

Fish Entrainment and Impingement Progress Report  
October 2007

**SECOND DRAFT INTERIM REPORT OF PROGRESS**  
**26 October 2007**

**Assessment of Entrainment and Impingement at the Claytor Hydroelectric Project**

The Claytor Lake Entrainment/Impingement Assessment was begun in March 2007, following a draft Table of Contents (TOC) submitted with the initial progress report. The assessment is largely a desktop study augmented by a field intake velocity component. Progress on portions of the report drafted since the last progress report for May 2007 is discussed below, following TOC section numbering. Drafts of Sections 1.0, 2.0, and 3.0 were largely completed earlier, as outlined in the previous progress report. Since that submittal, information was received from operations staff to complete descriptions of turbine configurations that will be used, along with other information developed, to prepare Sections 4.0, 5.0, and 6.0.

The severe drought in the southeastern US has precluded collection of planned field velocity data at different operational levels. Originally scheduled for earlier in 2007, the 4<sup>th</sup> quarter of 2007 was identified as the back-up period for this phase of the study. Data collection may be further delayed into 2008 until inflow and project operations return to normal levels.

The draft of Section 4.0 contains a comparative analysis of the Claytor Project to other sites where entrainment data were obtained, particularly those listed in an EPRI database. Compared to most of the projects in the database, Claytor has larger turbine units, greater overall hydraulic capacity, and a higher net head.

Most of Section 5.0 has been drafted. The various subsections address potential entrainment rates for the target fish species in Claytor Lake, using largely EPRI data, describe cavitation potential of the Claytor units, and develop fish turbine passage survival assessments. For the latter, general survival estimates were derived from the EPRI data. Additionally, several empirical studies of passage survival at Francis units were included for several of the Claytor target species such as smallmouth bass. The task of calculating blade strike probability remains, as additional turbine configuration data are needed.

Work on Section 6.0, the overall assessment, has begun. The assessment examines factors such as intake siting, including depth and relation to the littoral zone, species composition in the reservoir, hydraulic capacity, and water quality, among others. For Section 7.0, the literature utilized to prepare the swim speed information was previously submitted; additional entrainment literature citations are also being compiled.

The Claytor Lake Entrainment/Impingement Assessment was begun in March by developing the attached Draft Table of Contents (TOC). Portions of the report drafted to date are discussed below in reference to the TOC section numbering.

Drafts of Sections 1.0, 2.0, and 3.0 are largely completed. The following refers to sub-sections of Section 2.0. A suitable map to accompany the report would be that included in the AEP Study Plan. The map can be inserted at any time. Some data on project specifications has been received. Additional information on other project specifications such as the number of buckets on the Francis runners is needed. (More detailed turbine specification data will likely be needed to perform some of the mortality/survival calculations in Section 5.4). Some detail that describes the "restricted peaking" operations in the summer months is also needed. After reviewing available literature, no species of concern (sub-section 2.4) were identified in Claytor Lake.

Finally, Normandeau has had discussions with AEP personnel about available evidence of entrainment or impingement problems (sub-section 2.5). Direct evidence of entrainment is available only for alewife, as they have been collected as they are transported through turbine penstocks in moribund condition in winter. Indirect evidence of striped bass, hybrid striped bass, and gizzard shad entrainment exists as populations of these species have become established downstream as far as Bluestone Lake in WV. However, the evidence is indirect since emigration out of Claytor Lake could also have occurred via spillage; exit routes have not been determined. VDGIF, through various reports prepared by John Copeland, has expressed interest in learning more about striped bass or hybrid striped bass juveniles or adults exiting Claytor Lake through tagging studies. Telemetry and conventional tagging studies' results were reported in Masters Theses from VaTech. No information on exit route or entrainment of the target species resulted from these studies.

Swim speed information (Section 3.0) for 8 of the 11 Claytor Lake fish species of interest was located. Data for spotted bass, black crappie, and hybrid striped bass was lacking. However, sufficient data for closely related species (congeners) in each instance enabled reasonable estimates of swim speed to be determined. For example, white crappie information was used to estimate swim speed of black crappie. Among the 11 species, black crappie and bluegill appear to be the poorest swimmers.

Within Section 5.0, only sub-section 5.1 has been drafted. Sub-Section 5.1 addresses the life history characteristics and behavior of the 11 species of interest as related to the entrainment potential through project turbines. Information was compiled on distribution and abundance of these species in Claytor Lake, and other species characteristics such as intra-lacustrine migrations, juvenile dispersal, or cold tolerance that might affect a species' susceptibility to entrainment.

No work on Section 6.0 has begun. In Section 7.0, the literature utilized to prepare the swim speed information (sub-section 7.1) has been compiled in a draft bibliography. The swim speed bibliography is attached to this progress report.

## **Draft Table of Contents for Claytor Project I&E Assessment**

### **1.0 INTRODUCTION AND BACKGROUND**

### **2.0 CLAYTOR LAKE DESCRIPTION AND GENERAL APPROACH**

- 2.1 Reservoir Description and Characteristics
- 2.2 Project Facilities
- 2.3 Fish Populations and Management Species
  
- 2.4 Species of special concern
  
- 2.5 Current Evidence of I&E Problems
  - 2.5.1 Brief description of operations
  - 2.5.2 Evidence of entrainment/impingement problems

### **3.0 SWIM SPEED LITERATURE REVIEW**

- 3.1 Striped bass adults and juveniles
- 3.2 Hybrid striped bass
- 3.3 Gizzard shad
- 3.4 Largemouth bass
- 3.5 Smallmouth bass
- 3.6 Spotted bass
- 3.7 White bass
- 3.8 Walleye
- 3.9 Alewife
- 3.10 Bluegill
- 3.11 Black crappie

### **4.0 COMPARATIVE ANALYSIS OF SIMILAR PROJECTS/DEVELOPMENTS**

### **5.0 ENTRAINMENT ASSESSMENT**

- 5.1 Characteristics and behavior of selected species
  - 5.1.1 Striped bass adults and juveniles
  - 5.1.2 Hybrid striped bass
  - 5.1.3 Gizzard shad
  - 5.1.4 Largemouth bass
  - 5.1.5 Smallmouth bass
  - 5.1.6 Spotted bass
  - 5.1.7 White bass
  - 5.1.8 Walleye
  - 5.1.9 Alewife
  - 5.1.10 Bluegill
  - 5.1.11 Black crappie
  
- 5.2 Review of Entrainment Rates-EPRI (1997)

5.3 Blade Strike and Cavitation Potential of Existing Turbine Units

5.4 Turbine Passage Survival Assessment

**6.0 PROJECT ENTRAINMENT ASSESSMENT**

**7.0 LITERATURE CITED**

7.1 Swim Speed Literature

7.2 Entrainment/Fisheries Literature

## 7.0 Literature Cited

### 7.1 Swim Speed Literature in Table 3-1 and report text

ASCE (American Society of Civil Engineers). 1995. Chapter 7, Fish Passage and Protection. in: Guidelines for design of intakes for hydroelectric power plants. American Society of Civil Engineers, New York.

Bainbridge, R. 1960. Speed and stamina in three fish. J. Exp. Biol. 39:129-153.

Beamish, F.W.H. 1970. Oxygen consumption of largemouth bass, *Micropterus salmoides*, in relation to swimming speed and temperature. Canadian J. Zoology 48:1221-1228.

Beamish, F.W.H. 1978. Swimming capacity. In: Hoar, W.S. and D.J. Randall, eds. Fish Physiology, Volume 7, Locomotion. Academic Press, NY. 576 pp.

Bell, M.C. 1991. Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Boyd, G. and G. Parsons. 1998. Swimming performance and behavior of golden shiner, *Notemigonus crysoleucas*, while schooling. Copeia 1998(2): 467-471.

Bunt, C.M., C. Katapodis, and R.S. McKinley. 1999. Attraction and passage efficiency of white suckers and smallmouth bass by two Denil fishways. N Am. J. Fish. Mgt. 19:793-803.

Carlander, K.D. 1977. Handbook of freshwater fishery biology, Volume Two. Iowa State University Press, Ames Iowa.

Castro-Santos, T and A. Haro. 2005. Biomechanics and fisheries conservation. Chapter 12 in Fish Physiology: Fish Biomechanics, Volume 23. Elsevier, Inc.

Chick, J.H. and M.J. Van Den Avyle. 2000. Effects of feeding ration on swimming speed and responsiveness to predator attacks: implications for cohort survival. Can J. Fish. Aquat. Sci. 57: 106-115.

Clay, C.H. 1961. Design of fishways and other fish facilities. Department of Fisheries of Canada, Ottawa. 301 pp.

Cooke, S.J., E.C. Grant, J.F. Schreer, D.P. Philipp, and A.L. Devries. 2003. Low temperature cardiac response to exhaustive exercise in fish with different levels of winter quiescence. Comparative Biochemistry and Physiology, Part A, 134:157-165.

- Dahlberg, M.L., D.L. Shumway, and P. Douderoff. 1968. Influence of dissolved oxygen and carbon dioxide on swimming performance of largemouth bass and coho salmon. J. Fish. Res. Bd. Canada 25:49-70.
- Deng, Z, M.C. Richmond, G.R. Guensch, and R.P. Mueller. 2004. Study of fish response using particle image velocimetry and high-speed, high-resolution imaging. Prepared for U.S. Department of Energy by Pacific Northwest National Laboratory, Richland, Washington.
- Dow, R.L. 1962. Swimming speed of river herring, *Pomolobus (Alosa) pseudoharengus* (Wilson). J. Cons., Cons. Perm. Int. Explor. Mer. 27:77-80.
- Drucker, E.G. and G.V. Lauder. 1999. Locomotor forces on a swimming fish; three dimensional vortex wake dynamics quantified using digital particle imaging velocimetry. The Journal of Experimental Biology 202: 2393-2412.
- Farlinger, S. and F.W.H. Beamish. 1977. Effects of time and velocity increments on the critical swimming speed of largemouth bass. Trans. Amer. Fish. Soc. 106: 436-439.
- Gardner, A.N., G.D. Jennings, W.F. Hunt, and J.F. Gilliam. 2006. Non-anadromous fish passage through road culverts. Paper No. 067034, Annual Meeting, American Society of Agricultural and Biological Engineers, St. Joseph, MI.
- Gleason, E.V. 1982. A review of the life histories of striped bass (*Morone saxatilis*) and white bass (*M. chrysops*) hybrids and an evaluation of their suitability for stocking. California Department of Fish and Game, Inland Fisheries Administrative Report No. 82-9.
- Haro, A., T. Castro-Santos, J. Norieka, and M. Odeh. 2004. Swimming performance of upstream migrant fishes in open-channel flow: a new approach to predicting passage through velocity barriers. Can. J. Fish. Aquat. Sci. 61:1590-1601.
- Hocutt, Charles H. 1973. Swimming performance of three warmwater fishes exposed to a rapid temperature change. Chesapeake Science 14(1): 11-16.
- Houde, E.D. 1969. Sustained swimming ability of larvae of walleye, *Stizostedion vitreum vitreum*, and yellow perch, *Perca flavescens*. J. Fish. Res. Bd. Canada 26:1647-1659.
- Jones, D.R., Kiceniuk, J.W., and O.S. Bamford. 1974. Evaluation of the swimming performance of several fish species from MacKenzie River. J. Fish. Res. Bd. Canada. 31:1641-1647.
- Kerr, J.E. 1953. Studies of fish preservation at the Contra Costa steam plant of the Pacific Gas and Electric Company. Calif. Dept. Fish and Game, Fish Bull. 92:1-66.

- King, L.R. 1969. Swimming speed of the channel catfish, white crappie, and other warm water fishes from Conowingo Reservoir, Susquehanna River, PA. Ichthyological Associates, Bulletin No. 4.
- Kolok, A.S. 1991. Photoperiod alters the critical swimming speed of juvenile largemouth bass, *Micropterus salmoides*, acclimated to cold water. *Copeia* 1991(4):1085-1090.
- Larimore, R.W. and M.J. Deuver. 1968. Effects of temperature acclimation on the swimming ability of smallmouth bass fry. *Trans. Am. Fish. Soc.* 97: 175-184.
- Peake, S., R.S. McKinley, and D.A. Scruton. 2000. Swimming performance of walleye, *Stizostedion vitreum*. *Can. J. Zool.* 78:1686-1690.
- Schmulbach, J. C., Tunink, D. H., and Zittel, A. E. (1981). "Swimming performance of fishes endemic to the Missouri River in South Dakota." U.S. Department of the Interior.
- Schuler, V.J. 1968. Progress report of swim speed study conducted on fishes of Conowingo Reservoir. Ichthyological Associates, Progress Report 1B.
- Smiley, Jr., P.C. and G.R. Parsons. 1997. Effects of photoperiod and temperature on swimming performance of white crappie. *Transactions of the American Fisheries Society* 126: 495-499.
- Tatham, T.R. 1970. Preliminary report of studies of swimming speed of white perch, striped bass, and other estuarine fishes. Ichthyological Associates, Middletown DE.
- Tunink, D. H. (1975). "The swimming performance of fishes endemic to the middle Mississippi River," M.S. thesis, University of South Dakota.
- Webb, P.W. 1978. Hydrodynamics: non-scombroid fish. In: Hoar, W.S. and D.J. Randall, eds. *Fish Physiology, Volume 7, Locomotion*. Academic Press, NY. 576 pp.
- Webb, P.W. 1998. Entrainment by river chub, *Nocomis micropogon*, and smallmouth bass, *Micropterus dolomieu* on cylinders. *J. Exp. Biol.* 201:2403-2412.
- Wilcox, D.B., and 7 co-authors. 2004. Improving fish passage through navigation dams on the Upper Mississippi River system. Interim Report. ENV Report 54, U.S. Army corps of Engineers, St. Paul, MN
- Williamson, K.L. and P.C. Nelson. 1985. Habitat suitability index models and instream flow suitability curves: gizzard shad. U.S. Fish and Wildlife Service, Washington, DC.
- Young, P.S. and J.J. Cech, Jr. 1993. Improved growth, swimming performance, and muscular development in exercise-conditioned young-of-the-year striped bass, *Morone saxatilis*. *Can. J. Fish. Aquat. Sci* 50:703-707.

Wardle, C.S. 1980. Effects of temperature on the maximum swimming speed of fishes. in Ali, M.A., ed. The Environmental Physiology of Fishes. Plenum, New York. P 519-531.