VARIABLE FLOW WASTE LOAD ALLOCATION IN SUPPORT OF N.P.D.E.S. PERMIT APPLICATION

E. Zia Hosseinipour[1], Scott N. Heefner[2], Larry A. Neal[3], and Robert W. Olson[4]

AUTHORS: [1]Senior Water Resources Engineer, [2]Principal Water Resources Engineer, [3]Principal Water Resources Engineer, [4]Principal Water Resources Engineer, Law Engineering and Environmental Services, 112 Town Park Dr., Kennesaw, Georgia 30144.
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Abstract. Industrial effluent discharges to receiving waters are regulated by federal and state Environmental Protection Agencies. To discharge treated effluent, industrial facilities must obtain a National Pollutant Discharge Elimination System (NPDES) permit that specifies discharge limits for specific chemical constituents. These limits depend on constituent type, receiving water flow regime and assimilative capacity, tolerance of aquatic species within the water body, background water quality, etc. The goal of the project was to determine the appropriate waste load allocations to meet the EPA guidelines for "best practicable control technology currently available" (BPT) and maintain the dissolved oxygen (DO) standard within the river during dry season, while remaining cost effective. A water quality modeling package was developed to assess the waste load assimilative capacity of the receiving water as a function of flow and temperature. The model was applied to develop tables of permissible discharges based on previous day flow and today's temperature to be submitted in support of NPDES permit application.

INTRODUCTION

Along the stretch of the river that is the subject of this study, two major industrial facilities discharge treated effluent. The previous NPDES permit limits for the mills were originally derived from EPA technology guidelines and were not based upon receiving stream water quality considerations. However, through river monitoring and water quality modeling, it has been established that the segment of the river which is receiving discharge effluent is water-quality limited during certain low flow/high temperature conditions. On days that the river can not safely assimilate the permitted BOD load based on BPT, the river is said to be water quality limited by the DO content. Currently both mills provide treatment that produces better effluent quality than that established by the EPA technology based requirements.

Preliminary analyses suggested that the two mills would need to reduce their final effluent loads to about one-third of the EPA technology guidelines in order to maintain a minimum instream DO standard of 5.0 mg/l during the 7-day 10-year low flow (7Q10). Because of the high cost and fundamental questions about technical feasibility for meeting such stringent treatment requirements, the two mills asked the State Environmental Agency to consider permit limits that would vary according to available stream flow and associated assimilative capacity. This is called flow- variable permitting and requires the mills to discharge based on the EPA technology guidelines, unless the combination of low flow and high temperature in the river creates a water-quality limited situation. When the river is water-quality limited for DO, the mills would further restrict their effluent loads and/or inject oxygen into the river in accordance with permit requirements designed to maintain instream DO criteria. To monitor the effectiveness of the flow-variable discharge permitting, the mills have been conducting periodic instream DO surveys to document the applicability of the method. The study showed that by using flow-variable permitting in conjunction with oxygen injection, the mills can adequately protect receiving waters without spending limited resources on unnecessary treatment or excessive oxygen injection.

Initially, the State environmental officials expressed reservations about the use of flow-variable permitting, primarily due to concerns about the extra staff time and effort required to administer these permits. Other concerns raised included: uncertain acceptance by EPA, difficulty in using EPA's computerized permit compliance system (PCS), setting precedent for permit applicants to seek flow-variable permits, and unsatisfactory experience with certain other flow-variable permits. Nevertheless, the regulatory officials expressed willingness to further discuss the matter and to consider any information regarding how other states handle flow-variable permits. Accordingly, surveys of several State water quality and effluent discharge permitting requirements were conducted, to determine the extent to which flow-variable permits were being used and, to identify problems associated with their administration. This paper presents the results of the survey and modeling efforts for the project to address the above concerns.

Status of Flow Variable Permitting

As a part of the initial phase of this study contacts were made with regulatory representatives from many states in the late 1980's. Among the states contacted were: Alabama, Florida, Georgia, Ohio, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia. The purpose of these inquiries was to identify existing flow-variable permits and determine any restrictions or problems associated with such permits.

Ten of the states contacted had already issued flow-variable permits, and one was actively negotiating a flow-variable permit. Several different approaches have been used to express specific flow-variable limits in the permits reviewed. One approach employs a series of flow-based equations for different stream flow ranges. Another approach uses a table of allowable BOD discharges for various combinations of stream flow and temperature. This latter approach was adopted for this study. Other flow-variable permits have been written to vary the allowable effluent flow as a percentage of receiving stream flow. Similarly, the effluent limit may be set by a specified minimum dilution ratio in the receiving stream. It is apparent that flow-variable permitting is an established approach for water-quality limited situations, where conventional or seasonal approaches are too costly. Furthermore, it is generally acknowledged that existing flow-variable permits will be continued and new ones issued as more water-quality limited situations are discovered. From this survey, it was found that flow-variable NPDES permits are widely recognized as a means for cost-effective management of discharges to water-quality limited streams. None of the states surveyed have any regulations that prohibit the use of flow-variable permits. In fact, many of the flow-variable permits were actually initiated and developed by state or EPA personnel.

Each of the flow-variable permits reviewed were based upon site-specific water quality considerations. Most flow-variable permits require periodic monitoring of the receiving stream to document and verify water quality conditions. In this project, monitoring data showed that very seldom the water quality criteria are not met based on permitted discharges. The modeling results also confirmed that finding during high temperature and low flow situations. If water quality standards are not maintained, permit limits are subject to modifications. For those occasions that river DO are below criteria, oxygen is injected based on modeling projections in order to offset the excess BOD.

Analysis of Water Quality Management Alternatives

To meet the water quality criteria established by the regulatory authorities during critical conditions, several management alternatives were analyzed to develop an optimum management scheme that is economically feasible and, at the same time, protective of water quality. The following alternatives were investigated: oxygen injection, storage and treatment of effluent, and artificial wetlands.

Oxygen injection was considered as an option to increase DO levels in the stream during the critical conditions. Storage and treatment of effluent was also considered as a treatment alternative. This option required that the mills discharge at the modeled allowable limit, and store remaining excess BOD5 for subsequent discharge during periods when the river has more assimilative capacity. However, the cost of storage proved prohibitive; and hence this alternative was eliminated on economic grounds. Artificial wetlands were considered as the third alternative. Treatment of effluent by natural systems, specifically constructed wetlands, has been reported in the literature as an effective means of waste treatment. These systems have been demonstrated to be applicable for secondary and advanced treatment (Gersburg, 1989). The BOD5 removal capacity of municipal constructed wetlands is reported to range from 51 to 96 percent (Watson, 1989). Results of another study, where constructed wetlands were used to further treat the secondary treated bleached kraft mill effluent, suggest that a lower BOD5 removal of 27 to 49 percent is attainable (Thut, 1989). Based on this recent research, a full scale constructed wetland would require 460 to 740 acres of land. The cost of development, operation and maintenance would be very high according to the estimates from recent research (Watson, 1989). In summary, the costs for alternatives considered were: storage $39.6 million; additional treatment $18 million; oxygen injection $9.5 million; and artificial wetlands $34 million. As seen from these figures, oxygen injection is by far the most cost effective method for meeting the water quality criteria and maintaining the DO resources of the river.

Oxygen injection was selected because of economic feasibility. Two oxygen injection systems were proposed at locations 30 miles apart where DO sag would occur downstream of the two mill discharge points. The two systems would be operated jointly by the mills. The capacity of the systems were 12,000 and 40,000 lbs/day, respectively. Oxygen would be injected only during the water quality limited periods, and would first be injected to the waste flow from the upstream mill to offset excess BOD5. If the excess BOD5 is greater than the injection capacity of the upstream system, then the second system would come on line to offset the difference. This option was acceptable to the mills and the regulatory agencies.

WATER QUALITY MONITORING

The specific assimilative capacity of a receiving stream is affected by numerous factors. These factors include stream flow, water temperature, background water quality, stream hydraulic properties (e.g., velocity, depth, slope, width), deoxygenation rates, photosynthesis/respiration and other less significant factors. Obviously, assimilative capacity can vary continuously as the factors also vary.

Once assimilative capacity is suitably defined by specific operating experience and/or water quality modeling, it is typically found that assimilative capacity is dominantly a function of stream flow and water temperature. In effect, once a suitable assimilative capacity model is developed, stream flow and water temperature can be used to extrapolate or predict available assimilative capacity for different conditions within the receiving stream. Weekly river survey are conducted during the critical season at locations near the DO sag points to measure DO level, pH and water temperature. As a part of their NPDES permit requirements, both mills also monitor their effluent discharges to the river and perform a river survey that includes measuring water quality parameters such as DO, pH, and temperature within the river at specified locations downstream from the discharge point. A sample is collected for chemical analysis every day from the effluent prior to discharge. Each sample is analyzed for BOD5, suspended solids (SS), pH, and temperature. These data and the effluent discharge rate are collected and submitted to the State to fulfill the NPDES permit requirement. These reports are referred to as the Discharge Monitoring Report (DMR) and the River Survey Report (RSR).

WATER QUALITY AND FLOW MODELING

Water quality management alternatives were analyzed with the aid of a water quality modeling package to project discharge limits based on the flow regime of the receiving waters, ambient water temperature, and the 5-day biochemical oxygen demand (BOD5) of the discharged effluent. The water quality modeling package used included a flow recession code (FLOWREC), an iterative dissolved oxygen deficit code (DOSAGIT), a potential oxygen injection code (DOLOAD) for injection system design, and a code to calculate the required daily oxygen injection to meet water quality criteria (CALC5). CALC5 also produces the Discharge Monitoring Reports (DMR) based on the previous year actual effluent discharges.

Water quality modeling was performed with the aid of a conventional steady state model applied in a pseudo-dynamic fashion. The modeling scenarios were designed to provide information to be used for river water quality management during the periods that BPT guidelines would not maintain dissolved oxygen criteria within the stretch of interest. At this particular site, EPA's BPT guidelines would not maintain instream DO criteria during certain critical conditions associated with low flow and high temperature. The resulting water quality limited condition required water quality management approaches that not only would maintain the water quality standards for allowable effluent discharges based on BPT during non-critical conditions, but also maintain DO criteria during critical situations.

Discussion of Modeling Results

The water quality model was executed using the latest flow records, BPT loads and water quality data. The simulations were performed assuming that the "other" mill is always discharging at its allowable waste load, and that a minimum DO criteria is maintained throughout the river. The DO information produced by DOSAGIT was used by DOLOAD and CALC5 models to provide data for potential oxygen injection, and daily oxygen requirements to maintain DO criteria within the river. DOLOAD uses the DOSAGIT output and calculates the amount of oxygen needed to offset the DO deficit from saturation. Modeling results based on the actual river flows for the past 9 years (1985-1993), and the effluent discharge records for the past 2 years (1992-1993), showed that during the potential water quality limited period (May-November), at most there would have been a need for oxygen injection on 27 days. In reality, the river survey data showed no need for oxygen injection confirming that the modeling results are conservative. The design oxygen injection systems are readily capable of adding the projected oxygen requirements to the river in order to maintain the DO criteria.

CONCLUSIONS

The water quality management alternatives enumerated here were analyzed for cost effectiveness toward the selection of the most feasible method. Analysis of alternative management procedures demonstrated that oxygen injection was the preferred alternative to meet the NPDES requirements and improve/maintain the assimilative capacity of the river system. Modeling results showed that the flow-variable discharge, in association with oxygen injection, on occasions when instream DO levels require addition of oxygen, is practical, as well as, economically feasible to provide adequate oxygen resources within the river. Finally, in considering the flow-variable concept, it should be noted that there are several factors and assumptions, that collectively provide a margin of safety and protection for the DO resources of the river. Some of the factors are:

- The retention times used are longer than necessary; they are based on the retention time from the upstream boundary location above the mills rather than the retention time from each mill to the sag point. This assumption further reduces the recessed flow used to establish allowable BOD loads.

- For each mill, sufficient oxygen is added to fully offset each pound of excess ultimate BOD. This provides more oxygen than necessary because all of the discharged BOD5 is not exerted upstream from the sag point.

- The concept of using flow recession automatically assumes that river flow is always decreasing. In fact, at least 80 percent of the time river flow is either increasing, or decreasing (exceedance probability of 0.8 is used in the flow recession model) at a lesser rate than that computed from the flow recession data. This alone, tends to provide a margin of safety when computing the daily allowable BOD5 discharge.

- The methodology presented in this paper provides a functional tool for management of riverine water quality that can be used to enhance the assimilative capacity in the absence of spatial and temporal data requirements for dynamic modeling.

- As a matter of course, the mills will tend to operate conservatively since they will not know today's BOD5 until five days from today. This means that the mills will actually operate at some fraction of the allowable BOD load and add more oxygen than necessary to avoid permit violations.

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