Making Decisions About Nonpoint Source Pollution

POINT/NONPOINT SOURCE TRADING PROGRAM FOR DILLON RESERVOIR AND PLANNED EXTENSIONS FOR OTHER AREAS

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INTRODUCTION

The Clean Water Act was designed to protect the quality of the Nation's waters. Much progress has been made in water pollution control since its passage in 1972. Although the population and economic activity have grown markedly, water quality has improved throughout the United States (U.S. Environ. Prot. Agency, 1984).

What approaches might be used for remaining problems? Sophisticated controls have already been placed on most point sources. Further improving water quality will require either additional, incrementally more expensive point source controls, or an expansion of focus to include nonpoint sources. In many cases, point sources may already be controlled to the degree that it is more cost effective to control pollutants from nonpoint sources.

Nonpoint sources play a major role in our remaining water quality problems. Virtually all States have some water quality problems because of nonpoint sources, and half those States say nonpoint sources are the major or significant cause of degraded water quality (Elmore et al. 1984). Generally speaking, nonpoint sources are the largest remaining uncontrolled pollution problem. Controlling nonpoint source pollution from forestry, agriculture, mining, and urban runoff has been studied extensively. Now we need to implement that knowledge.

The basic approach taken by the Clean Water Act for managing point sources—application of uniform technological control to classes of dischargers—is not appropriate for managing nonpoint sources. In fact, the Act offers little incentive to manage nonpoint source pollution. The diversity of the nonpoint source problem makes national guidelines difficult. As EPA's recent report to Congress on nonpoint sources points out, flexible, site- and source-specific decisionmaking is the key to effectively controlling nonpoint sources (U.S. Environ. Prot. Agency, 1984b). This poses a challenging opportunity as State and local governments begin to address nonpoint source problems.

One innovative approach to encourage nonpoint source control is to tie nonpoint sources into the existing National Pollution Discharge Permit System (NPDES). This is a feature of a new program in Colorado that will clean up runoff and save local governments millions of dollars annually. The Dillon Reservoir Trading Project in Summit County grants wastewater treatment plants credit for cleaning up runoff (nonpoint source) pollution. This pollution trading program is the first of its type in the Nation.

This paper will describe the Dillon Reservoir Trading Program in detail, discuss ongoing analyses related to the Dillon concept, and evaluate Dillon's implications for other regions of the country.

DILLON RESERVOIR'S POINT/NONPOINT TRADING PROJECT

Problems of Nutrient Overload

Dillon is a 20-year old reservoir located in Summit County, Colorado. Constructed as Denver's primary West Slope

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water supply reservoir, Dillon quickly became a recreation center for fishing, camping, and boating. One of the reservoir's main attractions is its reputation for clear, deep blue water.

Summit County grew to be a popular, year-round recreation-oriented community upon the completion of several major ski areas. The area is one of the fastest growing counties in the Nation, with a permanent population of 10,000 and peaks exceeding 60,000 during winter (Northw. Colo. Counc. Gov. 1984a). This popularity may be Dillon's downfall. Its deep blue color changes to green as algae bloom in the summer, fed by phosphorus entering the lake from natural and manmade activities. If algae growth continues the lake will become eutrophic. Dillon would lack the oxygen necessary to support a high quality water recreation experience. A clean Dillon Reservoir is very important to Summit County's recreational economy and key to Denver's water supply.

Approximately half the phosphorus entering Dillon is from background runoff and direct precipitation to the Reservoir. These natural sources exist in the absence of any human population. Difficult or impossible to control with existing technology, natural sources would in themselves not cause the lake to become eutrophic (West. Environ. Anal. 1983).

The other half of Dillon's phosphorus load is from human activities. Significant sources include: point source discharges from municipal wastewater treatment facilities, runoff from parking lots, erosion from construction sites, seepage from septic systems, and other nonpoint sources (West. Environ. Anal. 1983). This half of Dillon's phosphorus load is controllable.

The four municipal waste dischargers to the reservoir have installed advanced treatment equipment to control for phosphorus (less than 0.2 mg/L discharge). The Dillon 1983 Clean Lakes Study found, however, that even if these dischargers were kept to zero by complex and expensive treatment methods, nonpoint sources of phosphorus from manmade activities would cause eutrophication (West. Environ. Anal. 1983). Control of manmade nonpoint sources was necessary to inhibit Dillon's eutrophication. The Colorado Water Quality Control Commission asked local agencies to develop plans for addressing the phosphorus problem in the Dillon Reservoir basin (Northw. Colo. Counc. Gov. 1984a). A moratorium on sewer taps—effectively a growth freeze—appeared imminent.

The 'Phosphorus Club'

The Northwest Colorado Council of Governments is the water quality planning agency for Summit County. The Council had assembled a group representative of the public and private sector to develop a phosphorus control strategy. Calling itself the "Phosphorus Club," the committee consisted of officials from the County, the six incorporated municipalities, two unincorporated urban areas, three ski areas, four municipal dischargers, the Denver Water Department, U.S. EPA, the Colorado Department of Health, and Amax, a major molybdenum mine (Northw. Colo. Counc. Gov. 1984b).

The Phosphorus Club members were wary of "hidden agendas" and of a strategy development process that could decrease any source's discharge allowance. Lower discharge allowances, for example, could limit a municipality's growth potential. Initial competitiveness was lessened by the decision that all committee conclusions had to be unanimous. While realizing that difficult compromises would probably be necessary, Phosphorus Club members also realized they had common goals: preservation of Dillon Reservoir and avoiding a tap moratorium. Early tensions dissipated as members saw they must cooperate to protect Dillon (Northw. Colo. Coun. Gov. 1984a). The committee realized a successful strategy would have to encourage the control of nonpoint sources.

The committee met weekly for 6 months to discuss sources of phosphorus in the basin, control options, administration, monitoring, and costs of different strategies. They soon focused on the point/nonpoint trading concept (Northw. Colo. Coun. Gov. 1984a). Under the strategy, point source dischargers receive credit for cleaning up existing nonpoint sources of phosphorus. This credit can be traded for increased phosphorus discharge from the wastewater treatment plant. Local governments must require state-of-the-art controls on growth areas. This accommodates growth with no overall increase in Dillon's phosphorus loadings. Equally important, the strategy affords a built in incentive to clean up the nonpoint sources and maintain Dillon's current, high level of water quality.

The first issue raised in developing the trading strategy concerned the target level of phosphorus loadings. The group decided that phosphorus in Dillon should be maintained at 1982 levels. The goal was viewed both as realistic and as maintaining the water quality level (Northw. Colo. Coun. Gov. 1984a).

A second issue was how to allocate the phosphorus load among municipal wastewater treatment plants. After much discussion, each plant was given a share of the available load based on its total flow for 1983. This provided an equivalent growth margin for each community through 1990 (Northw. Colo. Coun. Gov. 1984c).

The Colorado Department of Health was concerned about future nonpoint sources. If a Dillon nonpoint source control strategy allowed continued population growth, that growth in itself would create more nonpoint sources. The Phosphorus Club agreed that a successful point/nonpoint source trading program would require that old nonpoint sources be cleaned up and new ones minimized. To account for uncertainties in the system, a 2:1 tradeoff ratio was established. For each pound of credit assigned to a point source, 2 pounds of phosphorus must be removed from a nonpoint source that existed prior to 1984 (Colo. Water Qual. Control Comm. 1984).

Another issue was the long-term management of a point/nonpoint source control strategy. Local agencies were reluctant to create a new agency that might be costly to operate and possibly reduce local control of land use decisions. The Colorado Department of Health wanted a stable oversight agency for the trading program. The approach, accepted by the State, was a committee established by intergovernmental agreement among local agencies to manage the trading program on a day-to-day basis (Colo. Water Qual. Control Comm. 1984). The State would oversee activities and document all trades in a NPDES permit.

"HIGS" AND EPA ASSISTANCE

The Phosphorus Club believed that a demonstration project was necessary to test nonpoint source control aspects of the proposed trading system. A demonstration project provided data on both cost and effectiveness of technology for nonpoint source control. Low technology methods can remove phosphorus from runoff. Settling ponds can remove roughly half the phosphorus in urban runoff, while rapid sand filters can remove another quarter. Percolating runoff through unsaturated soil can remove virtually all the phosphorus. Settling ponds and percolating pits are much less expensive to construct and operate than wastewater treatment plants. They also demand much less energy and generate little sludge, in contrast to advanced treatment. The group believed that such controls might be a viable, low-cost alternative to new high technology controls on point sources. In the spring of 1982, the Council of Governments applied for U.S. EPA funds for a pilot facility. EPA became interested in Dillon's point/nonpoint trading strategy, and agreed to provide partial analytical support and funding for the demonstration project.

Low technology nonpoint source controls were tested at Frisco, Colorado. Urban runoff from a 32-ha (81-acre) watershed was collected in a stilling basin that overflowed into a settling pond (called a hole-in-ground treatment system, or "HIG"). The sand and rock in the HIG were separated by a geotextile erosion control fabric that lined the device entirely. In eight runoff events, settling removed 45 percent of incoming phosphorus. Filtration raised the total removal to 68 percent. The Council believes using a soil treatment matrix would raise removal efficiency to virtually 100 percent (Northw. Colo. Coun. Gov. 1984a).

EPA and the Phosphorus Club were very interested in the relative costs of point versus the HIG nonpoint source control device. The pilot system cost $4,200 to build, with land and much of the labor donated by local groups. When land and excavation costs are added, a more practical cost estimate would be $50,000. This initial cost could be lower if public land is used for the control device. The 2-year pilot project indicated the pond will need to be drained and cleaned at least every 5 years. The sand and filter fabric will need to be replaced annually. The expected annual labor and materials cost is $980 (Northw. Colo. Coun. Gov. 1984a).

EPA commissioned an economic study comparing the cost of low technology nonpoint source controls with the advanced treatment alternative (higher levels of control) for municipal wastewater plants. The study found substantial cost savings with HIGs, up to 88 percent cheaper than upgrading existing point source controls (IEC, 1984).

The Dillon Management Plan

The Phosphorus Club now had (1) a cost-effective and environmentally sound nonpoint source control technology, and (2) the outline of a point/nonpoint trading system to encourage its use and that of other nonpoint source controls. Realizing that Dillon's water quality relies on the long-term management of phosphorus, the group designed a detailed control strategy. The key element in the trading strategy is immediate control of future nonpoint sources in growth areas. As future nonpoint source loadings are minimized, older nonpoint sources will be controlled, allowing for point source growth in the future. In this manner, nonpoint controls will be traded for point sources growth (Table 2). As mentioned, these reductions in nonpoint sources can be achieved relatively inexpensively. The control strategy has six major elements:

1. 1982 levels of phosphorus in the reservoir are the baseline for water quality.
2. Point sources will continue to receive advance wastewater treatment and will meet individual annual phosphorus totals.
3. State-of-the-art nonpoint source controls will be required by local governments for all new developments. No credits will be granted for these controls. New developments must also contribute to an NPS Control Facilities Investment Fund. The fund will be used by the Summit Water Quality Committee, established by the Phosphorus Club, to construct controls for pre-1984 nonpoint sources of phosphorus and oversee the entire Dillon Nonpoint Management Plan.
4. Point source growth beyond 1990 will be accommodated by reducing nonpoint sources that existed prior to 1984. The management plan encourages cleaning up old sources and minimizing new sources.
5. The Summit Water Quality Committee will monitor the success of the control program and manage phosphorus trading between point and nonpoint sources. The trading ratio will be 2:1. This committee provides for long-term management of the control program, while continuing strong local input in decisionmaking.
6. The Water Quality Control Commission has authorized effluent trading and will use their NPDES program for enforcement where necessary. The Water Quality Control Division, the operating arm of the Commission, documents a trade in a revised (NPDES) permit after the nonpoint source control device's effectiveness is determined and the 2:1 ratio has been applied. A *specific discharger* is given the phosphorus credit and responsibility for maintaining the nonpoint source control device. Failure to operate and maintain these controls results in enforcement action for an NPDES violation (Northw. Colo. Coun. Gov. 1984b).

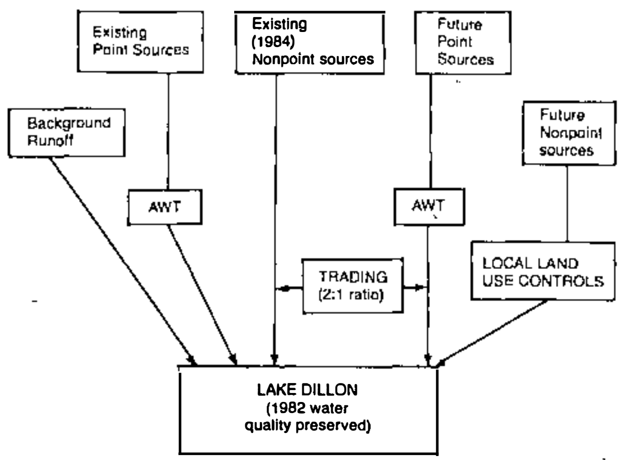
The Dillon Water Quality Management Plan relies on a Federal/State/local regulatory partnership. Local land use authorities hold future runoff sources to an acceptable level by requiring erosion and runoff controls and streamside setbacks. The State water quality agency uses the NPDES to ensure that the lake receives long-term protection. The NPDES permit revisions assign phosphorus "credit" and nonpoint operation and maintenance responsibilities. The Summit Water Quality Committee, formed by intergovernmental agreement, runs the trading program on a daily basis.

Public hearings on Dillon's proposed trading plan were held by the State of Colorado in May 1984. The State formally approved the plan in June; EPA Region VIII approved it in July. With that approval, Dillon Reservoir became the first approved point/nonpoint source trading system in the United States (Colo. Water Qual. Control Comm. 1984).

Table 1.—Point and nonpoint controls for phosphorus removal.

	Annual Cost Typical Plant $	Phosphorus Removal Efficiency %	Annual Cost Per Pound Phosphorus $
Land treatment	451,000	100	824
Activated alumina	353,000	75	860
Reverse osmosis	3,871,000	90	7,861
Pilot project "HIG"	8,708	68	67

Table 2.—The Dillon management strategy.



NATIONAL APPLICATIONS OF DILLON

Dillon Reservoir showed that point/nonpoint source trading can be a cost-effective means of pollution abatement for lakes and impoundments. Trading provides an economic incentive for local communities to control new and existing sources of nonpoint pollution, where no controls formally exist under the Clean Water Act. As in the case of Dillon, *trading can achieve water quality standards when even zero point source discharge cannot.*

Several circumstances at Dillon Reservoir helped make the demonstration project successful.

1. All parties had common goals: preserving Dillon Reservoir and avoiding a tap moratorium. If degradation continued, economic growth would slow because of fewer recreational opportunities. Drinking water quality would drop. An unambiguous goal—1982 levels of phosphorus—was readily decided upon.

2. All point sources were already at advanced treatment levels. No inexpensive conventional control approaches were available. Studies indicated that additional equipment leading to zero point source discharge would slow but not halt eutrophication. Nonpoint sources had to be controlled to maintain water quality.

3. Stakeholders had continuing input into the design and operation of the demonstration project. The State, county, municipalities, and local industries were all represented in the Phosphorus Club.

4. Water quality data and projections were available to highlight implications of various control strategies. Types and magnitude of phosphorus sources were well understood throughout the demonstration project's design and implementation. The 1983 Clean Lakes Study found that both point and nonpoint sources must be included in a strategy to protect Dillon Reservoir.

5. The Phosphorus Club designed a trading system which outlined clear liability for maintaining controls. Ambiguous responsibilities could have had a disastrous effect on Dillon's water quality.

6. The system relies on good communication and cooperation between Federal, State and local agencies. Different aspects of the trading system are overseen by the agency with the most appropriate regulatory authority. Because each level of government was involved in the development stage, no unexpected objections arose during implementation and formal adoption.

Dillon has fostered thinking on the wide application of trading, given the phasing out of the Construction Grants Program and the increasing recognition of nonpoint source pollution. Control of pollution discharges to advanced treatment levels will be required on many stream segments to achieve water quality goals. However, advanced treatment requirements can be achieved in a number of different ways.

An enforceable trading arrangement could result in a cheaper and more stringent control system than using advanced treatment technology on a point source discharger. First, through trading ratios, nonpoint source BMP's can remove more pollution from the environment than the additional amount a point source might discharge. Second, the enforcement agency could require that credit not be given for planned or existing BMP's—resulting in more cost-effective control than by traditional means. Third, the municipality would be required to lease or buy the land on which the BMP is located, and to construct, operate, and maintain that BMP at no cost to the landowner.

Can this trading approach be applied to other locations, or is Dillon unique? The quality of virtually all lakes is controlled by a delicate balance of nutrients such as phosphorus. Many coastal rivers and bays are also affected by phosphorus pollution. Trading may present a cost-effective pollution control option for all such waterbodies and is currently being considered by several localities for lakes and reservoirs with problems similar to Dillon's.

While trading shows tremendous promise, Dillon left several questions unanswered. For example, EPA is exploring whether or not trading will work on other waterbodies—free flowing streams or estuaries—or for other types of nonpoint sources such as agriculture. Can the regulatory, enforcement, and institutional framework developed at Dillon be adapted to other locations? Dillon is an epitome of Federal/State/local cooperation. When goals are less well defined, can local groups reach consensus on desired means and ends? Will other types of nonpoint source BMP's prove to be as cost effective as those at Dillon?

The Office of Policy, Planning, and Evaluation (OPPE) at EPA Headquarters, in cooperation with EPA's Office of Water, Region III, the Chesapeake Bay Program, and the States of Maryland, Virginia, and Pennsylvania, is examining the application of a "Dillon type" point/nonpoint approach to the Chesapeake Bay. The Bay has a major nonpoint source problem resulting from agricultural activity in its stream drainages. Analysis should be completed by late summer 1985.

OPPE is also providing technical assistance to several State/local governments interested in using trading to solve current or future water quality problems caused by both point and nonpoint sources. OPPE is exploring, particularly with respect to agricultural nonpoint sources, the legal and institutional implications of a point source constructing, operating and maintaining BMP's at no cost to the contributing source to take credit for pollutants controlled in the NPDES permit. This approach would be useful, for example, to a POTW with secondary treatment facing an upgrade to higher levels of treatment where nonpoint source is a major, controllable contributor to water quality problems.

In conclusion, point/nonpoint source trading appears to offer a cost-effective approach to controlling nonpoint sources. Many questions remain after the successful implementation of point/nonpoint trading at Dillon Reservoir. However, trading and other innovative approaches are receiving increasing attention from States who view nonpoint source as a significant yet uncontrolled problem.

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OPTIMIZING POINT/NONPOINT SOURCE TRADEOFF IN THE HOLSTON RIVER NEAR KINGSPORT, TENNESSEE

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INTRODUCTION

The Office of Policy, Planning, and Evaluation of the U.S. Environmental Protection Agency is studying a variety of innovative approaches for controlling water pollution from point and nonpoint sources. Among them is the trading of effluent loads of water pollutants. This approach differs from current EPA water policy in that the State or regional authority responsible for issuing discharge permits for pollutants under the Clean Water Act may modify those limits if two or more dischargers propose a reallocation, or a trade. The reallocation allows dischargers with lower treatment costs to control more pollution and those with higher costs to control less. Thus, the dischargers comply with the same total load limit and achieve in-stream water quality standards at a total lower cost.

Three types of trading are possible: within a plant with multiple outfalls, between or among plants located on the same stream, and between point and nonpoint sources. This regulatory approach is similar to the "multifacility bubble concept" adopted by EPA's air program. However, it differs from that concept in that technology-based permit limits, required under the Clean Water Act, continue to apply to individual outfalls, rather than to the outfalls as a group.

Since the passage of the Federal Water Pollution Control Act of 1972 (P.L. 500), as amended, dischargers of waste waters along the Holston River near Kingsport, Tennessee, have invested heavily in facilities to treat their wastes; but portions of the stream remain designated as "water quality limited." This term generally indicates the likelihood for increasingly stringent waste treatment controls and restrictions on the construction of new and expansion of existing facilities.

For this reason, EPA's Office of Policy, Planning and Evaluation and the Tennessee Valley Authority's Office of Natural Resources and Economic Development initiated this study of trading among point and nonpoint sources of pollution along a 32-km (20-mile) reach of the Holston River. Local dischargers and the Division of Water Management of the State of Tennessee cooperated. The major dischargers in the study area are four point sources—Tennessee Eastman Co., Mead Paper Co., Kingsport's publicly-owned treatment works, and the Holston Army Ammunition Plant—and one nonpoint source—Fort Patrick Henry Dam.

We selected dissolved oxygen (DO) as the variable of interest and examined several means to enhance DO in the river: further restrictions of the discharges of oxygen-demanding wastes (for example, five day Biochemical Oxygen Demand (BOD)), varying flow regimes, injecting air into the stream, and trading between point and nonpoint sources. With these various treatments available, the study evolved into a question of cost-effectiveness: For a given stretch of waterway with specified upstream and downstream boundaries, what mix of point and nonpoint sources and sinks of oxygen will achieve desired DO concentrations at key times and places at the lowest total annual (incremental) cost?

METHODOLOGY

The study's methodology can be divided into two major parts: selecting the study area and simulating treatments for increasing DO concentrations in the river.

Selecting the Study Area

In selecting the study area, we used the following criteria:

- The site must have been designated as a water quality limited stream;
- All point source dischargers must be in compliance with effluent limitations set forth in their permits;
- Baseline information must be available for both point and nonpoint sources in the study area; and
- Future economic growth and development are or have the potential of being adversely affected by poor water quality.

The 32-km reach of the Holston River met these criteria. The study area extended from South Fork Holston River, RM+8 (upstream) to Holston River, RM−12 (downstream). Industrial and municipal discharges enter the Holston and South Fork Holston Rivers as shown in Figure 1. This stream reach is subject to flow regulation by Fort Patrick Henry Dam near RM+8. Downstream from three

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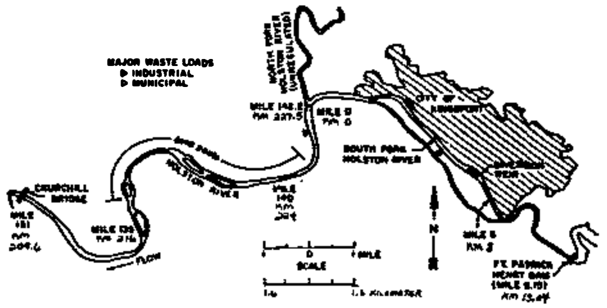

Figure 1.—Location map.

of the major point sources, the South Fork Holston River is joined by the smaller, unregulated North Fork Holston River (RM0). Previous investigations have shown that a DO sag develops under certain late summer low-flow conditions in the reach 4.8–11.2 km (3–7 miles) downstream of the confluence of the two rivers. Definite DO recovery is evident at the downstream end of the study reach (RM – 12).

Simulating Treatments

Setting Water Quality Goals

The Division of Water Management of the Tennessee Department of Health and Environment (1982) sets forth the following criteria for DO concentrations:

> Dissolved Oxygen—The dissolved oxygen shall be a minimum of 5.0 mg/L except in limited sections of streams where it can be clearly demonstrated that (i) the existing quality of the water due to irretrievable man-induced conditions cannot be restored to the desired minimum of 5.0 mg/L dissolved oxygen; (ii) the cost for application of effluent limitations more stringent than those defined through Section 301(b) of the Federal Water Pollution Control Act (P.L. 92-500) is economically prohibitive when compared with the benefits to be obtained; or (iii) the natural qualities of water are less than the desired minimum of 5.0 mg/L. Such exceptions shall be determined on an individual basis but in no instance shall the dissolved oxygen concentration be less than 3.0 mg/L. . . . The dissolved oxygen concentration of recognized trout stream shall not be less than 6.0 mg/L. . . .

The Division has generally interpreted the 5.0 mg/L value as a monthly average, and does not offer guidance on how to average the 3.0 mg/L value.

Faced with a range of DO values, we generalized the problem by computing the most cost-effective methods (or combination of methods) to meet DO values of 3, 4, 5, and 6 mg/L for various points in the river, to achieve:

1. The minimum 6-hr running average of DO concentration in the sags downstream of RM–3;
2. The daily average of DO concentration in the sags downstream of RM–3;
3. The minimum 6-hr running average of DO concentration from RM + 8 to RM – 12 (the whole 32-km reach); and
4. The daily average of DO concentration from RM + 8 to RM – 12 (the whole 32-km stretch).

Selecting Technologies

Through model simulation, the study considered a number of treatments:

- Seven traditional treatments that would further restrict the discharge of oxygen-demanding wastes, thereby reducing sinks of DO;
- Eight innovative treatments that would add oxygen or flow to the stream, thereby creating sources of DO; and
- Eight combinations of these traditional and innovative treatments.

Establishing an Analytical Sequence

We identified and analyzed the cost-effective combinations of traditional and innovative treatments using the following sequence:

- We specified one scenario for computer simulation by enumerating the various inputs.
- We used the water quality model to simulate (1) the daily average DO concentration profile and (2) the minimum of the 6-hr running average DO profile for the entire 32-km study area.
- We computed the total incremental annual cost for the methods in place for this particular scenario.
- For each particular scenario with its given set of treatments, we used the profiles of the DO concentration and the cost calculation to develop a cost-effectiveness plot. Each plotted point represents the results of one complete simulation (72 hrs) and one cost calculation.

Developing the Modeling Approach

DO concentrations were predicted using a state-of-the-art unsteady mathematical model calibrated with field data and process rates from two earlier field surveys. The modeling system consists of an unsteady flow model and a mass transport water quality model (Hauser and Ruane, 1984). The flow model provided flows, velocities, and depths at short time intervals for the water quality model. The water quality model predicted temperature, carbonaceous and nitrogenous biochemical oxygen demands (CBOD and NBOD, respectively). DO concentrations were also simulated over time to denote diurnal variations. Modeled sources and sinks of DO include upstream and lateral inflow sources, natural reaeration, macrophyte photosynthesis and respiration, CBOD, NBOD, and residual sediment oxygen demand (SOD).

Improvement strategies were explored by comparing the predicted movement in DO regime to a base that corresponded to the release of current permitted waste loads to the stream during critical low-flow conditions. Critical low-flow (base case) on the South Fork Holston River is a daily average of 750 cfs, provided by pulsing Fort Patrick Henry Dam under contractual agreement with one of the industries downstream.

Simulating DO Sinks. The relative influence of each DO sink in the calibrated model is shown in Figure 2. In a series of simulations, each DO sink was removed sequentially from the base case (lower line in each plot) until DO saturation levels were approached. The simulations were of several days' duration and included diurnal variations in DO.

In Figure 2, results of the base case simulation are shown as the lower curve in each plot. Release DO from the Dam (RM + 8) was assumed to be 3.0 mg/L. Moving downstream, the predicted daily average DO in the base case reaerated to around 4.5 mg/L at the diversion weir, RM – 4.5. The small dip in the predicted DO at this location was due to Tennessee Eastman Co.'s withdrawal of cooling water from a diversion weir pool. Below the pool, this withdrawal reduced the amount of water, and the flow volume reached nearly zero when the Fort Patrick Henry turbines were off, creating nearly stagnant conditions between the point of withdrawal and the point of return. The model predicted a significant drop in saturation DO just below the weir, because the industrial cooling water was returned at a temperature elevated approximately 10°C.

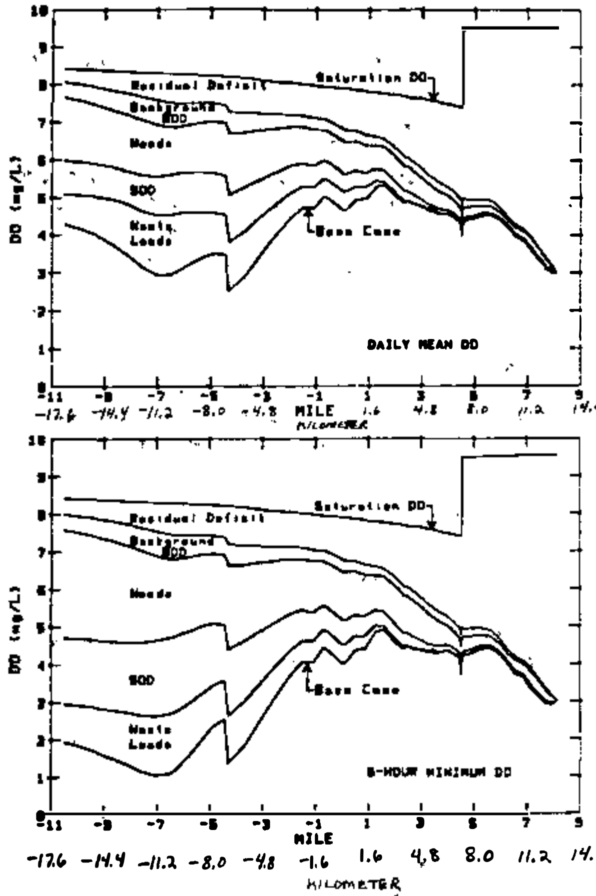

Figure 2.—Relative influence of DO sinks.

Downstream, another pool beginning at RM – 1.0 and extending to a shoals section at RM – 4.3 contributed greatly to DO depletion because of the assumed high SOD and longer residence time. At the shoals section at RM – 4.3, a third important pool begins. The model predicted about a 1 mg/L recovery across the shoals due to natural reaeration, a value insensitive to the exact form of the reaeration equation assumed. In the base case, a predicted DO minimum of 2.5 mg/L (daily mean) occurred at RM – 4.3, and a predicted DO minimum (minimum of 6-hr running average) of 1 mg/L occurred at RM – 7.0.

DO sinks were removed in the following order: waste load, SOD, photosynthesis and respiration of macrophytes, and background CBOD and NBOD. A deficit remained because cumulative reaeration was insufficient at this location to bring the large upstream deficit to saturation. Under critical base case conditions, approximately 30 percent of the deficit in daily mean DO at the predicted sag was from SOD, and about 25 percent from background CBOD and NBOD and the residual deficit. Aquatic weeds played a greater role in the 6-hr minimum DO because each night they use oxygen with no compensating oxygen-producing photosynthesis, thereby creating an early morning minimum. For base case conditions, approximately 30 percent of the predicted deficit in the 6-hr minimum DO was from the weeds, 25 percent from SOD, 25 percent from waste loads, and 20 percent from background CBOD and NBOD and the residual deficit.

Simulating Waste Loads. All municipal and industrial effluent loadings are within current permit limitations. These permits allow a monthly average load and a maximum daily load. Although the maximum daily permit level represents the heaviest loading, it was considered extremely improbable that all dischargers would be at maximum day permit levels simultaneously. We decided it was more plausible to simulate one of the larger dischargers at maximum day permit load and all others at monthly average permit loads. Wasteload permit and average wasteloads are shown in Table 1. Although Tennessee Eastman Co. currently holds the highest maximum day permit load, its actual discharges seldom reach the monthly average permit load. Mead holds the second largest permit and has an effluent that more frequently approaches its maximum day permit load. The loading scenario used for the base case, therefore, was Mead at maximum day permit load and all other dischargers at their monthly average permit load.

NBOD loads were assumed to be 598 kg/day (1,328 lb/day), 269 kg/day (598 lb/day), and 195 kg/day (433 lb/day) from Tennessee Eastman, Mead, and the Holston Army Ammunition Plant, respectively. NBOD from the treatment works was not included because of the lack of data, and

Table 1.—Industrial and municipal BOD discharges in the study area.

(lbs/day)	TEC	MEAD	KPOTW	HAAP		TOTAL
SFHRM	3.5	2.35	2.3	141.6		
HRM						
Permitted (current)						
Maximum day (May–Sept.)	8,500	6,000[1]	4,670	1,620		20,790
Monthly average (May–Sept.)	4,000[1]	3,500	2,335[1]	810[1]		10,645
Maximum day (Oct.–April)	13,000	7,200	4,670	2,430		27,300
Monthly average (Oct.–April)	6,000	4,800	2,335	1,215		14,350
Actual (current)						
Monthly average (May–Sept.)	1,540	2,900	600	220		
SFHRM	4.5	2.35	2.3	4.0		
HRM					139.1	
Actual (past)						
July 1969 survey average	69,300	11,700	500	23,480	32,220	137,200
July 1977 survey average	2,330	3,920	1,160	270	3,530	11,210

[1]Base case loadings (total loading = 13,145 lb/day).

SFHRM = South Fork Holston River mile
HRM = Holston River mile
TEC = Tennesse Eastman Co.
MEAD = Mead Paper Co.
KPOTW = City of Kingsport Publicly-Owned Treatment Works
HAAP = Holston Army Ammunition Plant

we thought its effect on DO was insignificant. Critical DO conditions would be expected to occur during late summer when DO at the Dam was 3.0 mg/L, flow was 800 cfs, and water temperature was 30.5°C downstream of TEC discharge. Seasonal permit loads for May–September were therefore selected for the base case.

Calculating Costs

To calculate the incremental annual costs, we worked with each participant to identify possible methods by performance, technology, and economic life (in years) (Indus. Econ., 1984). With the exception of the city of Kingsport, for which we made a separate calculation, each of the participants submitted the incremental costs of each option—in 1983 dollars—disaggregated into three cost components (as applicable):

- Capital costs: one-time (before tax) cost to design, purchase, and install the equipment;
- Operation and maintenance costs: the recurring (annual) costs for routine maintenance;
- Power costs resulting from changes in release pattern: the recurring annual difference in costs between current operation and possible future operation at the dam, using on peak and off peak (replacement) prices for a kilowatt hour of electricity.

SIMULATION RESULTS

From the individual simulation results, we were able to identify opportunities for cost-effective treatments.

Individual Simulations

We conducted the analysis in four steps. First, we developed a base case that depicted 1983 conditions in the 32-km reach. Second, we assessed the opportunity for cost-effective interplant trading among the four industrial and municipal dischargers. Third, we assessed the cost-effectiveness of three sets of innovative treatments that added oxygen or flow: aeration at the dam, changes in the schedule of releases from the dam, and in-stream aeration near the confluence of the South Fork and North Fork Holston River. Lastly, we assessed the cost effectiveness of the different combinations of the traditional and innovative methods.

Base Case

To assess changes in DO concentrations, we simulated the DO profile for five scenarios: maximum permit day—when all four plants discharged their permitted values for maximum day BOD simultaneously; typical permit day—when all four plants discharged the amounts of BOD as listed on their permits for average day; average permit day—when three plants discharged the amounts of BOD as listed on their permits for average day and one plant discharged the amount equal to its maximum day; average actual day—when all four plants discharged the amounts of BOD that are the actual average of their long-term discharge; and zero discharge—when all four plants totally eliminated their discharge of BOD.

As the base case, the typical permit day scenario best represents a typical day of BOD loads. Figure 3 shows the calculated profiles for daily average DO and the minimum

Table 2.—Traditional treatment options.

Discharger	Economic Life (yrs)	Capital Costs	O & M Costs	Annual Costs	Hypothetical Permit Value for BOD (lbs/day)
		(thousands of $)			
Tennessee Eastman[1]	20	30,000	24,000	27,203	1,500
Mead Paper[2]	25	12,000	2,500	3,702	3,600
Holston Army Ammunition Plant[3]	(25)	0	0	0	0
City of Kingsport Sewage Treatment Plant[4]	20	1,662	263	440	600

[1]Treatment technology is the company's confidential information and hence not listed here.
[2]New activated sludge treatment plant and sludge handling system.
[3]Total recycle at no extra cost.
[4]Mix-media filter.

Table 3.—Scenarios with innovative methods.

Methods	Economic Life (yrs)	Capital costs	O & M costs	Replacement power costs	Annual costs
			(thousands of $)		
Aeration at Fort Patrick Henry Dam[1]					
1. Low option	25	187	18	0	37
2. Medium option	25	382	73	0	111
3. High option	25	662	199	0	265
Increased flow at Fort Patrick Henry Dam[2]					
4. Low option	25	0	0	49	49
5. Medium option	25	0	0	129	129
6. High option	25	0	0	233	233
In-stream aerators[3]					
7. Single	25	350	59	0	94
8. Double	25	700	142	0	212

[1]Install pumps and diffusers to release pure oxygen in the reservoir just above the turbine intake to achieve DO in the tail waters of 4.0 mg/L at low option, 5.0 mg/L at medium option, and 6.0 mg/L at high option.
[2]Modify the operation of the Dam to release extra pulses so that more than 750 cfs of water flows on critical days: low option–875 cfs flow; medium option—1,000 cfs flow; high option—1,125 cfs flow.
[3]Install one or two aerators, each capable of delivering 16,000 lbs/day of DO, via supersaturating side-stream diffusers: single–operate 15 days/yr; double–operate 128 days/yr.

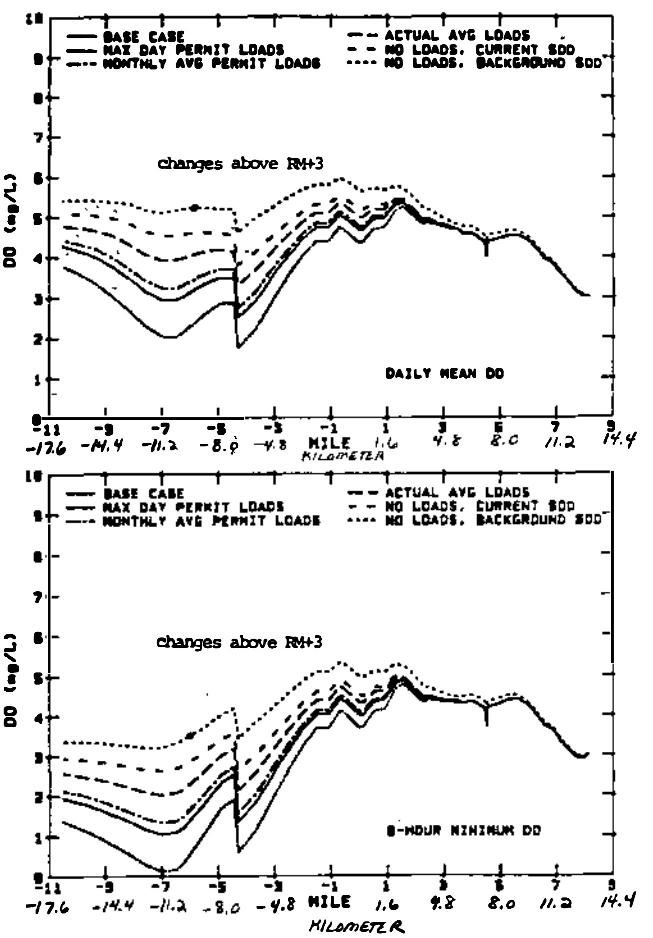

Figure 3.—Calculations for the base case.

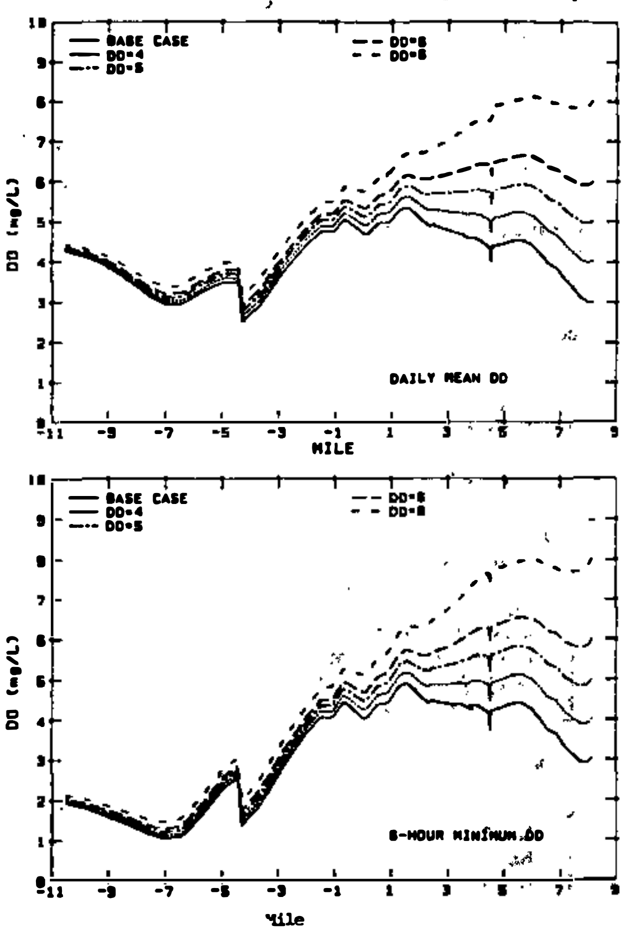

Figure 4.—Aerating Fort Patrick Henry releases.

of the 6-hr running average DO. For the base case, the lowest daily average value for the whole 32-km reach is 2.6 mg/L, and the lowest 6-h minimum is 1 mg/L.

Traditional Treatments

We estimated the annual cost for incremental treatment based on the information that each discharger provided and assumed hypothetical permit values for BOD for each discharger (Table 2). From the base case scenario, we used these suggested treatments to compose seven scenarios. Of these new scenarios, the first four correspond to the base case loadings of BOD except that the suggested treatment is turned ON one at a time for each of the four dischargers. The fifth scenario, called ALL ON, corresponds to having all treatments turned ON simultaneously

The last two scenarios, called Trading No. 1 and Trading No. 2, have almost identical BOD but very different annual costs. In Trading No. 1, Tennessee Eastman is OFF, and the other three are ON. This scenario has a total BOD load of 3,690 kg/day (8,200 lbs/day) and an annual cost of approximately $4.1 million/yr. In Trading No. 2, Mead is OFF, and the other three are ON. This scenario has a total BOD load of 3,685 kg/day (8,100 lb/day) and an annual cost of approximately $27.6 million/yr.

For each of these seven scenarios, the predicted DO profiles are slightly better than the base case profiles below the confluence but not changed above RM + 3. The results summarized in Table 5 show that further restrictions on the four dischargers create modest water quality improvements at high costs because the dischargers have already installed equipment that removes over 90 percent of BOD in the raw wastewater. These treatments affect the DO profile below the outfalls; they produce no change above RM + 3.

Innovative Methods

Based on the information that TVA provided, we estimated the annual cost and performance of three innovative methods to improve DO in the river: aeration at the dam, increased flows from the dam by the release of extra pulses of water, and in-stream aeration near the confluence. All of these innovative methods cost less annually than the traditional treatments.

We used these suggested innovations to compose the eight scenarios shown in Table 3. Quite simply, each new scenario consists of the base case conditions, with each innovation turned ON one at a time to simulate the response in water quality. These results are summarized in Table 5. The model shows that aeration at the Dam improves water quality near the Dam but has little lasting effect below the Dam (Fig. 4). Increasing flow at the Dam creates little DO improvement immediately below the Dam but substantial improvement below the confluence (Fig. 5). We found that in-stream aeration can simply increase the DO concentrations, but that these concentrations attenuate rapidly downstream (Fig. 6).

We considered several options for augmenting flow, including increasing pulsing frequency to once every 3rd hour, adding flow to the current 4th–hour pulses, and adding pulses between the usual 4th–hour pulses. The model predicted that adding the first 125 cfs resulted in approximately 1 mg/L DO improvement, with diminishing improvement for the additional flow increments. Subsequent to this modeling effort, a field study verified the suspected DO improvement from flow augmentation. Because the

Table 5.—Summary statistics

Treatment options	Below the confluence: Minimum 6-hr average DO	Below the confluence: Minimum daily average DO	Whole 20-mile reach: Minimum 6-hr average DO	Whole 20-mile reach: Minimum daily average DO	Annual cost
	mg/L	*mg/L*	*mg/L*	*mg/L*	*($ thousands)*
Base case	1.0	2.6	1.0	2.6	—
Traditional treatments					
A. Tennessee Eastman	1.3	2.8	1.3	2.8	27,203
B. Mead Paper	1.3	2.8	1.3	2.8	3,702
C. Holston Army	1.2	2.6	1.2	2.6	0
D. Kingsport	1.3	2.7	1.3	2.7	440
E. All	1.9	3.3	1.9	3.0	31,345
F. Trading No. 1	1.6	3.0	1.6	3.0	4,142
G. Trading No. 2	1.7	3.1	1.7	3.0	27,643
Innovative methods					
H. Dam—low aeration	1.2	2.7	1.2	2.7	37
I. Dam—medium aeration	1.3	2.8	1.3	2.8	11
J. Dam—high aeration	1.4	2.9	1.4	2.9	265
K. Dam—low augmentation	2.0	3.6	2.0	3.0	49
L. Dam—medium augmentation	2.8	4.3	2.8	3.0	129
M. Dam—high augmentation	3.3	4.6	3.0	3.0	223
N. In-stream—single	1.9	3.6	1.9	3.0	94
O. In-stream—double	2.0	4.6	2.0	3.0	212
Combinations					
P. No. 1	2.3	3.9	2.3	3.9	98
Q. No. 2	3.0	4.6	3.0	4.6	178
R. No. 3	2.4	4.3	2.4	4.3	133
S. No. 4	3.3	4.9	3.3	4.9	213
T. No. 5	3.3	4.4	3.0	3.0	148
U. No. 6	3.2	4.7	3.2	4.7	178
V. No. 7	3.6	5.1	3.6	5.1	282
W. No. 8	4.0	5.4	4.0	5.4	268

field results did not support the initial model results, we consider conclusions on flow augmentation as tentative pending further investigations and modeling.

We simulated the effect of adding oxygen at a rate of 7,200 kg/day (16,000 lb/day) for a 12-hour period (not 3,600 kg/day (8,000 lb/day)) at locations upstream of the predicted sag. The model predicted that the DO improvement from instream aeration rapidly diminished downstream from the aeration source.

Combination of Methods

Each of the innovative methods has either (or both) relatively lower cost or higher performance than the traditional methods; but because no single innovative method performs well at both the upstream and downstream ends of the 32-km segment, we explored various combinations of both the traditional and innovative methods. We composed eight scenarios based on low cost and methods that complement each other. While we make no claim that these scenarios will be ultimately optimal, they show promise in and of themselves; and combinations of innovative methods are much more attractive than traditional methods.

Table 4 shows cost components and estimated annual cost for each combination. Combinations No. 1 through No. 4 improve DO both above and below the confluence because the methods complement each other: aeration improves DO above the confluence and flow augmentation improves DO below the confluence. Combination No. 5 leaves DO concentration essentially unchanged from the base case above the confluence but substantially improves DO concentration below the confluence. The promise of the complementary innovative methods, Combinations No. 6, No. 7, and No. 8, is shown in Table 5. For example, Combination No. 8 achieves a daily average DO concentration of more than 5 mg/L everywhere along the 32-km reach. We generally conclude that complementary combinations of innovative methods can achieve desirable DO concentrations in the stream not reached by traditional methods or by single innovative methods.

Water temperature plays a significant role in modeling stream water quality for two reasons. First, the driving force for aeration is the DO deficit below saturation, and saturation DO decreases with an increase in temperature. Second, the rates of important DO sinks and sources, such as DO demands from stabilization of organic wastes or weed respiration and natural reaeration, increase with an increase in temperature. Because removal of heat load implies the use of cooling towers and in TVA's experience, cooling towers are not a cost-effective alternative, we have not simulated heat removal in this study.

Opportunities for Cost-Effective Innovations

In Table 5 we summarize the results of the analyses conducted for the base case; for the seven traditional scenarios labeled A through G, the eight single innovations labeled H through O, and the eight combination scenarios labeled P through W. Given annual costs and a measure for water quality—the minimum 6-hr average and the daily average DO concentrations both below the confluence and for the entire 32-km stretch, we can find the most cost effective way to reach the chosen concentration of DO. For example, the cheapest option for achieving minimum daily average DO concentration of 3 mg/L for the whole 32 km is innovative method K. Similarly to achieve a daily average DO concentration of 5 mg/L or better for the 32

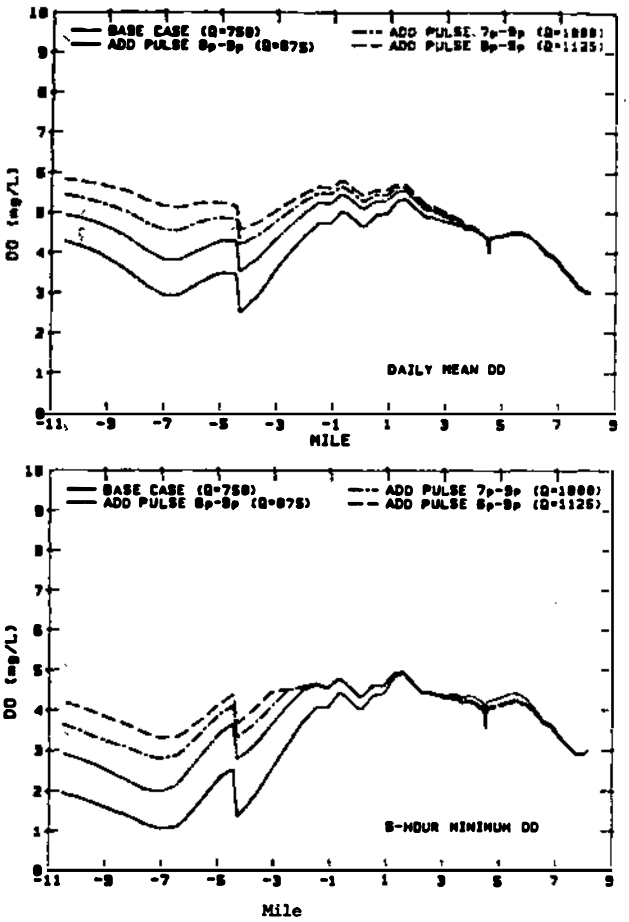

Figure 5.—Flow augmentation with additional evening pulses.

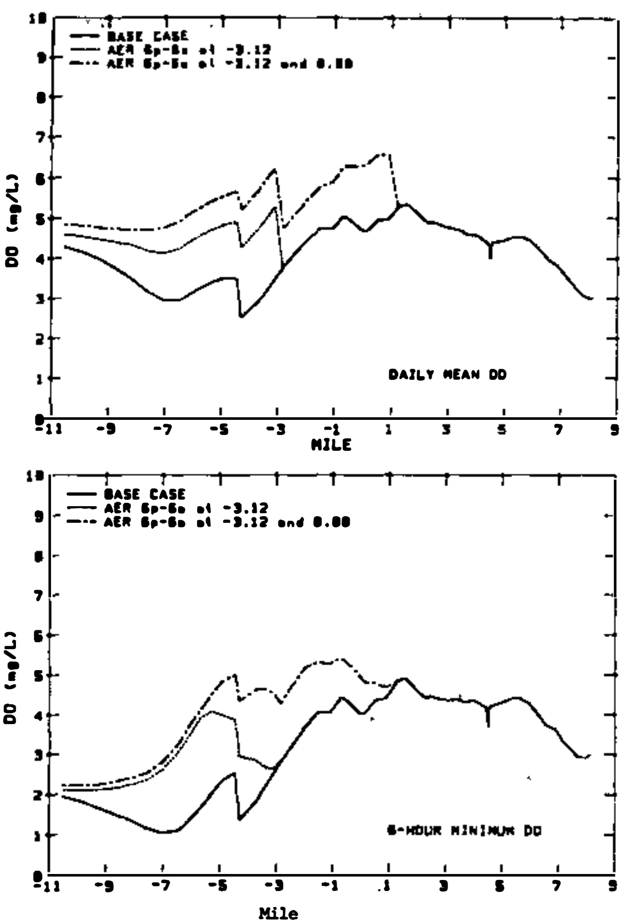

Figure 6.—In-stream aeration.

km, we find that Combination No. 8 costs the least. No other methods that we evaluated could achieve this DO concentration.

To examine more closely various combinations of innovative methods, we have plotted points P through W: concentrations of DO on the X-axis and annual costs on the Y-axis. For daily average of DO concentration throughout the 32-km reach, Figure 7 shows that the estimated costs rise steeply as an increasing function of DO concentrations. A point lying wholly to the right of and below a second point is preferred in terms of cost effectiveness. That is, the first point has both higher performance and lower costs than the second. We have drawn the most cost-effective frontier possible, that is, the straight-line segments connecting the points lowest and farthest to the right. Points lying on the cost effectiveness frontier are more economically efficient than points to the left of or above the curve. The cost-effective frontier in this chart consists of Base, P, R, U, S, and W. A few other observations are:

- Point W is always preferred to point V on purely economic grounds because the single in-stream aerator more than compensates for the lower augmentation, and
- Point U is always preferred to point Q because the zero-net-cost option at Holston Army Ammunition Plant does improve water quality.

OVERALL OBSERVATIONS

This exploratory study has yielded us two major conclusions that apply regardless of the water quality measure:

- For the same results, innovative techniques generally have annual costs at least an order of magnitude lower than the traditional methods. For a given DO concentration, the estimated cost savings can range as high as several millions of dollars per year.
- Complementary combinations of certain innovative methods can achieve DO concentrations that traditional methods cannot. For example, even if the four industrial and municipal dischargers stopped discharging BOD, the DO concentrations in some segments of the river would not reach the concentrations achievable with combinations of innovative methods, such as in-stream aeration and increased flow.

Taken together, all the scenarios and simulations in this explanatory study form a "menu for opportunities:" With care, one may find the lowest cost set of treatments that meets the desired ambient water quality standards. Two examples will illustrate the method and show the magnitude of the potential cost savings:

- If the State set the ambient Do standard at a daily average of 3 mg/L for the entire 32-km reach, the most cost-effective combination of traditional treatments has an annual cost of over $4 million/year, while the most cost effective innovative treatment has an annual cost of under $50,000.
- If the State set the ambient DO standard at a daily average of 5 mg/L for the entire 32 km reach, no combination of traditional treatments could achieve this goal, but the most cost-effective combination of innovative treatments has an annual cost of under $275,000.

Next Steps

In the Clean Water Act, the Congress did not anticipate such opportunities as this study has explored. Federal and State laws and regulations focus almost exclusively

Table 4.—Combination scenarios.

Label	Method	Economic Life (yrs)	Capital costs	O & M costs	Replacement power costs	Annual costs
			(thousands of $)			
P	Combination No. 1	25	248	73	0	98
Q	Combination No. 2	25	248	153	0	178
R	Combination No. 3	25	400	93	0	133
S	Combination No. 4	25	400	173	0	213
T	Combination No. 5	25	350	64	49	148
U	Combination No. 6	25	248	153	0	178
V,	Combination No. 7	25	248	257	0	282
W	Combination No. 8	25	598	208	0	268

NOTE: For a combination, the capital costs and the O & M may be less than the sum of the corresponding costs for the component methods due to savings from parttime operation. These combinations are:

Combination No. 1: Low augmentation (875 cfs) and high aeration (6 mg/L) at the Dam.

Combination No. 2: Medium augmentation (1,000 cfs) and high aeration (6 mg/L) at the Dam.

Combination No. 3: Low augmentation (875 cfs) and superhigh aeration (8 mg/L) at the Dam.

Combination No. 4: Medium augmentation (1,000 cfs) and superhigh aeration (8 mg/L) at the Dam.

Combination No. 5: Medium augmentation (1,000 cfs) at the Dam and in-stream single aeration at RM – 3.12 for 16 hrs/day.

Combination No. 6: Zero discharge at HAAP, and medium augmentation (1,000 cfs) and high aeration (6 mg/L) at the Dam.

Combination No. 7: Zero discharge at HAAP, and high augmentation (1,125 cfs) and high aeration (6 mg/L) at the Dam.

Combination No. 8: Zero discharge at HAAP, medium augmentation (1,000 cfs) and high aeration (6 mg/L) at the Dam, and in-stream single aeration at RM – 3.12 for 16 hrs/day.

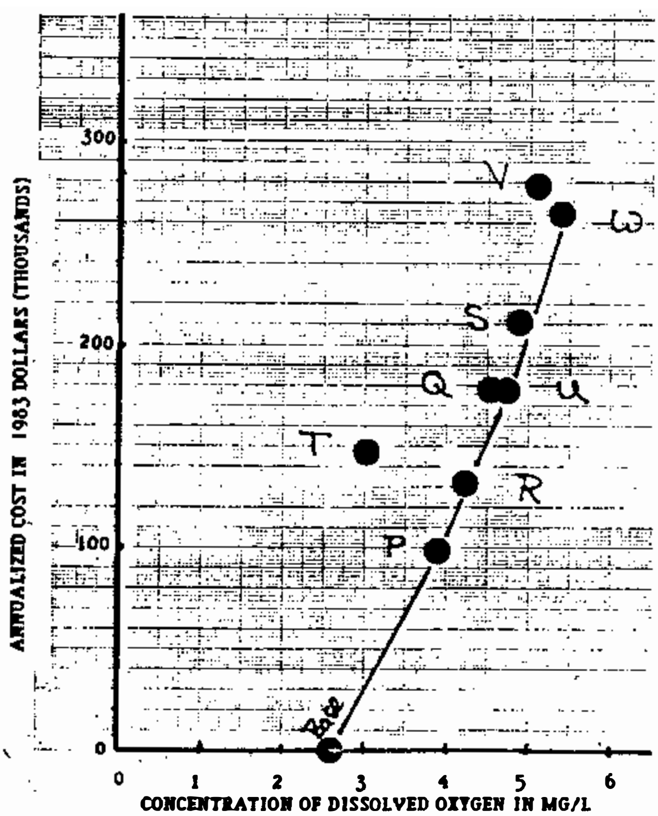

Figure 7.—Cost-effectiveness of combinations of innovative methods (P–W) using the lowest value of the daily average of dissolved oxygen concentration throughout the 20-mile reach.

on reducing discharges from industrial and municipal plants (basing permit limits on either categorical standards or ambient water quality standards); and various Federal court decisions have exempted dams from discharge requirements. More narrowly, Federal and State laws and regulations discourage flow augmentation as a way to reduce pollution, and they say little, if anything, on aeration.

The realization of these opportunities will require negotiation among the participants, including the regulatory authorities. Their general acceptability may be based on such factors as efficiency–least cost, equity–fairness, enforceability, and ease of administration. The participants will then need approval through regulatory, administrative, or legal channels to implement any proposed agreements. The final plan may well allow for cash payments among the participants or even the creation of a new nonprofit corporation to own and operate in-stream or at-the-dam aerators. Realizing these complementary combinations of innovative methods will require bold thinking about the institutions and their interdependencies.

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PROTECTING TILLAMOOK BAY SHELLFISH WITH POINT/NONPOINT SOURCE CONTROLS

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Tillamook Bay, located on the North Oregon Coast 96 km west of Portland, is Oregon's second largest estuary but produces the State's largest amount of commercially grown oysters. Because of its close proximity to the metropolitan area of Portland, it is also a popular recreational area for clam diggers, fishermen, swimmers, and sightseers.

In 1979, the bay waters and many of the streams draining into the bay were found to be contaminated by fecal material from, at that time, sources unknown. The water quality conditions threatened closure of the Bay to the shellfish harvesting that supported a portion of the local economy of approximately 13,000 people.

Under U.S. Environmental Protection Agency Section 208 funds the Oregon Department of Environmental Quality conducted a project from July 1979 to June 1981. The goal was to establish a comprehensive Tillamook Bay Fecal Waste Management Plan for protecting the beneficial use of the water, that is, Tillamook Bay's shellfish resource. The objectives of the project were to: (1) analyze existing and new data to quantify the problem, (2) identify the fecal bacteria sources, and (3) develop a plan to protect the shellfish resource by establishing necessary best management practices (BMPs), rules, and standards to minimize fecal waste discharges to the surface waters of the basin.

The intent was to preserve and protect the shellfish, a natural resource, as a beneficial use and, at the same time, to allow activities identified as sources of bacterial pollution to continue in a sensible, sanitary manner. The management plan would not achieve zero bacteria discharge from identified sources.

During the investigation, six major fecal sources were examined: sewage treatment plants (five located in the bay watersheds), recreation, forestry activities, industries, agricultural operations (120 dairies; 19,100 cows; 256,360 metric tonnes (282,000 tons) of manure annually), and onsite subsurface sewage disposal systems (serving approximately 40 percent of the population).

The project identified malfunctioning sewage treatment plants, some malfunctioning or inadequate on-site subsurface sewage disposal systems, and some agricultural operations discharging fecal material to the streams and bay that created a health hazard for consumption of bay shellfish and endangered swimmers in the tributaries.

Once the fecal source types were identified, corrective actions had to be determined. Existing control programs and new actions were investigated to determine the best suited corrective method for each fecal source type of water pollution problems. Tradeoffs of control came into play.

Alternatives were considered that required tradeoffs in timing implementation (do everything now or sequence the cleanup over a number of months or years), tradeoffs in identifying controls for the sake of human health or stream health, tradeoffs in what was to be corrected (the point sources or the nonpoint sources) and finally tradeoffs in strategy of controls (control the land activity and sources of the problem or control the water activity by closing the bay).

The word "tradeoffs" used in the context of this panel discussion suggests that point or nonpoint controls of water pollution can be traded back and forth to fit the situation, that such controls depend on a person's likes and dislikes. This might be appropriate up to a point. When choosing effective controls, the decisionmaker(s) must have a clear picture of the problem, its specific occurrences and the ultimate correction goal.

In the Tillamook Bay situation a number of factors dictated or limited the tradeoff choices. A compendium of controls resulted and have proved to be very effective in improving the water quality of Tillamook Bay and its rivers.

Current health risk was the key element to the Tillamook control strategy. This effectively eliminated the option of maintaining a status quo, in other words, doing nothing. The luxury of months and years to correct the problem was unavailable; however, correcting the fecal contamination problem from identified sources would take time. A tradeoff was identified. Instead of immediately closing the bay to further shellfishing until corrective actions could be completed at the pollution sources, shellfish harvesting was allowed when the known major fecal discharges were not contaminating the bay and was prohibited when they did discharge.

To institute the cleanup of the pollution problems, the who, when, and where factors of the dischargers had to be known. Placement of the cleanup emphasis became another tradeoff decision with the cleanup goal firmly in mind. Oregon, as is the case in most places, strives to get the biggest cleanup for the least dollars. This becomes an easy task if the interaction of pollution sources is known.

In the Tillamook situation, the primary problem of storm runoff from dairy barnyards occurred during every storm no matter how saturated the ground. Because of the pervasiveness of the problem, inadequate on-site subsurface sewage disposal systems became a secondary problem. The third was that occasional sewage treatment plant breakdowns caused raw sewage to enter the bays. Hence, cleanup emphasis was placed on the dairy waste management. This did not preclude action on the serious raw sewage bypass problem if and when it occurred.

The water quality is improving basinwide from cleanup activities dealing with dairy wastes and on-site subsurface sewage problems in localized areas. The infrequent sewage treatment plant malfunctions have been monitored when they occur.

What does this all mean? An accurate assessment of the problems, use of that information, and subsequent tradeoff decisions enable the State to make the biggest improvement towards alleviating the health risk.

No one has had to close a business. Shellfishing occurs, but with the knowledge of the bay water quality conditions. The local area has gained a cleaner bay and rivers.

POINT/NONPOINT SOURCE INTERFACE ISSUES IN WISCONSIN

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Recognition that water quality problems can result from combined point and nonpoint source pollution impacts is important in making cost-effective management decisions. Information gathered to assess whether combined impacts are important can be useful both in planning general water quality program strategies and evaluating site-specific pollution control options. Program areas where such information would be useful include: standards and effluent limits development, facilities planning, point and nonpoint source pollution abatement grants, and enforcement. The focus of the Wisconsin program is to determine what controls are needed for *both* point and nonpoint sources in achieving our water quality objectives.

Two types of point/nonpoint source issues have become apparent in Wisconsin. The first type occurs when wastewater treatment plants are upgraded to maintain water quality standards in the receiving stream, yet when the new plant goes on line the standards and beneficial uses are not achieved because of nonpoint sources. The typical situation here involves a relatively small (less than 5 mgd) treatment plant providing advanced treatment and a small receiving stream (less than 5 cfs) impacted by agricultural runoff or other nonpoint sources.

An example of this issue is the south fork of the Lemonweir River at Tomah. The Tomah wastewater treatment plant discharges to the stream 1.4 miles below the outlet from Lake Tomah, a highly eutrophic impoundment of the Lemonweir River. Lake Tomah is shallow and algae choked and receives the runoff from an agricultural watershed. The wastewater treatment plant was upgraded in 1981 to provide advanced treatment for biological oxygen demand, suspended solids, and ammonia. However, dissolved oxygen levels remain severely depressed both upstream and downstream of the effluent discharge because of the dead algae in the outflow from Lake Tomah.

The second type of issue involves the achievement of nonpoint source control objectives in the presence of a point source discharge, typically a large wastewater treatment plant. The key question is whether water quality improvements from a priority watershed project to control nonpoint sources would be negated by water quality degradation by point sources. This has become an important issue in Wisconsin's Nonpoint Source Grant Program.

An example of this second type of issue occurs on Turtle Creek in southeastern Wisconsin. A project was developed for the Turtle Creek watershed under the Wisconsin Fund Nonpoint Source Grant Program following significant demonstrated local support. It was chosen as a Priority Watershed. The main water quality objective for this watershed project was phosphorus reduction through agricultural best management practices (BMP's). However, the Walworth County Metropolitan (Walco Met) wastewater treatment plant discharges to Turtle Creek. This plant was built in 1981 to divert effluent from Lake Delavan and discharge it downstream to Turtle Creek. The lake previously acted as a sink for the phosphorus in the wastewater effluent. Some of the questions that arise from this situation are:

- Can the water quality objectives of the priority watershed project be achieved given the presence of the Walco Met discharge?
- Should phosphorus control be required at the Walco Met plant?
- Can we remove enough phosphorus from Turtle Creek through voluntary BMP's to not worry about the phosphorus load from Walco Met, that is, are tradeoffs involved?

Two types of interfaces can occur. The difference is significant. In one instance, both sources have similar effects on the stream, that is, the impacts are additive. A dissolved oxygen sag caused by both sources is an example. In the other instance, the point and nonpoint sources affect the stream differently, that is, the impacts are independent. Physical habitat degradation, by sedimentation due to nonpoint sources, coexisting with chemical degradation from point source discharges (biochemical oxygen demand or nutrients) is an example. Additive impacts may involve tradeoffs between the two pollutant sources since both use the same stream assimilative capacity. Independent impacts do not allow for the same tradeoffs; pollution control in both sectors is necessary to achieve the stream's beneficial uses.

Wisconsin Department of Natural Resources (DNR) decided to study point/nonpoint source interface issues in more detail and produced a report, The Role of Nonpoint Source Information and Control Programs in Achieving Water Quality Improvements at Point Source Discharge Sites. Prepared by Steven Skavroneck and John Pfender, this report represents a joint effort of the Water Resources Planning and Policy Section and the DNR Southern District Office.

The overall goal of the project was to integrate information concerning point and nonpoint source pollution impacts, controllability of these pollution sources, and the ability to attain water quality standards under different control options into pollution control strategies. Major objectives of the study included the following:

1. development of a site assessment procedure to assess relative impacts in a stream from point and nonpoint related problem sources,
2. development of a method to establish municipal enforcement priorities based on potential water quality improvement, taking into account the effects of nonpoint sources of pollution,
3. development of a method for determining background water quality in wastewater treatment plant (WTP) impact zones coimpacted by nonpoint sources,
4. development of a framework for determining target water quality criteria and the significance of water quality improvements resulting from different point source treatment levels, and
5. development of a method for evaluating the controllability of nonpoint sources.

A site assessment procedure was developed to determine which stream reaches are actually or potentially impacted by both point and nonpoint sources of pollution. The procedure should be viewed as a way for water resources staff to "order their thinking" about a stream reach, using all available information. This procedure aids in the identification of water quality problems, determination of the relative rôles of point sources and nonpoint sources in causing the water quality problems, and providing a general indication of whether or not desired water quality improvements can be attained through point source controls alone. This site assessment procedure has been incorporated into the water quality management plan update process.

A three-step process for evaluating the water quality of selected stream reaches is envisioned. The first step is to determine which stream reaches to assess. The second step is to apply the site assessment procedure to those stream reaches. The third step is to perform a detailed analysis of attainable goals for those stream reaches identified as priorities based on the site assessments.

The point/nonpoint source issues discussed in this paper are being addressed through several of Wisconsin's Water Resource Management programs including Water Quality Management Plans, Effluent Limit Setting, and the Nonpoint Source Grant Program through Priority Watershed Plans. Regardless of the program, the overall framework for addressing point/nonpoint source issues should be:

1. problem identification,
2. analysis of the relative contribution of point and nonpoint pollution sources to the water quality problem,
3. definition of water quality improvement objectives based on the identified problems,
4. assessment of the ability to meet water quality improvement objectives with various combinations of point and nonpoint source controls, and
5. development of a management plan recommending appropriate point and nonpoint source controls.

If necessary, modifications might be made to the previously established water quality improvement objectives to reflect their attainability.