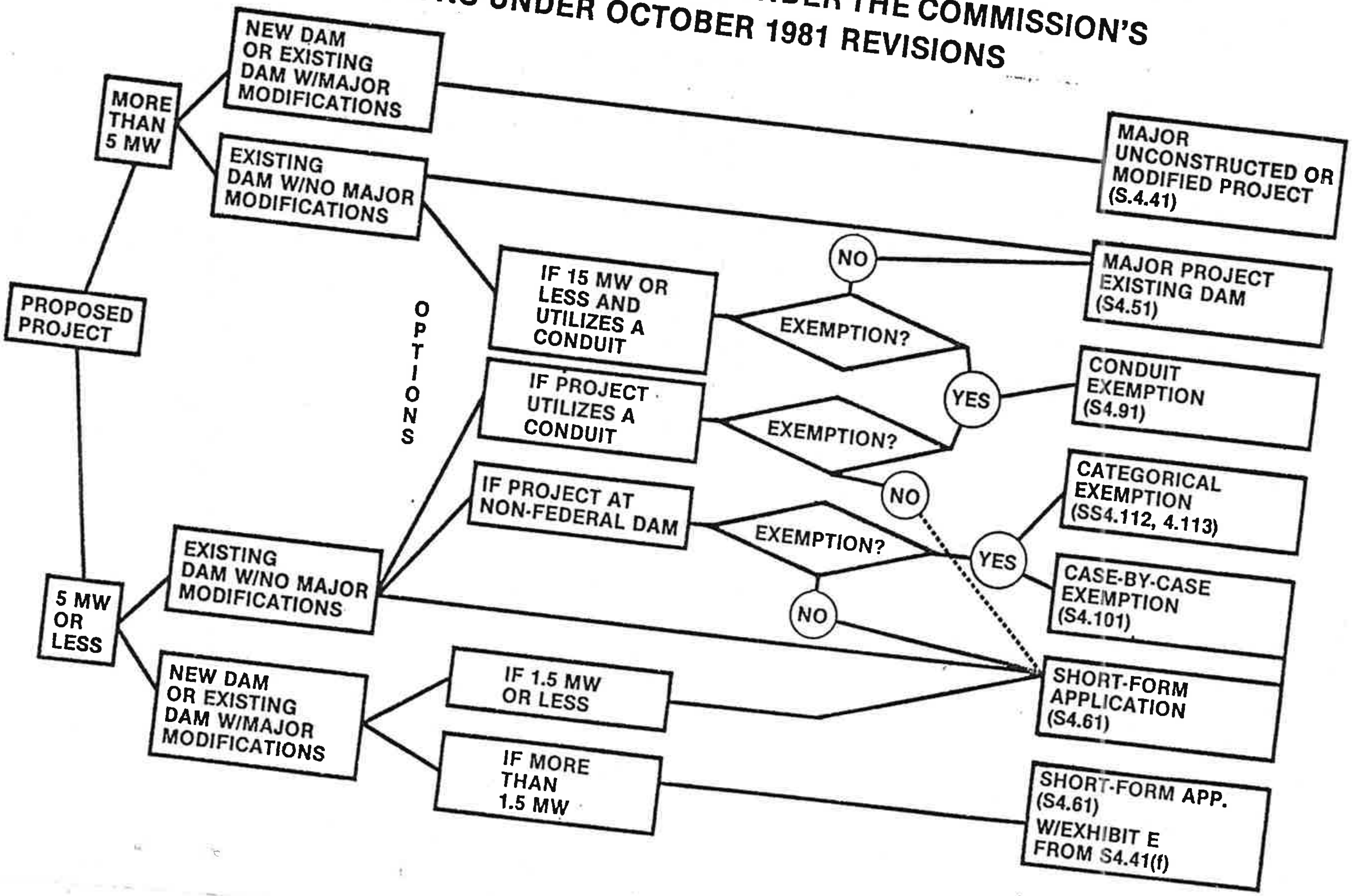
There are specific regulations for categories 1 and 2. Each has special requirements to fit the scope of development and to deal with specific engineering, economic, and environmental considerations. Category 1 represents less than 10 percent of all projects currently before FERC and category 2 represents about 40 percent.

Category 3 is of special interest because developers have two possible choices for developments of this type. A developer may choose to obtain a license or an exemption from licensing. Because these are very small projects, the so called case-by-case exemption and the license regulations (known as short-form license) have been significantly simplified. Most of the emphasis is on environmental issues. We have further divided the exemption regulations into two parts, case-by-case and generic exemptions. All exemptions are issued automatically, 120 days after application for the case-by-case exemption and 30 days after application for the generic exemption. The generic exemption will affect a very limited number of projects because of the very stringent environmental criteria that must be satisfied before one can qualify for such an exemption.

We believe it is very important to emphasize the concept that was followed in structuring the regulations. The regulations are based on the premise that those involved in development, such as agencies, environmental interests, economic interests, and the developer will interact at the formulation stage of the project and resolve as many problems at that level as possible . This approach encourages discussion, negotiation, and timely resolution of problems at the local level. This is particularly important for very small projects. It is only through this cooperative approach that we can rationally and sensibly deal with the large number of developments.

All developers will not be successful, nor will all other interests always be ideally addressed. Compromises are necessary. Adopting the

FIGURE 1. LICENSING OPTIONS UNDER THE COMMISSION'S REGULATIONS UNDER OCTOBER 1981 REVISIONS



ideal solution for any single interest will usually produce an unresolved issue. It is at this point that the FERC must moderate the outcome. We must minimize the issues. This approach is desirable for all interests, cost-effective and less time consuming. Ideally, all concerned will approach hydro development openly and constructively. Confontation is not the road to success.

Before closing, I would like to mention some other initiatives now under consideration. The FERC is currently finalizing rulemakings. We expect to issue in the near future a final regulation for the so-called "natural water feature" project so that such projects can qualify for the case-by-case exemption. Also, the Commission should be issuing a proposed rulemaking to change the current annual charges assessed licensees. This latter rule is expected to include filing fees for all applications and a special section on charges for the use of government dams. Finally, we have had rehearing applications filed on our previous regulations. The Commission should be dealing with the rehearings very soon.

Legislation related to hydro development has received a significant amount of attention in recent months. Rather than provide a detailed discussion of the legislation, some of the more important proposals are briefly summarized below:

1. S.1299, legislation to increase the 1.5 MW waiver authority of the Commission to 15 MW.
2. S.2500, legislation to establish an owner preference to sites, and a municipal/state preference on other sites.
3. FERC proposal to Congressman Bevill for one-stop federal licensing/permitting.
4. Legislation to clarify the avoided cost and interconnection issues that the courts recently ruled on as a result of the AEP case regarding the FERC regulations under the Public Utility Regulatory Policies Act (PURPA).
5. Legislation to remove certain economic incentives available to hydro, particularly leasing.
6. A legislative proposal by western states that would give state water rights boards veto power over FERC permits, licenses, exemptions and amendments of license.
7. An FERC proposal, introduced by Senator McClure, providing authority to assess filing fees.

This is not an exhaustive list, but it represents the legislation we believe to be most important to the future of hydro development.

If we leave this meeting with any conclusion, be it that all parties will endeavor to cooperate to ensure optimum development of the nation's water resources. We should also resolve to agree that because there are competing uses of water, no one use should always prevail, nor should any one use supersede all other interests in every situation. Compromise always yields the best results for all parties.

HYDROELECTRIC POWER - ONTARIO'S ENERGY PAST AND FUTURE

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WATER POWER AND ONTARIO: PAST AND PRESENT

Waterpower has been a guiding force in the history of Ontario. The "urban" settlement pattern in Southern Ontario was largely predicated on the 550 water power sites that were once active. Many towns and villages still have an old mill and a few of these are still producing mechanical power.

Electricity from water power began very early in Ontario with a small plant in Ottawa starting in 1881. Development was rapid and in 1906 an agency of the province, Ontario Hydro (until 1972 called the Hydro Electric Power Commission of Ontario), was formed to distribute power. By 1914 Ontario Hydro had built their own generation facilities. At present Ontario Hydro serves virtually the whole province and obtains about one third of its electric power from 69 hydroelectric facilities. An additional 20 or so generating stations are operated by municipal utilities and about a dozen generating stations (not including micro-hydro) are operated privately. Almost all of these stations are old. For example, 51 out of the 69 Ontario Hydro stations are more than 50 years old and only 5 are less than 20 years old.

Interest in hydroelectric sites waned in Ontario during the era of cheap fossil fuels. Coal and even oil burning stations were built in the 50's, 60's and early 70's and large-scale CANDU nuclear units came on stream in 1972.

The era of cheap fossil fuels is now over. Economics, environmental impact and energy security are causing Ontario to look towards indigenous supplies of energy. One of these, in fact the principal one after nuclear power, is hydroelectric power. Ontario Hydro is now working towards a target of 2000 MW of additional peak hydroelectric generation in their system by 1995. Small and micro-hydro are also receiving attention.

THE ENCOURAGEMENT OF SMALL HYDRO

A major thrust of Ontario Hydro in 1982 is to develop a comprehensive program to encourage small hydro. The objectives of Ontario's program are modest in terms of power production but ambitious in terms of growth. The installed capacity of small hydro (less than 2 MW) in Ontario is approximately 33,000 kw at 69 sites. We aim to double the installed capacity in 5 years by adding 33,000 kw at 50 to 100 sites

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and then double again by adding 67,000 kw by 1995 at 100 to 200 sites. This 100,000 kw or 100 MW will be additional to the 2000 MW to be added by Ontario Hydro over this same period.

We'll need to pull people into developing small hydro by offering the most attractive purchase price possible for power. We are currently studying specific incentives to encourage development. A consulting contract has been let to examine the constraints encountered by municipal utilities, conservation authorities and private interests when they consider small hydro. We'll need to streamline the approval process and make sure that people don't get discouraged while dealing with the regulations and the regulators. Technical assistance through Ontario Hydro is already available to small site developers and we will continue to provide this service.

A major way of spurring prospective developers into activity will be the public offering, for lease, of small hydro sites. These sites will be identified by an inventory of hydraulic resources now under way. Phase I of this inventory is almost complete with more than 200 sites examined so far. The best sites identified will be offered for lease.

The provision of technical information and publicizing the program are also important. In this area we have published a very successful booklet on micro-hydro which is now in 2nd printing. We also have sponsored demonstrations in northern and southern Ontario and I am now organizing a workshop on small hydro to be held on September 27, 1982 in Toronto.

ROLE OF ONTARIO HYDRO

The Ministry of Energy can't act alone in encouraging small hydro; Ontario Hydro has an important role. They set the purchase rate and the service conditions for interconnection. Hydro also provides electrical inspection and certification of an installation under the Electrical Safety Code. They have taken the position that they are willing to assist people doing this small site work.

Interconnection of any size generating site is possible but prevailing electricity rates favor developments producing more than 50 kw. Sites that produce less than 50 kw are eligible only for "At Will" rates for energy; 1982 "At Will" energy rate is 1.6¢ per kwh. Larger sites that can provide capacity during peak load periods are eligible for capacity as well as energy rates. Capacity rates are up to $4.28 per kw per month and energy rates average about 1.6¢ per kwh.

ENVIRONMENTAL REGULATION OF SMALL HYDRO

Ministry of Natural Resources (MNR) and Conservation Authorities have an important regulatory role. Together they control most of the dams in the province and MNR, as guardian of fish of the province, is the main regulatory agency. The approval process shown in Figure 1 is mainly handled by MNR. Access to hydroelectric sites on crown land by investor groups and others has been clarified recently in Ontario.

development. Small scale sites, with existing dams will be developed by either the public sector (municipalities or conservation authorities) or the private sector (investor groups, site owners, and industries) as the sites become economic. The steps being taken now in Ontario should stimulate the development of 100-200 of these small scale sites by 1995. There will be several hundred more sites to consider beyond 1995.

CONCLUSION

Water power has had and will have an important role in Ontario. It is renewable and indigenous and it produces no emissions. Small site development at existing dams is, on balance, beneficial to the environment. Larger scale developments which may require large dams and extensive flooding require close scrutiny. This is provided in Ontario by the Environmental Assessment Act. I expect that many of the sites currently under study could pass this test because of their long-term displacement of coal fired generation.

The amount of small hydro that can be produced in Ontario is limited, but I know we can produce more than we are doing now. China has over 70,000 small hydro sites in production while in Ontario we have about 70. Of course it's the year 4680 in China - perhaps they've had a chance to really sort out the benefits of water power.

ASSESSING THE IMPACTS OF REGULATED FLOWS AT HYDROPOWER PROJECTS

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INTRODUCTION

With very few exceptions, hydropower development is accompanied by streamflow regulation that has the potential to adversely affect upstream and downstream fisheries resources. Downstream effects of regulated flows are associated with the issue of instream flow needs (Orsborn and Allman 1976). Water resource conflicts involving instream flows arose first in the western United States (Stalnaker 1977, 1979a; Anderson 1982), but they are becoming a very real problem in the East, especially in relation to hydropower development (Davis 1981: IECI 1981, Knapp 1981). Upstream effects of regulated flows are usually related to water-level fluctuations within a storage reservoir (Hildebrand 1980). This paper is an overview of the current capabilities for assessing the impacts of regulated flows. My main objective is to provide a literature review that can lead to more detailed study of these subjects. This discussion is limited primarily to the physical effects of hydropower development. Further information on water quality effects can be found in Walker (these proceedings) and Cada et al. (1982).

RESERVOIRS AND FLOW REGULATION

The first step in assessing flow regulation impacts is to obtain a description of the hydropower reservoir and project operation. Three types of hydro projects can be distinguished by the ways in which they utilize reservoir storage and schedule their releases. Run-of-the-river projects are those with zero storage volume available for hydroelectric production. Therefore, total release (overflow) is equal to inflow at all times. Pulsing projects use reservoir storage to withhold streamflows until storage volume is full, then generate at or near full capacity until storage volume is empty. Release schedules at pulsing projects are not determined by the system load to which the electricity is distributed. Peaking projects also use storage to withhold streamflow, but their release schedule is a function of the system load. Hydroelectric generation and reservoir releases at peaking projects are concentrated during the time of the day when consumer demand for electricity is the highest.

Upstream and downstream effects of flow regulation are directly related because a mass balance of water flowing through the reservoir must be maintained. Water not stored, withdrawn or evaporated from the reservoir must be released downstream. Downstream releases can be of

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protect the integrity of the aquatic ecosystem (Table 1). Hydraulic-rating methods have also been called single-transect methods

TABLE 1. PHYSICAL VARIABLES USED AS SURROGATES FOR BIOLOGICAL RESPONSE IN HYDRAULIC-RATING METHODS.

Physical variable	Biological response	Reference
Depth in riffles	Fish passage	Thompson 1972, 1974
Maximum depth and mean velocity	Spawning success	Thompson 1972, 1974
Depth in pools and undercut banks	Rearing success	Wesche and Rechard 1980
Wetted perimeter	Food production and rearing success	Bartschi 1976

(Stalnaker and Arnette 1976) because they often involve collecting physical data along individual transects across the affected stream. More importantly, they do not directly apply any habitat suitability criteria to evaluate target species preferences (see below).

Field surveys are required to quantify the response of the surrogate variables to changes in streamflow. Transects are located in areas where the selected variable is most responsive to flow. Data consist of depth/velocity observations and a cross-sectional profile of the channel. Procedures are essentially those used by USGS to calculate volumetric discharge. To construct a response function, data can be collected at several (4 or more) different stream flows, or a hydraulic modelling approach can be used. Empirical models, such as the Manning Equation (Stalnaker and Arnette 1976; Bovee and Milhous 1978) are used in conjunction with the hydraulic-rating methods to minimize field work.

Minimum flow recommendations generated from hydraulic-rating methods are calculated by plotting the surrogate variables vs streamflow. Two different criteria have been used to define a critical threshold. Bartschi (1976) used a "habitat retention criterion" that consisted of maintaining no less than 75% of the wetted perimeter that was present at bank-full conditions. The second criteria is the "inflection point" technique. The inflection point is defined in this case as a point on the response curve (e.g., wetted perimeter vs flow) where a sharp change in slope occurs. That point is interpreted as the threshold below which habitat quality becomes significantly degraded. Both of these criteria are somewhat arbitrary, especially the inflection point approach. In many cases there are either no inflection points or mulitple inflection points, depending on the shape of the channel cross section and the placement of the transect.

Habitat-rating methods

The most advanced methods for evaluating instream flow needs are those that apply habtitat preference criteria to quantify the "usability" of physical conditions within the stream. Several methods can be included within this third category, including some of the earliest research on flow requirements conducted by the Pacific Gas and Electric Company (Waters 1976) and the Washington Department of Fisheries (Collings 1972, 1974). Current work by Newcombe (1981) in British Columbia and the Vermont Department of Water Resources (Tom Willard, personal communication) also falls in this category. The Incremental Methodology and its physical habitat simulation (PHABSIM) computer model developed by the U.S. Fish and Wildlife Service (Stalnaker 1979a, 1981; Milhous et al. 1981; Bovee 1982) are the most sophisticated of the habitat-rating methods. The superiority of the PHABSIM lies in its use of hydraulic simulation models to predict the response of physical habitat to altered streamflows [see Bovee (1982) for the most current description of the Incremental Methodology].

The basic habitat modeling approach employed in the Incremental Methodology and other habitat-rating methods is to calculate an index of habitat condition that incorporates both the availability (i.e., quantity) and suitability (i.e. quality) of the instream environment. In the PHABSIM model, this is done by first selecting a representative stream reach and dividing it into a matrix of discrete mapping elements centered on several transects spaced along the reach. Variables that are important in determining habitat suitability (depth, velocity, substrate, etc.) are either observed directly in each mapping element or are predicted as a function of streamflow by using hydraulic simulation models (Bovee and Milhous 1978). Then the habitat index, Weighted Usable Area (WUA, units in hectares per kilometer), is calculated at a specified flow as follows:

$$WUA = \sum_{i=1}^{n} \hat{S}_i a_i$$

where:

$\hat{S}_i$ is the composite habitat suitability for the ith mapping element,

a_i is the surface area of the ith mapping element, and

n is the total number of mapping elements used to model stream.

Habitat suitability is a relative measure, ranging between 0.0 and 1.0, that represents the behavioral preferences or tolerances for individual life stages of a target fish species (i.e., evaluation species). Various types of suitabiltiy functions have been suggested. Binary suitability functions are those in which only two conditions are represented: suitable (s_1 = 1.0) or unsuitable (s_i = 0.0). Examples of the use of binary functions are the Usable Width method (Thompson 1972), the Preferred Area Mehod (Collings 1972), and the recent work in Vermont (T. Willard, personal communication). The

Incremental Methodology uses continuous suitability functions that are based either on actual field data, literature sources, or expert opinion (Bovee 1978; Bovee and Cochnauer 1977). Several recent studies were directed at evaluating the procedures that build suitability functions (Orth et al. 1982; Larimore and Garrels 1982; Bain et al. 1982). Although several of these studies have demonstrated that the individual components of suitability are not independent of each other (e.g., Orth et al. 1982; Orth and Maughan 1982), the most commonly used formulation for WUA assumes independence among the components of composite suitability:

$$\hat{S}_i = s_d(d_i)\ s_v(v_i)\ s_s(s_i)$$

where:

> $s_d(\cdot)$, $s_v(\cdot)$ and $s_s(\cdot)$ are univariate suitability functions for depth, velocity, and substrate for a specific evaluation species; and
>
> d_i, v_i and s_i are the predicted depth, velocity, and substrate predicted for the ith mapping element.

The final output from a habitat-rating method is some type of habitat-response function (e.g., a plot of WUA vs streamflow). These habitat-response curves are the basis for making a minimum flow recommendation. Again, several different approaches have been used. Orth and Maughan (1981) established their minimum flow recommendation at the so-called "inflection" point (location of a sharp break or change in slope) on the response curve. Stalnaker (1979b) recommended the minimum flow be set at the lowest flow that could provide the WUA value present at the mean monthly flow. More recent studies examined the temporal variability of WUA values under normal and altered flow regimes (Trihey 1982; Sale et al. 1982a). Sale et al. (1982a) proposed a criterion for conserving fish habitat that based a minimum flow determination on a habitat-duration curve derived form the Incremental Methodology. Habitat-response data were also used in reservoir optimization models to examine tradeoffs between downstream fisheries resources and other project objectives such as hydropower production (Sale et al. 1982b).

The use of habitat indices such as WUA to evaluate impacts of flow regulation assumes a direct relationship between the index and some biological response such as standing crop or fish production. The validity of these assumptions must be carefully evaluated before using a habitat evaluation technique (Bovee 1982). Although Stalnaker (1981) presented data to support this assumption in Wyoming trout streams, in other lotic systems (e.g., warmwater streams) this relationship has yet to be demonstrated (Orth and Maughan 1982). Binns and Eiserman (1979) and Oswood and Barber (1982) demonstrated correlations between habitat variables and fish abundance. However, in both studies, the independent variables included in the predictive equations were not easily related to streamflow. Investigations of the relationship between fish response and habitat variables are currently being conducted on smallmouth bass populations in Pennsylvania under contract from the U.S. Fish and

Wildlife Service and on trout populations in the southern Appalachian mountains by Oak Ridge National Laboratory.

One aspect of instream flow needs that is often overlooked is sediment transport (e.g., Grenney and Porcella 1976; Richardson and Simons 1976). An excellent summary of the state-of-the-art of assessing regulated flow impacts on sediment transport is provided by Simons et al. (1981). Predicting sediment dynamics in river systems remains a very difficult problem.

ASSESSING IMPACTS OF WATER-LEVEL FLUCTUATION

Water-level fluctuations within hydropower reservoirs can result in physical/chemical changes in lentic habitats leading to reduction in standing crop, production, and species diversity (Hildebrand 1980; Hildebrand and Goss 1981). The physical/chemical alterations include:

- resuspension and redistribution of bed and bank sediments;
- leaching of soluble materials from sediment in the littoral zone;
- changes in sediment and nutrient retention (trap efficiency) of the impoundment as a result of changes in circulation patterns; and
- water quality changes coupled to circulation patterns.

Although prediction capabilities for the physical aspects of water-level fluctions are available, prediction of the biological consequences is generally lacking (Hildebrand and Goss 1981). One study that did implicate water-level fluctuations as a determinant of fish standing crops was a multiple regression analysis by Aggus and Morais (1979). Their results showed that the mean annual fluctuation in pool elevations accounted for a significant amount of the variability in both total fish and individual species standing crops in hydropower reservoirs in the South and Southwest (U.S. Fish and Wildlife Regions 2 and 4, respectively). These regression equations are not directly applicable to reservoirs in other regions of the country, but the approach would be if an adequate regional data set could be assembled.

Tschantz and Tam (1980) developed a modeling approach that is useful for assessing the impacts of water-level fluctuations. This method involves determination of (1) the vertical extent of fluctuations, (2) the area of littoral zone affected by these fluctuations, and (3) the relative biological importance of these affected areas. The addition of habitat suitability coefficients to Tschantz and Tam's model has not been attempted, but if it were done, it would provide a habitat-rating method analogous to the Incremental Methodology used for downstream effects.

CONCLUSIONS

In a review of the status of the nation's waters more than ten years ago, Wolman (1971) warned that stream regulation rather than chemical pollution "may have the most far-reaching effects on the character of many river systems." Hydropower decelopment accounts for a large share of these modifications to lotic ecosystems. Although much work remains to be done, many assessment techniques are available for evaluating the effects of altered streamflows. The challenge is for fisheries managers to utilize these techniques in a constructive way to accomplish their management objectives and for hydropower developers to find creative design and operation solutions to make thier projects compatible with environomental goals and constraints.

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IMPACTS OF HYDROPOWER DEVELOPMENT ON DOWNSTREAM FISH PASSAGE

by James M. Loar 1/

INTRODUCTION

The effects of hydroelectric dams on migratory fishes have been well documented, especially in the Northwest where construction of large dams on major rivers, such as the Columbia and Sacramento, has had a significant adverse impact on anadromous salmonids (e.g., chinook salmon, steelhead trout). Mortality during downstream passage has been identified as the major factor responsible for the decline of salmon and steelhead runs in the Columbia River (Columbia River Fisheries Council 1981). Restoration of these fisheries may depend on the success of approaches being employed to reduce impacts of dam operation on downstream migrants. Development of hydropower resources at existing dams in the smaller river basins of the Northeast could result in impacts on downstream fish passage similar to those observed at large hydroelectric projects in the Northwest. Effective methods are needed to reduce these impacts and to ensure that hydropower development in the Northeast is compatible with the continued existence and well-being of important fisheries.

The purpose of this paper is to briefly review the impact of hydroelectric development on downstream fish passage and summarize the various approaches that have been employed to reduce adverse impacts. Extrapolating the results of research conducted at large hydroelectric projects in the Pacific Northwest to substantially smaller projects in the Northeast is obviously difficult. For instance, direct transfer of specific technologies that were successful at large dams may not be feasible due to differences in dam design and construction. Moreover, different species with potentially different behavior patterns occur in the two regions. With the exception of the work conducted in the Maritime Provinces of eastern Canada (e.g., DuCharme 1972, Semple and McLeod 1976, Semble, 1979, Conrad 1980, Ruggles 1980), most research on downstream fish passage has been directed toward species native to the West Coast, especially chinook salmon and steelhead trout. Difficulties in transferring existing knowledge to the Northeast can be avoided by focusing on the general approaches that have been taken rather than on the technology per se, which is still in a research and development stage.

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SOURCES OF IMPACTS ON DOWNSTREAM FISH PASSAGE

Regardless of size (i.e., height of the dam or capacity), hydroelectric dams can have a significant adverse impact on anadromous fishes. The major sources of these impacts are associated with turbine passage and flow regulation (Figure 1). Adults can be successfully passed around dams to reach upstream spawning areas, but the progeny (e.g., juvenile American shad and Atlantic salmon smolts) as well as spent (spawned out) adults that migrate downstream can suffer direct and indirect mortality when they pass through turbines. When indirect losses from predation on stunned or injured fish are included, overall mortality can be significant (Table 1). Losses due to turbine passage may be much higher during low-flow years when spill is minimal and most of the river flow passes through the turbines. Inadequate streamflow caused by hydropower peaking operations can also delay downstream migration, causing residualism (i.e, entire life cycle is spent in freshwater) and/or increased exposure to predation, disease or pollutants (Raymond 1976).

Table 1. CUMULATIVE MORTALITY TO DOWNSTREAM MIGRANTS AS A FUNCTION OF THE NUMBER OF DAMS PASSED AND BASED ON THREE ESTIMATES OF AVERAGE MORTALITY PER DAM (Case 1 =2%; Case 2 = 15%; Case 3 = 30%)[a]

Number of dams	Cumulative mortality %		
	Case 1	Case 2	Case 3
2	4.0	27.8	51.0
4	7.8	47.8	75.9
6	11.4	62.3	88.2
8	14.9	72.8	94.2
9	16.6	76.8	96.0
10	18.3	80.3	97.2

[a] 2% = mortality during spillway passage (Washington Department of Ecology 1980).
15% = average mortality per dam (Salo and Stober 1977; Washington Department of Ecology 1980; Columbia River Fisheries Council 1981).
30% = includes indirect losses from predation as observed at Ice Harbor Dam on lower Snake River (Long et al. 1968, 1975, as cited in Raymond 1976).

Cumulative mortality can be substantial if downstream migrants must pass several dams. Juvenile salmonids in the upper Columbia and lower Snake Rivers must negotiate as many as eight or nine dams before reaching the estuary below Bonneville Dam.

FIGURE 1. SUMMARY OF IMPACTS OF HYDROELECTRIC DAMS ON DOWNSTREAM MIGRATORY FISHES.

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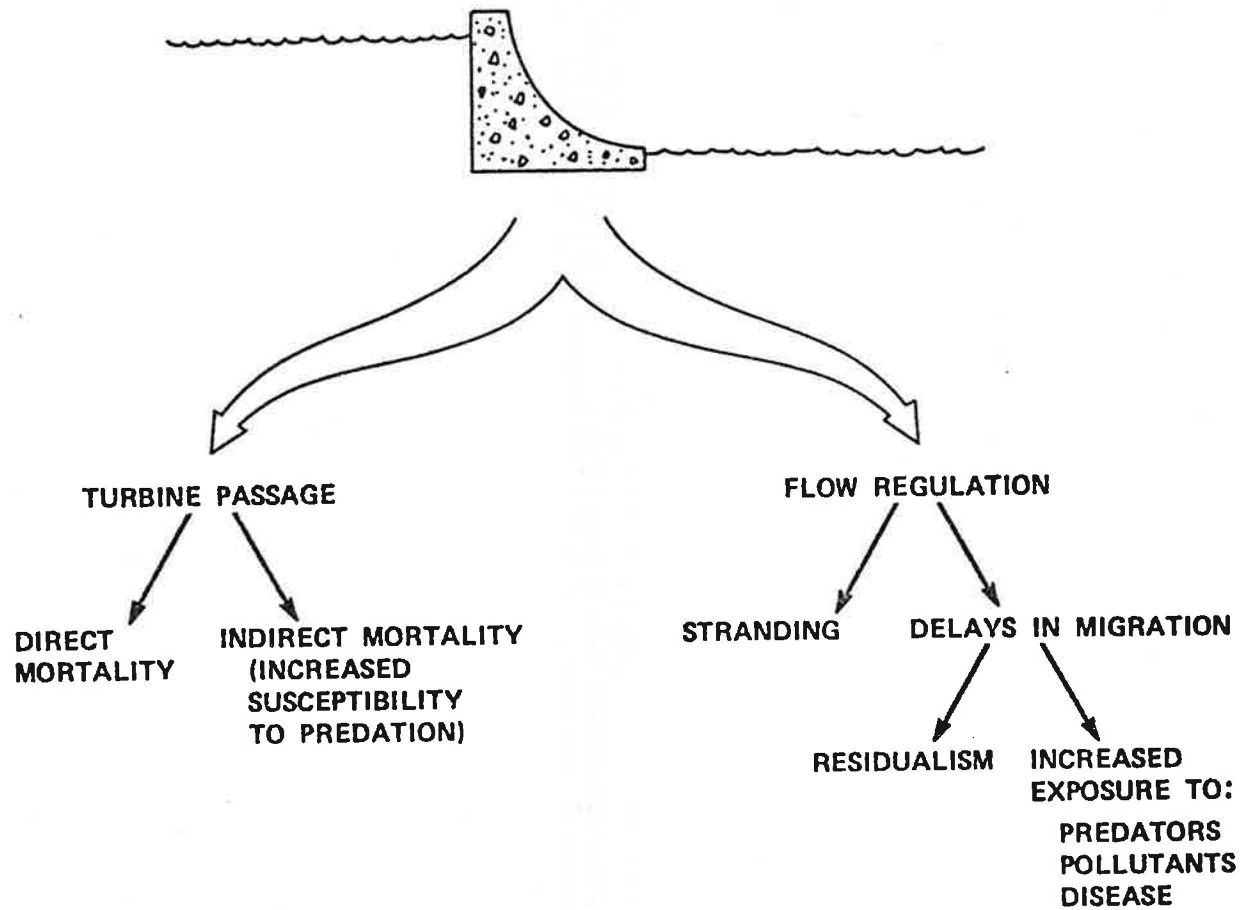

The 95% loss of chinook and steelhead smolts measured between Little Goose and The Dalles Dams in 1973, a record low-flow year, was similar to the predicted cumulative loss of 92% for seven dams with an average loss of 30% per dam (Raymond 1976). Even if mortality from turbine passage at small hydroelectric projects is only 10 to 15%, extensive development of the hydropower resources within a river basin can result in significant overall losses of downstream migrants. In the Northeast these migrants include adults that could return to spawn again, so cumulative mortality is a potentially greater issue than in the Northwest where adult Pacific salmon (*Oncorhynchus* spp.) die after spawning.

METHODS OF REDUCING ADVERSE IMPACTS ON DOWNSTREAM MIGRANTS

The numerous methods developed to reduce the adverse impacts of hydroelectric dams on downstream migrants generally fall into two categories, minimization and compensation. These approaches involve mitigation of impacts. However, because the term 'mitigation' has widely different meanings within the context of impact assessment and can include either or both approaches (see, for example, Swanson 1979), it is not used in the discussion that follows. Minimizing impacts on downstream migrants has generally focused on methods that provide safe passage around dams. For example, mortality resulting from turbine passage can be minimized by diverting downstream migrants away from the turbine intakes. Compensation involves replacement of losses, usually by artificial propagation of salmonids to supplement natural production irretrievably lost when spawning areas were inundated by dams. Only recently were hatchery and rearing facilities proposed as compensation for mortalities (primarily from turbine passage) incurred at existing dams such as those on the mainstem Columbia and lower Snake Rivers (Armacost 1979, Columbia River Fisheries Council 1981). These and other methods used to either minimize mortality or compensate for such losses are discussed in detail in Loar et al. (in preparation) and are summarized below.

Minimization

Mortality resulting from passage through turbines can be minimized if downstream migrants can be diverted away from the turbine intake and into a bypass which safely returns fish to the river below the powerhouse. The actual bypass can be a conduit with an entrance near the surface of the turbine intake, the same fishway utilized by upstream migrants, or an ice-trash sluiceway connected to the gatewell by a submerged orifice (typical of large dams on the Columbia River). Systems that utilize screens or louvers to achieve diversion appear to be the most promising. In tests conducted at dams on the Columbia and lower Snake Rivers, guidance efficiencies of 70% or greater were obtained using angled traveling screens (50° to 65° angle to flow) to guide juvenile salmonids into the gatewell (Park et al. 1979). Because they have greater reliability and lower capital and operating costs than conventional traveling screens, non-traveling bar screens were also tested; fish-guiding efficiences averaged 42 to 75%, and no problems were observed from descaling, impingement or debris accumulation (Krcma et al. 1978). At the Tusket Falls hydroelectric project in Nova Scotia, a floating screen deflector consisting of screen panels suspended from floating platforms at a 45° angle to the flow had an average bypass effciency of 72% for Atlantic salmon smolts (Semple and McLeod 1976). However, when similar tests were conducted at Malay Falls, Nova Scotia, the deflector actually reduced bypass efficiency (average efficiency was 20 and 52% with and without the deflector, respectively) (Semple 1979).

Louver diversion systems, which consist of a vertical array of panels or bars typically set at a 10 to 15° angle to the flow, were tested at several hydrelectric facilities with mixed results. Bypass efficiencies as high as 80% were achieved with Atlantic salmon smolts (Ducharme 1972). However, because other applications were often less successful due to unsuitable locations and facility design, Ruggles (1980) recommended that louvers be used at sites that are relatively shallow with high approach velocities and uniform flows. The varying success of both louvers and angled screen diversion systems implies that each application requires a substantive commitment to additional research. Studies will be needed to evaluate the efficiency of the particular diversion/bypass system at each site and to ensure the proposed system does not exacerbate the problem (e.g., the use of floating screen deflectors at Malay Falls, Nova Scotia, where smolts sounded under the screens and could not locate the bypass outlet), and that no significant delay in downstream movement occurs as a result of the bypass system.

Another method of reducing both turbine mortality and delays in migration is an extension of the bypass concept to a much larger scale where migrants are collected upstream and hauled, either by truck or barge, past one or more dams to a downstream release site. This approach has been used extensively to bypass juvenile downstream migrants around several dams on the lower Snake and Columbia Rivers. Comparisons of the percentage of returning adults between transported and non-transported (control) groups indicated that survival of steelhead was increased significantly by transportation, especially during low-flow years (Ebel 1980). Although application of this method at small-scale hydroelectric sites in the Northeast has not been evaluated, use of transportation to minimize downstream mortality will depend on the existence of suitable sites where large numbers of migrants can be collected.

Adverse impacts associated with turbine mortality and delays in migration can be minimized by altering the operational mode of hydroelectric projects during critical periods of the year. For example, maintenance of adequate instream releases during low-flow periods (e.g., late summer and early fall when juvenile American shad are abundant in many coastal rivers of the Northeast) will not only minimize delays during outmigration but will also protect downstream nursery/rearing habitat. Stranding of downstream migrants can be minimized by controlling the rate of change as well as the volume of downstream releases.

Controlling spillway releases during the period of peak outmigration has been used successfully on the Columbia River to pass juvenile downstream migrants. The effectiveness of spilling depends on spill volume and timing, fish distribution in the water column and powerhouse operation, including sequential load dropping and reduced powerhouse generation (e.g., Carlson et al. 1981). Spilling is currently used as an interim measure for minimizing turbine mortality at those dams on the Columbia and lower Snake Rivers without adequate downstream bypass facilities (Columbia River Fisheries Council 1981). Although additional research is needed to optimize spillway and powerhouse operation for bypassing downstream migrants, the existing program for the Columbia River basin is an example of a flexible plan coordinated among many individual projects for manipulating spill to enhance downstream passage. Similar efforts are possible elsewhere.

Compensation

Reducing adverse impacts of hydroelectric dams on downstream fish passage has also been accomplished through compensation. This approach involves the replacement of losses, either directly by artificial propagation in hatcheries or spawning channels or indirectly by restoration or improvement of spawning and nursery habitat. Construction of hatcheries and rearing facilities has generally been associated with, construction of large dams in the Northwest to compensate for the loss of upstream spawning habitat. Because of critical declines in salmonid stocks of the Columbia basin in the early 1970s, immediate action was required. A large-scale hatchery program was initiated in 1970, and today, artificial production accounts for over 50 percent of all fish returning to the Columbia River basin (Washington Department of Ecology 1980).

Extensive research on artificial spawning channels was conducted in the mid-1950s through the early 1970s at several dams on the mainstem Columbia River (e.g., Meeken et al. 1971, Allen and Meeken 1973). Although the channels were sized to accommodate the adult spawner population displaced from the inundated reach above the dam, they were unable to maintain the runs of chinook salmon in the Columbia River due to numerous problems, including siltation, poor water quality and disease. However, artificial spawning channels have been very successful in enhancing the runs of pink and sockeye salmon in the Frazier River basin in British Columbia (Cooper 1977).

Retrofitting existing small dams in the Northeast for hydroelectric generation would rarely require consideration of artificial propagation as a method of reducing adverse impacts on downstream migrants. However, construction of new dams on historically important Atlantic salmon rivers could necessitate such an evaluation, especially in view of the major effort currently being made to restore the runs in several rivers of the Northeast (Stolte 1980). Extensive development within a basin could also prompt such an evaluation, as the impacts on downstream migrants that must pass several dams are cumulative (Table 1). The Mactacquac Hatchery in New Brunswick, for example, was built by a power company to compensate for impacts of seven hydroelectric dams in the

Saint John River basin and has been successful in increasing the size of Atlantic salmon runs in the basin (Ruggles and Watt 1975). However, artificial propagation may not be successful for other anadromous species. Jessop (1975) indicated that American shad hatcheries failed to maintain stock abundance and that future efforts should be directed toward harvest management and improvement of the riverine environment.

Within the framework of small-scale hydroelectric development, compensation could include habitat improvement measures. Such measures could enhance existing natural production by restoring important spawning and nursery areas that were degraded by past activities (e.g., logging, road construction, mining, overgrazing of riparian vegetation). Numerous approaches are available (e.g., Nelson et al. 1978), including removal of obstructions resulting from logging operations, bypass of natural barriers, stabilization of streambanks and installation of various instream devices (e.g., current deflectors and check dams). Instream structures such as gabion weirs have been successfully used in Washington streams to stabilize pink and chum salmon spawning beds by reducing gravel shifting and scouring caused by high flows (Wilson 1976, Allen et al. 1980). Other techniques, such as gravel addition or replacement and gravel cleaning, have also been extensively applied and evaluated in Washington (e.g., Allen et al. 1980). Success, as measured by increased salmon production, is highly dependent upon proper site selection (Wilson 1976). Benefits are greatest where large numbers of adult salmon utilize a small area for spawning in streams with stable discharges and low bedload transport (Andrew 1981).

Although the long-term stability of habitat improvement measures is largely unknown, the long-term benefits will never be realized without effective management of the entire watershed. Strategies should not be limited to control of land-use practices upstream to minimize stream sedimentation. Restoration of upstream spawning areas or introduction of hatchery smolts to supplement wild stocks may not enhance salmonid production if potential sources of mortality to downstream migrants is not given adequate consideration. Unless these migrants are safety bypassed around hydroelectric dams, little if any benefit will be derived from whatever compensation is provided.

ASSESSMENT OF POTENTIAL IMPACTS

Assessment of the potential impacts of hydroelectric dams on downstream fish passage requires information on sources of impacts, design and operation of the project, and fishery resources of the river. Although emphasis may be placed on threatened and endangered and anadromous species, resident species that exhibit localized migrations should not be ignored. Equally important is the need to address cumulative impacts by considering the extent of hydro development in the basin. Additional regulation of the river, for example, could result in significant delays in migration, depending on the location of major spawning sites and the location and operation of proposed and existing projects. The cumulative mortality resulting from turbine passage at a number of dams could also be significant (Table 1).

It is within the context of cumulative impacts that consideration of methods for reducing losses becomes important, especially for small hydro projects. Identification of the need for such measures should occur during the early stages of project development, so that additional costs can be included in the evaluation of the economic feasibility of the project. Interim measures, such as controlled spill or replacement of losses due to turbine passage with hatchery-reared smolts, must be distinguished from potential long-term solutions to the downstream fish passage problem, such as the installation of diversion and bypass systems. If the latter are considered, then a careful analysis of their expected performance may be required (i.e., the minimum acceptable level of bypass efficiency). For example, if juvenile downstream migrants must pass as many as 8 to 10 dams, even a 50% reduction in turbine mortality per dam may not be sufficient (compare Cases 2 and 3 in Table 1). Minimization or compensation programs may also fail if other, non-hydro-related sources of mortality or stress on the populations (e.g., degraded water quality, commercial and recreational fishing) are ignored. Resolution of many of these problems can only be accomplished if interactions between regulators and developers of proposed hydroelectric projects occurs when feasibility studies are conducted.

SUMMARY AND CONCLUSIONS

The sources of potential impacts of hydroelectric dams on downstream fish passage are generally well known due largely to research conducted at large hydroelectric projects in the Pacific Northwest. If the hydropower resources of small river basins in the Northeast are extensively developed without adequate provisions for protection of the fishery resources, significant adverse impacts could result. Consequently, a need exists for further research and evaluation of available techniques to minimize these impacts, especially mortality due to turbine passage. Limited information is available on the mortality rates associated with many of the turbines currently being installed at small-scale hydroelectric projects (e.g., tube and bulb turbines). Additional research is also needed to determine effective methods of bypassing downstream migrants. Controlled spills can be used as an interim measure but may not be a satisfactory long-term solution. Using angled screens or louvers to guide or divert fish into a downstream bypass holds promise, but additional research, including greater application to small hydroelectric projects, is needed. Compensation should be considered when construction of new dams or modification of existing dams results in the inundation of important spawning or nursery areas above the dam. Where the impacts of turbine passage cannot be minimized by structural or operational modifications because of high capital or operating costs, compensation may be an appropriate interim approach to ensuring the continued protection of fish stocks while other solutions are sought. Selecting the appropriate approach to reducing potential adverse impacts is a critical component of the assessment process and will require close cooperation between developers and regulators. Such cooperation is essential to the success of anadromous fish restoration at a time of increasing emphasis on development of hydropower resources.

ACKNOWLEDGMENTS

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POTENTIAL IMPACTS OF HYDROPOWER DEVELOPMENT ON UPSTREAM FISH PASSAGE

Ted Vande Sande 1/

STREAMFLOW AND UPSTREAM PASSAGE

Presently there are sixteen different methods of assessing the impact of changes in streamflow (Wesche and Rechard 1980). Only one method describes criteria for upstream passage of salmonids (Thompson 1972). It requires that a stream transect have minimum depth and maximum water velocity over 25% of the total width and a minimum continuous portion having at least ten% of the total width. The method works well to describe satisfactory fish passage conditions in a streamn with gravel substrate (Leopold and Maddox 1953). In other situations, such as a stream with a rock chute or other factors that could expose fish to a substantial travel distance at a high water velocity, I believe the criteria used should include fish swimming capability. The Alaska Department of Fish and Game uses an envelope curve, Swimming Capability of Migrating Salmon in Freshwater (Zeimer 1961), which relates horizontal travel distance between resting pools to average water velocity. This type of curve is valid when there is a large data base of laboratory observations on the swimming capability of the fish (Weaver 1962).

Upstream passage in controlled flow conditions should approach 100% success. However, in conditions that are not fully controlled, a reasonable reduction in passage success is acceptable when it can be shown that the fishery resources will not be adversely impacted. An evaluation of passage delay, or curtailment, should examine total number of days fish could not pass, consecutive number of days fish could not pass, number of days fish were available for passage, and effect of the delay on fish spawning success. The evaluation should correlate all available flow data, including flood, average, and drought years with

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fish migration data (Davidson 1967). When total river flow is diverted to a hydro powerhouse, upstream migration in the natural channel is prohibited. Many alternative passage methods must be evaluated. A separate channel may be used exclusively for fish migration, as on the Clackamas River in Oregon, or a structure can be combined with the diversion works. In such situations diverting and screening fish requires major physical works. A system designed to trap fish and transport them to an upstream release site may require a large capital cost investment in the transport system due to the timing and magnitude of the run. For example, on the Fraser River in British Columbia it was estimated (Anon 1971) that $40 million would be required for the six hundred and seventy five trucks necessary to haul the maximum daily number of adult sockeye. Movement of fish in the natural channel is preferred, although delays frequently occur when more water discharges from a powerhouse than flows in the channel. Fish may be led to the smaller flow with fish barrier dams, picketed fences, and in some cases electric fences (Bell 1973).

Power peaking causes delays in upstream migration. Junge's (1971) analysis of fish passage in the Columbia River during power production showed that 14 to 80% more fish passed through Priest Rapids fishways during nonpeaking power periods than peaking power periods. Turbulence fromhigh power plant discharges can overwhelm fishway attraction flows, while major daily changes in river flows induce interruption of upriver migration. Fluctuations in forebay and afterbay water surface elevations create changing exit and entrance conditions which frequently upset migration patterns.

Reduced water flow and velocity can indirectly cause migration blockage or delay due to low oxygen levels resulting from a reduction in the capacity of a river to assimilate organic waste (Ruggles and Watt 1974). If a reservoir becomes low in oxygen and the downstream release can not be aerated, reservoir aeration should be evaluated. Several systems are available, each with unique properties that must be considered at individual sites (Fast and Lorenzen 1976, Fast et al. 1976).

Reservoir discharges with high water temperature caused prespawning mortality and reduced spawning success of fall run salmon in some California rivers. Bottom discharge of cold water during spring and summer depleted the hypolimnion leaving only warm water from the epilimnion available for fall release. Use of multilevel outlets, or a shutter system, allowed planning for withdrawal of cooler water for migrating fall-run salmon. The ability to select withdrawals from different levels of water for quality considerations may be more beneficial than the cost of multilevel outlets when viewed over the life of a project. For example, balancing discharge water temperatures for early upstream migration of shad can produce a higher rate of return in subsequent years (Leggett 1973) and generate positive economic value. Reduction in migration mortality or increased return in any fishery, due to water temperature control, has enormous economic value when considered in perpetuity.

Spill over dams can create upstream passage delays due to fish wandering across the face of the uniform spill unable to readily locate and enter fishways (Junge and Carnegia 1972). A good practice in large dams with high discharges is to have the greatest spill at a point farthest from the fishway entrance with reduced spills closer to the fishway entrance. This creates a lead to the fishway entrance along the edge of the spill turbulence. Where there are fishways at each side of the dam, the greatest spill should be at the center.

Spill over dams can cause supersaturation of dissolved atmospheric gases with the associated effect labeled 'gas bubble disease'. Both adult and juvenile fish suffer substantial mortalities if exposed for a sufficient time at levels above 120% saturation, even when they have the option to sound to compensate for supersaturation. The work of Bentley et el (1974) showed that at 126% total dissolved gas (TDG) Squawfish, Ptychocheilus oregonensis suffered 100% mortality in 20 hours, 60% mortality in 12 days at 120% TDG, and 32% mortality in 12 days at 117% TDG. Adult chinook salmon suffered nearly 50% mortality within 10 days at 118% nitrogen (Weitkamp and Katz 1980). Salmonid mortalities related to gas bubble disease have occurred at Bonneville Dam since 1955. In the lower Columbia, eighteen species of fish have been observed with gas bubble disease. The nonlethal exposure of adult fish to gas bubble disease usually results in death from secondary infection of the lesions. One means of reducing supersaturation from spill is use of spillway deflectors as on several Columbia River dams. The deflectors cause the water to be deflected horizontally along the water surface instead of plunging deeply into the water of the stilling basin, thereby reducing nitrogen saturation.

An upstream passage phenonmenon associated with large spill flows is fallback, when fish are swept downstream through a dam spillway. A field study made at Ice Harbor Dam on the Columbia River by Johnson (1964) measured fallback as high as 18.7% at low flows with sonic tagged fish and perhaps higher at high flows. After fallback, an observed 50% of spring run chinook were capable and willing to ascend 80 to 100 feet of rise in fishways. Fallback may be reduced by locating fishway exits separate from spillways and maintaining reservoir water velocity conditions that do not exceed the fish's cruising speed, but provide upstream orientation.

FISHWAY DESIGN CONSIDERATIONS

The fishery impact that occurs when the designed fishway does not readily pass fish is the most difficult to quantify and correct. Usually the dam builders view is that the fishway passes fish, and that's it.

Conditions for an effective fishway were stated over a hundred years ago in the annual report to the U.S. Fish Commission in 1872 by C. G. Atkins:

1) it must be accessible, that is the foot of the fishway must be so located that fish will readily find it;
2) it must discharge a sufficient volume of water to attract fish to it; and
3) the water must be discharged with such moderate velocity that fish may enter and swim against the current.

At the present time we are fortunate to have fishway design books by Bell (1973), Clay (1961), and Decker (1964). I recommend that these references be obtained and used. They complement each other in many areas.

To complete a coherent fishway design requires the biologist, hydrologist, and engineer to establish all the conditions that will exist when the fishway is operating. The biologist must be able to identify the beginning, peak, and end of the migration period of each species of fish, and their probable numbers and sizes. Other required information includes swimming characteristics of each fish such as cruising, sustained, and darting speeds, and whether it is a leaper or an orifice swimmer. The location of migration routes, normal resting pools, and the time of day most movement occurs must also be identified.

The hydrologist must provide historical streamflow data so the preproject conditions in the river can be compared with the proposed project conditions of water flow, velocity, and depth at fishway location during the migration period. With this information the fishway designer should be able to proceed.

Questions to consider include:

1) What must be done to allow the fish to reach and find the fishway entrances under all flow conditions?
2) Is an artificial lead such as a barrier dam, required, (USCE 1976)?
3) Is a transportation channel and/or additional attraction water necessary (USCE 1979)?
4) What entrance configuration is superior, swim-in, overpour weir, vertical slot, or submerged orifice? and
5) Is the fishway entrance(s) at the most upstream location the fish will reach at all expected flows?

Additional attraction water released into the fishway must be evenly distributed over the area of the diffuser, usually at 1/4 to 1/2 fps, to prevent hold up of fish or jumping (Gauley and Thompson 1964). The lower reach of the fishway must be sized to take the additional flow and to present an attractive water velocity to entering fish. If there is serious doubt that fish will be able to reach the fishway entrance under various flow conditions, build a hydraulic model, as was done for Turners Falls Dam on the Connecticut River (White and Pennino 1980), to determine water velocity and depth at all flows. If necessary, model fishway structures may be built and tested to assure hydraulic conditions favorable to fish passage.

Swimming capability information on the specific fish is necessary to determine if it can move through the fishway without undue stress. The swimming capabilities of races of fish, such as resident rainbow trout and steelhead, may be quite different. If such information is not available, it can be developed by flume and/or tunnel tests (Bell & Terhune 1970).

A recent fishway design for Cui-ui, Chasmistes cujus Cope of Pyramid Lake, Nevada was based on the swimming capability of suckers of the Columbia River and an Ice Harbor Dam fishway was used. The Cui-ui were unable to negotiate the structure, possibly due to the 1-foot water surface differential between pools. When the pool water surface differential was reduced to 1/2 foot, the Cui-ui readily ascended the fishway.

Many fishways have been empirically designed, an acceptable technique if each is like the one before. However, we should be aware that variations in fishway hydraulic characteristics caused by changes in pool length, width, depth, crest shapes of weirs, depth of water, presence or absence of sills, orifice location, and other factors are almost innumerable. There is always the possibility of an unfavorable response by the fish to altered hydraulics in the design (Prentious and Andrews 1948).

Fish moving up a fishway that has turbulent flow conditions are more likely to leap from upwelling flow points. If the upwelling occurs at bends in the fishway, the fish may leap out of the fishway unless walls or other barriers prevent exit. Changes of fishway direction should create smooth hydraulic conditions with curved walls, instead of square corners.

Fishway capacity should be based on the maximum number of fish anticipated during a particular time period, usually an hour. Data from the Columbia River show that as high as 20% of the maximum day's run occurred in one hour and that some species of fish had a maximum day's run approximating 10% of the annual run. A fishway should be conservatively sized to accommodate great variability in maximum numbers of fish per hour among salmonids. For example, the fish capacity of a 30' long Denil type Steeppass (at the Bonneville Fisheries Laboratory) ranged from 650 to 1140 salmon per hour in the 1960s. In 1975 a 66' long Steeppass passed only 175 per hour due to fallbacks and other unknown conditions. This 3 to 6 fold decrease in fishway capacity may be indicative of the energy limit of the fish.

If required, capability for physical handling of fish for management purposes should be provided for in the initial design rather than jury-rigged after construction. The handling apparatus must be designed to minimize danger of stress or injury to the fish. Holding, lifting, and turning of fish should be minimized and done mechanically. Operator safety should be maximized and include protection against physical injury from falling, lifting, weather, and electrocution.

Underwater observation windows with remote television monitors can record a 24-hour fish run that can later be viewed and analyzed in a fraction of that time. Species, size, sex, and condition of fish is noted remotely by color television monitors in fish ladders at some Columbia River dams. Sophisticated fish counters can enumerate hundreds of fish a minute, if fish pass that fast. Otherwise the old- fashioned, but usually reliable, human observer can be used.

Fishways operating with daily or hourly changing water flows such as those associated with peaking power generation, can cause delay in fish passage. The vertical slot fishway is most suitable for operation under fluctuating flows and water surfaces. However, caution should be exercised in its design and intended performance. Model studies are advised to determine the hydraulic conditions throughout its forecasted range of operating flows.

Fishway exits should orient fish to shorelines and water movement and encourage them to continue upstream. Exits close to spillways can allow fish to fall back, be injured and lost to the fishery. It is wise to provide areas where fish can rest after exiting from fishways, be it required due to the effort of ascending the fishway or the time of day that upstream migration ceases.

SUMMARY

Having just read some of the tribulations that have occurred in major upstream passage facilities, you may realize that the state-of-the-art of fishway design is based upon science, observation and experience. Fisheries engineers on the west coast have dedicated a portion of their time to observing, learning and demonstrating what has been done in their respective states to others in the profession. Almost every year, on a rotational basis, one state hosts engineers of other states to show their fish facilities and exchange information on new developments, problems and solutions. This procedure helps the new engineer and the old timer to acquire a broader understanding of what has been done and how well it performed. Everyone has the opportunity to ask questions at any time without political concern. The interest is in providing the greatest exchange of fisheries engineering knowledge.

At present, the best source of experience and information on fisheries engineering is the Bio-Engineering Section of the American Fisheries Society. Member engineers are interested in the fisheries resource and are trying to improve dissemination and exchange of relevant fisheries information. Take advantage of their expertise and experience.

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A REVIEW OF TURBINE MORTALITY AND ITS ROLE IN SMALL SCALE/LOW HEAD HYDROELECTRIC DEVELOPMENT

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INTRODUCTION

The placement of dams in rivers has reduced anadromous fish populations in numerous drainage basins (Baxter 1977). These reductions were caused principally by the inablility of adult fish to migrate upstream past these barriers to spawning areas. Subsequently, the design and installation of successful upstream fish passage facilities have resulted in partial recovery or restoration of many affected populations. The ability of anadromous fish stocks to respond to successful upstream fish passage of adults is dependent upon the successful passage of outmigrating juveniles (and adults in some species). Mortality occurring during outmigration can result from many factors but of principal concern at hydroelectric sites are the losses caused by passage through hydraulic turbines (Cramer and Oligher 1964; Ruggles 1980). Bell (1973) stated that turbines of modern design have fish passage efficiency of 85% or greater. This information was derived from studies of Francis and Kaplan turbines installed at sites with rated heads ranging up to 610 meters. Most of these estimates have been obtained using various Pacific salmon, Oncorhynchus spp., in the northwest United States. Comparatively little information is available for anadromous species occurring on the eastern coast of North America (Turbak et al. 1981).

Atlantic salmon (Salmo salar) in eastern North America were reduced and in many instances extirpated from portions of their historical range during the eighteenth and nineteenth centuries. Dams and pollution of rivers during settlement and the industrial revolution were major causes of the declines (Netboy 1974). Populations in Canadian rivers have persisted and rivers in the New England states have been the focus of extensive restoration efforts over he last decade. Similar declines and attempted restoration efforts have taken place with American shad, Alosa sapidissima and to a lesser extent striped bass, Morone saxatilis. The recent resurgence in low head and small scale hydroelectric development is expected to have major effects at a large number of sites in the northeast U.S. and Canada.

The smaller scale and low head characteristics of many hydroelectric sites in the northeast pose several potential impacts, including changes in stream water quality and quantity, upstream and downstream fish passage, and turbine mortality. Information on turbine

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mortality impacts at low head hydroelectirc sites is very limited (Turbak et al. 1981). Several new turbine designs, including Bulb and Ossberger Crossflow turbines, represent technological advances which will be available for use at these low head small sites.

Resource managers, developers, and regulatory agencies must make recommendations and decisions regarding the potential for adverse effects on fish passing through hydraulic turbines at many of these sites. Substantial mitigation measures may be required if turbine mortality is determined to be a major factor at a site, thereby contributing to the design, complexity of operation, and cost of the project.

The purpose of this paper is to provide an overview of what is and isn't known about turbine mortality in order to provide a relatively concise source of immediate information and pertinent references. It is assumed that characteristics of the fish populations in question are or will be known well enough that an assessment of the likelihood of various diadromous fishes passing through power dams can be made. Variations in life history patterns, queues for migration, water column positioning, and directional or attraction factors will not be considered.

HYDRAULIC TURBINES

Hydraulic turbines can be divided into two major categories based on the way they transform the energy of passing water into mechanical energy (Table 1). Reaction turbines develop mechanical power from the action of water pressures (head) and velocity produced in a closed system. Impulse turbines utilize mainly kinetic energy (velocity) of water which is usually at atmospheric pressure to drive buckets or blades positioned on the circumference of a wheel (Cramer and Oligher 1964). Virtually all fish mortality investigations have been conducted on reaction type turbines.

TABLE 1. GROUPING OF COMMON TURBINES BY TYPE.

TURBINE TYPE	
Reaction	Impulse
Francis Kaplan Bulb Tube	Pelton wheel Ossberger Crossflow

The most widely used and best understood reaction turbines are the Francis and Kaplan. Common components of these and other turbines are guide vane and wicket gates used to regulate volume and direction of flow to the runner which is the rotating portion attached to the shaft. The runner may have different numbers of blades in a fixed or variable position. Francis turbines are mixed flow systems in which the water enters the runner perpendicular to the shaft and leaves parallel to the shaft. Kaplan turbines are propeller type units where the water flow may be like that of a Francis or may be completely parallel to the shaft (axial-flow).

Impulse turbines such as the Ossberger Crossflow have larger numbers of fixed blades on the runner. Descriptions of the structure and operation of Francis and Kaplan units are given in Turbak et al. (1981) and Ossberger turbines are described in Knapp et al. (1982).

Many factors may affect the decision as to which type(s) of turbine will be installed at a particular site. Although site characteristics (Table 2) often suggest which unit or combination of units are best, other considerations such as streamflow patterns and power usage will also be determinants. Potential mortality of anadromous fish species during downstream passage may also suggest that certain types of turbines would be better than others.

TABLE 2. RANGE OF SITE CHARACTERISTICS AND ASSOCIATED POWER OUTPUT RANGE MOST SUITABLE FOR POPULAR TURBINE TYPES.

Turbine	Head (meters)	Flow (meters^3 sec^{-1})	Output MW
Propellor			
Bulb	3-20	0.2-625	1-60
Tube	3-20	7-85	.03-10
Other (Kaplan)	3-80	0.8-225	.45-150
Francis	30-800	8.5-700	.6-625
Impulse			
Pelton	6-Unlimited	0.3-3.5	.01-270
Ossberger	3-200	0.03-15+	.05-1

Ruggles et al. (1981) described four general categories of factors producing mortality during turbine passage:

1) Mechanical damage due to contact with fixed or moving equipment.
2) Pressure induced damage due to exposure to low pressure conditions within the turbine.
3) Shearing action damage due to passage through areas of extreme turbulence or boundary conditions.
4) Cavitation damage due to exposure to regions of partial vacuum.

The extent to which any one of these factors is important varies from turbine to turbine and with operating conditions. Cavitation is an undesirable facet of turbine operation both from an engineering viewpoint and in that it is a major cause of fish mortality at high head dams. Mechanical damage is generally more important in systems with high runner speed and/or small clearances between structural components.

METHODS OF ESTIMATING TURBINE MORTALITY

The approaches which have been used to estimate turbine mortality can be considered in two broad categories. The first involves the kind of system or facility at which studies were conducted, i.e. model or prototype and the second considers the means of recovery for test fish. Prototype studies have predominated in previous work and will probably continue to do so. Model studies were thought to be a good way of elucidating specific design and operating factors contributing to mortality (Table 3).

TABLE 3. ADVANTAGES AND DISADVANTAGES OF TRADITIONAL METHODS OF ESTIMATING TURBINE MORTALITY.

MODEL	VS	PROTOTYPE
Few Logistical Problems		Major Logistical Problems 1. Introduction 2. Recovery a. Full b. Partial
Increased Experiment Flexibility		Less Design Flexibility
Difficult to Scale		Highly Realistic 1. Assumes adequate recovery

The estimates of mortality from model studies have not generally been different from prototypes estimates (Turbak et al. 1981). It seems probable that the added expense of building and operating model systems is not warranted.

The second major facet of estimating turbine mortality is the introduction and particularly the recovery method employed. Recovery methods have varied from styrofoam floats attached to experimental fish to assessing the return of adult fish from a group of marked smolts. The most commonly used method however involves the use of either full or partial recovery nets (Table 4). Full recovery methods are preferred, when feasible, because of the small numbers of fish required for similar statistical accuracy[1] and the fewer number of assumptions involved in their use. Several variations of full and partial recovery nets have been described (Cramer and Donaldson 1964, Knapp et al. 1982). Partial recovery nets many be more apropriate in instances where high discharge velocities produce too many injuries in full recovery nets or indigenous populations are migrating and too valuable to sacrifice. Clupeids and striped bass appear especially sensitive to net impingement problems.

1/ Partial recovery may require introductions of thousands to tens of thousands of marked fish dependent upon the level of mortality difference detection desired (Paulik 1961).

TABLE 4. CHARACTERISTICS OF TRADITIONAL RECOVERY METHODS.

	Full	Partial
Recovery Efficiency	High	Low
Marks Required	Test, Control (2)	Alive Test, Dead Test Alive Control, Dead Control (4)
Impingement Loss Potential	High	Low-Moderate
Effect on Indigenous Fish	High (during migration)	Low to Moderate
Predation Loss	Low to None	Moderate

Possible alternative approaches for estimating mortality of these fishes includes positioning of recovery nets so that only survivors are captured or the use of tagging to determine the fate of test fish (Knapp et al. 1982). The use of surrogate species for estimating mortality in salmonids may be appropriate as well.

AVAILABLE TURBINE MORTALITY DATA

Virtually all of the existing estimates of fish losses from passage through hydraulic turbines have come from a series of projects conducted in the Pacific northwest. These have been summarized by Bell (1973) and Turbak et al. (1981). Mortality data from lowhead and particularly small scale facilities are very limited (Semple 1979, Ruggles et al. 1981, Knapp et al. 1982). Although general ranges of anticipated mortality for salmonids are available (Table 5), some turbine designs simply have not had a sufficient amount of experimentation done to provide highly reliable estimates. Recent data from Ruggles et al. (1981) suggest that even the Francis turbine mortality figures cannot be generalized to all sites. They found much higher mortality (40-70%) for Atlantic salmon smolts in a vertical Francis operating at 514 RPM and with small clearance between structural components. Their results also show that mortality rate is strongly affected by fish size (total length) as I have found with the Ossberger Crossflow turbine (Tables 6 and 7). It appears that small scale units may be likely to cause higher mortality than has traditionally been assumed from work on large-scale hydraulic turbines, particularly for larger smolts.

TABLE 5. SUMMARY OF AVAILABLE MORTALITY DATA FOR VARIOUS TURBINES.

Turbine	Anticipated Mortality Range (Salmonids, %)
Kaplan	5-15[1]
Francis	5-15[1]
Pelton	7-12[2]
Bulb	4-12[2]
Ossberger	10-65[3]
Tube	40-67[4]

[1] Under optimal operating/design conditions
[2] Very limited data available
[3] Dependent on fish size
[4] Pumped storage: 26-66 cm fish

TABLE 6. OPERATING CHARACTERISTICS OF OSSBERGER TURBINES AT GOODYEAR LAKE, NEW YORK.

Rated output (kw)	Diameter of runner (m)	Revolutions per minute	Maximum discharge (m^3 sec^{-1})	Design head (m)	Horse-power
650	1.00	135	8.5	10	850
850	1.25	104	11.5	10	1150

TABLE 7. ESTIMATED MORTALITY RATES (percent) FOR ATLANTIC SALMON SMOLTS PASSING THROUGH OSSBERGER TURBINES AT LOW HEAD HYDROELECTRIC SITES (95% confidence intervals are less than ± 2% for all estimates).

Total length (mm)	Unit (kw)	
	650	850
100	18.6	9.9
130	27.0	16.3
160	36.2	23.9
190	46.1	32.5
220	56.1	41.8
250	65.9	51.1
280	74.9	60.6

A major component of anadromous fish populations on the eastern coast of North America are several species of clupeids, including American shad and blueback herring (*Alosa aestivalis*). Although the sensitivity of these species to handling and transportation stresses is widely recognized, until recently very little was known regarding their susceptibility to turbine induced mortality. Recent experiments on Kaplan and Ossberger turbines (Knapp et al. 1982) suggest that mortality rates for shad and blueback herring are appreciably higher than those of salmonids. Acute mortality for juvenile shad (80-90 mm) passing through an 850 kw Ossberger turbine was estimated at 50 percent. Acute mortality in combined test groups of shad and blueback herring ranged from 63-83 percent at a large Kaplan (17 MW) turbine on the Connecticut River.

Methodological approaches combined with the sensitivity of these species to handling precluded any estimates of delayed mortality. I am unaware of other turbine mortality data for clupeids.

CONCLUSIONS

The impending proliferation of hydroelectric development at existing and new sites will challenge the resource manager to make objective decisions about the need to consider turbine mortality at each site. In many instances these decisions will be dictated by the fishery or fish populations and be relatively easy. The presence of anadromous or other migratory fishes will require specific knowledge about the ecology of the fish and particularly the effects of passage through various hydraulic turbines.

Technological developments have provided opportunities to pass migrating fishes both upstream and downstream although techniques for the latter are still being refined. The importance of implementing passage measures may often rest on being able to determine the potential for turbine mortality at a site. Planning may involve a complex of issues including multiple species and multiple sites in a single basin. The differential response of various species to turbine passage and upstream and downstream passage techniques will necessitate an integrative approach with established priorities by management agencies.

Additional information on efficiency of fish passage at a variety of sites under different operating conditions with different turbines is needed to allow definitive judgments on the need for mitigation or prophylactic measures.

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WATER QUALITY IMPACTS AND ASSESSMENT PROCEDURES FOR HYDROPOWER PROJECTS

William W. Walker, Jr. 1/

INTRODUCTION

Water quality concerns associated with hydropower development can be classified into seven groups:

(1) sedimentation
(2) erosion
(3) eutrophication
(4) stratification
(5) gas supersaturation
(6) oxygen depletion
(7) assimilative capacity

While these are important to consider in the design and operation of reservoirs used for any purpose (Driver and Wunderlich, 1979), there are aspects which are unique to hydro projects. Potential effects associated with dam and power facility construction activities (runoff, erosion, etc.) or routine maintenance of the facilities (such as disposal of waste oils, etc.) also need to be considered, but are not focused on here.

Impoundment and/or river basin characteristics which influence water quality impacts include:

(1) morphometry
(mean depth, maximum depth, area, volume, shoreline development)
(2) inflow water quality
(sediment, nutrients, oxygen demand)
(3) hydrology
(annual and seasonal inflows)
(4) reservoir operations
(storage/release schedules, outlet levels, pool level fluctuations, turbine designs)
(5) downstream river channel characteristics
(hydraulic geometry, assimilative capacity)

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(6) water standards and uses
(upstream, reservoir, downstream)

Site-specific combinations of the above characteristics determine problem severity and need to be considered in impact assessments.

Impact potentials are not necessarily related to potential power production. Hydraulic residence time, computed as the reservoir volume divided by outflow, is a more fundamental parameter because it is an indicator of the amount of time or opportunity available for the physical, chemical, and biological processes responsible for changing the quality of water moving through the impoundment. Many small-scale (e.g., 30 megawatts), run-of-the-river projects tend to have a low water quality impact potential, not because of low power production, but because they tend to have low hydraulic residence times and do not significantly regulate downstream flows. Water quality impacts must be assessed case-by-case, not generalized on the basis of power production.

Hydropower projects may induce high frequency (daily/weekly) fluctuations in pool levels and discharge atypical of reservoirs operated for other purposes, such as water supply, flood control, or recreation. In assessing potential water quality impacts associated with retrofitting an existing reservoir for hydropower, other impact mechanisms are less likely to be of immediate concern, since these processes and their resultant water quality impacts already exist (Thrall and Anderson 1980). They are not out of the picture, however, as the mechanisms are interrelated and influenced to some extent by how the reservoir is operated, in terms of pool level, release schedule, and outlet configuration. For example, severe oxygen depletion may be present in an existing reservoir with a surface outlet, but not be viewed as a significant water quality problem until a bottom outlet is used, as might be required for hydropower.

Assessment techniques for water quality impacts may be broadly categorized as "simplified" or "complex". Simplified techniques consist of procedures or empirical models which provide a framework for assessment of probable conditions based on interpolation of data and impacts observed in similar systems. More complex methods may attempt to simulate the relevant transport processes and physical, chemical, and biological mechanisms in detail. While they attempt to be more "realistic" and provide greater flexibility for examination of specific strategies, simulation models are not necessarily more accurate than simplified techniques because of limitations in the state-of-the-art and relatively demanding requirements for input data and user expertise. Simplified techniques are generally practical and, in most cases, adequate for preliminary assessments of hydropower/water quality impacts. A general familiarity with water quality processes and awareness of the method limitations and constraints are required for application of any assessment procedure.

The key parameters and relationships involved in each of the above water quality impact mechanisms are discussed below. Typical assessment procedures are described with an emphasis on simplified methods. For discussions of simulation models applicable to reservoir systems, the reader is referred to articles by Ford et al. (1980) and Johnson (1980). Additional background information on reservoir water quality impacts can be derived from a review by Baxter and Glaude (1980) and proceedings of recent symposia dealing with impoundments and their environmental effects (Driver and Wunderlich 1979, Stefan 1980, Canadian Water Resources Journal 1982). The Oak Ridge National Laboratory has published a series of reports which review the environmental effects of small-scale hydroelectric developments, some of which deal partially with water quality issues (Loar et al. 1980, Hildebrand et al. 1980, Cada et al. 1982).

SEDIMENTATION

Sedimentation is a predominately physical process which involves the settling of suspended solids in the reservoir pool. These solids may enter the reservoir from upstream watersheds, be eroded from shoreline areas, and/or be generated within the impoundment as a result of photosynthesis. The important parameters of this process include watershed characteristics which determine erosion and sediment transport rates (climate, topography, soils, land use, etc.) and the reservoir characteristics which influence the settling process, including hydraulic residence time, depth, and outflow level.

The Agricultural Research Service publishes periodic summaries of reservoir sediment survey data which are useful for preliminary assessments of potential sedimentation rates on a regional basis (Dendy and Champion 1978). Relationships developed empirically by Bruyne (1953) can be used to estimate the sediment trapping efficiency of an impoundment as a function of mean annual hydraulic residence time. For example Bruyne's curves indicate trapping efficiencies of 30-50% and 80-95% at residence times of .01 and .1 years, respectively. Sediment trap efficiency also varies with inflowing sediment particle size, location and operation of the reservoir outlet, reservoir shape and water chemistry (Hildebrand et al., 1980).

In some cases, a new reservoir may have a beneficial impact on downstream water quality (reduction in average suspended solids and turbidity concentrations) as a result of the sedimentation process. The accumulation of sediment within the reservoir pool may interfere with power generation unless mitigating measures are taken. Secondary water quality effects should be considered if dredging operations are required to maintain project operation (Loar et al. 1980). The fate of accumulated sediment is of potential concern with respect to downstream water quality. Bottom scouring by intermittent storm events, dredging, and/or sluicing operations may cause sudden increases in suspended solids concentrations in the reservoir and its discharge which may interfere with downstream water uses and biota. Accumulating sediments may also be of concern because they may provide substrate for rooted aquatic plants and contain appreciable quantities of nutrients, pesticides, trace metals, or other toxic materials. These materials may be released in the water column in soluble (more mobile and biologically available) forms, particularly if severe reducing conditions develop in the bottom of the reservoir as a result of hypolimnetic oxygen depletion.

EROSION

Operation of hydropower projects can cause erosion of reservoir shoreline areas and downstream river banks as a result of fluctuations in pool level and discharge, respectively (Hildebrand et al. 1980). Shoreline erosion problems are related to the extent and frequency of pool level fluctuation, to the morphometry of the impoundment, which determines the area of bottom sediment exposed for a given elevation change, and to bottom sediment characteristics. Leaching of nutrients and organics from exposed sediment is a potential secondary water quality effect.

Conversion from run-of-the-river to peaking operations may in some cases lead to disruption of the downstream balance between erosion and sedimentation and have marked influences on the geomorphology of downstream river reaches (Baxter and Glaude 1980). Formerly stable streambeds and banks may begin to erode, whereas formerly silt-free reaches may suddenly be subject to excessive siltation. These effects are related to the altered periodicity, duration, and amplitude of downstream velocities and water levels. Long-term aggradation and degradation processes can have primary effects on vegetative and other biological habitat and secondary effects on water quality. Streambank erosion can destroy vegetative buffer zones which would otherwise absorb nutrients and sediment in runoff from adjacent (often agricultural) lands and cause increases in downstream turbidity and nutrient levels.

EUTROPHICATION

Eutrophication is a complex biological process associated with increasing nutrient levels and growth of aquatic plants to levels which may interfere with beneficial water uses. Plant growth can have significant impacts on water transparency, tastes and odors, pH, ammonia, organic matter, and oxygen depletion. Recent work has also indicated that algae are potentially important precursors to trihalomethanes in water supplies (Oliver and Shindler 1980).

Important parameters include inflowing nutrient concentrations (especially, dissolved phosphorus), impoundment depth, and impoundment hydraulic residence time. As part of their Environmental and Water Quality Operational Studies Program (EWQOS), the Army Corps of Engineers (CE) is currently conducting a systematic evaluation of simplified predictive methods for reservoir eutrophication, based on data from CE reservoirs throughout the U.S. (Walker 1981a, 1982). Impoundment eutrophication responses have been characterized by surface, growing-season levels of total phosphorus, chlorophyll-a, transparency and organic nitrogen. A principal components analysis yielded the following statistic which explained 89% of the variance in the individual measurements as a composite indicator of eutrophication:

$$PC1 = .57 \log(P) + .61 \log(B) - .44 \log(S) + .33 \log(No)$$

where,

PCl = first principal component
P = total phosphorus (mg/m3)
B = chlorophyll-a (mg/m3)
S = transparency (m)
No = oprganic nitrogen (mg/m3)
log = base-10 logarithm

The magnitude and scale of PCl are somewhat arbitrary; computed values for CE reservoirs range from 1.4 to 3.5. Comparison with "trophic states", asessed by the EPA National Eutrophication Survey (EPA 1976), indicates that oligo/mesotrophic and meso/eutrophic boundaries lie at PCl values of approximately 1.5 and 2.0, respectively.

Systematic evaluation of sixteen different phosphorus loading models compiled from the literature indicates that PCl and each of the individual response measurements are most strongly correlated with the following normalized phosphorus loading expression:

Pn = Pi / (1 + .001 Pi Z)

where,

Pn = normalized phosphorus loading (mg/m3)
Pi = annual average inflow total phosphorus concentration (mg/m3)
Z = mean depth (m)

This expression explains 89% of the variance in PCl, based on data from 26 reservoirs with inflow total N/P ratios less than 10 and non-algal turbidities (inverse transparencies, corrected for light extinction by chlorophyll-a) less than 1.58 1/m.

Residuals analyses indicate that phosphorus loading models of the type described above tend to over-predict chlorophyll concentrations in impoundments with any of the following characteristics:

(1) non-algal turbidity > 1 1/meter
(2) inflow total N/P < 10
(3) inflow ortho-P/total-P < .25
(4) mean hydraulic residence time < .015 years

The last constraint is perhaps the most significant to assessments of hydropower projects in the Northeast, many of which have residence times less than .015 years (5 days). The residence time effect may indicate control of algal populations by flushing; i.e., as residence time decreases, flushing becomes increasingly important in relation to other processes controlling algal populations, including respiration, settling, and predation; i,e., biomass is flushed out of the system before it has time to accumulate. The CE data base contains only a few impoundments in the low-residence-time category and additional data compilation and analysis is required to quantify the effect. The significance of seasonal variations in inflow quantity and quality in these rapidly flushed impoundments, also warrant further investigation. The above framework provides conservative assessments of eutrophication phosphorus concentrations do not increase during summer, low-flow periods as a result of upstream and/or local point sources.

The models discussed above suggest that mean depth is an important variable determining the trophic status of CE reservoirs. Generally, shallower reservoirs have less capacity for the retention of inflowing nutrients. The importance of depth is probably related to a greater potential for internal nutrient recycling in shallower reservoirs due to wind-induced resuspension of bottom sediments and releases of dissolved phosphorus from anoxic bottom waters. Hypolimnetic oxygen depletion tends to be more severe in shallower impoundments provided that stratified conditions are maintained. Pool level fluctuations caused by hydroelectric operations may result in a reduction of the seasonally-averaged mean depth of an impoundment, an increase in internal nutrient cycling, and a reduction of the assimilative capacity of the reservoir for external nutrient loadings, provided that the impoundment has adequate residence time to permit the biological manifestation of nutrients.

STRATIFICATION

Reservoirs may stratify vertically during the summer months, depending on climate, depth, flushing rate, outlet level, and wind fetch. Stratification results from solar warming of surface waters and the reduction in water density with increase in temperature. As a result of stratification the surface waters of an impoundment may be warmer and bottom waters, cooler, than the parent river. An immediate consequence is that temperatures, in and downstream of the reservoir release, depend upon reservoir operation and withdrawal level. Stratification creates a potential for the depletion of oxygen from bottom waters and associated secondary water quality effects in and below the pool.

Downstream temperature may be significant from a water quality point of view because of concerns for wildlife propagation (e.g. coldwater vs. warmwater fisheries) or for waste assimilation capacity. Impacts of temperature modifications are not necessarily harmful; for example, a reduction in stream temperature below the reservoir resulting from a bottom discharge might enhance (or permit) a coldwater fishery. Pool level fluctuations induced by converting an existing reservoir to hydropower generation are more likely to have a destablilizing than a stabilizing effect on thermal stratification (Hildebrand et al. 1980).

Data from 148 CE reservoirs have been analyzed to develop an approximate basis for predicting stratification potential as a function of impoundment morphometric characteristics. Using temperature contour diagrams (depth x season) derived from mid-pool or near-dam stations, impoundments have been classified into three categories, based on summer stratification tendency: (1) unstratified; (2) weakly or intermittently stratified; and (3) stably stratified. The following statistic can be used to predict group membership:

$$Ds = \log(Zmax) - .15 \log(V)$$

where,

Ds = discriminant function for stratification potential
Zmax = impoundment maximum depth (m)
v = impoundment volume (million m3)

Probabilities of group membership are plotted against Ds in Figure 1. The significance of the volume term may be related to the fact that, at a given maximum depth, a reservoir with a larger volume (or surface area) would tend to a greater wind fetch, deeper thermocline, and less stable stratification. The effects of flushing on thermal stability also have to be considered in impoundments with low hydraulic residence times. (Fischer et al. 1979).

GAS SUPERSATURATION

Supersaturation of dissolved gases (principally nitrogen) is a potential water quality problem in and below impoundments (Fast 1978, Bouck 1980, Baxter and Glaude 1980). The potential for development of supersaturated conditions is related directly to the mixture of air and water under pressures above atmospheric. Supersaturation as low as 120% has been shown to be toxic to fish and could result from equilibration of air and water under two meters of hydrostatic head.

Impoundments can cause hyperbaric dissolved gas levels in a number of ways:

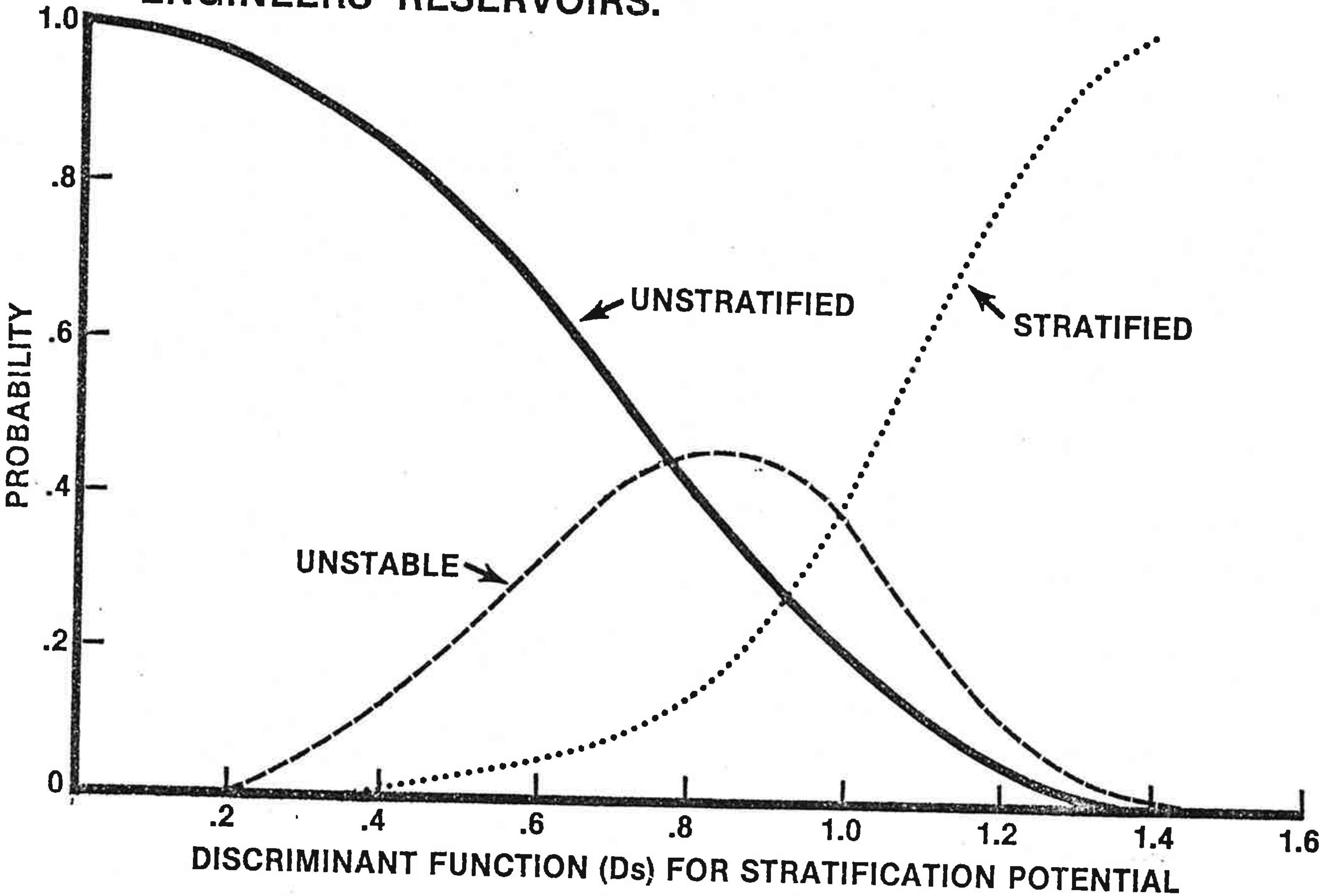
(1) entrainment of air into deep, turbulent stilling basins below spillways;
(2) direct injection of air into bottom waters for the purposes of mixing and/or oxygenating the reservoir;
(3) direct injection of air through turbine air valve systems;
(4) heating resulting from natural seasonal variations or discharge of heated effluents into stratified impoundments.

Any design or operation which promotes the mixture of air and water under pressure should be evaluated with respect to potential supersaturation problems. Concerns for supersaturation can be factored into the spillway and turbine design and operation of hydropower projects (Ruggles and Watt 1975, Smith 1976). In one sense, power production may reduce the potential for this type of problem by reducing spillway use. Bouck (1980) reviews a variety of measurement and assessment techniques and suggests criteria of zero supersaturation in hatcheries, 110% for "shallow" rivers, and 115% for "deep" rivers. Fish habitat and exposure also need to be considered in assessing this type of impact.

OXYGEN DEPLETION

Oxygen depletion is an extremely important consequence of stratification, eutrophication, and sedimentation. During a stratified period, bottom waters are isolated from oxygen sources and may undergo a steady decline in dissolved oxygen concentration. This results from the decay of organic particulates (algae or external sediment loadings)

FIGURE 1.
PROBABILITY OF RESERVOIR STRATIFICATION AS A FUNCTION OF RESERVOIR MORPHOMETRIC CHARACTERISTICS BASED ON DATA FROM 148 CORPS OF ENGINEERS' RESERVOIRS.



$Ds = \log(Z\ max, m) - .15 \log(V, m^3 \times 10^6)$.

which settle into the bottom waters. Depending on organic loading and reservoir morphometric characteristics, complete oxygen depletion may occur with several related water quality impacts, including solubilization of iron, manganese, trace metals, and nutrients from bottom sediments and production of hydrogen sulfide and reduced organic compounds. If the reservoir has a bottom outlet, these water quality effects are transported downstream. These problems can be attributed to the sources of oxygen demand, i.e., nutrient and sediment sources in the watershed, but vertical stratification in a reservoir pool creates a unique environment which is generally not present in a free-flowing river and which is necessary in order for oxygen depletion and related water quality impacts to occur.

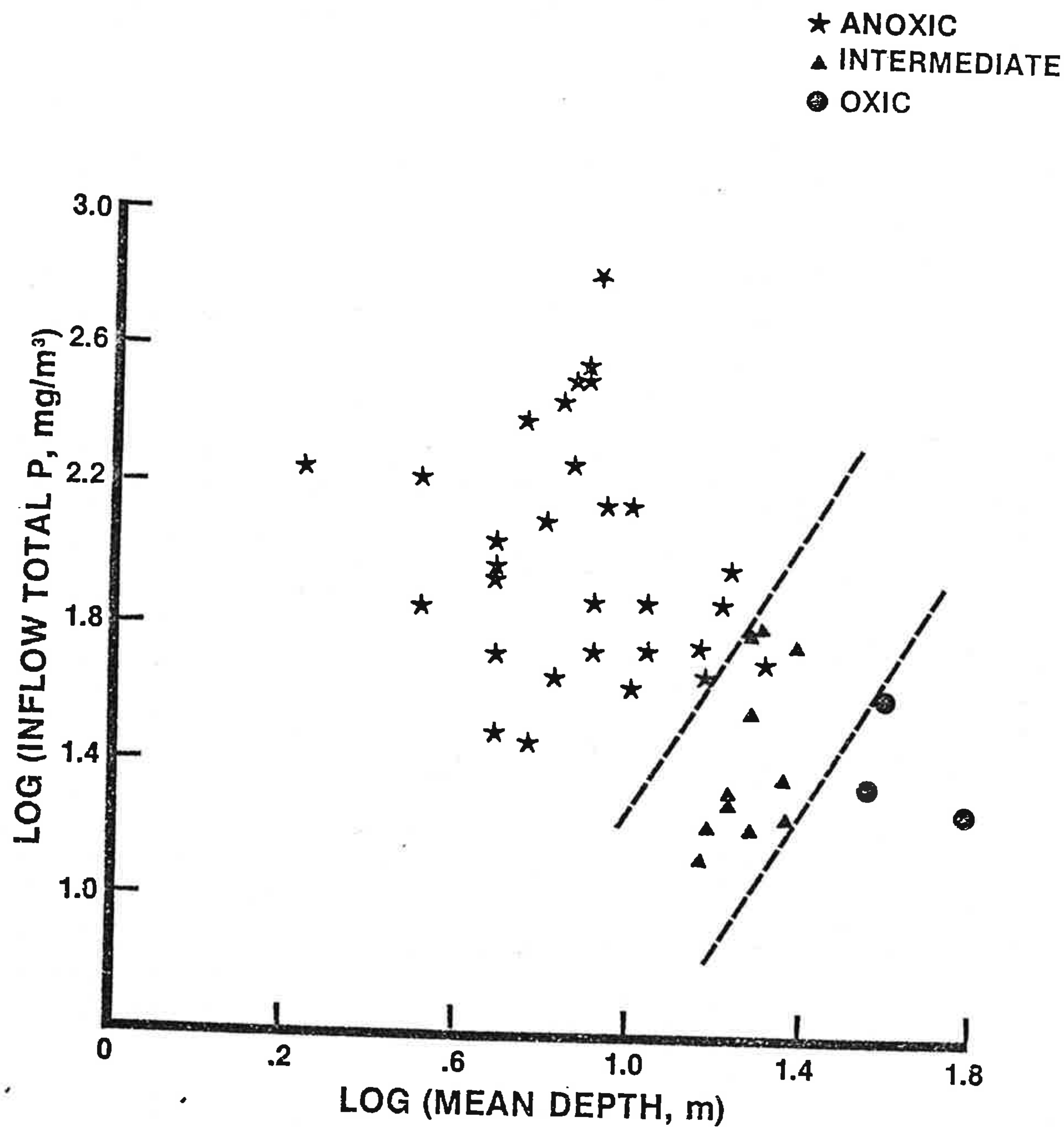
A variety of empirical models have been developed for predicting hypolimnetic oxygen depletion in lakes and reservoirs as a function of nutrient loadings and morphometric characteristics (Reckhow 1978, Rast and Lee 1978, Walker 1979, Cornett and Rigler 1979, Welch and Perkins 1980). Preliminary tests indicate that some of the methods may be applicable to CE reservoirs with stable summer stratification (Walker 1982). Oxygen profiles have been reviewed and used to classify reservoirs into three groups, based on the maximum extent of anaerobic conditions during the stratified period. The groups reflect the percent of the hypolimnetic depth which is anaerobic: (1) < 10%, (2) 20-80%, (3) > 80%. Different symbols are used to distinguish these groups in Figure 2, which plots inflow phosphorus concentration, a measure of eutrophication potential, against impoundment mean depth. Dashed lines discriminate among the oxygen status groups. Anoxic impoundments tend to lie above and to the left of the plot.

This model permits approximate assessment of oxygen depletion in stratified reservoirs. It tends to underpredict oxygen depletion in reservoirs which are not stably stratified during the summer. Reservoir morphometry is an extremely important regulator of oxygen depletion rates. All CE reservoirs in this data set with mean depths less than about 11 meters are classified as anoxic, regardless of inflow or impoundment nutrient concentrations. Because oxygen demand is exerted per unit area, (from bottom sediment and settling organic particulates) and the initial supply of oxygen at the beginning of stratification is proportional to the mean depth of the hypolimnion (Wetzel, 1975), the initial oxygen supply is insufficient to satisfy even modest area demands in relatively shallow, stratified reservoirs.

Hypolimnetic oxygen depletion is rather common in stratified lakes and reservoirs and few states consider it as a violation of oxygen standards. Tennesee oxygen standards, for example, are applicable only to the top 5 feet of the water column. The standards become issues downstream of reservoirs with bottom outlets, which discharge hypolimnetic waters to downstream river reaches. Concerns over effects of anoxic releases from reservoirs are particularly significant in view of a recent court ruling that EPA should regulate dams as point sources (Novak 1979); this ruling is currently being reviewed.

Because of the complexities of reservoir hydrodynamics and various types of withdrawal methods, the development of anoxic conditions in the

FIGURE 2. HYPOLIMNETIC OXYGEN STATUS AS RELATED TO INFLOW TOTAL PHOSPHOROUS AND DEPTH OF CORPS OF ENGINEERS' RESERVOIRS.



hypolimnion (rather typical of a stratified reservoir) does not necessarily impact oxygen levels in reservoir releases (Fischer et al. 1979). Some perspectives on the problem of low oxygen levels below reservoirs have been derived from nationwide data bases compiled by the Oak Ridge National Laboratory (ORNL) (Cada et al. 1982) and by the Corps of Engineers (Walker 1981a).

ORNL compiled oxygen data from USGS monitoring stations less than three miles below 145 operating hydroelectric facilities in the United States and analyzed "probability of non-compliance" (PNC), defined as fraction of samples with oxygen levels less than 5 mg/liter, as a function of season, region, and project characteristics. Summer oxygen data from 108 projects with impoundment morphometric information have been derived from this study and used to classify projects into two groups, "no violation" (PNC < 10%) and "violation" (PNC > 10%). The data base has been supplemented with information from monitoring stations located below 123 Corps of Engineer projects (Walker 1981a). CE projects have been classified using the annual mean minus two standard deviations and assuming a log-normal distribution: "no violation" (> 5 mg/liter) or "violation" (< 5 mg/liter). Overall, the results break down as follows:

Data Base	No Violation	Violation	%Violation
ORNL - < 30 megawatts	30	11	27
ORNL - > 30 megawatts	38	29	43
CE	95	28	23
Total	163	68	29
Total - Northeast	10	4	14

Reservoirs with downstreamn oxygen violations tend to have greater maximum depths, greater volumes, and longer residence times.

Downstream problems related to low oxygen levels in reservoir releases are unlikely in relatively small and/or rapidly-flushed reservoirs. Violations are apparent below only one out of 36 reservoirs with volumes less than 10 million cubic meters (8100 acre-feet) and in only two out of 35 reservoirs with mean hydraulic residence times less than .01 years (3.7 days). Probabilities of group membership are plotted against volume and residence time in Figures 3 and 4 respectively. Distributions as a function of maximum depth are less strong.

The observed oxygen distributions do not necessarily reflect impoundment effects alone; some of the violations may be attributed to point sources intervening between the dam and the monitoring station and/or low oxygen levels in waters entering the impoundment from upstream. Consideration of water quality factors (nutrient and BOD loadings) and reservoir outlet levels probably would provide additional

FIGURE 3.
PROBABILITY OF DOWNSTREAM OXYGEN VIOLATION AS A FUNCTION OF IMPOUNDMENT VOLUME.

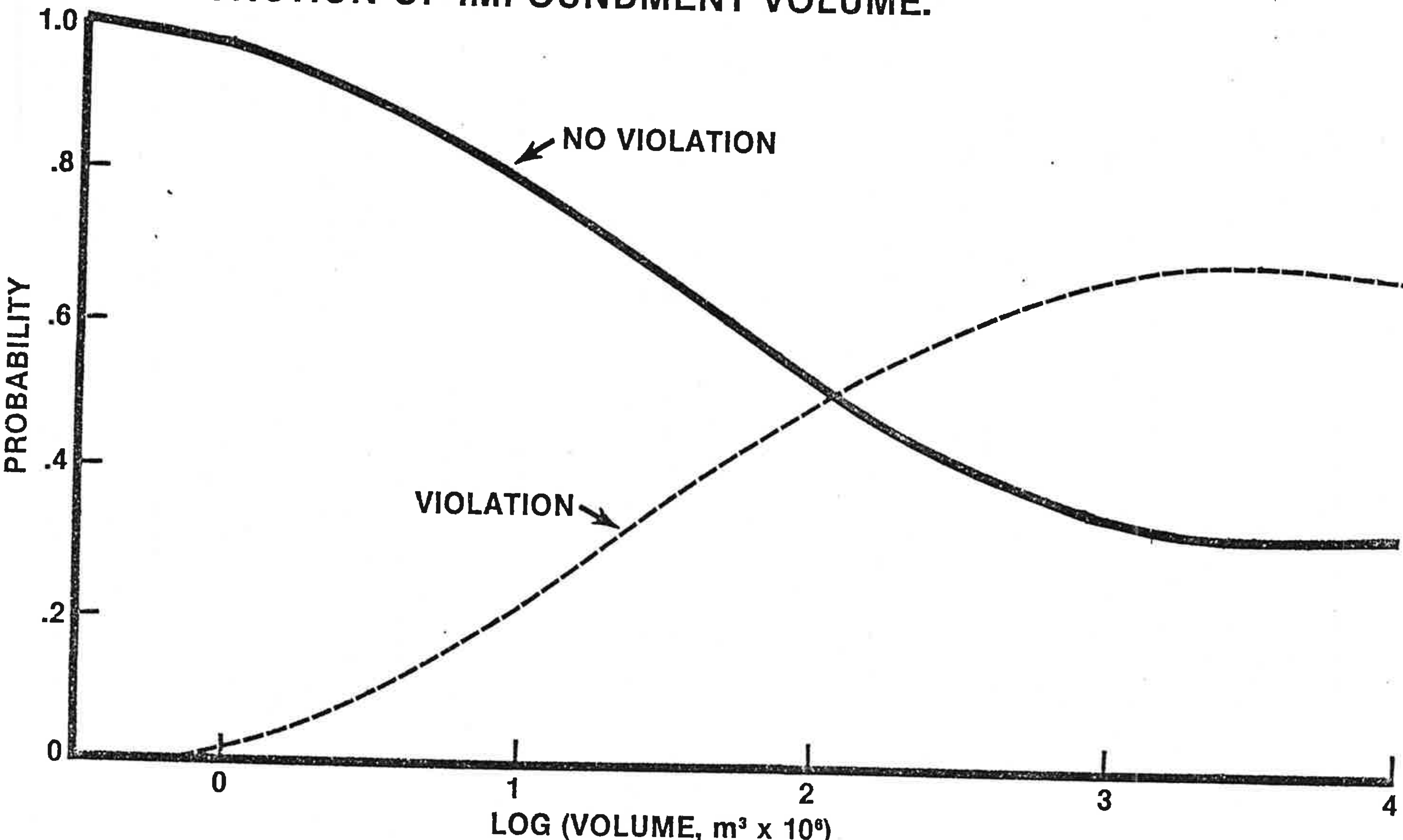
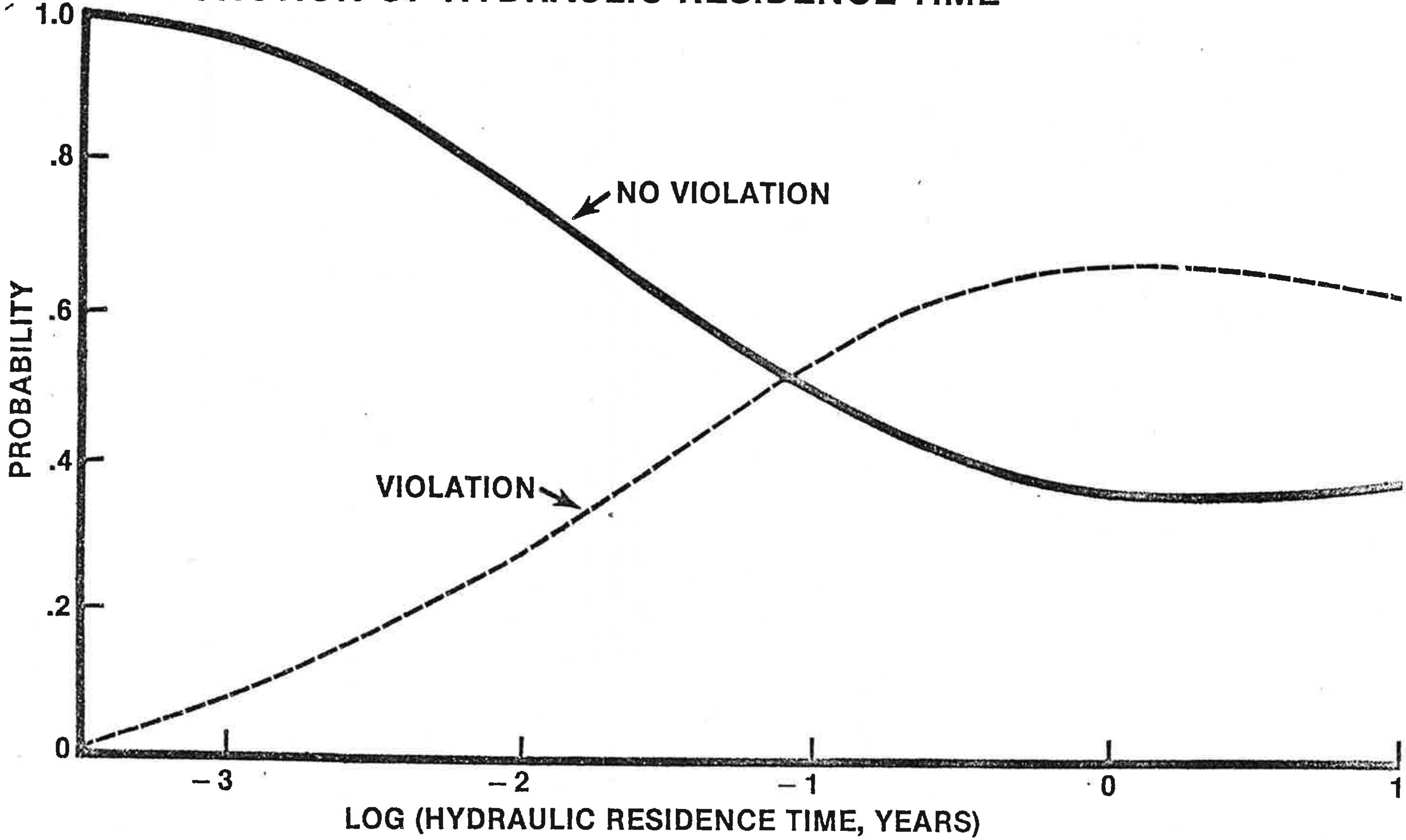


FIGURE 4.
PROBABILITY OF DOWNSTREAM OXYGEN VIOLATION AS A FUNCTION OF HYDRAULIC RESIDENCE TIME



discriminating power. A more detailed data base is required to refine the analysis and develop a better tool for screening purposes.

ASSIMILATIVE CAPACITY

Assimilative capacity can be broadly defined as the quantity of pollutants which a given water body can process without resulting in a violation of water quality standards at some acceptable frequency. Flow regulation, combined with other aspects of hydropower operation, tends to modify a stream's assimilative capacity This may result in conflicts with upstream or downstream waste discharges, particularly if the stream segment is or becomes "water quality limited", i.e., does not meet the stream standards with conventional waste treatment schemes.

Assimilative capacity for organic wastes, most often expressed as biochemical oxygen demand (BOD), depends upon many variables including flow, temperature, velocity, depth, and the initial concentratiopns of BOD and dissolved oxygen. Downstream oxygen problems are not necessarily resolved by aerating releases, particularly if a reservoir is eutrophnic and discharges high levels of ammonia nitrogen and reduced organic materials. Diversion of flow around natural river channels below hydropower dams is a related mechanism which may raise similar water quality concerns, particularly if there are waste discharges into the old river channel. Creation of an impoundment may impact upstream dischargers by reducing the natural reaeration capacity of the river channel. Flow regulation may be beneficial from a water quality point of view if the reservoir has enough storage to reduce the frequency and/or duration of natural low-flow periods. It is important to go beyond simple dilution calculations in analyzing potential conflicts with upstream and downstream waste dischargers.

The Winooski River, Vermont, is a good example of hydropower/ waste assimilation conflicts and assessment procedures. The Winooski originates in the Green Mountains and empties into Lake Champlain, draining 1044 square miles. In its last 20 miles, the river flows through the metropolitan Burlington area, where there are two power dams and several industrial and municipal point sources. The river is classified for coldwater fisheries and has a dissolved oxygen standard of 6 mg/liter. The last 10 miles are flat, slow-moving, and have a history of dissolved oxygen violations, which have also been observed between the two power dams during hot weather.

As a result of hydropower operation schedules during the summer, flows range from 50 cfs during non-generating hours and on Sundays (attributed to dam leakage) to about 1200 cfs during generating periods. This is compared with a natural 7Q10 flow of 142 cfs. Large diel fluctuations in oxygen are characteristic of the river at many locations. These result from the combined influences of photosynthesis by algae and periphyton and fluctuations in river flow. These two driving forces of oxygen variation are in phase. Photosynthesis and high flows tend to increase oxygen levels during the day, while algal respiration and reduced flows tend to decrease oxygen levels at night. As a result, diel swings as large as 8 mg/liter have been recorded.

Sustained violations have been observed under conditions of maximum temperature and die-off of algal blooms.

The Vermont Agency of Environmental Conservation (VAEC, 1982) is conducting a wasteload allocation study in order to determine advanced waste treatment is in order to satisfy the oxygen standard. Flow regulation by the two existing and a third proposed power plant are implicit issues. A version of the QUAL-II water quality simulation model has been calibrated to the river to aid the study (Walker 1981b, VAEC 1982). State variables in the model include nitrogen species, phosphorus species, algae, BOD, and dissolved oxygen. Application of this type of model requires intensive monitoring of the river and point sources and determination of river hydraulic geometry. The model has been calibrated to data from one summer and tested against data from another. Results indicate the model is adequate to assess the sensitivity of river oxygen levels to point-source treatment schemes and flows.

Because of concerns for Lake Champlain, point sources are scheduled for phosphorus removal to 1 mg/liter. Sensitivity of river oxygen levels to point source phosphorus removel under 7Q10 flows and bloom die-off conditions has been assessed by setting discharge concentrations to 0, 1, and 3 mg/liter and setting algal photosynthetic oxygen reduction to zero. Sensitivity increases moving downstream to a maximum range of 3 to 6 mg/liter at the mouth of the river. Results suggest that planned implementation of point-source phosphorus discharges to 1 mg/liter should markedly reduce the susceptibility of the river mouth to oxygen problems related to algal respiration and die-off.

Sensitivity to flow under die-off conditions has been assessed by setting headwater flows to 70, 142 (7Q10), and 200 cfs. These values are compared with 50 cfs, the estimated current minimum low-flows attributed to leakage from the hydropower dams. Sensitivity to flow increases moving downstream from each dam. Results indicate that the success of planned waste management strategies for the Lower Winooski may hinge on hydropower operations.

CONCLUSIONS

Assessment of water quality impacts associated with hydropower development and operation requires:

(1) general awareness of the relevant cause-effect relationships responsible for water quality changes and their underlying physical, chemical, and biological mechanisms;
(2) access to site-specific information on the controlling factors;
(3) implementation of analytical methods which can aid in the interpretation and projection of available data and which reflect key mechanisms of water quality impact; and
(4) consideration of water uses, standards, and criteria in the reservoir and river basin.

This paper has reviewed the dominant mechanisms of water quality impact and presented some typical assessment procedures. Because of the multiple factors involved, it is difficult to generalize about the severity of these impacts. They must be evaluated on a case-by-case basis and considered in relation to fisheries and other environmental concerns.

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FISHERIES ENHANCEMENT FROM HYDROELECTRIC DEVELOPMENT

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INTRODUCTION

Development of hydroelectric energy on streams supporting populations of valuable sport and commercial fish has long been opposed by fish management agencies as detrimental to the interests of the fish involved. History has shown that, indeed in many cases, damage to fish has resulted from such developments. It has also been evident that, in some cases, an overall enhancement has resulted, particularly in instances wherein careful planning and utilization of all factors available for enhancement have been employed. The current unprecedented proliferation of small hydroelecric projects may be looked upon with either dismay or as an opportunity by the fish manager. In many cases, it may be profitable to attempt to make the most of such developments, recognizing that many are economically marginal and cannot support a great deal of expenditure for things other than power development. If the project is not feasible because of affording full protection values, it probably should not be pursued, however.

Many resident fish require passage in order to complete their life histories, although this tends to be overlooked by both fish managers and hydroelectric constructors in general. In North America and elsewhere it has sometimes been taken into account. I provided fish passage facility designs for a very large dam (5,000 mw) in Argentina to provide passage for species which are resident but require migrations of up to 1,900 km for their spawning and rearing phases. In New South Wales, Australia, I have provided concepts for fish passage that involve principally resident fish at a great many dams. It has only belately been found there that passage is required to stem declines in abundance.

At least one species in New South Wales is catadromous; that is, it spawns in the ocean and rears in fresh water. This poses problems of fish migrating upstream at a size which makes use of many conventional fish passage facilities difficult. Depending on location, races of fish etc., resident trout may or may not require fish passage.

I would apportion interest in fisheries values under hydroelectric development into the areas of upstream and downstream passage of migrating fish and reservoir management.

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UPSTREAM FISH PASSAGE

Development of hydroelectric facilities frequently offers opportunities to provide fish passage that presently may not exist at an existing dam. Construction of hydro facilities at a natural barrier such as a falls or series of cascades which prevent fish passage may offer similar opportunities. It is sometimes difficult to require or convince the builder or developer of a new hydroelectric facility that he should provide passage at an existing natural barrier. However, this is not quite the deterrent at an existing dam that lacks adequate passage, particularly in areas that permit or require the fish management agency to require fish passage where hydroelectric facilities are in use. In the United States, the Federal Energy Regulatory Commission (FERC), can be expected to require fish passage wherever hydroelectric facilities are instituted. This is frequently the case even where natural barriers are concerned. Some agencies are now proposing passage in situations involving populations of migratory fish introduced above existing barriers.

In addition to the obvious benefits of passing potential spawning fish above such barriers, other benefits also accrue from fish passage. One is the opportunity to count upstream migrants by species, size and time of migration which is a useful management tool. It is difficult to adequately manage populations of fish without knowledge of their fluctuations in number and how they relate to other factors.

Upstream passage facilities may also be used to select species. In some instances certain species are shunted out of a fishway to be used as brood stock for fish culture or transported elsewhere for introduction to new spawning grounds or for other management purposes. Undesirable species may also, with use of certain facilities, be removed from the fish passage route. An example is the lamprey, which normally makes its way over an obstruction or up a fishway by using its sucking disc mouth to maneuver itself up and over barriers. Utilization of fishway surfaces of mesh screen or porous material prevents the lamprey from using its suction ability for attachment and thus inhibits its travel upstream.

I will not go into great detail on the many designs for upstream passage of fish. Suffice it to say that these are generally site and species specific. Some, such as the vertical slot or Denil, are more tolerant than others in accommodating a variety of species with varying habitats and athletic ability. At any locality, the weakest swimmer must be accommodated. Mechanical and hydraulic lifts are of various designs and useful in retrofit situations or where high dams are concerned because they are adaptable and less costly. The trap and haul method is usually of low cost and particularly desirable where distance is a factor. All of the mechanical and hydraulic means require some portions of formal fishways to collect and introduce fish into the system.

A variety of criteria for fishway design exist, not all of which are based on precise experimental data. These include for anadromous salmonids, 1.0 f of rise per pool and 2.0 f/s velocity transportation flows. The tidiness of these numbers indicates their derivation. Factually, they are what looked appropriate to someone many years ago and which have seemed to work pretty well. The British use a 1.5 f rise per pool criterion for anadromous salmonids which also seems to be satisfactory. Most fish are rather adaptable. I put a number of requirements for fish passage together in a paper some years ago which briefly summarizes what the developer may expect (Eicher 1973).

DOWNSTREAM FISH PASSAGE

Downstream-migrant fish also need to be protected at hydroelctric facilities. It does not do a great deal of good to provide upstream passage if downstream migrants (juveniles and, in some cases, adults) are unable to successfully return downstream past hydro turbines without substantial mortality.

Two alternatives present themselves as solutions to this problem. One is to provide turbines that are relatively safe for passage of fish and cause little damage. In this respect, no turbine is absolutely safe, and mortalities may be expected ranging from somewhere around 3-5% to 40% or more. Some of the newer developments, such as the bulb turbine, have been tested with survivals of over 95% with salmonid species. The tube type, which to my knowledge has not as yet been tested with fish, appears to have characteristics at least as favorable to fish as the bulb unit.

If better protection than that afforded by the turbine itself is desired, it may be necessary to screen fish from passage through the turbines. This is not always the ultimate protection. Sometimes screens provide certain amounts of mortality themselves through impingement or lack of adequate bypass conditions. There are several screening options. The simplest is the basic fixed screen, which frequently presents a cleaning problem. A clogged screen will cause insufficeint flow to serve the turbine and resultant impingement of fish. The self-cleaning travelling screen, which has been used extensively for this purpose, can provide relatively safe passage of fish as long as velocities into the screen are within safe limits and a good bypass is provided. Various types of inclined screens may offer good passage for fish, particularly if they are self-cleaning and well bypassed. Such screens may be used in a horizontal or a vertical mode and may employ mesh, perforated plate or wedgewire material to separate fish and debris from the water. Most of these arrays are atmospheric types; that is, they are on the surface of the water. However, I have recently developed a pressure type which is completely submerged within the penstock of a turbine, thus avoiding problems of compensating for forebay elevation change and other difficulties such as icing in winter.

Cost is a significant item, not only to the developer, but also to the fish management agency. If screens are too expensive, the developer simply will be unwilling or unable to provide them. They can be the difference between a project's being economically feasible or not.

Costs of screems are quite variable, depending on a great number of factors such as terrain, size and type of facility, and quantity of water. Clay (1960) cited costs of approximately $1,000 per cfs for travelling screens. This cost has probably tripled by this date. At a project in which I was recently involved, for a flow of 2,400 cfs into two turbines, a travelling screen installation was estimated at 3.7 million dollars, an atmospheric inclined screen at 1 million, and the pressure-passive screen at 270,000 dollars. Travelling screens require a great deal of money for operation and maintenance on a large installation such as this. The atmospheric screen, requires somewhat less, and the pressure penstock screen, very little.

The heart of a good screen installation for downstream migrant fish is the bypass, which should have characteristics of size, velocity and placement to quickly and safely move fish to a safe location. An excellent management tool produced by the bypass is the trapping opportunity which can be used to evaluate success and efficiency of the screening system. It can also provide a great deal of additional information on fish populations such as timing of downstream migrations by species, growth factors, survival from the parent-adult stage and even total numbers.

The responsibility for operation of both upstream and downstream counting facilities usually rests with the developer through the period of evaluation, after which some other arrangement must be made. Sometimes the operator of the hydroelectric plant may be persuaded to continue such work, and at other times the fish management agency may wish to carry it on under its own financing, depending on the importance it attaches to the particular population of fish involved.

RESERVOIR MANAGEMENT

If the hydroelectric project proposed involves a reservoir, it may provide, or be modified to provide, improved temperature and water quality regimes downstream of the project. In an existing reservoir without power production, spilling may introduce gaseous nitrogen into the water downstream. Diversion of spill through turbines may alter this by reducing the incidence and duration of spill. Passage of water through turbines does not introduce gaseous nitrogen into the water downstream.

Variable depth outlets from a reservoir may improve temperature and/or turbidity downstream of the project. Reservoirs may provide storage to reduce flood incidence and duration and enhance minimum flows and temperatures downstream. An outstanding example of this is the Shasta Reservoir on the Sacramento River in California. Prior to this project, temperatures of the Sacramento River at the City of Redding, immediately downstream, ranged from 0° C in winter to the high 20's in summer. The project has drastically compressed this range to a narrow band within the low teens. This has raised havoc with swimming in the lower river. However, it has greatly enhanced production of salmon, steelhead and trout, which now spawn in the river throughout the year. Moffett (1948) concluded that more fish were produced in the downstream area than in the entire system previously, in spite of occlusion of 51% of the original spawning area.

The benefits of flood control can be significant. The Washington Department of Fisheries has quantified this in studies on the Cedar River between 1966 and 1978, finding a highly significant inverse correlation between the magnitudes of peak flows during incubation and salmon presmolt production per spawner (r = - .93). This indicates that flooding can drastically affect anadromous fish production.

As in cases of anadromous fish, reservoir manipulation may be used to stabilize flows and temperatures for resident fish with good results. A frequently voiced or written premise is that fish of a given water have evolved in that particular set of circumstances, and it follows that it is most optimum for their growth and survival. This does not seem to be true in many cases. The mere fact that a fish or any other organism has survived in a given set of natural conditions for many generations does not necessarily mean that these conditions may not be improved. We all know of instances in which manipulations of habitat have resulted in significant proliferations of native fish populations. While these sometimes are not of desirable species, it is clear that conditions in which a fish has evolved over generations may not necessarily be the best possible for it.

Although many of us prefer to retain the native stream fishing opportunities that are removed by substitution of a reservoir, it is an inescapable fact that in the preponderance of cases, the much greater area of an impoundment can provide fishing opportunities that may be a manyfold the basic stream potential.

It would be naive to attempt to imply that all hydroelectric development can be made beneficial to fish. An area of concern that is practically without solution is the diversion that removes substantial percentages of flow between the diversion point and reintroduction at the powerhouse. The result is usually a varying loss of habitat and sport fishery. The only solution is upstream storage to provide instream flows that would otherwise be unavailable. This may be economically infeasible, however. The problem varies in severity with the length of stream affected and its normal use. If it is not a production area or used for fishing, no loss normally occurs. This is also true if the distance involved is short. Unfortunately, in many cases, these mitigations do not prevail.

SUMMARY

Hydroelectric development can be used by fish managers to benefit fisheries if careful attention and planning maximizes opportunities. Areas of benefit include provision of good upstream passage, protection of downstream migrants from turbines and enhancement of habitat through reservoir management where this is available.

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PUBLIC ACCESS TO RECREATION OPPORTUNITIES AT HYDROELECTRIC PROJECTS

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Unlike the majority of goods and services, many forms of outdoor recreation are intimately tied to or significantly enhanced by the natural resource base; the paramount one being water resources. As a result, the 1978 New York Statewide Comprehensive Recreation Plan (SCRP) presents the following as a high level priority:

> Water is an important part of outdoor recreation experience; water quality and access to water resources must continue as a primary concern. Priority will be given to preservation of water-associated lands, especially in or near urban areas. (NYSOPR 1978)

Moreover, the Third Nationwide Outdoor Recreation Plan states that, "Water is a resource which serves as a particularly strong attraction in many types of public recreation persuits" (USDOI 1979).

The following excerpt from the New York Statewide Comprehensive Recreation Plan Technical Report Series, Open Space places the state's water resource base into perspective:

> "New York State contains some 3,500,000 acres of lakes and ponds, 70,000 miles of rivers and streams, 9,200 miles of lake and marine shorelines, and substantial wetland areas and canal waterways. Together, they approximate 7 percent of the total area of the state. Most recreational activity in New York occurs in close proximity to these water resources. The ocean areas and salt water estuaries and bays, the Great Lakes (Erie and Ontario), the river and canal systems, and the Finger Lakes have all historically served transportation, recreation, domestic and commercial uses. This abundant supply of surface water area and shoreline provides a variety of open space potentials, ranging from miles of dune beaches on Long Island, where a third of the state's recreationists can be found on a summer weekend, to the pristine Adirondack wilderness streams which offer solitude and the challenge of nature. However, waterways are also the most threatened of all the state's resources potentials. Deteriorating water quality characterizes urban and industrial development throughout the state. Available shorelines are being developed at an extremely rapid rate, denying public access and often destroying scenic quality and ecolog-

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> ical values as well. Fortunately, considerable shoreline remains for protection and reclamation. Only 27 percent of the state's lake and marine shorelines are currently developed, leaving approximately 6,600 miles for feasible protective programs. The close association of most forms of outdoor recreation to water and the vulnerablity of this resource make preservation and improvement of the state's waterway system of prime importance" (NYSOPR 1981).

The real dilemma revolves around the fact that the greatest pressure on the state's water resources are at the sources of user populations, where water quality factors are most threatened.

The hydroelectric development program in New York State provides the opportunity for the Office of Parks, Recreation and Historic Preservation (NYSOPR) to request the licensee to contribute to the satisfaction of area recreational needs, and to the maintenance of such facilities as they may develop at their projected sites. This comes at a most opportune time when the State and NYSOPR are lacking the funds necessary to satisfactorily develop recreational programs and to provide for the existing and projected recreational needs. As of May 1982 there exists a total of approximately 246 such hydro project proposals within the state.

The formal approach to establishing needs for given recreational facilities is contained in the SCRP publication. The basic analytical framework is an inventory of outdoor recreation facilities matched against a survey of recreation participation and demand. That demand is distributed among available recreation opportunities based on the attraction of the opportunities and resistence to travel for the different forms of outdoor recreation. Finally, the demand on facilities is matched against the current conditions of opportunity availablility. Design day capacity utilization rates above 80% are high use pressures and indicate that capacities for the given activities are likely to need expansion. Survey data (NYSOPR 1981) indicate a need for expansion of fishing opportunities in 15 of New York's 62 counties. The statewide utilization rate was about 75% in 1978 and is likely over 80% currently.

Site-specific characteristics might dictate a departure from the analysis of demand alone. Unusual aesthetic or scenic beauty might encourage singularly heavy visitation, or large concentrations of population may be present. Of equal concern is protection of the resource proper and any existing recreational development which may be jeopardized by the proposed construction or facility.

We have sought to work effectively with the N.Y. State Department of Environmental Conservation to increase fishing opportunity, and have benefitted greatly from the close and willing cooperation and guidance provided. We have further sought to coordinate our review process with local municipalities, youth committees, municipal recreation commissions, and with the Department of Transportation (DOT) as their interests have appeared.

In some instances where constraints such as: limitation of property size; lack of available property for acquisition; unsuitable terrain; presence of rapids, etc., effectively preclude the development of on-site recreational amenities, we have suggested the license applicants provide such facilities at other locations. This has been a satisfactory alternative in some instances, while in others the suggestion has been rejected. The propriety of such alternative action has been commented upon by the Federal Energy Regulatory Commission, which in essence has stated that if an applicant for licensing and public agencies should agree that off-site recreational development in lieu of development at the project site is in the public interest, it will be given full consideration. Such actions assure contribution to recreational needs at locations of use, rather than no contribution because of site constraints, or development at remote locations where minimal use would be anticipated. Additionally, problems of maintenance can in some instances be minimized. In other instances the applicant is relieved of the necessity of acquiring property where none is readily available.

Concerns associated with hydroelectric power projects proper include those affecting waters used by recreational and/or commercial vessels. Unexpected currents caused by deflection of waters into penstock areas, or by tailrace discharge can create navigational hazards. In some instances the width and flow of a river, or the distances between the sites and the navigable channels may be so great that passing vessels are unaffected, while in others, such as in canal lock approaches, the effect of the currents are potentially hazardous. In all such potentially hazardous situations the developer is informed of our concern and is requested to ascertain the degree of hazard, if any, and to develop mitigative measures to minimize or eliminate such problems. In instances where DOT's Canals and Waterways are involved they take the lead action; another instance of beneficial cooperation in which agencies support one another in areas of common concern.

Additional concerns include the following, primarily taken from the FERC Guidelines:

> Effect of the facility upon recreational facilities downstream which could involve dewatering of areas below the dam, or short periods of increased flowage with storage and release operations. An example of the latter is present in the Salmon River area near Selkirk Shores State Park. In this situation, stream fishermen are exposed to hazards associated with stored water release and rapidly rising river which could cause upset, injury, and/or loss of life.
>
> Upstream flooding associated with dam construction or use of flash boards to increase the pondage, particularly where recreational facilities or historical place may be present is a further concern that must be evaluated and addressed to satisfaction.
>
> Protection of the aesthetic qualities of an area, not only from the intrusion of the power house but also from the high transmission towers and wires is also considered. Of

particular concern is the protection of boaters at launching sites, as for example the loss of life associated with the mast of a sailboat touching overhead wires a few years ago.

In essence our basic concerns are:

1. Protection of recreational facilities from every hydro activity which might adversely affect existing environmental, historic and recreational resources and activities.

2. Development, maintenance and operation of new recreational facilities.

3. Expansion and imnprovement of existing facilities.

4. Provision for greater recreational use of the state's resources.

5. Provision of access facilities to address special needs of the handicapped visitors.

To date agreements have been reached with applicants which provide for the developmenmt of boating and fishing access; trailways for hiking and/or biking; picnic and parking areas; fireplaces and grills; surfaced access roads; scenic overlooks, cross-country skiing and snowmobile trails; interpretive signage; toilet facilities; landscape plantings; and playground equipment. In all instances the provision of these amenities is predicated upon receipt of license and the safe and efficient operation of the facilities. The recreational components will, as far as practicable, proceed with the project's development.

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TAILWATER TROUT FISHERIES: PROBLEMS AND PROMISES

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INTRODUCTION

Tailwater trout fisheries may be subject to a wide range of effects from stream impoundment and reservoir operation, including elimination. An extreme consequence of impoundment would be the occasional dewatering of the stream below. If a stream becomes dewatered, a fishery can be reestablished only by requiring and maintaining minimum instream flows. In less extreme situations, the degree to which a tailwater fishery is affected by reservoir releases is determined by changes in water temperature, water quality, discharge pattern, and available habitat. The extent to which these physiocochemical characteristics are altered is determined primarily by the volume and depth of the reservoir and the design and operation of the dam (Walburg et al. 1981b.).

TYPES OF RESERVOIRS

Reservoirs are designed for various purposes--flood control, municipal water supply, recreation, irrigation, navigation, hydropower generation (e.g., run-of-the-river, peak power), or any combination of these. Reservoirs can be further classified by the depth at which water is withdrawn. Intake structures in a dam may be adjustable for withdrawal of water from several depth levels. The depth of withdrawal, the depth and volume of the reservoir, the volume of discharge, and the release regime interact to determine the water temperature, water quality, and habitat that can be maintained in a tailwater.

EFFECTS OF TAILWATER TEMPERATURE ON TROUT

If a tailwater has sufficient water to support fish, temperature is the most important factor in determining if the stream will support trout. If water temperatures cannot be maintained below 21°C, trout fisheries cannot be maintained, or, at best, are limited to a seasonal "put-and-take" status. A reservoir from which water is released near the surface or from upper levels can raise tailwater temperatures sufficiently to stress an existing trout population or eliminate a section of manageable trout water (England and Fatora 1978; Fraley 1978).

Most tailwater trout fisheries occur below deep-release reservoirs. Such reservoirs have often created tailwater "put-and-take" or put-grow--and-take" trout fisheries on former warmwater streams (Vanicekct et al. 1970; Butler 1973; Weithman and Haas 1980; Walburg et al. 1981a, 1981b). The success of these fisheries often depends on the amount of

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coldwater storage in the upstream reservoir. If storage is not adequate to maintain summer-long discharge of cold water, the tailwater may be only seasonally usable by stocked trout and may be unsuitable for native warmwater species (Pfitzer 1962). Tailwater temperatures below deep-release reservoirs on coldwater streams generally remain within the tolerance levels of coldwater fish species (Walburg et al. 1981b). Reduced temperatures below some large western reservoirs have been associated with a substantial decrease in trout harvest and migration of trout out of the tailwater (Weber 1959; Mullan et al. 1976). At Flaming Gorge Dam in Utah, alleviation of this situation required that the intake structure be modified to multi-level release capability at a cost of $4.2 million (Peters 1979). Low water temperature may also influence stocking schedules. Oatis (1975) recommended that trout not be stocked in Winsor Dam tailwater, Massachusetts, until water temperatures were warmer than 10.°C. Recently stocked trout that attempted to maintain themselves in the current when temperatures were between 7.2 and 10.0°C were subject to lactic acid buildup and death by acidosis. Temperatures below most deep-release reservoirs, however, are generally suitable for maintaining trout fisheries if coldwater storage capacity, water quality, and discharge volume are adequate.

EFFECTS OF TAILWATER WATER QUALITY ON TROUT

Water quality in a tailwater can be substantially altered by discharges from the anoxic hypolimnion of a stratified reservoir. Low dissolved oxygen concentrations in tailwaters have been associated with fish kills, reductions in faunal diversity, and reduced feeding and catchability of trout (Deppert 1978; Hill 1978; Weithman and Haas 1980). Reduced oxygen levels in tailwaters occur most frequently below large reservoir projects during the summer, particularly in the Southeast, the Ohio River Basin, and the Great Basin. Dissolved oxygen concentrations are generally adequate below most small hydropower projects (<30MW), particularly in the northern states and on the Pacific Coast (Cada et al. 1982).

Increased levels of hydrogen sulfide, iron, and manganese associated with discharges from the anoxic hypolimnion may also adversely affect tailwater fisheries. High levels of oxidized manganese have been implicated as a possible cause of trout mortaility in Greers Ferry National Fish Hatchery in Arkansas, where hypolimnetic discharge from Greers Ferry Reservoir is used as a water source (Nix and Ingols 1981). Elevated iron and manganese concentrations below Buford Dam in Georgia have tentatively been associated with observed irritation of the surface cells of trout gills and physiological stress in fish (Gilbert and Reinert 1979). High hydrogen sulfide concentrations prevented the establishment of a tailwater trout fishery below Spruce Run Reservoir in New Jersey (A.B. Pyle, personal communication, New Jersey Bureau of Freshwater Fisheries, Trenton).

Injection of liquid oxygen into the hypolimnion has been used to increase dissolved oxygen concentrations in Clark Hill Reservoir tailwater in Georgia. Ninety metric tons of liquid oxygen per day were required to raise the concentration of dissolved oxygen in the tailwater to 5.0 mg/l . However, oxygen injection disrupted stratification of the reservoir, appeared to raise tailwater temperatures slightly, and did not appear to alter the distribution of tailwater fishes enough to justify the cost (Dudley et al. 1980). Low dissolved oxygen concentrations that occur in Norris Lake tailwater in Tennessee from August through November are alleviated through cessation of discharge for 2-hour periods. Stopping the discharge of anoxic water increased dissolved oxygen in the tailwater from 1.5 mg/l at the dam to 4.0 and 8.0 mg/l at distances of 4.8 and 22.5 km downstream, respectively (Boles 1980).

Multi-level outlet structures can be installed in dams to meet both temperature and water quality requirements for trout in tailwaters. Such a structure should have more than two or three outlet levels to ensure flexibility of operation. Frequent monitoring of reservoir stratification and tailwater conditions would be required to ensure that the best release level is used.

EFFECTS OF FLOW REGULATION ON TROUT AND TROUT FOOD

Seasonal changes in flow occur below most reservoirs, and these changes can adversely affect trout eggs, fry, and adults. During low flows, fish losses can occur from desiccation, stranding, loss of cover, increased siltation, freezing, and increased temperature from solar warming (Parsons 1957, 1958; Corning 1970; Thompson 1970; Aggus et al. 1979; McMullin 1980; Walburg et al. 1981b). Little trout spawning occurs in tailwaters because of large variations in flow. Maintenance of a suitable sport fishery usually depends on the stocking of hatchery reared trout.

Hatchery trout seem to be more adaptable than wild trout to the reduced seasonal flows that occur in tailwaters. Studies in test channels in Idaho showed that after 2 weeks of reduced flow, 20% more wild trout emigrated from the test channel than from a control channel held at constant flow. Hatchery trout in the same channels were apparently unaffected, since a similar percentage remained in both the test and control channels (White et al. 1980).

Loss of cover because of reduced flows may limit carrying capacity of the tailwater. Maintenance of minimum flows has been recommended as a means of reducing the impact of flow reductions on tailwater biota. Loar and Sale (1981) discussed the relative merits of a number of methodologies used to determine "proper" minimum flows. Most of these methodologies have been developed for western streams. The U.S. Fish and Wildlife Service, East Central Reservoir Investigations, is testing the usefulness of a method developed in British Columbia by Newcombe (1981) in determining the instream flow needs for a coldwater tailwater below a flood control reservoir in Kentucky.

Minimum instream flows are also desirable in tailwaters below peaking hydropower projects where discharges are not only reduced seasonally, but are subject to daily fluctuations. Daily discharges from Hartwell Reservoir in South Carolina can range from leakage flows of 3 m^3/s during periods of nongeneration to as much as 700 m^3/s during peak generation (Walburg et al., in press). In such tailwaters, natural reproduction would not only be disrupted by the problems associated with reduced flows but would also be affected by high discharge velocities.

When discharge velocities are high, redds can be washed out and eggs destroyed by rolling gravel (Parsons 1957; Corning 1970). Eggs laid at high flows are also subject to desiccation and freezing when flows are reduced. Studies below Hungry Horse Reservoir in the Flathead River, Montana (McMullin 1980; McMullin and Graham 1981), indicated that when the maximum release levels during the November spawning period were limited, most eggs of kokanee salmon (Oncorhynchus nerka kokanee) were laid below the low water mark at minimum flow. Egg losses from desiccation and freezing were estimated to be less than 5% when spawning flows were regulated. During the previous year, when spawning flows were not restricted, egg mortality from dewatering exceeded 60%. The construction and use of a reregulating dam is expected to assist in the maintenance of suitable flows in this tailwater.

Rapid dewatering of portions of streams because of daily or seasonal reductions of flow may result in stranding of juvenile trout. The gradual reduction of flows, rather than abrupt cessation of discharge, may help prevent stranding (Kroger 1973). At peaking facilities with more than one turbine, it might be possible to gradually reduce flows over a 1- to 2-hour period through the successive shutdown of each turbine, rather than by the simultaneous shutdown of all turbines.

Flow fluctuations affect catchable trout primarily through changes in temperature, usable cover, and food availability. If these conditions remain adequate, stocked trout appear to remain in the vicinity of release (Walburgh et al., in press). However, water temperatures in tailwaters of peaking hydropower projects may increase to critical levels during periods of nongeneration on hot summer weekends. Adequate temperatures were maintained during nongeneration periods in Dale Hollow tailwater in Tennessee by the operation of one turbine for 1 hour during each 48 hours (Parsons 1957). Trout may be better able to survive flow reductions and the resultant high temperatures if adequate habitat exists in the tailwater. Trout were able to survive in stratified 3.7-m deep pools in Hartwell tailwater in South Carolina, when weekend discharge was limited to 3 m^3/s leakage flows supplemented by short-term daily releases (D.H. Barwick, personal communication, U.S. Fish and Wildlife Service, Clemson, SC).

Many tailwaters lack deep pools for refuge of trout during nongeneration in summer. In these tailwaters, reduced or zero flows limit the amount of usable cover, and hence the carrying capacity for trout. Maintenance of minimum flows would not only increase the amount of useable cover, but would also help maintain tailwater temperatures. Construction of wing-dikes and other habitat improvement structures, in conjunction with minimum flow releases, may further increase carrying capacity by increasing water velocities and available cover. Any habitat improvement structures must be able to withstand the high flows during power generation. Tailwaters appear well suited to habitat improvement, since many are readily accessible and are heavily used by anglers.

Daily flow fluctuations may limit the amount of invertebrate fish food that can be produced in a tailwater (Wright and Szluha 1980; Walburg et al. 1981b). It has been necessary to introduce food organisms in some tailwaters where production of native invertebrates was insufficient. Snails and amphipods were introduced below Glen Canyon Dam in Arizona (Mullan et al. 1976; Bancroft and Sylvester 1978, as cited by Schmidt et al. 1980), and amphipods were introduced in Table Rock Lake tailwater (Lake Taneycomo) in Missouri (Walburg et al. 1981b). In some instances, tailwater trout may rely on food exported from the reservoir--e.g., crustacean zooplankton, Chaoboridae, threadfin shad (Dorosoma petenese), and white crappies (Pomoxis annularis)--during at least part of the year (Parsons 1957; Little 1967; Trotzky 1971). Threadfin shad were introduced into Dale Hollow Lake in Tennessee to provide food for reservoir predators and trout in the tailwater (Parsons 1957). Food exported from the reservoir should not be relied on for a year-round food supply in the tailwater if water is discharged from an anoxic hypolimnion, since few organisms survive in this stratum.

Improvement of food production and availablility in tailwaters may require the modification of reservoir operations, and would appear to be best accomplished through the institution of minimum releases. Increased flows would not only provide more submerged substrate for invertebrate production within a tailwater, but would also allow increased export of food organisms from the reservoir during at least part of the year.

EFFECTS OF RESERVOIR OPERATIONS ON USE OF TAILWATERS BY ANGLERS

Reservoir operations, particularly peak releases, can limit angling in a tailwaer. Safety consideraions have prevented anglers from wading Norris Lake tailwater, Tennessee, because of sudden changes in discharge. Boat fishing is not possible because of large flow fluctuations and no minimum flow during periods of nongeneration (Boles 1980).

Lack of angler success caused by chemical or physical conditions may also decrease fishing in tailwaters. Low dissolved oxygen concentrations in Table Rock Lake tailwater, Missouri, during fall have reduced trout catches because fish feeding is reduced. Angler activity has declined during this season because fishing quality is poor (Weithman and Haas 1980).

CONCLUSIONS

The factors that determine the success or failure of a tailwater trout fishery are generally site-specific. The major requirement is maintenance of suitable water temperatures throughout the year. The usual method for maintaining temperatures is to sustain minimum flows. Minimum flows provide fish cover, increase areas for benthic production, and sometimes increase angler access.

There are problems and conflicts in obtaining a suitable minimum flow. Modification of the dam may be required to enable the maintenance of minimum flows. Conflicts may exist with project managers, since water released only for the maintenance of tailwater fisheries is essentially lost for hydropower generation. Fisheries management procedures in the tailwater may also conflict with other reservoir management strategies.

Minimum low flows should not be considered a cure-all, however. Other measures, including control of maximum flows, moderation of fluctuating flows, installation of reregulating dams, and modification of dam intake facilities to improve water quality, may also be necessary to protect or improve the fishery. Construction of habitat improvement structures in tailwaters may increase trout carrying capacity and result in increased angling. Higher angler demand may, in turn, require increased stocking.

Each tailwater must be examined individually to determine which management options are most suitable. Continued research is needed to test management strategies and provide new options. Problems and conflicts still need to be resolved, but trout fisheries have flourished in many tailwaters and it appears possible for others to be developed and improved.

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The panel addressing negotiations and trade-offs included:

Individual	Representing
James J. Case Hydropower Program NYS Electric and Gas Corporation Binghamton, NY	Developer
John J. Suloway C.T. Main, Inc. Boston, MA	Consultant
Dean L. Shumway Biological Resources Branch Federal Energy Regulatory Commission Washington, DC	Federal Regulator
Yvonne Weber Ecological Services U.S. Fish and Wildlife Service Washington, DC	Fish and Wildlife: Federal
J. Douglas Sheppard Bureau of Environmental Protection NYS Department of Environmental Conservation Albany, NY	Fish and Wildlife: State
Gerald A. Barnhart Bureau of Fisheries NYS Department of Environmental Conservation Albany, NY	Moderator

The discussions of the panel were based on the hypothetical case histories that follow. The case histories were assembled by J. Douglas Sheppard.

CASE HISTORY I: THE GENERATOR GULCH HYDROPOWER PROJECT

PROJECT PROPOSAL

The Divine Guidance Hydropower Company, a private hydropower developer, is proposing to construct a new hydropower generating facility on the Whitewater River (Figure 1). The development of the project will include:

- construction of a 25-foot high dam,
- creation of a 800-acre impoundment, approximately 4 miles long, with approximately 8,000-acre feet of storage,
- construction of 2,000 feet of penstock,
- construction of a powerhouse to house two Francis turbines (which will operate over a range of 300-4,000 cfs) and associated generating equipment,
- construction of 2.5 miles of transmission lines from the the project area to the nearest existing substation.

The developer intends to operate the facility in an almost run-of-river operational mode. The project will utilize the entire flow of the Whitewater River up to 4,000 cfs. During low-flow periods it will be necessary to drawdown the impoundment up to 1.5 feet, one or more times daily. When flows exceed 4,500 cfs, the excess water will be spilled over the dam to enhance the fish and wildlife resources in the downstream area. The projected generating capacity for this development is approximately 12 megawatts.

NATURAL RESOURCES BACKGROUND INFORMATION

The state agencies responsible for the review of hydropower projects have compiled the following background information for this section of the Whitewater River watershed.

Fisheries

The state fisheries agency has indicated that this section of the Whitewater River is currently being managed as a coldwater/coolwater fisheries resource which includes brown trout, rainbow trout, and walleye. The brown trout and rainbow trout stocks are supplemented by an annual stocking program, while the walleye stocks are self-sustaining. Unconfirmed reports indicate that walleye migrate upstream through the project area during their annual spawning run. The agency has no available quantification of the angling effort for this section of the Whitewater River, but they do consider the river to be one of the quality waters in the state. Although the state fisheries agency is still developing the anadromous fisheries segment of its statewide fisheries management plan, they have indicated that Atlantic salmon may have historically used this section of the river and, therefore, the potential for the re-introduction of this species should be retained.

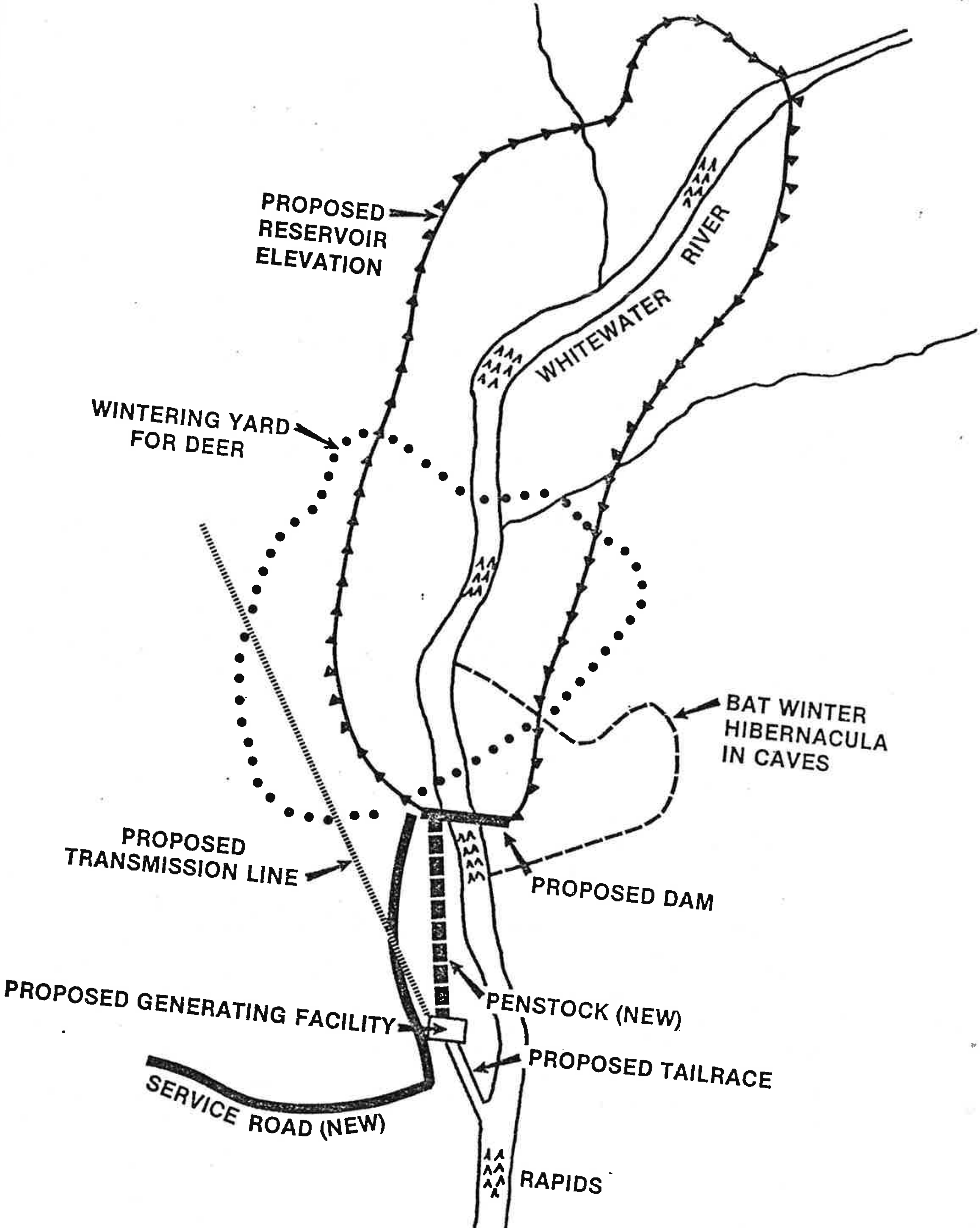

FIGURE 1. THE GENERATOR GULCH HYDROPOWER PROJECT

Wildlife

The state wildlife agency has indicated that, in or near the project area, there are:

- an overwintering area for deer on the west side of the river;
- the Whitewater River watershed is a migratory route for the bald eagle;
- a winter hibernacula for bats on the eastern side of the river; and
- a loss of approximately 600 acres of land by the creation of the impoundment.

Recreation

The state agencies concerned with recreational access have indicated a desire to have recreational access for public fishing, hunting, boating and/or swimming developed withing the project area, consistent with public safety and the safe operation of the facility.

CASE HISTORY II: THE UP-DOWN HYDROPOWER PROJECT

PROJECT PROPOSAL

The Brite-Lite Power Corporation, a publicly-owned utility, is proposing to license an existing hydropower facility, known as the Up-Down hydroelectric project, which has been in existence at its current location on Muddy Creek for the past 55 years (Figure 2). Currently, the project consists of:

- a 30-foot dam;
- a 150-acre impoundment which has approximately 1800 acre-feet of storage;
- a 2500-foot penstock;
- a powerhouse with a Francis turbine (which operates between 300 and 600 cfs) and associated generating equipment;
- a 250-foot tailrace;
- transmission lines of 0.5 miles in length; and
- no minimum downstream releases except for leakage from facilities.

As part of the licensing process, Brite-Lite proposes to also undertake these actions:

- install 3-foot flash boards on top of dam to increase head and storage capacity (Note: Flash boards had been previously utilized; however, practice was discontinued about 10 years ago);
- remove accumulations of sediment in the impoundment; and
- excavate an additional 5 feet of depth in the tailrace.

The project would continue to be operated in a storage-and-release, peaking operational mode; the impoundment drawdown would be increased from the present 2 to 5 feet to take advantage of the flashboards. Drawdown had been previously limited to 2 feet due to a municipal waste-water discharge at the head of the impoundment. The projected generating capacity for this facility is approximately 3 megawatts.

NATURAL RESOURCES BACKGROUND INFORMATION

The state agencies responsible for the review of hydropower projects have compiled the following background information concerning this project in the Muddy Creek watershed.

Fisheries

The state fisheries agency has indicated that this section of Muddy Creek is currently being managed as a coolwater/warmwater fisheries resource. The Up-Down impoundment fish community includes smallmouth bass, yellow perch, walleye, white suckers, and several species of cyprinids. Angler use on both the impoundment and the downstream area is light due to limited access and highly variable water flows in the downstream area.

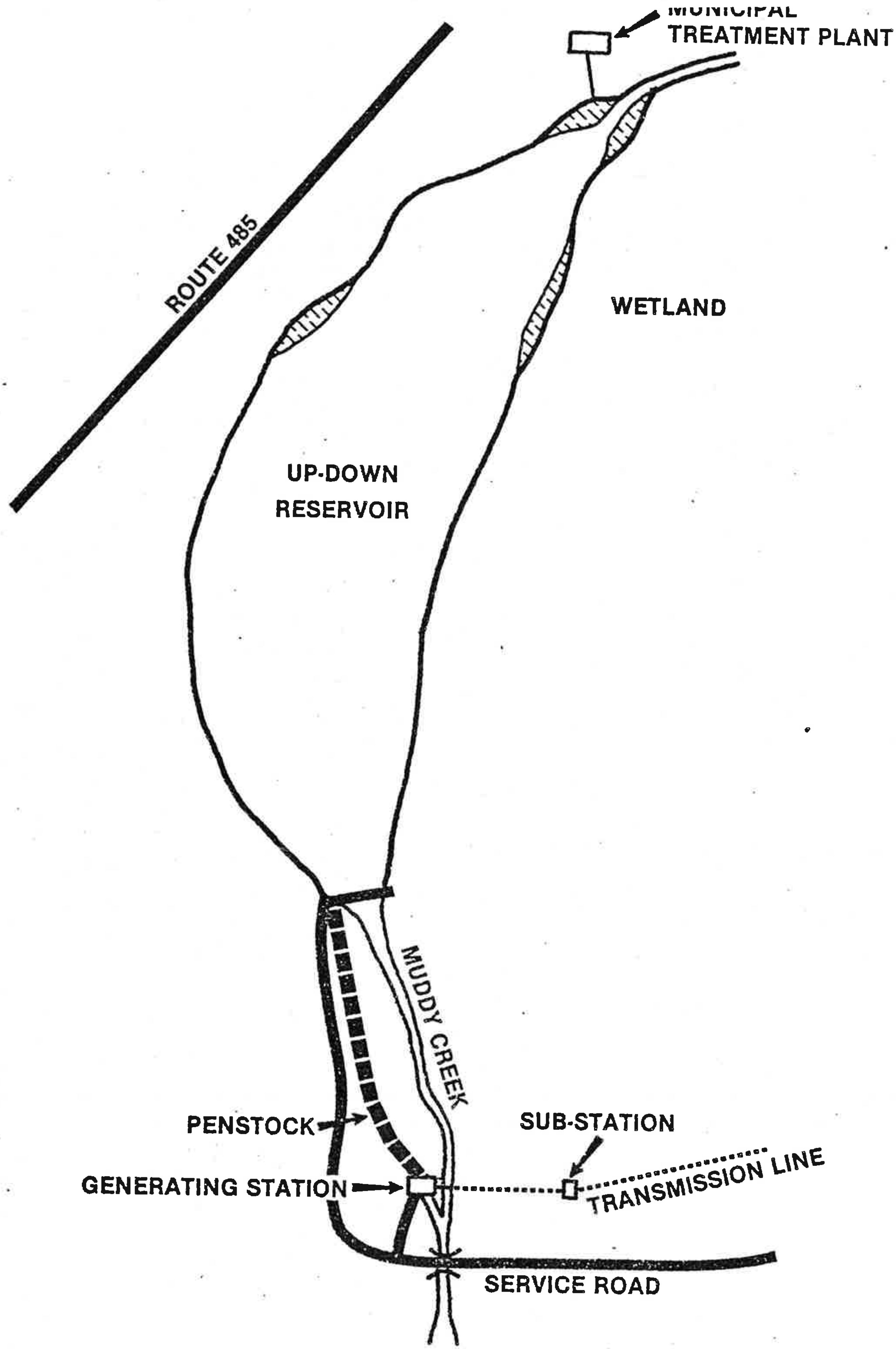

FIGURE 2. THE UP-DOWN HYDROPOWER PROJECT

Wildlife

The state wildlife agency has indicated that its natural resource inventory has identified approximately 20 acres of wetlands situated on or near the impoundment. Muskrat, beaver (occasional), great blue heron, black duck and common loon are some of the wildlife species reportedly occurring in the project area. Waterfowl hunters and trappers are known to utilize the impoundment.

Recreation

The state agencies concerned with recreational access have indicated a need for recreational access for public fishing, hunting and boating within the project area consistent with public safety and operation of the facility.

(Gerald Barnhart)

The first case history we are going to address is called the Generator Gulch Project. Biologists never were known for originality. This is a new project with a new dam.

Dean, would you tell us about the FERC guidelines and policies concerning licensing a new facility.

(Dean Shumway)

One of the factors that we take into account under this nice summary are the various types of license applications that might be filed. The one we're dealing with here is a major project and would require the most intensified environmental report. The environmental report is what an applicant will file with this commission (FERC). It also may be called the exhibit E. The exhibit E is in the application and contains all of the environmental information within the application.

There are a variety of exhibit E's depending on the particular application and the order which it is filed under; the 184 is the most stringent. Now if you're a fishery biologist or interested in water , plants, this sort of thing, there are two or three parts of the exhibit E that you would be interested in and involved in. There are a total of nine subreports that appear in the exhibit E including:

1) Water use and quality;
2) Fish and wildlife resources;
3) Botanical resources;
4) Historical and archeological resources;
5) Socio-ecomomics impacts;
6) Geology and soil resources;
7) Recreational resources;
8) Asthetic resouces;
9) Land use.

Tenth is, not a report, but a discussion of alternatives to the location and design of the project. Also included would be the literature that had been used in putting the exhibit E together and copies of the letters from all agencies, not just fish and wildlife agencies, but all agencies consulted while putting this exhibit together. If the applicant is unable to get letters, due to whatever reason, he must summarize the material and supply us with data on what went on so we have a record. We can then call the agencies and verify what we want. As you go down to the less complicated projects, projects that are already built, etc., you go to a different order and a different application and the exhibit E becomes less demanding. For example, you wouldn't have a specific project discussion of land use in any great detail if you have an existing project where it's already been established what the land use is; you have it under hydro development.

Each of these subreports follow a similar scenario and that is to describe the resource that will be affected. They will discuss the expected impacts, and what the resource agencies and others consulted have recommended to mitigate, enhance, or avoid effects. Then they will tell us what they propose to do, and we hope in many cases they're the same, but in some cases they're not. You can see that the exhibit E is compartmentized to the point that we can very quickly go through it and look at it. We (FERC) have about ten people, wildlife biologists or fisheries biologists, who look at all of the reports coming in from all over the country. We put these reports together in this form so we can very quickly get to the material that we need; and ask for all the letters so we can immediately contact the involved agencies. Basically, this is the approach that we take and what our regulations require.

(Barnhart)

Jim, from a developer's point of view, what goes into selecting a site like this? What do you consider when you are looking for a new site or consider building a new project?

(James Case)

I think the first thing you have to do is a preliminary assessment of the site. The bottom line from a developer's standpoint, unfortunately, is money. We just can't get away from that fact; the project must be economic when we're all said and done. The first thing you do is take a team of people into the field and take a preliminary look at the site. Do a minor assessment in order to assure yourself that, from a technical and environmental standpoint, a site has some viability, something that will allow you to go ahead with it.

Following that, it is very, very important that we do proper environmental work before we submit the application. If you don't, delays will cost you substantial amounts of money. A delay of a few months can mean thousands of dollars. Whether you're a utility company like ourselves, or a private developer that has a small organization that is attempting to do the job, you've set yourself a schedule and allocated money from that schedule. When you get into the latter part of that schedule, if things are being delayed, and being delayed substantially, you've incurred substantial interest or Allowance for Funds During Construction (AFDC). That can really kill you economically so you have to get these straightened out early on. From the environmental standpoint we have to look at the same things that have already been mentioned: water resources, fisheries, wildlife, and recreation. Does the site have historic value? What's the impact of the facility on the surrounding community? What are the dam stability problems and the dam design problems? All those have to be addressed before you progress with your license application. Technically, I couldn't over stress the importance of the civil works on a hydroelectric plant. When you look at a fossil plant it's pretty easy to cookbook from the standpoint that 5 - 10% of that facility represents civil works and the balance of it are things that you can put a pretty darn good economic handle on. But when you get to hydroelectric, its entirely different. Hydro is very site- specific. You've got to look at it from the standpoint that 50 - 60% of the cost is going to be site related and its very important to get a strong civil handle and geophysical handle on what you've got right off the bat.

Another thing you might want to look at technically, is standard VS custom units. You automatically save about 30% of the overall costs by purchasing a standard generator or adapting a standard unit to your needs because you're not paying for the engineering that you have to pay for if you buy a custom unit. You must understand the flow characteristics of the stream, or river, or body of water that you're building on. You must have a very good handle on flow duration curves associated with that development.

If its an existing facilty that you're going to update or enhance or add to, you've got to have a good assessment of the physical parameters associated with that existing facility. What kind of shape is it really in? How much is it going to cost to put that baby back into shape so you can produce something really substantial? All of these things have to be married together and that brings you to what we refer to as investment cost analysis. An investment cost analysis is subject to the scrutiny of the regulators. The analysis must show that you can make the benefits exceed the cost and that it's appropriate to go ahead. Now we have to measure that, being a private utility, against our existing system or what would be the cost of the least expensive other alternate that we could build. We have to show that our hydro facilities will not be any more expensive than that. We're subject, of course, not only to the regulation that you're familiar with here, but also to the Public Service Commission as well and we have to show that our economics are in order.

(Barnhart)

John, Jim has done the preliminary site work with his engineering staff and he comes to you as a consultant to work on the environmental aspects. What are you going to tell him he needs to do?

(John Suloway)

Well its going to be site-specific of course, and I think that's the first thing we have to realize because the costs that he talked about in the beginning are going to come to bear right away. We'll not only talk about environmental issues but other issues as well.

I was trained as an aquatic biologist, but I've learned a lot about what these things actually cost to build. This is a new facility and he wants to build a dam. How much is the dam going to cost? Also, one of the problems that we run into, and also the regulatory agencies, there's usually not enough information available. The agencies can't tell you enough right off the bat. We don't know if the developer owns this site, so land and water rights have got to be looked at.

Environmental issues here are going to become obvious right away. Another constraint though, before we get to that, is this a competing situation? One thing that really heightens the pitch that everybody works at is whether or not its a competing situation. Has somebody else noticed this site and are we going to have to compete with them to get this license application in? The environmental issues are obvious just by looking at the map. You can see that there is a wintering yard for deer, bat caves, positioning of the transmission which is going to go through the wintering area, and also the reservoir itself is proposed to cover a great deal of that.

We would go back, either in conjunction with another engineering firm, or our own, and look at the engineering aspects. We'd ask the developer what do you want to build here and how do you want to do it? You've given us a brief description, we need to know more detail about how you're going to operate it. Flow duration curves were mentioned, they are mandatory. We would talk to the developer, and his other consultants or his environmental staff, and tell them what sort of studies need to be looked into. One thought, a little more specific, concerning the deer yard: are there other yards that are close by that are being used by the same populations? The bat caves: will raising the water level by creating the impoundment interfere with the life history of these bats? It's not stated exactly what species of bats are involved. It might be an endangered species.

(Barnhart)

Doug, where do you want to get involved in this process now that Jim and John are working together?

(J. Douglas Sheppard)

We'd like to get involved as early as possible in the planning of these projects and help the developer to identify potential problem areas. That means that, in the case of a state agency, you have to go back to your field biologists and get survey information and everything else possible together that you know about the area now. Maybe what went on there in the past can be extrapolated to what is going to happen in the future. I know we've been somewhat complacent about planning by watershed. The best way to speed up that planning is to have a proposal like this suddenly land in your lap. Let me point out, again, that this is a site-specific situation, but it is part of a watershed. We don't know where it is in the watershed but we can guess its on the headwaters. How many dams are below? Are there others above or is this the only dam on this particular river? The watershed concept is a critical issue because, to compromise what you might have planned for that resource, you have to consider the whole system.

The bottom line is we try to encourage people to talk to us as soon as possible. We realized a couple of years ago that we can't always get down and work with these people arm in arm because we're trying to stay on top of 265 projects in New York State. Those of you who haven't had this experience yet, it's like on the job training. To keep up, we put together a piece of material that we hand out to anybody who says "hydro" and is coming in from the outside. We call it our generic concerns for environmental issues for the Division of Fish and Wildlife of New York State. What we're trying to do is identify, to the developer, the areas of concern that were mentioned by Bill Knapp and again by Dean today.

(Barnhart)

John, have you sometimes had trouble, because of the number of projects and the limited staff, getting together with Doug?

(Suloway)

Yes. I want to back up just a hair. I think we've been given a broad base of an outline to work from and it might be helpful if we know the problem we've got to attack with that application. Jim's kind of set it up; he's said we're going to have some preliminary studies by the developer. Then we usually move into a prefeasibility or a feasibility stage where the developer and the engineer look and see what they can do, and hopefully, they're getting some contact with their environmental staff or their consultant. I think that groups like NYSEG or some of the other bigger utilities that have done this a few times have learned now exactly where we have to and how quick we have to move in.

After a feasibility study we have discussion about Doug's generic concerns and the generic concerns of the Fish and Wildlife Service. We also try to set up a site visit with the agencies. That can be a problem scheduling. Then we can get some of their preliminary site-specific concerns about what we want to do. Then the developer and the consultant go back and put together an agency draft, something that initiates the consultation process with the agencies. They basically have 30 days to look at this and come back again with comments before we file with the FERC. We get the agency draft together addressing the generic and the specific comments and we put this to the agencies to get feedback. There's negotiation at this stage if it's possible. If you're lucky, it will go right through and then you're ready to file with the FERC. That's how C.T. Main and a developer would go after a license application for this site.

(Barnhart)

Yvonne, If you were on site with John and Doug and you were trying to do a preliminary identification of concerns, what are some of your more serious ones?

(Yvonne Weber)

If this were exposed to our agency, the first thing a person would do is flip through our handy-dandy threatened and endangered book and he would discover that, yes, indeed, that bat is the Indiana, and it's on our list, and, therefore, a section 10 consultation would be called for. During a site visit with someone from Doug's office and ours we would get site-specific on our concerns. For example, it appears that there's going to be a 2000-foot dewatering here and we would be interested to know how that decision was arrived at. It doesn't appear possible to sustain the fish species present in this outline if you wipe out 2000 feet of stream. These preliminaries are some of the concerns that we would stress on our site visit.

(Barnhart)

Doug, how about yourself? Any other concerns you'd like to highlight?

(Sheppard)

There are a couple of things we have to address. I would point out that even though you're a fisheries biologist, you have to remember that a resource agency has to look after all the elements of the environment. John pointed out that deer wintering area and Yvonne pointed out the bat question. Certainly you would want to find out if that population can be worked with. The question is: can the project go and not risk the habitat that's especially significant in that area? You would want to know whether or not that deer wintering yard is a significant area, in the watershed itself, or in the whole region. There are a lot of specific problems with this one. I would point out another general problem. You often have problems with people being consistent in telling you what they want to do. You'll find in the case history some errata. For example, one moment it says they're going to take flows up to 4000 cfs and in the next paragraph it says if flows exceed 4500 cfs. It's very disconcerting to someone trying to read an application to see a description like that. What exactly do you want to do? Are you telling us exactly the way it is? For example, from the map the deer yard appears to be on both sides of the river, but the narrative says it's only on the west side. Is that an error or is that an attempt to confuse the issue? We look to try and be up front and as honest as possible in identifying the areas of concern. If we don't know, for heaven sakes, let's get together, go out and find out. Then we'll try to base our conditions on that information to the best of our ability. The last thing we want to get involved in is a prolonged EIS, hearing, mess. I don't think any developer or any resource agency can afford that any more, because it's too long and costly and it doesn't really work. The licensing process is designed, as Dean has mentioned, to try and get the issues out on the table as soon as possible and ask the question: are they resolvable? If they aren't resolvable, you're better off taking a second look at whether you should be doing anything or not.

(Barnhart)

Jim, what kind of flexibility do you have when you go into a development like this? Are you more flexible to try and accommodate environmental concerns in this situation than you are in an existing facility?

(Case)

The flexibility is quite limited strictly from the standpoint that you're required, by FERC, to do the best job you can to maximize the gererating capability. When you do that, you do it very carefully. It's pretty necessary if you're in a situation where somebody else may be filing a competing application. To maintain your competitiveness you try to work the economics down to a pretty fine line. If you do this sort of thing you take a licking on the flexibility.

I have some problems with this overall description as well. First of all, I don't understand the choice of a Francis unit because, if my figures are right, when you work out the head of this system it's somewhere in the neighborhead of 42 feet. With tube units available that are good up to a 100 feet of head, there's just no reason why you couldn't apply a tube or some other standard type of machine to this situation and improve your economics quite substantially.

Second thing I'd have to say is, while the economics under very, very careful scrutiny may work out, at first glance it seems to us that it is basically impossible to construct a dam and a long penstock (2000') for a unit of this size and maintain any kind of a reasonable economic benefit on this job. We have a little bit of trouble with that.

Finally, from an operations standpoint, I'm sure that most of you have been acquainted at one time or another with the fact that the kilowatts are directly proportional to the head and the flow, times a constant. The constant is to take care of losses due to friction and things of that nature. Now if we can increase the head for a given flow we're going to get more output out of a facility. A facility this size, approximately 12 MW, if it's going to be connected to the neighboring utility company, such as a private developer would do while a utility might hook into their own system, would not have a substantial effect on the overall size and output of the central system of the utility. So the best thing the developer or operator of this small hydro facility can really do for himself is to maximize the output of the plant by holding head. The best head he could hold is to hold a constant high head and run the plant that way rather than trying to peak it. In other words, adopt a run-of-river operation for this small facility. This would be much, much more beneficial from an economic standpoint. Secondly, when you do that sort of thing you mitigate some of the problems associated with environmental aspects. You're not going to be fluctuating wetlands, etc.

One other point I think we should talk about is that when you get into these programs you don't want to see a faulty mixture after you're far into the job. You make a pretty good preliminary assessment and then you make a detailed feasibility study and you do a preliminary engineering study to start with. Then you make your application to the regulators and let's say the application gets approved. As an example I'd like to talk a little bit about a project, which is near-and-dear to my heart called Mechanicville. When we got pretty far into Mechanicville it became obvious that there were problems associated with the engineering details. We did some physical modeling studies of the upstream and downstream sides of the plant to determine details on what the flow patterns were going to be at the plant. We determined that we were going to have to put in some permanent coffer dam cells to straighten the banks on the upstream side in order to accommodate the Department of Transportation's (DOT) interests in the Barge Canal System. One of the promises we made was that we wouldn't screw up their canal boats with our darned hydro plant. The model studies showed that the tailrace we proposed was going to cause some considerable problems for the boats. Through the models we reconfigured the tailrace to take care of that problem. In fact, if anything, we're going to improve river conditions at the entrance to the DOT lock. When we got into it further we realized we were going to have to add a gantry crane on the upstream side of the plant to handle the shut-off gates to the plant. They were originally set up to operate with a truck crane, but it became obvious that wasn't going to work at all. We talked to the folks that operated a paper mill on this site prior to our acquiring the site and they told us about the ice problems they had had over the years. We decided we needed an ice sluice gate and things of this nature. So, things are not frozen in concrete. You have to leave yourself some room for latitude in the design and have to be thinking about things down-the-road. At Mechanicville it changed our installed cost of the plant from $37 to $48 million . You might say that was a terrible upset in your budget. But, by the same token, we added another thing to this. We talked to DOT and we learned that we could increase the height of the water behind the dam. By doing that we are going to bring some benefits to the job. All these things are trade-offs. Working together we will find in the long run we have a reasonably good and viable project.

There is another thing we have to consider from an economic standpoint and that is payback. In the case of Mechanicville the best I've been able to do, in spite of the fact that we have a good facility there, the best I've been able to get from FERC is a 40-year license. I'm not going to go into all the details of that, but you have to be very careful about your payback period. And in some instances where we're adding new units to an existing facility we've found that we're only going to have 20 or 25 years before our license expires and we might be subject to municipal takeover. In doing any economic study you've got to look very carefully at the payback period in order to get a really solid economic picture.

(Barnhart)

Dean, in the introduction to this case history it indicates that this stretch of river may have been used by Atlantic salmon at one time and that the state agency wants to reserve the right to manage that stretch of river for anadromous fisheries. How does it sit with you that they don't have any concrete objectives in that area? Would you look favorably on that?

(Shumway)

Let's explain what the sequence will be here. You've dealt here with the developer and the agency and they're talking about modifying the original plan so the application includes all of the environmental concerns mentioned. The engineers have redesigned so it now meets all the requirements for a good project and everybody is as happy as they can be under the circumstances. It's filed with us, it's a major project and we will look at it. We can reject it because the application's deficient. By that, we say that they should not expect to get the license in ninety days. There are some additional things they would have to do and then give us a corrected version. Now that could be engineering, environmental concerns, or any number or things. So we can call it deficient and give then a time period to correct the deficiency by getting us any information they can that will help us understand the project. Or we can ask for supplemental information. That is sort of an informal, formal request. It does not apply to the application.

A lot of biologists think that as soon as that application is filed, their job is over. That is not the case with a major project. It's a significant project with significant effects and there is going to be an Environmental Impact Statement (EIS) prepared by our agency. So they're looking at about a year and a half to two years from the time they file that application, assuming that it's a good application and that we can take up on it right away, for us to form a taskforce, come up and visit all the agencies, the site, start preparing an EIS, and go through the rigmarole of keeping tabs on those who will be seeing and reviewing its points.

So if Doug Sheppard's people are sitting there, they're going to see this over and over and over again. If they have resolved most of the issues and there are no serious problems, then, when the EIS process is over with, we'll go through the licensing; the license will be issued with the stipulations contained. If for some reason we haven't been able to resolve the issues, then we're likely to go to a hearing. Its not necessarily always environmental issues, it could be need for power, economics or other considerations.

The question that was asked dealt with the anadromous fish; how would we address that particular problem? We're going to go through an EIS process which means that everybody is going to read that and comment on it and know about it. By the time that process is through, there will be a specific and discrete understanding at our agency as to what the intent is for that particular resource. We will consider and note the objectives. If the objective is that the salmon run is to be reestablished, and you have a program of reestablishment including fishways, we will more than likely order that licensee, through the issuance of the license, to negotiate on acceptable fishway for passage of fish. If you have not got an objective that says by the year 1990 we want to pass fish here, then we'll include a condition in the license that will permit you to come back. In fact, most licenses have this, come back to the FERC and ask for those facilities later on. Now, when you do that, everybody has the right for a hearing on that matter and in many cases the licensee will say "Hey, we're not going to do this." So we would like to see a very discrete program developed, with a time frame, when an application comes in. If that's possible, then more than likely we will require that to be done. Remember, I'm staff, and that would be our recommendation in the case we're talking about. That recommendation will go to the Commission. Now those five citizens up there, the commissioners, may decide that isn't appropriate, for whatever reason. But, I think we're about 95% successful in getting the Commission to accept staff recommendations.

(Barnhart)

I'd like to give the audience an opportunity at these people with questions from the floor.

(Question)

Dean, what is the minimum amount of communication that you (FERC) are required to have with DEC?

(Shumway)

The FERC is guided, (assuming we stay out of certain areas and just talk about Fish & Wildlife), by the Fish and Wildlife Coordination Act. We pass much of this on to the applicant and require consultation. And then we examine this and ensure that there has been adequate opportunity for the agency to interact with the applicant. Anytime that we effect a complete application and we accept it, it is made available to the agencies. They'll see that this process is going on, are aware of the time frame, and are asked for comments in most cases. In this type of application you'll be asked for comments as soon as it's been effected. Notice that the application has been accepted will be sent to you, by the applicant in this case. You'll be asked to comment and we will meet with you during the scoping sessions for the draft EIS and the final EIS. In every case, we'll ask for your agencies' involvement. So, in this case, I imagine we would deal with the agencies at least eight or ten times, whether by mail or in person.

(Question)

I would like to know what happens after the developer and consultants work with the state agency and the federal agency and everybody is satisfied that the fishery resource will be protected except for the local government. If they have to issue a building permit or a zoning variance and they run an annual bass fishing tournament in that section of the river, or a white-water canoe race, and are opposed to the project, can they tell the State and Federal agencies they won't issue the appropriate permits?

(Case)

I think I can answer that for you because we've faced that problem. Under federal law, under the regulations that FERC has been given to administer this program, they are the designating agency. The only state requirement for a company like ours is the 401 water quality certificate that we get from DEC. The local folks have absolutely no input into this thing. They can't require a building permit or any other type or permit.

(Question)

John, using the agency draft, how successful have you been resolving differences of opinion after you've gotten to that stage? Your engineers have already designed what they think is the best configuration for the hydro project, you've sent this out to Fish and Wildlife and the appropriate state agencies, how are you going to resolve difference of opinion? Why do you do that agency draft rather than just make the application and let the discussion go on then?

(Suloway)

Okay, two questions: Why do we do it and how successful is it? We do it because if you don't do it, it gets you held out of the FERC process. Jim already talked about time is money, and a lot of money, and you just get held up. Also the agency draft, like the site visits, starts a rapport between the regulatory agencies and the developer. That's very important because if you can just get two groups of people to sit down and look at one another face-to-face, that's not usually an enemy situation. It's not a confrontation. It's always site-specific, of course, and this site would be difficult. There's no doubt that this would be a tough one to get through. But the sites we've worked with in New York State are going to get either exemptions or licenses because we managed to get the negotiations done. Now, in all of the cases, there was give on both sides. And I think that give is facilitated by the agency draft and the meetings that negotiations take place at. Recreational facilities are always helpful, fishing access comes up a lot as do spillage requirements. In some cases, agencies virtually dictate what they need for spill just because of water quality requirements for a 401 certificate. But even in cases where an agency is asking for spill to enhance the fishery resource downstream from the dam, if they talk to the developer maybe he can sacrifice 50 cfs and the agency will give the go ahead. The developer then can go-ahead and file and get the project on line. Then you've made up that money lost due to spillage because you haven't had to pay that extra interest, you haven't had the delays. As Jim described, you're going to have additional costs after the application is filed. There are going to be modifications all along. This just facilitates the process and saves the developer money.

(Barnhart)

The second case history is an existing dam with some modifications involved. Dean would you briefly give us the regulatory picture on this one?

(Shumway)

There are several options. They could file either for a license or an exemption. If they go for an exemption, it is a totally different case.

This is a small project. Incidentally, there is a term that's thrown out that I'll clear up quickly, major and minor projects. The breaking point is 1.5 MW; if its less its minor, if its over its major. In most cases, at an existing dam, the regulations that they would file under require a much briefer envrionmental document than is required for a new dam.

If they are filing an exemption, the agencies have almost complete control over fish and wildlife resources. If they file under a license, they'll go through the FERC procedure of us evaluating everything and setting the conditions for them. Under an exemption we do not set the conditions, such as minimum flow. There is an article in the exemption that requires whatever the agencies say will be done with respect to fish and wildlife resources. A recent order by the commission said that if two agencies comment, the most stringent requirement will be the one employed.

(Barnhart)

Jim, when you're looking at a site like this what things do you have to look for? What do you use to make a decision on whether you're going to go for an exemption or go for a license?

(Case)

Well in terms of licensing there are several areas that would be considered. First would be the competition from outside interests that are looking to license the project. We would consider the environmental demands that may be placed on us by the regulators. The dam inspection and the dam safety analysis will play a part in this because you can get into some rather substantial costs associated with those. The overall effective length of the FERC license would be considered because if it is an already licensed project you may not have the long-term to run. All those things would be weighed pretty carefully.

From the standpoint of this particular case I take a little issue with the 300-600 cfs spread. I don't think you can get a Francis unit to operate much below 40% up. In other words, something around 360 - 600 cfs would be about the maximum spread you could enjoy with this job. Again, I would suggest running this on a run-of-river basis at maximum head in order to maximize output and minimize environmental impact.

Another thing I'd like to discuss is the frequent talk about cheap low-head hydro. Everybody has to understand that there is no such thing as cheap hydro. These are expensive. The preliminary and initial costs are more than alternate forms of generation. Where you make up the difference is over a reasonable period of time when you don't have to pay for fuel. That's how you equate it out over a 30 or 40-year license and make money. Second thing is that just because you say low-head, it doesn't necessarily imply small hydro. We're building Mechanicville with two vertical Kaplan machines. The throat is 18.5 feet in diameter on each machine. The rotor hubs weigh 100 tons each and we have all the facilities that you would find at a rather large fossil site at our Mechanicville site. So low-head doesn't imply small and low-head doesn't imply cheap. Those are two erroneous connotations that are very often tied to hydo.

(Barhart)

John, Jim was so pleased with your help on the first one of these that he's come back to you again.

(Case)

Absolutely!

(Suloway)

I want to make one comment on Mechanicville relative to the size of hydro. When you come from an academic background or a laboratory background, and they throw you into license application where you have to turn out one of these thing in no time flat, get together with agencies, and get to the developer, you write some things that you see in other applications. And when he (Case) says its not cheap, its not small, believe him! I went to Mechanicville and I saw the hole that they had to dig. When I saw the construction workers down in the bottom of the hole they looked like ants. These are big projects; you have to see one.

We would follow a similar scenario in the sense that we would immediately talk to the developer about a prefeasibility study, and determine what kind of information they have. We'd talk about different alternatives to the operating mode that they have suggested because you know that DEC is going to be a little bit upset with the fact that the applicant is going to drop the level an additional three feet; the drawdown is going to be five feet. We are also going to have to talk to them about additional permits that are going to be required. According to this they're going to remove accumulations of some sediments which will require a 404 permit. Excavation of an additional five feet in the tailrace will require another 404 permit. And, depending on the river system here, we have a treatment plant upstream so the silt and bed load could have some toxic materials in them. Toxics may be a problem even downstream in some of the low current areas. So when the applicant proposes excavation of the tailrace and elimination of some silt, we're going to tell him he's probably going to have to do, we know he's going to have to do, some sediment analysis. It would probably be wise to do this up front. Because if you're loaded with PCB, and the treatment of PCB wastes and materials is very expensive, you may not be able to deal with this project at all financially. Also, an alternative to treating the material is landfill. But at this point in time its rather difficult to landfill PCB-laden sediments. In some areas of New York State there isn't a landfill that you could put it in. So, we would go through some issues that would have to be discussed right off the bat and see if the developer can move ahead with this project before we start preparing the agency draft. Then we would prepare the agency draft and consult with the agencies.

(Barnhart)

Doug and Yvonne, what concerns do you want to highlight here?

(Weber)

As it stands here now, despite Jim's recommendation to change to a run-or-river mode, we're addressing peaking. And I would consider the negative impacts on aquatic furbearers. It appears that muskrat and beaver are involved and we would want the impoundment held steady during the time that the beaver cubs and muskrat young are in the burrows.

Further it appears very likely that substantial areas of wetlands are going to be flooded out and this might be cause for some mitigation procedures.

Those are the two areas of concern that Fish & Wildlife could have. Doug?

(Sheppard)

I think that Yvonne has hit on some of the points. The big question that we're always faced with on an existing site is flashboards. The site has been abandoned and the flashboards blow off as they are intended to. At an abandoned site nobody has any interest in putting those flashboards back on because there's nothing in it for them. A developer comes back in and wants to add flashboards. The question is if you put three feet of flashboards back on the dam what are you going to do to the existing impoundment which has had ten years to stabilize? The riparian vegetation has had a chance to stabilize and now you're going to come back and add three feet on top. This is one thing we often ask FERC: what do you mean by an existing dam? Does that include flashboards that were once there but are not there now and will be put back on? Legally, the developer might be entitled to put them back on. If he does, he is going to change the situation in regards to wetlands, wildlife and fisheries.

The other issue is the operational mode. Peaking operations are always going to be a problem. Even though this is a coldwater workshop, remember that warmwater species in the reservoir may require a stable water level during the reproductive period. Daily or frequent fluctuations could cause a great deal of havoc with reproduction of these species in the impoundment itself or in backwater areas of the downstream reach. We need a minimum base flow downriver at times when they operate in a storage-and-release mode because probably they won't have the capacity to run run-of-river year-round in a situation like this. Can we get through the spring and early summer, which is the time of recruitment of the warmwater species present, without water level fluctuations? The case history describes the operational mode as almost run-of-river, that's what the catch is. We're going to run almost run-or-river operation. Except for June, July, August, and September when we will hold water and shoot it out when we get enough head to drop it down three feet and refill. Sorry boys, that's storage-and-release. The only thing that really means run-of-river is if you're doing it 365 days a year and you're keeping the impoundment level constant. If you're going to do true run-of-river, then you shut down and walk away from your project in June, July and August and don't start up except maybe when a thunderstorm comes through. That can hurt you considerably in capital investment. Small developers can't waste that money. But, the real question her is could we modify the operational mode? If so maybe we ought to look at the design specifications for the turbine unit and look at something with a much lower minimum flow, perhaps a different type of turbine. Sometimes we are forced to look at the developer's situation and ask him some questions. You had in front of you yesterday the weighting curve for different types of turbines, operating flows, and efficiencies. Ask them if they haven't got a better way of generating power than the one they propose. There is nothing wrong with that. He may look at you and say, "what the hell does a biologist know about engineering?" But you can turn around and say "what the hell does an engineer know about biology?" Welcome to the group; let's work it out together. In this case we would sit down and try to figure out. Is there a better way?

(Barnhart)

In any of these situations where we've identified issues that conflict with developing power, and you're talking with the developer and his consultants, are you conciously assigning priorities to these issues? Before you go into these talks, have you already determined what you're willing to give up to get something else?

(Sheppard)

It would certainly help if you had an estimate of minimum flow requirements derived fron the type of studies Mike Sale talked about yesterday in the workshops. But, for someone to go out and do a single reach study with the IFG (Incremental Methodology) you're talking about at least $20,000 a pop. Obviously, with a little developer, there's no way you're going to get that. You're going to have to extrapolate in some instances. But we are getting a generic feel for some aspects. Impoundment drawdown for instance, if its absoultely necessary to operate with some impoundment fluctuation we say, "All right what about no more than one foot drawdown?" Is that going to be possible? If you can hold it there, we're willing to take a risk on something like that in New York. We don't know that that's the right number, but we have found that it has helped projects get off the ground that might have had problems from our standpoint by drawing down three feet. We might be willing to take a look at bigger fluctuations in the impoundment at some times of the year. We might require a study to monitor a wetland impact or a fisheries impact.

Yes, it helps to have your priorities worked out. The recreational aspect is always a tough one because we've got to know:

1) what the resource agencies want;
2) what the local community wants; and
3) what the developer might be able to give.

There's always those three factors. We try is to get a recreational plan together that addresses recreation issues, fish and wildlife concerns, and the local communities. Lots of times we're all talking the same language and it makes it easier then to work with the developer to address them.

(Barnhart)

Let's get a few questions from the floor. Dean, you have a question?

(Shumway)

Not a question, just a comment. He's hitting on something that I've proposed for a long, long, time. A biologist should know enough about hydro projects to be able to talk to a developer at his level. The attorneys have something they call the "fatal" question. That's when you ask a question and you don't know what the answer is. So if you're talking to a developer, don't ask him a question that you don't know what he's going to tell you before you ask it. Because if you do, you are never going to win at negotiations. He'll give you an answer that you may or may not know is right. You must know what to expect in the way of answers. Do your homework and get in there and talk to him. He'll negotiate with you if he knows that you know when you're getting the right answer. If he doesn't, he'll tell you what he wants you to hear; tell you it can't be done. You've got to know whether or not it can be done.

(Case)

I'd add Dean, that the reverse is also true.

(Question)

I'm with the Corps of Engineers and I just want to communicate one thing that I know has been mentioned briefly in connection with Mechanicville. At all these hydro developments there is always a question of the Army Corps Department whether we have permit issuance responsibility or not. I was surprised that no one brought this out. I have so many applications in my office that I've got five people working on them.

Another thing, it's to your benefit to communicate with us early if you do have a permit application, a 404 permit for a coffer dam or a section 10 requirement for dredging in a navigable waterway for instance. We do require that some testing be done and it would be nice if the consultants would get to us early so we can have the testing done in due process rather than down the line somewhere.

The other question I have is a general question on the material in the exhibits in an application for licensing. I can't understand why there's no mention of other facilities, either existing or proposed, located upstream and downstream of the proposed project. I realize that all we've mentioned is site-specific to that project but it just seems a necessity to evaluate impacts, flooding or fisheries, whatever, on the entire watershed. It would be difficult not to look at other facilities and see what the synergistic impacts are. Is there a reason that these things aren't included in the application?

(Shumway)

Well to the extent that upstream projects affect the operation of a proposal that you're putting together they would be discussed. It would be part of the application. That's a very common thing where the Corps has storage facilities and they have release schedules that have to be taken into account in developing projects downstream. So basically I think its there even though its not specifically mentioned.

It is unfortunate that in looking at two projects, one immediately above the other, unless they are combined hydraulically and are the same project, they'll be looked at separately. To the extent that one's operation impacts the other one, they'll be addressed. But, we do not look at the two together unless we know they're coming in. Quite often, however, we are not aware of other projects being involved.

(Case)

Just to reinforce the first part of that question, I'd have to say, from a developer's standpoint, once we've reached the point that it becomes appropriate to approach the regulators about a project we go to three people, and it's almost simultaneous. We go to FERC, we go to the Corps and we go to the New York State Department of Environmental Conservation. We don't want our friends in the Corps to think that we aren't aware of you or that we've left you out of the picture, because that's far from the case.

(Sheppard)

Just remember that the 401 water quality certification, is the responsibility of the state agency. As part of our normal state commentary to FERC on projects, we will draw attention, wherever possible, to the implications on a basinwide situation, particularly if it affects water quality. In this particular case history there is a question of water quality. That has to be addressed and when we do that we also draw attention to other facilities or industries downstream that might be adversely affected by the project being put into existence, changing operational modes, or whatever. So, the answer to your question is yes, we are indirectly drawing FERC into looking at something more comprehensive than site-specific and we use the water quality certification as the mechanism to do it.

(Question)

What process does a downstream riparian owner have to address any problems during the construction and after the operation of a facility?

(Shumway)

The developer is required by the regulatory agency to get a license to operate. If there are specific problems one anticipates, such as changes in flow patterns and subsequent erosion problems, these are written in as articles of the license. The licensee will periodically and with the Corps, perhaps others, see what the impact has been, file reports with us, and take whatever action is necessary, to take care of the channel morphology.

(Question)

One of the things that we've consistently mentioned is the fact we don't have much information on what happens when these projects go in. Who, if anyone, is monitoring what's happening at the projects that are approved now in terms of biological effects?

(Shumway)

If you can demonstrate the need for a monitoring program, by that I mean you can say we really don't know what's going to happen here and we (FERC) agree we want this monitored because we'd like to have an accurate assessment, we (FERC) have no problem requiring that. We've found that licensees accept that readily. They like to see what the effect of their project is. If you believe in what you're talking about, it's a very inexpensive thing as far as they're concerned. You can get them interested in doing studies if they have some utility. There are some studies that do nothing but just gather data, but if they are oriented at solving problems then they will be required.

(Sulway)

I need to say something about that. It's applicable to a project we're setting up in New York right now. You can talk to a developer and say that we've got a minimum flow concern here to maintain water quality. But, DEC has agreed that they're not sure, based on the model, and they'll except a water quality monitoring program and the spillage requirement will be revised if necessary. Now, it's a gamble. It could turn out that you'll need more flow. But, in another way, it may be a good gamble depending on the characteristics of the site. They may get some more out of it by being able to spill less. So, I think what Dean says about developers often being willing to cough up a little is true.

(Weber)

I can add something more to that. In the terms and conditions of a case-by-case exemption, it is possible to write in a monitoring requirement.

(Question)

What if there are violations?

(Shumway)

It is the responsibility of the Commission, if it's a licensed project, to insure that the licensee does what the license says he'll do.

We don't always monitor; usually we do for something significant. But the records are always available to the public and the agencies involved. If we set a minimum flow, for example, the agencies are involved in that. They're aware that we've set it,its in the license that the licensee must maintain records on this and those are public records. And if they make a mistake a letter may be filed with us from somebody making a complaint. The complaint is resolved either through legal means or through negotiations with the licensee.

(Sheppard)

The bottom line is its basically the state agencies responsibility, with the developer, to solve all these on-going issues for the next 50 years. FERC will be involved whenever we can't resolve the dispute. But, Jim Case and somebody in DEC are really doing the job. Don't kid yourself, that's it guys. The states are the ones that are going to have to take on the brunt of resolving the problems. That's extra work on top of everything else that we've got to do now to make sure the developer is doing his job. The public can help you but, the monitoring for enforcement of conditions will basically be a state responsibility.

WORKSHOP SUMMATION

Norville S. Prosser 1/

I want to thank the organizers of the American Fisheries Society's Northeastern Division Coldwater Workshop for allowing me this opportunity to participate. The workshop was organized to address three major objectives. Although each objective was the subject of a discrete module within the overall program, the topics were so intrinsically interrelated that presentations and discussions commonly crossed the sessional lines. The final session, the panel discussion, addressed most of the issues discussed in the preceding sessions and I will use that material freely throughout this summation.

The first objective was to acquaint participants with the magnitude of hydropower development and to review current authorization and regulatory processes. From the federal perspective, it is obvious that our elected representatives have provided (via recent legislation), clear direction that responsible agencies must take a hard, careful look at the nation's flowing water as a potential source of electric energy generation. The Federal Energy Regulatory Commission (FERC), which regulates private hydro development, is attempting to respond to the new charge. It was noted by Ronald A. Corso (FERC) that the Commission has assumed a mandate to "ensure the comprehensive development of the nation's water resources for all purposes." Evidence of accelerated hydro development effort is explicit in the unprecedented increase in the number of hydropower licensing, permitting and exempting actions handled by FERC since 1979; from a total of 290 actions in 1979 to 1,657 actions in 1981.

No one should be misled, development of hydropower is not our elected officials' only concern with regard to flowing aquatic resources. Of concern, too, as clearly expressed in an impressive array of federal law, including major hydro development legislation, is the conservation and protection of fish and wildlife resources. Therefore, a cooperative responsive approach to hydropower development, involving regulatory agencies and fisheries agencies is clearly in the best interest of all concerned.

The regulatory review efforts required by individual states to responsibly, yet quickly, identify and represent the full range of riverine-dependent resources, has created regulatory reform pains for state bureaucracies, as well. As described by Murdock M. MacKenzie (NYS Department of Environmental Conservation), mechanisms are being hammered out to assemble and transfer the considered judgement of all state interest groups, and to provide coordinated input in a timely fashion.

The pressures for increased hydro development are not unique to the U.S. According to Larry Moore (Ontario Ministry of Energy), one-third

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of Ontario's electric power is provided by hydroelectric generation, and new development opportunities are being closely examined. The provincial government is encouraging private sector development for sites of less than 2 megawatts (mw) and the government-run power producer (Ontario Hydro) is actively studying larger sites with a view to adding 2,000 mw of peak hydroelectric power by 1995.

After presentation of this background information regarding the expected magnitude of hydropower and means of regulating such development, we turned our attention to environmental consequences, more specifically, fisheries impact questions. Dennis O'Dea (New York State Electric and Gas Corporation) reviewed the elements, engineering and operations of hydro facilities. An overview paper on fishery impacts by William E. Knapp (U.S. Fish and Wildlife Service) contained several ecological advisements. Perhaps key among those was a cautionary note that with virtually thousands of small-scale hydro development actions to be dealt with over a relatively short term, it is imperative that mitigation actions taken at any single development site be viewed in the context as being but one action in the potential systematic development of the entire watershed. Several recurring concerns at hydro sites were identified by several of the first session's speakers. Specifically, water level fluctuation; fish passage, both upstream and downstream; turbine mortality; and water quality.

Detrimental effects of hydro on fish can be direct or indirect, such as the effect of turbine passage increasing susceptibility to predation, or by direct turbine mortality. Other impacts are cumulative, such as the losses due to fish passage over a series of hydropower obstructions; fish may survive a single obstruction, but multiple exposure can be lethal. Therefore, assessment by biologists must strive to assure continued conditions adequate for perpetuation of fishery resources, not only at a hydro site, but within entire watersheds. It was noted that mitigation strategies that fail to provide this continuum, are not apt to achieve desired management objectives.

Workshop objective number two sought to expose the participants to fishery impacts, and techniques for their assessment in a series of rotating working group sessions. Michael J. Sale (Oak Ridge National Laboratory) discussed water level regulation. James M. Loar (Oak Ridge National Laboratory) addressed downstream fish passage and Ted Vande Sande (California Fish and Game) covered upstream fish passage. Turbine mortality was addressed by Steven P. Gloss (N.Y. Cooperative Fishery Research Unit) and water quality was addressed by William Walker (Environmental Engineer). These individual overviews seemed to share a common thesis; we know relatively little about the impacts of small scale hydro, and more so, how to deal with the impact assessments. Considerable information exists for large, western projects, but that technology appears to be less than directly transferable to the peculiar problems of small-scale hydro development in the northeast. Several speakers in the rotating workshops noted that a commitment to purposeful research and development is vital if resource agencies and regulatory agencies are to develop adequate data bases for the decision making process to work effectively.

During the workshop it was clearly, and rather emphatically noted that the relationships between hydro development and fisheries conservation need not necessarily be antagonistic. Opportunities sometime exist for both hydro and fisheries to benefit from development. The third workshop objective and session addressed ways in which hydropower development provides opportunities for enhancement of fishery resources and their utilization. A common thesis of these presentations, as well as some previous papers was the need for carefully planned, coordinated input at the earliest stages of project formulation.

George J. Eicher (Eicher Associated, Inc.) pointed out that many existing dams, long abandoned by their builders, continue to create impenetrable barriers to anadromous as well as locally migrant fish communities. Improvements in upstream passage facilities during hydro development, therefore, constitutes a potentially valuable fishery management opportunity. Little value is gained by this process, however if the resulting juvenile down-stream migrants are unable to successfully pass the facility, or a series of facilities, without substantial injury. The safest turbines for passage of fish must be provided. Alternatively, the migrants may be collected in some fashion and moved around the turbines. These actions may constitute difficult financial burdens on proposed developments which are marginal economically. However, if the project is not feasible because of affording full protection to fishery resources, it probably should not be pursued.

Tailwaters have intensified fisheries opportunities and problems. Under conditions of adequate flow, temperature, and water quality, concentrations of fish (and as a consequence, fishermen) have become commonplace at tailwater locations. This concentration of users interest brings intense pressure to provide and maintain adequate physical and chemical conditions in these locations. According to William Swink (U.S. Fish and Wildlife Service), the factors that determine the success or failure of a tailwater trout fishery, though site specific, generally involve flow and temperature. Provision of tailwater flows for fisheries can create conflicts with hydropower operators, and with recreational and other uses of the impounded reservoir. Therefore, considerable care must be exercised in formulating integrated release requests, and studies to resolve inherent conflicts of competing water uses must continue.

Robert A. Anderson (N.Y. State Office of Parks and Recreation) noted that ponded waters and downstream releases are strong attractors for recreational uses of many types. The variable physical characteristics of hydro projects demand special considerations of these opportunities as well as recognition and dealing with associated hazards.

The final session's panel discussion (involving developers, consultants, regulators and fish and wildlife experts) of specific example projects, was most enlightening, and was perhaps the most valuable and interesting session of the workshop. The panel would not have been as informative without the preceding day's presentations on specific problems and potential solutions, however. The panelists were: James J. Case from the NYS Electric and Gas Corporation (Developer), John J. Sulaway of C. T. Main, Inc. (consultant), Dean L. Shumway from the FERC (regulator), Yvonne Weber form the U.S. Fish and Wildlife Service (fish and wildlife) and J. Douglas Sheppard from the NYS Department of Environmental Conservation (fish and wildlife).

As professionals, interested in environmentally sound development of our national resources, we (developers, regulators, and biologists) are all faced with an unprecedented challenge in this era of accelerated hydro development. One key element to our ultimate success or failure in this undertaking will be the establishment of dialogue among all interested parties. The workshop played an important role in that process and the Sport Fishing Institute compliments the New York Chapter of the AFS and the New York State Department of Environmental Conservation for their efforts in organizing this highly successful workshop.

CLOSING REMARKS

Dean E. Arnold 1/

It's a pleasure to be back at my Alma Mater to contribute in a very small way to such a well-organized activity of the Division. Before we close, I'd like to ackowledge and thank the New York Chapter of AFS, the New York DEC, and the workshop committee: Gerry Barnhart and Carl Widmer, Co-Chairmen; Les Wedge, Larry Skinner, Dave Smith, Doug Sheppard, Ray Tuttle, Joe Gorsuch, Jim Haynes, Steve Gloss, and Walt Keller.

Many speakers here gave us much valuable information. Yet I have the feeling that we have still not progressed very far beyond the basics of interactions between hydropower and fisheries. Most of us needed this sort of basic introduction. But I wonder if anyone really knows much beyond the basics except in a very site-specific way. Are there really generally-applicable designs, formulae, or rules for solving these problems? It came through very clearly here that both the problems and the opportunities for fisheries in connection with hydropower are very site-specific. Each project requires a well-thought-out set of adaptations of ideas from previous projects, often involving extensive experimentation and modification.

Therefore, I see our responsibilities as follows:

(1) to become and remain competent and current in our own specialities.

(2) to obtain basic information on the fisheries aspects of hydropower so that we can converse with other disciplines which are "in on" any given project or proposal. That's what we're doing here, in addition to making those personal contacts with others in the field which are so important in science and in resource management.

By doing these two things, we've gained credibility. This allows us to achieve two important goals:

(1) ensure that fisheries effects and opportunities are considered seriously and early in the development of any hydropower project.

(2) educate the public concerning the pros, cons, and likely results of any project and its alternatives. Many of us work for public agencies, and we find as a rule that if treated honestly and informed, the public supports us, regardless of the political situation.

Hydropower is coming back in the Northeast. It can be good--lets make sure it is.

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