THIRD PARTY REVIEW OF PROPOSED INSTREAM FLOW STANDARDS FOR NORTHERN NEW CASTLE COUNTY, DELAWARE

Prepared for
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1. INTRODUCTION

The purpose of this report is to provide Delaware Department of Natural Resources and Environmental Control (DNREC) with a third party review of the instream flow standards recommended for northern New Castle County, Delaware. The proposed flow standards are presented in Phase I and Phase II: 7Q10 Assessment Reports (1995; 1997) prepared by DNREC. EA Engineering, Science, and Technology (EA) conducted the assessments, and developed conclusions and recommendations outlined in this draft report based on the contract scope of work which included:

Task 1 - Evaluation of Appropriate Instream Flow Standards (ISF)

- *Subtask 1A. Research and review relevant literature on ISF standards applicable to the study area to include 7Q10 and Wetted Perimeter. A meeting with the DEPARTMENT will be held to discuss the JTF Reports (Phases I and II) and a field inspection performed to conduct a separate literature search of ISF studies and protocols, water quality, and habitat criteria of relevant species.*
- *Subtask 1B. Compile background information on existing surface water supply intakes and assemble into tables to supplement the literature search conducted in Subtask 1A consisting of data determined in CONTRACTOR's best professional judgement as relevancy to the study area and the primary issue of passby flow standards.*
- *Subtask 1C. Produce a draft Report recommending appropriate standards for the designated stream reaches with supporting documentation and critical appraisal of the DEPARTMENT's ISF reports, Phases I and II.*

Task 2 - Presentation of Findings

- *Subtask 2A. Present to DEPARTMENT oral summary of findings following receipt of one set of written comments from DEPARTMENT of the draft report of Subtask 1C.*
- *Subtask 2B. Deliver final report to DEPARTMENT*

Based on the scope of work and on-going discussions with DNREC's Project Manager, EA's effort specifically focused on:

(1) determining if the proposed 7Q10 passby flow is adequate to protect indigenous instream aquatic habitat uses in Brandywine Creek and the Christina River Basin;

(2) evaluating the principles and techniques used by others to substantiate the 7Q10 recommendation; and

(3) comparing the selected principles and techniques to those typically used in the region to assess pass-by flows based on "best professional judgement, BPJ."

EA used a combination of information from scientific literature and technical staff best professional judgement to evaluate the passby flow requirements. Based on our experience in instream flow evaluations, differing viewpoints of water supply withdrawal rates typically exist among different water purveyors in a region and within groups associated with resource agencies responsible for management of the water resources. To make the review and recommendations as objective as possible, EA did not solicit input from any interest groups. Importantly, EA's scope of work did not include a task to consider alternative water supply options or other alternative strategies which might be required to meet the growing need for water in northern New Castle County.

This report focuses on the topics that are most critical to DNREC's conclusions and recommendations. Additional information gathered as part of the literature review, is summarized in tabular format and is not discussed in detail unless it is used to support major conclusions. The following section of this report discusses pertinent instream flow methodologies, fish habitat requirements, and water quality criteria. The third section provides a review of DNREC's Phase I and II reports. Conclusions and recommendations are discussed in the final section.

2. REVIEW OF EXISTING INSTREAM FLOW INFORMATION

Background Information: There are four major surface water withdrawals for public water supply in northern New Castle County, Delaware.

Location	Purveyor	7Q10 flow (MGD)	Maximum Withdrawal Capacity (MGD)	7Q10 + Max withdrawal (MGD)
Brandywine Creek at City Dam	Wilmington WTP	49.31	44	93.31
Christina River at Smalley's Pond	United Water Delaware	2.09	6	8.09
White Clay Creek at Newark	City of Newark	7.27	5	12.27
White Clay Creek at Stanton	United Water Delaware	17.20	30	47.20

Source: Phase I Report (1995)

Based on these withdrawal data, the natural flow would have to equal or exceed the 7Q10 flow plus the maximum water supply withdrawals to meet a 7Q10 minimum passby flow. Based on flow exceedence data at each water withdrawal location, the flow would be less than the 7Q10 plus maximum withdrawal between 10 and 20 percent of the time depending on the withdrawal location (DNREC 1995).

Review of Instream Flow Methodologies: Instream flow methodologies have been developed to estimate the minimum flow that could occur in a stream to protect the existing aquatic community downstream of water diversions or intakes. A list of methods that have been used to estimate the necessary minimum flow is presented in Table 2-1. The majority of these methods were identified in a comprehensive summary and review document of existing national instream flow methodologies funded by the Electric Power Research Institute (EPRI 1986). Since 1986, many of the instream flow methods have been slightly refined, altered, or modified, but no significantly different types of models have been developed. The most commonly or widely used methods, based on best professional judgement, are identified in Table 2-2 and have been characterized based on data needs, strengths, limitations, and other information relevant to each of the selected methods.

Different instream flow methodologies have been developed for regional use in various parts of the country. Based on information presented in Reiser et. al. (1986), a summary of the federal and state methods employed in the mid-Atlantic and New England areas was developed (Table 2-3). Instream Flow Incremental Methodology (IFIM) is the most commonly used method in the eastern part of the country, as well as throughout other regions, based on the 1986 survey of state and federal resource agencies. EA's observations indicate that the popularity of the IFIM method has increased since 1986, and in most parts of the country it is currently the preferred method of estimating minimum flows. IFIM is, however, one of the more data intensive methods and often requires substantial field data collection.

All of the existing instream flow methodologies have some limitations (Table 2-2). The 7Q10 flow statistic and the wetted perimeter method have been and are currently used by several states to estimate the required minimum flow (e.g., they have been used alone or in combination with other methods in Massachusetts, New Jersey, North Carolina, Pennsylvania, and Virginia).

- The 7Q10 flow statistic is related more to hydrology and water quality compliance assessments rather than to instream habitat; for example, the 7Q10 flow statistic is often used as the critical low flow for determining surface water discharge permit limits. Critical low flows for application of water quality standards are typically specified as *x*Q*y*, where *x* is the averaging period in days and *y* is the average frequency of occurrence in years. For example, the 7Q10 is the 7-day average low flow that occurs, on the long-term average, once every 10 years. These flows are derived from a statistical analysis of stream flow data, typically using a log-Pearson Type III estimation technique. For example, in Delaware, design flows for application of water quality standards are based on the following flow statistics:

Non-toxic substances	7Q10
Toxic substances	
Acute aquatic life criteria	1Q10
Chronic aquatic life criteria	7Q10
Human health criteria	
Carcinogens	Median flow
Non-carcinogens	30Q5

It is important to recognize that there is no demonstrated scientific basis to assume *a priori* that the 7Q10 flow also maintains suitable aquatic habitat. Rather, it is a statistically-based low flow that on average is expected to occur in a 10-year period and is affected by flow modifications such as dams, reservoirs and water intakes.

- The wetted perimeter method requires a low to moderate field data collection effort to estimate the minimum flow. The wetted perimeter is a conceptual model using discharge and hydraulic variables, and there is little evidence that the values used in the model have documented biological significance. Additionally, the wetted perimeter vs. stream flow curves are often smooth and the identification of inflection points (defined as critical flow values) is often subjective and influenced by the base flow used in the model.

Fish Habitat-Use Data: Habitat requirements of the fish species present in the stream of interest are important for determining and recommending a minimum flow that will maintain and protect the fish community. In an attempt to compile habitat data for use in the IFIM models, the U.S. Fish and Wildlife Service (USFWS) developed habitat suitability index (HSI) models for 40 fish species in the early 1980s (Table 2-4). Although no new USFWS HSI models have been developed, other groups continue to develop habitat suitability index models to meet the requirements of IFIM studies that are conducted across the country.

Tables 2-5 through 2-18 present the results of EA's literature search for habitat requirements of the fish that were identified as target species during the Phase I and II reports prepared for DNREC. Shaded text in the tables represents supplemental habitat information provided by EA scientists; non-shaded text represents information previously compiled by or for DNREC. For target species that DNREC had previously compiled habitat-use data, comparisons between values derived from supplemental literature and initial literature indicated that habitat use information was reasonably consistent.

Water Quality: Water quality can be altered by changes in the natural flow regime. The water quality parameters that are typically of interest in minimum flow studies are temperature and dissolved oxygen. For this project, salinity is also a parameter of concern because portions of the study area are tidally influenced and subject to saline intrusion.

Overall, there are no *obvious* water quality problems based on the data which are presented, and the summary conclusions in the Phase 2 report (Section 3B4) are reasonable given the data that were available. However there are minimal data for certain water quality parameters (particularly during low flow periods), and compliance with certain water quality criteria/ standards cannot be accurately determined because only one sample was collected per day (probably at the same time each day) and ambient criteria have important duration and frequency components.

For example, DNREC's freshwater dissolved oxygen (DO) standard is an average of ≥5.5 mg/L and a daily minimum value of ≥4.0 mg/L. Instream DO concentrations follow a fairly typical diurnal cycle where concentrations are lowest just before dawn and highest mid-afternoon when photosynthetic aquatic plants are producing the most oxygen[1]. As a result, a single DO sample cannot be properly be compared to daily average and daily minimum dissolved oxygen criteria. Similarly, pH varies throughout the day as a result of photosynthesis, and a single value taken at the same time each day may not be acceptable for determining compliance with daily average or minimum pH criteria.

Recognizing these limitations in the dataset, EA's evaluation of the water quality data presented in the Phase 2 report resulted in the following conclusions:

Smalleys Pond (Christiana Basin)
No water quality data are presented in the Phase 2 report for review.

Brandywine Creek at Wilmington
Less than 7Q10 flows occurred between 24 August and 14 September 1995. Only 4 DO measurements were made during this 3 week period, and two of these were 6.4 mg/L [DNREC's DO standard is 6.5 mg/L as an average, and 5.0 as a daily minimum]. Measured values of 6.4 mg/L may or may not indicate a problem depending upon the time of day these 4 daily samples were collected, and what actual daily average and minimum values were.

For pH, the reported values were very consistent (generally 7.1-7.3), *suggesting* the samples were collected at the same time each day.

White Clay Creek at Newark
Instream flows were at or below 7Q10 from 19 August-16 September. Only four DO measurements were made during this low flow period and these values ranged from 8-10 mg/L. Again, these cannot be compared to the instream criteria, although there does not appear to be a concern.

Instream temperature measurements ranged from 59-77 F. One value was listed as 86 F, but this value is inconsistent with the rest of the dataset, and is believed to be incorrect.

Reported pH values ranged from 7.5-8.1, but there were only 4 values during the four week low flow period (10 values over 3 months), and these all appear to be individual grab samples. As pH values can vary significantly over a 24-hour period, it is not possible to compare these daily results to the DNREC standard of 6.5-8.5 units. No chloride data were reported in the Phase 2 report.

White Clay Creek at Stanton
Instream flows were at or below 7Q10 for only a short period of time (~6-7 September 95). DO measurements were not reported for this low flow period, but single daily values of 6 mg/L were presented for 11 and 14 September. These single measurements are close to DNRECs 6.5 mg/L

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1 A typical diurnal cycle for dissolved oxygen might range from 4 mg/L at 5AM up to 12 mg/L at 5PM (Thomann and Mueller 1987).

average and 5.0 minimum values, but clear conclusions cannot be made because sample times are not presented, and these single values do not reflect diurnal variability.

Instream chloride data show a sharp increase from 31 August through 6 September when flows are decreasing and saltwater intrusion is increasing. Values exceeding EPA's SMCL (human health-based) value of 250 mg/L occurred at instream flows as high as 18.4 mgd.

The flow:chloride regression presented on page 22 of the Phase 2 report concludes that the chloride levels will begin to exceed 250 mg/L when the flow in White Clay Creek drops below 18.1 cfs. However, there is a reasonable amount of variability in this fairly small dataset and it might be better to use an upper 95th percentile confidence limit value rather than the "mean" value for this analysis. This recommendation is further supported by the fact that an instream chloride value of 600 mg/L was reported at a flow of 18.4 mgd (1 September), and a value of 230 mg/L was reported at a post-rain flow of 69.2 mgd (8 September).

Finally, the Phase 2 document does not mention U.S. EPA's (1988) ambient water quality criteria for chloride which presents a 1-hour average (acute) criterion of 860 mg/L and a 4-day average (chronic) criterion of 230 mg/L for the protection of freshwater aquatic life. These numbers should be considered in the analysis of aquatic impacts in addition to the human health-based SMCL.

3. CRITICAL REVIEW OF PHASE I AND PHASE II REPORTS

EA critically reviewed DNREC's Phase I and II reports for weaknesses or limitations that in our professional judgement could be used to question the results and conclusions outlined in the reports. The limitations that EA identified in these reports are outlined as follows:

General Comments

- The 7Q10 flow value used in the analysis was based on data from the Churchman's Marsh EIS (Metcalf and Eddy, 1991). While EA is confident that the 7Q10 analysis developed for this project was done according to standard procedures, it would be helpful to future readers unfamiliar with standard protocols, to briefly summarize how the values were determined (e.g., the data set used, USGS gauge locations, period of record).

HEC-2 Model

- The rationale for selecting the length of stream to be considered as the study reach for each of the four water withdrawals is unclear. For example, it is unclear from existing documentation how the longitudinal limits of the "impacted" area that warranted evaluation were determined.

- The HEC-2 stations included in the FEMA model input data are heavily influenced by dams and bridges, the hydraulic controls of concern for *high* flow analyses. The hydraulic controls in the free flowing sections at low flow are typically different and may not have been properly represented in the FEMA data set. DNREC realized this potential problem and ten additional transects were surveyed in riffle (free flowing) sections within the study area. While, it may have been beneficial to have even more transects in these areas, it was not practical given budget and time constraints.

The following table summarizes the number of transects that were placed at dams or bridges in each of the four study reaches. Based on these data, approximately 50% of the transects at Brandywine Creek and White Clay Creek at Newark were associated with dams or bridges and were not representative of free flowing conditions.

Site	Total Number of Stations	Stations at the Crest of Dams	Stations Upstream / Downstream of Hydraulic Controls	Free Flowing Stream Stations	
				Pool	Riffle
Brandywine Creek	17	3	6	4	4
Christina River at Smalley's Pond	14	1	1	12	0
White Clay Creek at Newark	22	3	8	5	6
White Clay Creek at Stanton	27	0	0	25	2

- The flow assessment presented in the Phase I report relies on extrapolating the "maximum" depth at each section longitudinally (along the length) along the river to estimate the proportion of study area greater than one foot in depth. The inclusion of crest of dams and cross-sections directly upstream and downstream of hydraulic controls is expected to slightly alter the results from what would be expected if only free flowing channel cross-sections were included in the analysis. The free flowing sections were the primary focus of the biological portion of the analysis.

- The pool/riffle designation used in the above table was based on the usage in Tables 6 to 9 of the Phase I Report. An examination of the depths and velocities in Tables 6 to 9, however, indicates inconsistencies in classification of transects as pools or riffles. Based on data presented in these tables, the maximum depth at cross-sections classified as riffles ranged from 0.07 ft to 2.79 ft with velocities ranging from 0.24 ft/sec to 4.42 ft/sec. Pools varied in maximum depth from 0.07 ft to 7.96 ft and average velocity ranged from 0 ft/sec to 3.0 ft/sec. Definitions of riffles and pools should have been developed and consistently used. DNREC realized this inconsistency and the riffle sections that were included in the wetted perimeter analysis conducted in the Phase 2 study reflect more consistent definitions of riffles.

- The "up to 0.4 ft error" indicated for the HEC-2 model, while relatively small, is significant relative to the 1 foot depth criterion used for habitat assessment. At many of the shallower transects, a change in depth of this magnitude could result in 200% variation in stream velocity. A more detailed discussion of model accuracy relative to low flow habitat assessment would be important.

Habitat Assessment

It is important to realize that the fishery evaluations used in the Phase 1 and 2 studies were not designed or intended to address the habitat use or preference of fish species in any of the drainages. The objectives of the study were to address the more fundamental issue of fish survival during extreme low flow events and the habitat information gathered was used to support the survival evaluation. However, because of the limited time and budget available, these data were determined to be the best available and subsequently were used in evaluating suitable habitat at different stream discharges. The limitations presented below are not a criticism of the methodology or conclusions drawn in that report relative to fish survival under low flow conditions. Rather they represent limitations relative to what ideally is considered in evaluating fisheries habitat assessments.

- The rationale for selecting 1 foot as the critical depth is not consistent with what ideally would be used in minimum flow studies. Depth criteria are usually coupled with minimum velocity criteria and typically include a full range of depths used by resident species.

- The habitat characterization of the sites based upon the longitudinal extrapolation of maximum depth does not adequately address the issue of what percent of the stream reach is greater than 1 foot in depth. The use of maximum depth results in an over estimation of the portion of stream that exceeds 1 foot in depth and thus an overestimation of the amount of suitable habitat as defined in these reports.

- While habitat analysis based on average velocity (as used in DNREC's assessment) is more appropriate than maximum velocity, it still provides insufficient information to make habitat-based flow decisions because it is an oversimplification of the available velocities.

- Riffles, runs, and pools are all important habitat types for various fish species and lifestages. Ideally all these habitat types are included in a habitat-based analysis. For example, the percentage of area greater than 2 or 3 feet in depth can be important for centrarchid species. The premise that if depth in riffles is maintained, depth in pools (artificial or natural) is also maintained is true in terms of fish survival, but, may not be true in terms of preferred habitat for species that utilize pools.