UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of ENTERGY NUCLEAR INDIAN POINT 2, LLC, ENTERGY NUCLEAR INDIAN POINT 3, LLC, and ENTERGY NUCLEAR OPERATIONS, INC. (Indian Point Nuclear Power Station)	Docket Nos. 50-247, 50-286

DECLARATION OF DOUGLAS G. HEIMBUCH, PH.D.
IN OPPOSITION TO RIVERKEEPER CONTENTION EC-1 AND
NEW YORK ATTORNEY GENERAL CONTENTION 31

I, Douglas G. Heimbuch, Ph.D., declare as follows:

QUALIFICATIONS

1. I am a Technical Director in the Natural Resources Group at AKRF, a respected multidisciplinary provider of environmental, planning, and engineering services. I have 25 years of professional experience in the fields of fisheries science and biostatistics, with expertise in the statistical analysis of environmental data, development of environmental sampling designs, estimation of parameters of fish populations, the assessment of effects of power plant operations on fish populations, and the study of fish population dynamics. More specifically, my expertise is in assessing the potential aquatic impacts of power-plant operations under Clean Water Act ("CWA") §316(b) and equivalent state law, where I have analyzed the effects of entrainment and impingement on fish populations for several power plants, including the PSEG Salem plant on Delaware Bay in New Jersey, the mid-Hudson River power plants (Roseton, Danskammer, Lovett, Bowline, and Indian Point), the WE Energies Oak Creek power plant on Lake Michigan in Wisconsin, the Rockland Cape May Holdings, LLC B.L. England plant on Great Egg Harbor Bay in New Jersey, and the New York Power Authority Poletti plant on the East River in New York. I also have evaluated the effectiveness of restoration measures implemented to address §316(b) or equivalent state law, and have worked with resource economists to link the results from my analyses of fisheries data to information on the recreational and commercial value of fish as part of cost-benefit or cost-effectiveness analyses.

2. I have extensive, first-hand experience analyzing fish abundance and distribution data from the Hudson River. I began working with the Hudson River Biological Monitoring Program ("HRBMP") database in the mid-1980s, and have continued my work there to the present. During the 1980s and 1990s, under contract to

the owners of several Hudson River power plants, I assisted the New York State Department of Environmental Conservation ("NYSDEC") and the owners of those power plants in: (1) evaluating alternative methods for assessing potential power-plant effects on fish populations based on that HRBMP data; and (2) evaluating the adequacy of the HRBMP data for those assessments. I also prepared a report, under a grant from the Hudson River Foundation, entitled *Distribution Patterns of Eight Key Species of Hudson River Fish* (Heimbuch et al. 1994). For that report, I summarized data from the HRBMP to support characterizations of River-wide distribution patterns of relative abundance and presence-absence of the target species of fish.

3. I have worked under contract to federal and state agencies to design statistically rigorous large-scale fish sampling programs and associated data analysis methods. Examples include my work for: (a) the USEPA in developing and implementing data analysis methods for analyzing data from coast-wide estuarine fish sampling programs (Heimbuch, et al. 1998); (b) the State of Maryland in designing a multi-year, statewide fish sampling program for estimating the total number of fish in streams within the State of Maryland (Heimbuch, et al. 1997, and Heimbuch, et al 1999); (c) the Atlantic States Marine Fisheries Commission ("ASMFC") to develop methods for assessing coast-wide effects of entrainment and impingement on fish populations (Heimbuch, et al. 2007); and (d) the U.S. Army Corps of Engineers to develop a method for estimating the fraction of the Hudson River population of juvenile striped bass that inhabited an inter-pier area on the Manhattan shoreline (Heimbuch and Hoenig, 1989). All of these publications were subjected to peer review.

4. I hold a Ph.D. degree from the Department of Natural Resources at Cornell University, with a major in Fishery Science, and a minor in Biometrics. I hold a Masters of Science degree in Natural Resources from Cornell University, and a Bachelor of Science degree in Conservation of Natural Resources from the University of California at Berkeley. My current curriculum vitae, including a list of my peer reviewed scientific publications, is attached hereto as Attachment 1.

<u>THIS PROCEEDING</u>

5. I understand that this proceeding ("Proceeding") before the Nuclear Regulatory Commission ("NRC" or the "Commission") concerns the May 2007 application by Entergy Nuclear Operations, Inc. ("Entergy") to renew, for a period of 20 years, the operating licenses for Entergy Nuclear Indian Point 2, LLC ("IP2") and Entergy Nuclear Indian Point 3, LLC ("IP3"), nuclear power generating units located in Buchanan, New York. I understand that Riverkeeper, Inc. ("Riverkeeper") and the New York Attorney General ("NYS") have filed petitions ("Petitions") to intervene in this license renewal proceeding, in which they specifically request a hearing before the NRC with respect to certain issues that they maintain are not adequately addressed in Entergy's license renewal application ("LRA").

6. I have reviewed Riverkeeper Contention EC-1 and NYS Contention 31 (the "EI Contentions"). I have reviewed the declarations of Drs. Richard Seaby and Peter Henderson in support of Riverkeeper's Contention EC-1, and accompanying reports co-

authored by Drs. Seaby and Henderson *Status of Fish Populations and the Ecology of the Hudson River* ("Pisces Hudson Report") and *Analysis of Entrainment, Impingement, and Thermal Impacts at Indian Point Power Station* ("Pisces EI Report"). I have also reviewed the declaration of Roy A. Jacobson, Jr., in support of NYS Contention 31.

7. This Declaration is submitted in support of Entergy's response to the EI Contentions.

AEI REPORT

8. Together with Drs. Lawrence W. Barnthouse of LWB Environmental Services, Inc., Webster Van Winkle of Van Winkle Environmental Consulting, and John Young of ASA Analysis & Communications, Inc., I have prepared a report, entitled *Entrainment and Impingement at IP2 and IP3: A Biological Impact Assessment* (Jan. 2008) ("AEI Report"). The AEI Report is attached as Attachment 2 to the Barnthouse Declaration and is incorporated herein by reference. To the best of my knowledge, the factual statements in the AEI Report are true and accurate, and the opinions expressed therein are based on my best professional judgment.

9. As detailed therein, the AEI Report contains a comprehensive evaluation of whether entrainment and impingement by the respective cooling-water intake structures at IP2 and IP3 has caused an adverse environmental impact ("AEI"), using biologically-based definitions of AEI that are consistent with established definitions and standards of ecological risk assessment and fisheries management.

10. The AEI Report confirms that, considering all of the fish species for which abundance trends can be evaluated, there is no relationship between long-term trends in fish abundance and susceptibility to IP2 and IP3's respective CWIS.

11. My role in the preparation of the AEI Report was to: (a) conduct the correlation analyses that were used to test hypotheses, in order to be able to validate the conclusions reached in the AEI Report through statistical assessment; (b) prepare an appendix that addressed the magnitude of forage biomass potentially consumed by striped bass in the Hudson River in comparison to the biomass of forage fish in the Hudson River, in order to determine whether the potential consumption of forage by striped bass predation was sufficient to cause declines in abundance of the forage populations; and (c) prepare an appendix that compared species-specific fish abundance indices from the HRBMP to corresponding abundance indices from other federal or state fisheries management and assessment programs in order to provide additional validation of the data used in the AEI Report.

12. The AEI Report relies on the HRBMP database. In my professional opinion, the HRBMP database is the most extensive and robust database on abundance of egg, larval and juvenile life stages of estuarine fish currently available on the East Coast of the United States. The HRBMP database consists of over thirty (30) years of data collected consistently according to statistically rigorous sampling designs. The HRBMP annual studies include stratified-random sampling of the Hudson River from Manhattan

to the Federal Dam at Troy, New York, a 152 mile stretch, in which Indian Point is located at River mile 42. Multiple types of sampling gear are used to collect ichthyoplankton and juvenile fish in bottom, water column, and shorezone habitats. By sampling multiple habitats over such a large geographic expanse, the HRBMP minimizes the chance that some portion of a fish population of interest is inadvertently unsampled.

RESPONSE TO PISCES HUDSON REPORT

13. The Pisces Hudson Report addresses the larger and general Hudson River ecosystem without regard to IP2 and IP3 (or even any mention of it). Therefore, the Pisces Hudson Report does not permit any inferences to be made regarding the possible effects of Indian Point's operations on the ecosystem.

RESPONSE TO PISCES EI REPORT

14. Below, I respond to the Pisces EI Report. In general, the Pisces EI Report argues that impingement and entrainment at IP2 and IP3 are "large," and therefore necessarily must be responsible for what Drs. Seaby and Henderson maintain are observed trends in certain fish populations, particularly, Atlantic tomcod, bay anchovy, river herring, American shad, and white perch, in the Hudson River. As described below, the assertion that entrainment and impingement are presumptively the cause of certain fish population declines is incorrect, as established in the AEI Report and elsewhere.

15. The conclusions regarding the impacts of entrainment and impingement at IP2 and IP3 that are presented in the Pisces EI Report are offered with no scientific justification or reasoning. Drs. Seaby and Henderson claim:

> *"The impact of the mortalities caused by impingement and entrainment and thermal discharges on the fish populations of the Hudson is large."* (Summary, page 1)
>
> and
>
> *"In a system that is under stress from many sources, the entrainment of 1.2 billion fish attributable to Indian Point is significant."* (Section 3.4, page 11)
>
> and
>
> *"The number of fish impinged at Indian Point, as estimated in the DEIS, is large, at over 1.2 million fish."* (Section 4.4, page 18)

However, the authors do not define "impact," "large," or "significant," and they provide no discussion of any biological linkage between numbers of fish entrained or impinged and impacts to fish populations. Much of fishery science is devoted to the study of how much mortality can be imposed on fish populations (through harvesting and by-catch mortality) without affecting the sustainability of the populations. It is well understood that fish populations are renewable resources and that the removal of fish from a population is not equivalent to an adverse impact (e.g., jeopardizing population sustainability). This is the premise of commercial and recreational fishing and fisheries management which allows for removals of fish while maintaining population sustainability. The Pisces EI Report appears to completely ignore this scientific principle.

16. The proposition that large numbers entrained equate to large impacts on fish populations is not scientifically valid, as explained in Section 2.2 of the AEI Report (*Why entrainment losses alone are insufficient to demonstrate AEI*). Reproductive strategies of fish that spawn in estuaries (e.g., producing very large numbers of eggs), ensure that sufficient offspring will survive to sustain the populations, even in an environment characterized by the presence of multiple stressors. For example, more than 99.99% of striped bass eggs die from natural causes within 60 days following spawning. Less than one striped bass egg in 100,000 is likely to survive to become a one-year-old fish, and less than one in a million is likely to survive to reach six years of age, the median age at which female striped bass become sexually mature. Because nearly all of the eggs and larvae entrained at IP2 and IP3 would have died in any case, counts of total numbers entrained reveal nothing meaningful about the potential impact of IP2 and IP3 on fish populations.

17. To provide additional context for understanding the assessment presented in the Pisces EI Report, I reviewed Dr. Henderson's recent paper on fish populations in the Severn Estuary/Bristol Channel (Henderson, P.A. 2007. *Discrete and continuous changes in the fish community of the Bristol Channel in response to climate change. J. Mar. Biol. Ass. U.K.* 87, 589-598). In that paper, Dr. Henderson reports on his analysis of a 25-year time series of impingement data collected at the Hinkley Point B power plant on the Severn estuary. He concluded that the observed changes in the fish community were due to climatic changes (affecting temperature, salinity, and the North Atlantic Oscillation ("NAO"):

> *"In conclusion, there have been marked changes in the fish community of the Bristol Channel over the last 25 years. Increased water temperatures have produced a steady increase in species richness as more southerly distributed fish enter the estuary in greater numbers. In the mid 1980s there was an abrupt change in relative abundance of the permanent members of the community, which was likely caused by changes in the NAO and offshore plankton productivity. In the early 1990s, a second abrupt change in the total species assemblage occurred which could be related to temperature increase."*

The impingement data (referred to as the Severn Estuary Data Set ("SEDS")) Dr. Henderson analyzed for his 2007 paper were collected, at least in part, to assess power plant effects on the fish populations of the Severn Estuary/Bristol Channel:

> *". . . SEDS is an unique ecological resource. It has four principal uses. First, it provides for the detection and analysis of ecological change caused by industrial water users such as power stations. Second, it provides a robust indicator of recent trends in animal abundance in the Bristol Channel. This benefits fisheries management interests, the*

> *examination of long-term trends in environmental quality, and the understanding of ecological systems. Third, it provides a superb database for the study of population dynamics and community ecology. Finally, it helps the Hinkley Point power stations to address the concerns of regulatory organisations."* (Henderson, P.A. and R.M.H. Seaby. 2000. *Fish and crustacean captures at Hinkley Point B nuclear power station: report for the year April 2000 to March 2001*. Pisces Conservation, Ltd.)

In their 2000 Hinkley Point B report, Drs. Henderson and Seaby raised the question of possible effects of entrainment and impingement on fish populations in the estuary, but offered no conclusion:

> *"It is shown that the recent closures of direct-cooled power stations in the region are coincident with the increased abundance of common fish and crustaceans at Hinkley Point. These observations do not prove that power stations have, in the past, reduced animal abundance. However, the SEDS data set will offer over the coming 2 years the best opportunity available in the world to test for the impact of direct-cooled power stations."* (Henderson, P.A. and R.M.H. Seaby, 2000)

Henderson and Seaby listed 7 power plants on the Bristol Channel, 4 of which stopped operations between 1989 and 2000. They reported the total cooling water flow rate for the 7 plants to have been 270.3 m^3/sec. Over the 11-year period (1989-2000), they reported that the flow rate was reduced by more than half to 123.5 m^3/sec, and the estimated annual number of fish impinged dropped from 6.88 million to 3.44 million (a reduction several times greater than the estimated impingement at Indian Point).

As promised, slightly more than two years later Henderson did publish results of his analysis of the SEDS dataset (Henderson, 2007). By concluding that the observed changes in the fish community were due to climatic changes, and never mentioning the closure of power plants, Henderson's 2007 paper strongly suggests that the power plant closures did not materially affect the fish community. However, he did not describe the method he used to discriminate between possible effects of climate and possible effects of reduced entrainment and impingement. Absent such a method, the conclusions from his 2007 paper appear speculative.

Furthermore, basing conclusions about the fish community of the Severn Estuary/Bristol Channel on the SEDS dataset seems quite speculative in itself. Sampling consisted of one (1) six-hour sampling event per month, or twelve (12) six hour samples per year. Samples were collected from debris screens at Hinkley Point B power station, which withdraws water from a point location 640 meters offshore adjacent to a 40 square kilometer mud flat (Henderson 2007). It seems very unlikely that sampling from a single near-shore point would provide data representative of the entire fish community of Severn Estuary/Bristol Channel – "the largest estuarine system in the British Isles" (Henderson, 2007).

18. Henderson's 2007 paper and associated documents did not provide definitions of "impact," "large," or "significant" that could be used to better understand the conclusions of the Pisces EI Report. To the contrary, Henderson's 2007 paper provides an example of impingement numbers that are far larger than the impingement numbers from IP2 and IP3. Nevertheless, in his 2007 paper, Henderson apparently concluded that the impingement numbers did not cause adverse impact. Consistent with the Pisces EI Report, the 2007 Henderson paper did not present a method for discriminating between alternative hypotheses to explain observed changes in fish population abundance. In both the Pisces EI Report and the 2007 Henderson paper, the conclusions appear to have been drawn without consideration of alternative explanations, and therefore should be viewed as opinion and speculation, rather than matters of science.

RESPONSE TO JACOBSON DECLARATION

19. Below, I respond to the Jacobson Declaration. In general, the Jacobson Declaration argues that impingement and entrainment at IP2 and IP3 have caused an adverse impact to the fish populations and community of the Hudson River. More specifically, in reference to impingement and entrainment, the Jacobson Declaration concludes that:

> *"The millions of fish that are killed each year from operations at Indian Point represent a significant mortality and a stress on the River's fish community."* (paragraph 15)

20. Like the Pisces EI Report, the Jacobson Declaration provides no discussion of any biological linkage between numbers of fish entrained or impinged and impacts to fish community. Rather, the Jacobson Declaration lists several fish species that have exhibited declines in abundance, implying a link between entrainment or impingement and the declines in abundance of those species, but presenting no scientific analysis to establish that linkage.

21. As noted above (paragraph 14), the proposition that large numbers entrained equate to large impacts on fish populations is not scientifically valid, as explained in Section 2.2 of the AEI Report (*Why entrainment losses alone are insufficient to demonstrate AEI*). Reproductive strategies of fish that spawn in estuaries (e.g., producing very large numbers of eggs), ensure that sufficient offspring will survive to sustain the populations, even in an environment characterized by the presence of multiple stressors. For example, more than 99.99% of striped bass eggs die from natural causes within 60 days following spawning. Less than one striped bass egg in 100,000 is likely to survive to become a one-year-old fish, and less than one in a million is likely to survive to reach six years of age, the median age at which female striped bass become sexually mature. Because nearly all of the eggs and larvae entrained at IP2 and IP3 would have died in any case, counts of total numbers entrained reveal nothing meaningful about the potential impact of IP2 and IP3 on fish populations.

CONCLUSION

22. The Pisces Hudson Report addresses the larger and general Hudson River ecosystem without regard to IP2 and IP3 (or even any mention of it). Therefore, the Pisces Hudson Report does not permit any inferences to be made regarding the possible effects of Indian Point's operations on the ecosystem.

23. The Pisces EI Report and Jacobson Declaration present no scientific analyses to support their conclusions, but rather appear to rely on opinions and assumptions that render their conclusions speculative and unreliable as a matter of science. In contrast, the AEI Report rigorously considers and evaluates alternative hypotheses to explain observed changes in the Hudson River fish community. In addition, the HRBMP data used in the AEI Report were collected in a statistically rigorous manner to ensure representativeness of the data.

24. In my professional opinion, nothing in the Pisces EI Report or Jacobson Declaration alters the conclusion set forth in the AEI Report that entrainment and impingement associated with Indian Point's respective CWIS has not adversely impacted Hudson River fish populations.

Signed this 18th day of January, 2008.

Douglas G. Heimbuch, Ph.D.
Technical Director, AKRF

ATTACHMENT 1

DOUGLAS G. HEIMBUCH, PH.D.

TECHNICAL DIRECTOR

Douglas Heimbuch, Ph.D., a technical director at AKRF, is an environmental scientist with 25 years of experience in natural resources, and is an acknowledged expert in the fields of fishery science and biostatistics. He is experienced in the study of population dynamics, statistical analysis of environmental data, development of environmental sampling designs, estimation of parameters of animal populations, and assessment of effects of power plant operations on fish populations. He has published numerous articles on fish, water quality, and related issues in academic peer review journals. Before joining AKRF's Natural Resources group in 2002, Dr. Heimbuch served as Associate Vice President at PBS&J, Vice President and co-founder of Coastal Environmental Services, Inc., and Systems Manager at Martin Marietta.

Dr. Heimbuch has analyzed the effects of entrainment and impingement on fish populations for several power plant projects, including the 316(b) Demonstration for the PSEG Salem plant, the mid-Hudson River Power Plants, and studies sponsored by NYPA to assess fish abundance and distribution in waterbodies surrounding New York City. He has evaluated the effectiveness of mitigation measures implemented to address 316(b) issues and has worked with resource economists to link the results from his analyses of fisheries data to information on the recreational and commercial value of fish as part of cost-benefit analyses.

BACKGROUND

__Education__

Ph.D., Natural Resources/Fishery Science (Biometrics minor), Cornell University, 1982

M.S., Natural Resources, Cornell University, 1978

B.S., Conservation of Natural Resources, University of California at Berkeley, 1973

__Years of Experience__

Year started in company: 2002

Year started in industry: 1982

RELEVANT EXPERIENCE

Studies of the Effects of Entrainment and Impingement on Fish Populations Conducted in Response to USEPA's 316(b) Phase II Rule

Dr. Heimbuch assisted Wisconsin Electric in conducting analyses and in preparing Comprehensive Demonstration Studies for several electric generating stations on Lake Michigan. The analyses included estimation of calculation baseline conditions and projections of reductions in entrainment for compliance with USEPA's performance standards for existing power plants. Dr. Heimbuch has also estimated confidence limits for the projected reductions to provide additional support for a regulatory determination that the technology proposed would achieve compliance with the performance standards.

Dr. Heimbuch also assisted Atlantic Electric in the design and implementation of entrainment and impingement studies to address the 316(b) Phase II Rule. His work with Atlantic Electric also included providing assistance in developing a regulatory compliance strategy, and conducting analyses of data to demonstrate compliance.

Public Service Enterprise Group (PSEG) Salem Plant 316(b) Demonstration, Salem, NJ

Dr. Heimbuch conducted studies for PSEG to evaluate possible cooling water intake structure effects on Delaware River fish populations. Dr. Heimbuch's work included identifying potentially relevant data sets, evaluating and analyzing data to determine trends in abundance of juvenile fish within Delaware Estuary. Dr. Heimbuch also conducted the statistical analyses of PSEG's latent impingement survival data, which demonstrated that the screen modifications PSEG had implemented reduced the mortality of impinged fish. Dr. Heimbuch also presented the findings of his analyses to the NJDEP and to the Monitoring Advisory Committee that oversees the design and implementation of Salem's biological monitoring program.

316(b) Rule Making Support

Dr. Heimbuch was retained by the Utility Water Act Group in 2002 to conduct an independent evaluation of the United States Environmental Protection Agency's (USEPA or Agency) case studies of power plants that the Agency was using to justify its estimate of the benefits from the 316(b) rulemaking. Dr. Heimbuch's analyses identified numerous errors in USEPA's methodologies and data. Dr. Heimbuch represented the industry in numerous conference calls with USEPA and its consultants to discuss these issues. He also prepared written comments for UWAG that were an essential part of industry's comments on the Proposed Rule.

Dr. Heimbuch was also retained by PSEG to provide expert support from 2001 through 2003 in connection with PSEG's response to USEPA's 316(b) Rule Making. This included participating in several meetings with USEPA and its consultants concerning the Salem-specific component of USEPA's Delaware River Case Study, preparing a critique of the final Case Study Report and responding to subsequent inquiries from USEPA's Consultant. Dr. Heimbuch also assisted with the overall preparation of PSEG's comments on the Proposed Rule and also conducted a comprehensive review of, and response to USEPA's Notice of Data Availability (NODA). The NODA project included a review of USEPA's supporting documentation for various calculations of fish and marsh production, commenting on alternative metrics for meeting performance standards and issues of inter-annual variability, and the scientific support for including a benefit-cost test in the proposed rule.

Atlantic States Marine Fisheries Commission (ASMFC) Expert Panel on Power Plant Effects on Coast-Wide Stocks

Dr. Heimbuch was a key member of the ASMFC expert panel charged with developing a method for conducting coast-wide assessments of power plant effects on stocks managed by the ASMFC. The method developed is consistent with and directly linked to stock assessment models, such as Virtual Population Assessment (VPA) or Forward Projection models, used by ASMFC to manage coast-wide stocks under the Commission's jurisdiction. The Panel also evaluated whether the method could be used to estimate power plant effects on a stock using generally available data and developed recommendations for future data collection programs.

New York Power Authority (NYPA) Charles Poletti Power Plant Study to Determine the Effects of Entrainment and Impingement, New York, NY

Dr. Heimbuch served as co-project manager and co-principal investigator on this study sponsored by the New York Power Authority (NYPA) to track fish distribution and abundance in the East River, Long Island Sound, and New York Harbor. This multi-faceted field sampling program was designed to produce data needed to estimate conditional mortality rates due to entrainment and impingement from power plant operations. Dr. Heimbuch was responsible for overseeing the study; developing sampling designs for ichthyoplankton trawl, juvenile trawl, and juvenile mark-recapture field sampling programs; and creating statistical methods for utilizing data from the field sampling programs to produce estimates of conditional mortality rates.

Effects of Power Plants on Hudson River Fish Populations, Hudson River, NY

Dr. Heimbuch served as Project Manager and Principal Investigator for this study, sponsored by electric power utilities operating power plants on the Hudson River, including NYPA, Con Edison, Central Hudson Gas & Electric, and Orange and Rockland Utilities. The study estimated the effects of entrainment and impingement on fish populations inhabiting the Hudson River and assesses the health of Hudson River fish populations. Dr. Heimbuch was responsible for assessing the effectiveness of potential mitigative measures for reducing entrainment and impingement mortality rates; developing an outage scheduling method, based on the principal of Pareto-optimality, for evaluating the effects of the timing of planned power plant outages on entrainment mortality; and designing a mark-recapture program for Hudson River striped bass and estimating survival and abundance of Hudson River striped bass using mark-recapture data.

Maryland Biological Stream Survey, Various Locations, MD

Dr. Heimbuch served as Project Manager and Co-Principal Investigator for this study, sponsored by the Maryland Department of Natural Resources, to estimate the state-wide abundance of fish populations inhabiting streams in Maryland. Dr. Heimbuch was responsible for the development of sampling design and statistical data analysis methods for a state-wide survey of the status of fish populations inhabiting streams in Maryland.

U.S. Environmental Protection Agency (EPA) EMAP Estuaries Program, Various Locations

Dr. Heimbuch acted as Co-Principal Investigator for several studies funded by EPA's Environmental Monitoring and Assessment Program (EMAP). Dr. Heimbuch evaluated sampling designs for monitoring estuarine resources of the East and Gulf Coasts of the United States. He also developed statistical methods for analyzing data collected by the EMAP Estuaries program and analyzed data from the EMAP Estuaries program.

Charlotte Harbor Estuary Program, Gulf Coast, FL

Dr. Heimbuch served as Co-Principal Investigator for studies to design a long-term environmental monitoring program for the Charlotte Harbor, on the Gulf Coast of Florida. He assessed the spatial and temporal variability in environmental measurements taken in Charlotte Harbor and its watershed, and quantified the relationships between rainfall, river flow rate, and salinity regimes in the Peace River tributary to Charlotte Harbor.

Tampa Bay National Estuary Program (TBNEP), St. Petersburg, FL

Dr. Heimbuch served as Co-Principal Investigator for studies to design a long-term environmental monitoring program for Tampa Bay. He developed sampling designs and data analysis protocols, and synthesized historical biological data from Tampa Bay. He also developed a data management strategy for TBNEP, evaluated physical impacts to habitats, and mapped living resources within Tampa Bay.

Atlas of Hudson River Fish Distributions, Hudson River from Albany to the Battery in New York City, NY

Dr. Heimbuch served as Project Manager and Principal Investigator for this project sponsored by the Hudson River Foundation for Science and Environmental Research. Dr. Heimbuch compiled and analyzed historical data on fish populations in the Hudson River to determine distribution and movement patterns of eight key resource species within the river.

Westway Highway Fish Studies, New York, NY

Dr. Heimbuch acted as Co-Principal Investigator for these studies sponsored by the U.S. Army New York District Corps of Engineers in connection with a proposal to construct a new highway along the West Side of Manhattan in New York City. He developed a statistical methodology for estimating the fraction of the Hudson River juvenile striped bass population that inhabited the Westway site on the western shore of Manhattan, as well as sampling designs for the New York District Corps of Engineers fish sampling program for the Westway project. He also performed analysis and interpretation of data collected by the Westway Fisheries Studies for the project's Final Supplemental Environmental Impact Statement.

PUBLICATIONS

Heimbuch, D.G., E. Lorda, D. Vaughan, L.W. Barnthouse, J. Uphoff, W. VanWinkle, A. Kahnle, B. Young, J. Young, and L. Kline. 2007. Assessing coastwide effects of power plant entrainment and impingement on fish populations: Atlantic menhaden example. North American Journal of Fisheries Management 27:569-577.

Heimbuch, D.G., D.J. Dunning, Q.E. Ross, and A.F. Blumberg. 2007. Assessing potential effects of entrainment and impingement on fish stocks of the New York-New Jersey Harbor Estuary and Long Island Sound. Transactions of the American Fisheries Society 136:492-508.

Dunning, D.J., Q.E. Ross, A.F. Blumberg, and D.G. Heimbuch. 2006. Transport of striped bass larvae out of the lower Hudson River estuary. In: Hudson River Fishes and Their Environment. American Fisheries Society Symposium 51:273-286

Dunning, D.J., Q.E. Ross, M. Mattson, and D.G. Heimbuch. 2006. Distribution and abundance of bay anchovy eggs and larvae in the Hudson River and nearby waterways. In: Hudson River Fishes and Their Environment. American Fisheries Society Symposium 51:215-226.

Blumberg, A.F., D.J. Dunning, H. Li, R.C. Geyer, and D.G. Heimbuch. 2004. A particle-tracking model for predicting entrainment at power plants on the Hudson River. Estuaries Vol.27, No.3, p. 515-526 .

Heimbuch, D.G., J.C. Seibel, H.T. Wilson, and P.F Kazyak. 1999. A multiyear lattice sampling design for Maryland-wide fish abundance estimation. Journal of Agricultural, Biological, and Environmental Statistics. Vol 4, No. 4.

Weisberg, S.B., H.T. Wilson, D.G. Heimbuch, H.L. Windom, and J.K. Summers. 1999. Comparison of sediment metal:aluminum relationships between the eastern and gulf coasts of the United States. Environmental Monitoring and Assessment.

Heimbuch, D.G., H.T. Wilson, and J.K. Summers. 1998. Design-based estimators and power analyses of trend tests for the proportion of fish that exhibit gross pathological disorders. Environmental and Ecological Statistics. 5, 65-80

Heimbuch, D.G., H.T. Wilson, S.B. Weisberg, J.H. Volstad, and P.F. Kazyak. 1997. Estimating fish abundance in stream surveys using double-pass removal sampling. Transactions of the American Fisheries Society. 126:795-803.

Heimbuch, D.G., D.J. Dunning and J. Young. 1992. Post-yolk-sac larvae abundance as an index of year class strength of striped bass in the Hudson River. In: (C.L. Smith ed.) Estuarine Research in the 1980's: The Hudson River Environmental Society Seventh Symposium on Hudson River Ecology, p. 376-391.

Dunning, D.J., Q.E. Ross, W.L. Kirk, J.R. Waldman, D.G. Heimbuch and M.T. Mattson. 1992. Postjuvenile striped bass studies after the settlement agreement. In: (C.L. Smith ed.) Estuarine Research in the 1980's: The Hudson River Environmental Society Seventh Symposium on Hudson River Ecology, p. 339-347.

Heimbuch, D.G., D.J. Dunning, H. Wilson, and Q.E. Ross. 1990. Sample size determination for mark recapture experiments: Hudson River case study. American Fisheries Society Symposium 7:684-690.

Heimbuch, D.G. and J.M. Hoenig. 1989. Change in ratio estimates for habitat usage and relative population size. Biometrics 45, 439 451.

Rose, K.A., J.K. Summers, R.A. Cummins and D.G. Heimbuch. 1986. Analysis of long term ecological data using categorical time series regression. Canadian Journal of Fisheries and Aquatic Science 43:2418 2426.

Summers, J.K., T.T. Polgar, J.A. Tarr, K.A. Rose, D.G. Heimbuch, J. McCurley, R.A. Cummins, G.F. Johnson, K.T. Yetman and G.T. DiNardo. 1985. Reconstruction of long term time series for commercial fisheries abundance and estuarine pollution loadings. Estuaries Vol. 8, No. 2A, p. 114-124.

Polgar, T.T., J.K. Summers, R.A. Cummins, K.A. Rose and D.G. Heimbuch. 1985. Investigation of relationships among pollutant loadings and fish stock levels in northeastern estuaries. Estuaries Vol. 8, No. 2A, p. 125-135.

Rothschild, B.J. and D.G. Heimbuch. 1983. Managing variable fishery management systems. In: Proceedings of the Expert Consultation to Examine Changes in Abundance and Species Composition of Neritic Fish Resources, San Jose, Costa Rica, 18 29. April 1983. FAO Fisheries Report No. 291.

Youngs, W.D. and D.G. Heimbuch. 1982. Another consideration of the morphoedaphic index. Transactions of the American Fisheries Society 111:151 153.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of ENTERGY NUCLEAR INDIAN POINT 2, LLC, ENTERGY NUCLEAR INDIAN POINT 3, LLC, and ENTERGY NUCLEAR OPERATIONS, INC. (Indian Point Nuclear Power Station)	Docket Nos. 50-247, 50-286

**DECLARATION OF CHARLES C. COUTANT, PH.D.
IN OPPOSITION TO RIVERKEEPER CONTENTION EC-1 AND
NEW YORK ATTORNEY GENERAL CONTENTION 30**

I, Charles C. Coutant, Ph.D., declare as follows:

QUALIFICATIONS

1. I have extensive experience as a private consultant assessing the impacts of thermal discharges on freshwater, estuarine, and marine environments. As a consultant, I have assessed the effects of thermal discharges by numerous power plants and have authored or advised the preparation of multiple Clean Water Act ("CWA") §316(a) Demonstrations. I have served as an expert scientific consultant involved in assessments of the potential impacts of cooling water withdrawals and elevated-temperature releases on biological resources.

2. I have significant first-hand experience with the Hudson River estuary and other east coast estuaries. My relevant Hudson River experience includes participation in the initial Atomic Energy Commission licensing of Indian Point 1 and 2 in 1971-1975; NY SPDES permitting for the Danskammer and Roseton power plants in the late 1990s and early 2000s; and fish population assessments for Hudson River utilities in the late 1990s. My relevant experience with other east coast estuaries includes NJ PDES permitting for the Salem Nuclear Power Plant on Chesapeake Bay, New Jersey and the Hudson Generating Station on the Hackensack River/Newark Bay, New Jersey; and evaluation of a water intake on the Mattaponi River/York estuary, Virginia.

3. I have authored over three hundred scientific papers and publications regarding such subjects as: (i) the thermal impacts on fish growth and survival; (ii) the effects of once-through cooling on aquatic systems; (iii) fish and wildlife management and restoration programs; (iv) the protection of anadromous fish; (v) the effects of climate change on freshwater fish habitat; and (vi) temperature and fish habitat selection.

I was also a co-author of the EPA's 1977 technical guidance document for §316(a) demonstrations.

4. In addition to my own research, I have extensive experience reviewing and evaluating environmental reports produced by major power plants, many in the Northeast. I have evaluated reports for such plants as: Danskammer and Roseton Power Plants in Newburgh, New York; Salem Nuclear Power Plant in Lower Alloways Creek Township, New Jersey; Shoreham Nuclear Power Plant in Nassau County on Long Island, New York; Palisades Nuclear Power Plant near Benton Harbor, Michigan; North Anna Nuclear Power Plant in Louisa County, Virginia; and Vermont Yankee Nuclear Power Station in Vernon, Vermont; as well as Indian Point 2 and 3 in Buchanan, New York.

5. Prior to beginning work as a private consultant, I spent 35 years at the U.S. Department of Energy's ("DOE") Oak Ridge National Laboratory ("ORNL"). At ORNL, I assisted in the creation of numerous assessments under the National Environmental Policy Act ("NEPA") including assessing the impacts of discharges from both nuclear and hydropower projects. At ORNL, I also managed multi-million dollar research programs in which I directed and oversaw the activities of up to 15 researchers conducting field, laboratory, and modeling studies related to ecological effects of power station cooling systems. Before joining ORNL, I was a Research Scientist at Battelle-Pacific Northwest Laboratories in Richland, Washington, conducting research on thermal discharges to the Columbia River.

6. I have received a number of awards recognizing my scientific work including: (i) the 1963 Darbaker Prize by the Pennsylvania Academy of Science; (ii) the 1987 Distinguished Publication Award by the American Society for Information Science; and (iii) the 1997 Distinguished Service Award by the American Society for Information Science. I was also named the Distinguished Scientist of the Year in 2002 by ORNL.

7. I am a fellow at the American Association for the Advancement of Science and the American Institute of Fishery Research Biologists. I have held numerous offices at the American Fisheries Society, including president, and am a member of the American Society for Limnology and Oceanography and the Ecological Society of America. I hold Ph.D., Masters, and Bachelors degrees in Biology from Lehigh University in Bethlehem, Pennsylvania. My current curriculum vitae, including a list of my peer reviewed scientific publications, is attached hereto as Attachment 1.

THIS PROCEEDING

8. I understand that this proceeding ("Proceeding") before the Nuclear Regulatory Commission ("NRC" or the "Commission") concerns the May 2007 application by Entergy Nuclear Operations, Inc. ("Entergy") to renew, for a period of 20 years, the operating licenses for Entergy Nuclear Indian Point 2, LLC ("IP2") and Entergy Nuclear Indian Point 3, LLC ("IP3"), nuclear power generating units located in Buchanan, New York. 72 Fed. Reg. 26,850 (May 11, 2007). I understand that Riverkeeper, Inc. ("Riverkeeper") and the New York Attorney General ("NYS") have

filed petitions (the "Petitions") to intervene in this license renewal proceeding, in which they specifically request a hearing before the NRC with respect to certain issues that they maintain are not adequately addressed in Entergy's license renewal application ("LRA").

9. I have reviewed Riverkeeper Contention EC-1 and NYS Contention 30, with particular focus on assertions by Riverkeeper and NYS that the cooling water intake systems ("CWIS") at IP2 and IP3 cause "heat shock" or other thermal discharge impacts (the "Thermal Contentions"). I have reviewed materials submitted by Riverkeeper and NYS in purported support of the Thermal Contentions: (i) the declaration of Dr. Richard Seaby; (ii) the declaration of Dr. Peter Henderson; (iii) accompanying reports co-authored by Drs. Seaby and Henderson entitled *Status of Fish Populations and the Ecology of the Hudson River* ("Pisces Hudson Report") and *Analysis of Entrainment, Impingement, and Thermal Impacts at Indian Point Power Station* ("Pisces EI Report") (together, the "Pisces Reports"); and (iv) the declaration of Dr. David W. Dilks.

10. This Declaration is submitted in support of Entergy's response to the Thermal Contentions.

RESPONSE TO THERMAL CONTENTIONS

11. Below, I reply in part to the Thermal Contentions, and the materials submitted by Riverkeeper and NYS in purported support of the Thermal Contentions. I disagree with many of the opinions offered in these materials. The fact that I do not specifically address a particular opinion or contention in this Declaration does not mean that I agree with such opinions or contentions.

Pisces Hudson Report

12. The Pisces Hudson Report addresses the larger and general Hudson River ecosystem without regard to IP2 and IP3 (or even any mention of it). Therefore, the Pisces Hudson Report does not permit any inferences to be made regarding the possible effects of Indian Point's operations on the ecosystem, including possible thermal effects.

Failure to Tie General Thermal Principles to Operation of IP2 and IP3

13. Pisces and Dr. Dilks repeatedly cite well-known principles of thermal biology and ecology, in an apparent attempt to suggest that these general principles support the existence of adverse environmental impacts at Indian Point. For example:

- The Pisces Hudson Report states that "[t]emperature can affect survival, growth and metabolism, activity, swimming performance and behaviour, reproductive timing and rates of gonad development, egg development, hatching success, and morphology." Pisces Hudson Report, at 3.

- The Pisces EI Report asserts that "[a] temperature exceeding 100°F will produce lethal conditions for aquatic life of all kinds, including algae, crustaceans and fish." Pisces EI Report, at 1; *see also id.* at 32 ("Maximum temperatures in the discharge may exceed 35°C. Therefore, it seems inevitable that the heated discharge will result in death of, or harm to, any American shad, Atlantic tomcod, and river herring early life stages in the region of the discharge.").

- The Dilks Declaration states that "[i]ncreases in water temperature have been shown to have numerous biological consequences." Dilks Decl. ¶ 8 (listing four well-known potential effects of increased water temperature, ranging from lethal to indirect effects); *see also id.* ¶ 7.

14. I do not disagree with these general principles of thermal biology and ecology. Pisces and Dr. Dilks wholly fail, however, to demonstrate the relevance of these principles of thermal biology and ecology to IP2 and IP3. Notably, none of the statements of principle is followed by an analysis or scientific estimation of what in fact occurs under the actual operating and environmental conditions at Indian Point. Absent a reasoned scientific connection between assertions of general principle and the operation of IP2 and IP3, the statements of Pisces and Dr. Dilks are nothing more than unscientific speculation, and a reasonable scientist would not rely on these statements to reach any conclusions regarding the potential thermal impact of IP2 and IP3.

Inability to Draw Biological Conclusions From 1999 Hydrothermal Modeling

15. Pisces and Dr. Dilks heavily rely on predictions of the size, location, and persistence of the thermal discharge plume in order to postulate regarding the potential thermal effect of IP2 and IP3's operations on the Hudson River ecology. *See, e.g.*, Dilks Decl. ¶ 7 ("The heated water, when initially discharged, is poorly diluted and is contained in what is called a thermal plume. Because heated water is less dense (i.e., lighter) than cooler water, this discharge plume rises in the water column until it meets the water surface. At this point, the plume spreads out and is transported by natural river currents and tidal flows. Temperatures are generally much higher in the discharge plume than in the surrounding water. Furthermore, for large discharges such as IP2 and IP3, temperatures are noticeably raised outside of the discharge plume, because the quantity of heat released is greater than the capacity of the river to fully dilute it."); Pisces EI Report, at 21 ("[T]he surface extent of the thermal plume produced by Indian Point covers a high proportion of the width of the river.").

16. Because Pisces and Dr. Dilks heavily rely on such predictions of the size, location, and persistence of the thermal discharge plume in reaching purported conclusions regarding the ecology of the Hudson River, I have reviewed submissions from Charles V. Beckers, Jr., who performed the hydrothermal modeling reported in Appendices VI-3-A and VI-3-B of the Draft Environmental Impact Statement ("DEIS") referenced at page 3-36 of Entergy's Environmental Report (the "1999 Hydrothermal Modeling"), and from an independent reviewer of the original hydrothermal modeling, J. Craig Swanson, Ph.D. *See* Declaration of Charles V. Beckers, Jr. (Dec. 19, 2007); Declaration of J. Craig Swanson, Ph.D. (Jan. 18, 2008). As a biologist, I frequently depend on reliable estimates of temperature conditions as a starting point for biological evaluations. Therefore, I reviewed these submissions in order to determine whether a reasonable scientist would reach conclusions about the possible thermal effect of IP2 and

IP3's operations on the Hudson River ecology based on the 1999 Hydrothermal Modeling.

17. For the purposes of this analysis, I accept as true and accurate Mr. Beckers' description of the input conditions selected by the New York State Department of Environmental Conservation ("NYSDEC") for the 1999 Hydrothermal Modeling. I also accept as true and accurate Dr. Swanson's conclusion that the 1999 Hydrothermal Modeling yields extremely wrong answers, because that modeling was based on conditions that could not occur, under any circumstances, in the River near Indian Point.

18. As documented by Mr. Beckers and Dr. Swanson, the 1999 Hydrothermal Modeling was run using environmental conditions that are impossible. Because, as Dr. Swanson opines, the temperature and spatial and temporal distribution of the Indian Point thermal plume, as predicted by the 1999 Hydrothermal Modeling, could not occur, under any circumstances, in the River near Indian Point, I conclude that the 1999 Hydrothermal Modeling is unreliable as a basis for informed biological assessments. In my professional opinion, no reasonable biologist would draw conclusions regarding possible biological impacts based on the 1999 Hydrothermal Modeling.

19. Accordingly, purported biological analyses by Pisces and Dr. Dilks that rely on the 1999 Hydrothermal Modeling – such as conclusions regarding alleged thermal effects on fish and benthic organisms, *see, e.g.*, Pisces EI Report, at Section 5.4 – are not supported as a matter of science.

Heat Shock

20. The Pisces EI Report suggests that "[w]hen Indian Point discharges warm water into the river, it mixes with the receiving waters. Any small organisms in the receiving water with which it mixes will also be subjected to sudden changes in temperature that are potentially harmful." Pisces EI Report, at 29; *see also id.* at 36 (entitled "heat shock"). Pisces' suggestion that organisms subjected to sudden changes in temperature or "heat shock" as a result of IP2 and IP3's operations will incur an adverse effect is incorrect.

21. The term "heat shock" or "thermal shock" is an older, imprecise term that generally refers to a fish or other organism being exposed to an abrupt temperature change. It does not quantify a biological effect. Generally, there are discrete components of rapid temperature change ("heat shock") that are important for determining biological effects and that can constitute protective criteria. These are the initial acclimation temperature of the fish, the new temperature to which the fish is exposed, and the duration of that exposure. These were explained years ago, for instance, in a 1970 article I wrote (Coutant, C.C., *Biological Aspects of Thermal Pollution: Entrainment and Discharge Canal Effects*, CRC Critical Reviews in Environmental Control 1(3):341-381 (1970)) and in the Heat and Temperature chapter of the National Academy of Sciences/National Academy of Engineering Report (National Academy of Sciences/National Academy of Engineering, Water Quality Criteria – 1972, Environmental Protection Agency Report EPA.R3.73.033, Washington, D.C. (1972)).

22. The biological effects of rapid temperature changes (again, "heat shock"), such as direct death, loss of equilibrium, or increased vulnerability to predation, need to be expressed as the result of combinations of these components to be meaningful.

23. For the purposes of this analysis, I accept the conclusions set forth in the report entitled *Entrainment and Impingement at IP2 and IP3: A Biological Impact Assessment* (Jan. 2008) ("AEI Report"), attached as Attachment 2 to the Declaration of Lawrence W. Barnthouse, Ph.D. Although the AEI Report is not a §316(a) Demonstration and does not draw conclusions about potential thermal effects of IP2 and IP3's operations, it nevertheless provides a basis for certain reasoned inferences to be drawn regarding the potential thermal effects of IP2 and IP3's operations on the Hudson River ecosystem. Thus, while the focus of the AEI Report was on impacts of fish losses due to entrainment and impingement, I believe the analysis also relates directly to allegations regarding "heat shock" raised by Pisces. *See* Pisces EI Report, at 29, 36.

24. Specifically, the AEI Report uses Conditional Mortality Rates ("CMRs") as inputs to the assessment in order to critically examine the hypothesis that entrainment and impingement by IP2 and IP3's respective CWIS are related to reductions in the abundance of key fish species in the Hudson River over approximately three decades of monitoring. As noted in the Appendix to the DEIS, CMRs reflect the risk of impingement and entrainment for life stages of fish located within the appropriate sphere of influence of Indian Point (i.e., the regions from which water is withdrawn by Indian Point). "Heat shock" (the abrupt raising and lowering of temperature in a cooling system and discharge plume), if occurring, would occur in an area significantly smaller that than this sphere of influence because the thermal plume covers only a fraction of this area. Accordingly, heat shock, if occurring, would occur within the same region of the River in which the AEI Report (through its use of CMRs) evaluated the risk of mortality due to impingement and entrainment.

25. The AEI Report concludes, as a function of CMRs, that entrainment and impingement losses of fish as a result of Indian Point's operations are not responsible for changes in fish population numbers in the Hudson River. Accepting for the purposes of this analysis the conclusions of the AEI Report, it is my professional opinion that Hudson River fish populations are not experiencing adverse effects of heat shock as a result of the IP2 and IP3's operations.

CONCLUSION

26. The Thermal Reports: (1) fail to connect assertions of general thermal principles to the actual operations of IP2 and IP3; (2) improperly rely on the 1999 Hydrothermal Modeling results; and (3) reach incorrect conclusions regarding "heat shock." The Thermal Reports' assertions of adverse environmental impact are therefore unsupported as a matter of science and the practice of environmental assessment and do not provide evidence in support of the Thermal Contentions.

Signed this 18th day of January, 2008.

Charles C. Coutant, Ph.D.

ATTACHMENT 1

RESUME

CHARLES C. COUTANT

Present Position

Oak Ridge National Laboratory, retired. Private consultant. (October 1, 2005-present)

Born

Jamestown, New York, August 2, 1938

Education

Ph. D.	Lehigh University, Bethlehem, Pennsylvania	Biology 1965
M. S.	Lehigh University, Bethlehem, Pennsylvania	Biology 1962
B. A.	Lehigh University, Bethlehem, Pennsylvania	Biology 1960

Previous Positions

Distinguished Research Ecologist, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6036 (2003-2005)

Senior Research Ecologist, Environmental Sciences Division, Oak Ridge National Laboratory, (1982-1985; 1986-1988; 1992-2003)

Manager, ORNL Exploratory Studies Program, Central Management, and Senior Research Ecologist, Oak Ridge National Laboratory (1989-1992)

Manager, DOE Global Carbon Cycle Program, and Senior Research Ecologist, Environmental Sciences Division, Oak Ridge National Laboratory (1985-1986)

Team Leader, Multi-Media Modeling Project and Senior Research Ecologist, Environmental Sciences Division, Oak Ridge National Laboratory (1979-1982)

Manager, Thermal Effects Program, and Research Ecologist, Environmental Sciences Division, Oak Ridge National Laboratory (1970-1979)

Research Scientist, Biology Department (later Ecosystems Department), Battelle-Pacific Northwest Laboratories, Richland, Washington 99352 (1965-1970)

U. S. Public Health Service Predoctoral Fellow, Lehigh University, Bethlehem, Pennsylvania, 18015 (1963-1965)

Professional Societies

American Association for the Advancement of Science (Fellow)
American Institute of Fishery Research Biologists (Fellow)

American Fisheries Society (numerous offices, including President)
American Society for Limnology and Oceanography
American Society for Testing and Materials (lapsed)
Ecological Society of America
Sigma Xi
Water Pollution Control Federation (lapsed)

Professional and Academic Honors

2002	Distinguished Scientist of the Year, UT-Battelle (manager of ORNL)
2001	Distinguished Publication Award, American Society for Information Science (E. TN Chapter)
1999	Scientific Achievement Award, Southern Division, American Fisheries Society
1997	Distinguished Service Award, American Fisheries Society
1996-97	President, American Fisheries Society
1993-1996	Progression from Second Vice Pres., First Vice Pres., Pres. Elect, American Fisheries Society
1993	Elected as Second Vice President, American Fisheries Society
1991-1994	Coeditor, *Transactions of the American Fisheries Society*
1990-1991	President, Oak Ridge Chapter, Sigma Xi
1987-1989	President, Water Quality Section, American Fisheries Society
1987	Distinguished Publication Award, American Society for Information Science
1986-1988	Editorial Board, *Transactions of the American Fisheries Society*
1986-1987	President, Southern Division, American Fisheries Society
1986	President, Tennessee Chapter, American Fisheries Society
1986	Outstanding Publication Award, Martin Marietta Energy Systems, Inc.
1985	Present-Elect, Southern Division, American Fisheries Society
1984	Achievement Award for Excellence in Fisheries, Tennessee Chapter American Fisheries Society
1983	Fellow, American Association for the Advancement of Science
1980	Southeast Regional Lecturer, Sigma Xi
1978-1979	Editorial Board, *Environmental Science and Technology*
1978	Fellow, American Institute for Fishery Research Biologists
1975-1982	Editor, Underwater Telemetry Newsletter
1968	Best Award, Battelle-Northwest, Richland, Washington (Power Plant Siting Study)
1968	Director's Award, Battelle-Northwest (Power Plant Siting Study)
1963	U.S. Public Health Service Predoctoral Fellowship in Water Pollution Control
1963	Darbaker Prize, Pennsylvania Academy of Science (Excellent Microbiology Paper)

Professional Experience

Water Quality

Research and analysis on interactions between water quality and the biological integrity of water, including pollution monitoring and field studies for industry through Lehigh University (graduate assistant) and in private consulting (1960-1965) and annual literature reviews on thermal effects of Water Pollution Control Federation (1967-1978).

Member of National Academy of Sciences Committee on Water Quality, Panel on Freshwater Aquatic Life and Wildlife, and coauthor of the "Blue Book" on water quality, Water Quality Criteria 1972 (National Academy of Sciences/National Academy of Engineering 1973).

American Society for Testing and Materials (ASTM) Task Group Chairman for developing standard practice for evaluating transport/fate models for chemicals in the environment (1981-1984).

Aquatic Ecology and Fisheries

Ph.D. dissertation research on effects of dam discharges on stream ecology; Masters and Postdoctoral research on aquatic macroinvertebrate community responses to pollutants.

Research and analysis on aquatic resources of the middle Columbia River (1965-1970), particularly their responses to thermal effluents. Member, Independent Scientific Advisory Board (previously called the Scientific Review Group and Independent Scientific Group) overseeing the Columbia River Fish and Wildlife Program for Bonneville Power Administration, Northwest Power Planning Council, National Marine Fisheries Service and Columbia River Tribes (1989-2005). Member, Independent Scientific Review Panel for the Northwest Power and Conservation Council (formerly called the Northwest Power Planning Council) for evaluating proposals for the BPA-funded Columbia River Basin Fish and Wildlife Program (1997-2005).

Research and analysis on thermal, entrainment, and impingement effects of thermal power station cooling systems on aquatic organisms, principally fishes.

Thermal ecology of the striped bass (*Morone saxatilis*) and Chinook salmon (*Oncorhynchus tshawytscha*).

Thermal niche partitioning of lakes and estuaries.

Management of power station thermal discharges for environmental benefits.

Introduction of the concept of turbulent attraction flow (simulation of stream turbulence) for guiding migrating fish.

Environmental Impact Assessment

Environmental impact assessments (NEPA EISs) and hearing testimony on impacts of nuclear and fossil-fuel power stations on water quality and aquatic ecology and fisheries for Atomic Energy Commission, Nuclear Regulatory Commission, and Department of Energy (Palisades Nuclear Plant, Shoreham Nuclear Plant, Indian Point Nuclear Plant, Kyger Creek Power Plant).

Environmental impact assessments (NEPA EISs) for the Federal Energy Regulatory Commission on two hydroelectric dams in Alaska (Susitna Project), hydropower development in the upper Ohio River basin (cumulative impacts of 19 projects), nine hydropower projects in the Skagit River basin (Washington), and existing hydropower projects on the Mokelumne and Tuolumne rivers, California. Mentored ORNL staff for other FERC EIS projects.

Project Management

Technical direction and budgetary management for power station cooling systems research and multimedia (air, land, water) modeling projects, each with funding in the $0.5-1 million per year range (1970s dollars), including supervision of up to 20 staff.

Development of a project evaluation process for the Bonneville Power Administration's Columbia River Fish and Wildlife Program.

Management (from ORNL) of the Department of Energy's $4 million/year national research program on environmental determinants of carbon dioxide in the atmosphere as related to $C0_2$-induced global climate change.

Management of Oak Ridge National Laboratory's $8-12 million per year Exploratory Studies Program to support innovative new research ideas.

Advisory Capacity

Research coordination projects, including book preparation, for United Nations Educational, Scientific and Cultural Organization (UNESCO) and International Atomic Energy Agency (IAEA).

Research consultation with governmental agencies: Sweden, Federal Republic of Germany, United Nations Food and Agriculture Organization (FAO), Province of Ontario (Canada), and numerous review boards.

National Advisory Council for Electric Power Research Institute (EPRI).

Regulatory guideline preparation and review for implementation of Section 316(a) of the Clean Water Act for the Environmental Protection Agency (EPA).

Member or chair of several technical advisory committees for resolution of specific energy-environment conflicts.

Program reviewer for USGS Biological Resources Division, USEPA Western Ecology Laboratory (chair), South Carolina Water Department of Natural Resources, NOAA Fisheries' Northwest Fisheries Science Center

Member, Scientific Review Group for Bonneville Power Administration's Columbia River Fish and Wildlife Program.

Member, Independent Scientific Advisory Board for Northwest Power and Conservation Council, National Marine Fisheries Service, and Columbia River Tribes

Member, Independent Scientific Review Panel for Northwest Power and Conservation Council for scientific review of funding proposals to Bonneville Power Administration Fish and Wildlife Program.

Industrial Technical Assistance

Environmental consulting for power station thermal effects studies (Virginia Power Company, Commonwealth Edison Company, Electricity Corporation of New Zealand, Georgia Power Company, Carolina Power & Light Co., Public Service Electric and Gas Co., Pacific Gas and Electric Company, Dynegy, Dominion Power, Vermont Yankee), hydropower development (Beak Associates, Puget Power), and water diversions (Sacramento County (California), City of Newport News). Author of thermal effects 316(a) Demonstration for Blue Ridge Paper Products. Technical advisor to a stakeholder group evaluating revision of Colorado temperature standards.

Publications

Coutant, C. C. 1962. The effect of a heated water effluent upon the macro-invertebrate riffle fauna of the Delaware River . Proceedings of the Pennsylvania Academy of Science 36: 58-71.

Coutant, C. C. 1963. Steam plankton above and below Green Lane Reservoir. Proceedings of the Pennsylvania Academy of Science 37 :122-126.

Coutant, C. C. 1964. Insecticide Sevin: Effect of aerial spraying on drift of stream insects. Science 146:420-421.

Coutant, C. C. 1966. Bacteria in an impounding reservoir. Journal of the American Water Works Association 58:1275- 1277.

Coutant, C. C. 1966. Positive phototaxis in first instar caddis larvae. pp. 122-123. IN Pacific Northwest Laboratory Annual Report for 1965. BNWL-280. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1967. Biological considerations in water management. pp. 75-84, IN The Use of Simulation in Water Research. Water Resources Research Institute, Oregon State University, Corvallis, Oregon.

Coutant, C. C. 1967. Upstream dispersion of adult caddis flies, pp. 186-187. IN Pacific Northwest Laboratory Annual Report for 1966. BNWL-480, Vol. 1. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1967. Retention of radionuclides in Columbia River bottom organisms. pp. 170-171. IN Pacific Northwest Laboratory Annual Report for 1966. BNWL-480, Vol. 1. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C., D. G. Watson, C. E. Cushing, and W. L. Templeton. 1967. Observations on the life history of the limpet snail Fisherola nutalli Haldeman. pp. 190-191. IN Pacific Northwest Laboratory Annual Report for 1966. BNWL-480, Vol. 1. Battelle-Northwest Laboratories, Richland, Washington.

Cushing, C. E., D. G. Watson, R. B. Hall, and C. C. Coutant. 1967. Environmental effects of extended reactor shutdown fish. pp. 71-75. IN The Environmental Effects of an Extended Hanford Plant Shutdown, BNWL-CC-1056. Battelle-Northwest Laboratories, Richland, Washington.

Harty, H., R. F. Corlett, C. C. Coutant, R. E. Brown, J. F. Fletcher, H. E. Hawthorn, R. T. Jaske, C. L. Simpson, W. L. Templeton, W. A. Watts, M. A. Wolf, J. B. Burnham, J. G. Rake, and G. L. Wilfert. 1967. Final report on nuclear power siting in the Pacific Northwest to Bonneville Power Administration, Portland, Oregon. Battelle-Northwest Laboratories, Richland, Washington. 545 pp.

Watson, D. G., C. E. Cushing, and C. C. Coutant. 1967. Environmental effects of extended reactor shutdown - plankton and invertebrates. pp. 67-70. IN The Environmental Effects of an Extended Hanford Plant Shutdown. BNWL-CC-1056. Battelle-Northwest Laboratories, Richland, Washington.

Watson, D. G., C. E. Cushing, C. C. Coutant, and W. L. Templeton. 1967. Radionuclides in Columbia River organisms. pp. 164-169. IN Pacific Northwest Laboratory Annual Report for 1966. BNWL-480, Vol. 1. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1968. Responses to elevated temperature of fishes near Prescott, Oregon important to the commercial or sport fisheries of the Columbia River. Report to Portland General Electric Company, Portland, Oregon. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1968. Behavior of adult salmon and steelhead trout migrating past Hanford thermal discharges. p. 9.10. IN Pacific Northwest Laboratory Annual Report for 1967. BNWL-714, Vol. 1, Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1968. Effect of temperature on the development rate of bottom organisms. p. 9.13. IN Pacific Northwest Laboratory Annual Report for 1967. BNWL-714, Vol. 1. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1968. Thermal pollution - biological effects. A review of the literature of 1967. Journal of the Water Pollution Control Federation 40:1047-1052.

Coutant, C. C., and C. R. Cole. 1968. Modeling of aquatic systems. p. 9.30. IN Pacific Northwest Laboratory Annual Report for 1967. BNWL-714, Vol. 1. Battelle Northwest Laboratories, Richland, Washington.

Coutant, C. C., and C. D. Becker. 1968. Information on timing and abundance of fishes near Prescott, Oregon, important to the commercial and sport fisheries of the Columbia River. Report for the Portland General Electric Company, Portland, Oregon. Battelle Northwest Laboratories, Richland, Washington.

Coutant, C. C., and R. G. Genoway. 1968. An exploratory study of interaction of increased temperature and nitrogen supersaturation on mortality of adult salmonids. Contract No. 12-17-0001-1785. U.S. Bureau of Commercial Fisheries. Battelle-Northwest Laboratories, Richland, Washinqton.

Coutant, C. C. 1969. Debate on thermal issue continues. Environmental Science and Technology 3(5):425-427.

Coutant, C. C. 1969. Responses of salmonid fishes to acute thermal shock. pp. 2.19-2.26. IN Pacific Northwest Laboratory Annual Report for 1968. BNWL-1050, Vol. 1, Part 2. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C., C. D. Becker, and E. F. Prentice. 1969. Passage of downstream migrants. pp. 2.27-2.30. IN Pacific Northwest Laboratory Annual Report for 1968. BNWL-1050, Vol. 1, Part 2. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1969. Behavior of sonic-tagged chinook salmon and steelhead trout migrating past Hanford thermal discharges. pp. 2.39-2.44. IN Pacific Northwest Laboratory Annual Report for 1968. BNWL-1050, Vol. 1, Part 2. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1969. Temperature, reproduction and behavior. Chesapeake Science 10(3-4):261-274.

Coutant, C. C. 1969. Effects of thermal loading: The Columbia River story. pp. 34-39. IN Nuclear Power and the Environment: An Enquiry. Conservation Society of Southern Vermont, Bondville, Vermont.

Coutant, C. C. 1969. Thermal pollution - biological effects. A review of the literature of 1968. Journal of the Water Pollution Control Federation 41(6): 1036-1053.

Becker, C. D., and C. C. Coutant. 1969. Experimental drifts of juvenile salmonids through effluent discharges at Hanford. Part 1. 1968 Drifts. BNWL-1499. Battelle-Northwest Laboratories, Richland, Washington. 35 pp.

Cushing, C. E., D. G. Watson, C. C. Coutant, and W. L. Templeton. 1969. Effect of Hanford reactor shutdown on Columbia River biota. pp. 291-299. IN Symposium on Radioecology, D. J. Nelson and F. C. Evans (editors). CONF-670503 U.S. Atomic Energy Commission. National Technical Information Service, Springfield, Virginia.

Jaske, R. T., W. L. Templeton, and C. C. Coutant. 1969. Thermal death models. Industrial Water Engineering 6(10):24-27.

Coutant, C. C. 1970. Thermal resistance studies on salmonid fish. pp. 3.19-3.20. IN Pacific Northwest Laboratory Annual Report for 1969. BNWL-1306, Vol. 1, Part 2. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1970. Thermal pollution - biological effects. A review of the literature of 1969. Journal of the Water Pollution Control Federation 42(6):1025- 1057.

Coutant, C. C. 1970. Relative vulnerability of thermally shocked salmonids to predation. p. 3.11. IN Pacific Northwest Laboratory Annual Report for 1969. BNWL-1306, Vol. 1, Part 2. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1970. Thermal resistance of adult coho and jack chinook salmon and steelhead trout from the Columbia River. BNWL-1508. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1970. Behavior of sonic-tagged Chinook salmon and steelhead trout migrating past Hanford thermal discharges (1967). BNWL-1531. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1970. Exploratory studies of the interactions of gas supersaturation and temperature on mortality of juvenile salmonids. BNWL-1529. Battelle Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1970. Biological aspects of thermal pollution. I. Entrainment and discharge canal effects. Critical Reviews in Environmental Control 1(3):341-381.

Coutant, C. C. 1970. Biological limitations on the use of waste heat in aquaculture. pp. 51-61. IN Conf. Beneficial Uses of Thermal Discharges. New York State Dept. of Environmental Conservation, Albany, New York.

Auerbach, S. I., D. J. Nelson, S. V. Kaye, D. E. Reichle, and C. C. Coutant. 1970. Ecological considerations in reactor power plant siting. pp. 804-820. IN Environmental Aspects of Nuclear Power Stations. International Atomic Energy Agency Symposium 146/53, Vienna, Austria.

Coutant, C. C., and C. D. Becker. 1970. Growth of Columbia River limpets, Fisherola nuttalli (Haldeman), in normal and reactor-warmed water. BNWL-1537. Battelle Northwest Laboratories, Richland, Washington. 12 pp.

Coutant, C. C., J. M. Dean, and C. R. Cole. 1970. Modeling thermal death of fishes in fluctuating lethal temperatures. pp. 3.9-3.11. IN Pacific Northwest Laboratory Annual Report for 1969. BNWL-1306, Vol. 1, Part 2. Battelle Northwest Laboratories, Richland, Washington.

Becker, C. D., C. C. Coutant, and E. F. Prentice. 1970. Plume drifts with juvenile salmon. pp. 3.18-3.19. IN Pacific Northwest Laboratory Annual Report for 1969. BNWL-1306, Vol. 1, Part 2. Battelle-Northwest Laboratories, Richland, Washington.

Jaske, R. T., W. L. Templeton, and C. C. Coutant. 1970. Methods of evaluating effects of transient conditions in heavily loaded and extensively regulated streams. Chemical Engineering Progress Symposium Series 67(107):31-39.

Nelson, J. L., V. Bruns, C. C. Coutant, and R. Carlile. 1970. Behavior and reactions of copper sulfate in an irrigation canal. Pesticide Monitoring Journal 3(3):186.

Templeton, W. L., and C. C. Coutant. 1970. Studies on the biological effects of thermal discharges from nuclear reactors to the Columbia River at Hanford. pp. 491-614. IN Environmental Aspects of Nuclear Power Stations. International Atomic Energy Agency Symposium 146/53, Vienna, Austria.

Watson, D. G., C. E. Cushing, C. C. Coutant, and W. L. Templeton. 1970. Radioecological Studies on the Columbia River, Parts I and II. BNWL-1377. Battelle-Northwest Laboratories, Richland, Washington. 46 pp. + appendices.

Coutant, C. C. 1971. Thermal pollution - biological effects. Journal of the Water Pollution Control Federation 43(6):1292-1334.

Coutant, C. C. 1971. Effects on organisms of entrainment in cooling water: Steps toward predictability. Nuclear Safety 12(6):600-607.

Coutant, C. C. 1971. Great Lakes ecology. pp. 93-123, IN F. A. Butrico, C. J. Touhill, and I. L. Whitman (editors), Resource Management in the Great Lakes Basin. Heath Lexington Books, Lexington, Massachusetts.

Becker, C. D., and C. C. Coutant. 1971. Bionomics of Columbia River limpets in normal and reactor-warmed water. pp. 2.27-2.28. IN Pacific Northwest Laboratory Annual Report for 1970. BNWL-1550, Vol. 1, Part 2. Battelle-Northwest Laboratories, Richland, Washington.

Becker, C. D., C. C. Coutant, and E. F. Prentice. 1971. Experimental drifts of juvenile salmonids through effluent discharges at Hanford. Part II. 1969 drifts and conclusions. BNWL-1527. Battelle-Northwest Laboratories. Richland, Washington. 61 pp.

Templeton, W. L., and C. C. Coutant. 1971. A Bibliography of Ecological Publications Supported by the U.S. Atomic Energy Commission Related to Columbia River Thermal Effects Studies. BNWL-1543. Battelle-Northwest Laboratories, Richland, Washington.

Watson, D. G., C. E. Cushing, C. C. Coutant, and W. L. Templeton. 1971. Cycling of radionuclides in Columbia River biota. pp. 144-157. IN D. D. Hemphill (editor), Trace Substances in Environmental Health - IV. University of Missouri, Columbia, Missouri.

Coutant, C. C. 1972. Index for annual reviews 1967-1970. Thermal pollution-biological effects. ORNL/EIS-71/25. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 120 pp.

Coutant, C. C. 1972. Successful cold branding of nonsalmonids. Progressive Fish-Culturist 34(3):131-132.

Coutant, C. C. 1972. Ecological effects of power plant cooling. Interdisciplinary Seminar for the Water Resources Development Program. Report No. 17:23-44. Water Resources Research Center, The University of Tennessee, Knoxville, Tennessee.

Coutant, C. C. 1972. Effect of thermal shock on vulnerability to predation in juvenile salmonids, I. Single shock temperature. BNWL-1521. Battelle-Northwest Laboratories, Richland, Washinqton.

Coutant, C. C. 1972. Effect of thermal shock on vulnerability to predation in juvenile salmonids, II. A dose response by rainbow trout to three shock temperatures. BNWL-1519. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C. 1972. Biological aspects of thermal pollution. II. Scientific basis for water temperature standards at power plants. Critical Reviews in Environmental Control 3(1):1-24.

Coutant, C. C. 1972. Some biological considerations for the use of power plant cooling water in aquaculture. pp. 104-113. IN J. L. Gaudet (editor), Report of the 1970 Workshop on Fish Feed Technology and Nutrition. U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Resource Publication 102. Superintendent of Documents, Washington, D.C.

Coutant, C. C., and J. M. Dean. 1972. Relationships between equilibrium loss and death as responses of juvenile chinook salmon and rainbow trout to acute thermal shock. BNWL-1520. Battelle-Northwest Laboratories, Richland, Washington.

Coutant, C. C., and C. P. Goodyear. 1972. Thermal effects. Journal of the Water Pollution Control Federation 44(6):1250-1294.

Coutant, C. C., E. E. Huber, and H. A. Pfuderer. 1972. Thermal effects on aquatic organisms: Annotated bibliography of 1971 literature. ORNL/EIS-72/28. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 155 pp.

Mattice, J. S., and C. C. Coutant. 1972. AIF topical conference on water quality problems. Nuclear News 15(11):122-126.

Coutant, C. C. 1973. Effect of thermal shock on vulnerability of juvenile salmonids to predation. Journal of the Fisheries Research Board of Canada 30:965-973.

Coutant, C. C. 1973. Heat and temperature. pp. 151-171. IN Water Quality Criteria 1972. Environmental Studies Board, National Academy of Sciences/National Academy of Engineering. U.S. Environmental Protection Agency, EPA.R3.73.033. Washington, D.C.

Becker, C. D., C. C. Coutant, and E. F. Prentice. 1973. Ecological evaluation: Migration of juvenile salmon in relation to heated effluents in the central Columbia River. pp. 528-536. IN D. J. Nelson (editor), Radionuclides in Ecosystems. Third National Symposium on Radioecology. CONF-710501 U.S. Atomic Energy Commission. National Technical Information Service, Springfield, Virginia. 1268 pp.

Bowen, S. H., and C. C. Coutant. 1973. Thermal effect on feeding competition between rainbow trout and bluegill. pp. 1029-1033. IN D. J. Nelson (editor), Radionuclides in Ecosystems. Third National Symposium on Radioecology. CONF-710501 U.S. Atomic Energy Commission. National Technical Information Service, Springfield, Virginia.

Coutant, C. C., and C. D. Becker. 1973. Growth of the Columbia River limpet, Fisherola nutalli (Haldeman), in normal and reactor-warmed water. pp. 564-568. IN D. J. Nelson (editor), Radionuclides in Ecosystems. Third National Symposium on Radioecology. CONF-710501 U.S. Atomic Energy Commission. National Technical Information Service, Springfield, Virginia. 1268 pp.

Coutant, C. C., and H. A. Pfuderer. 1973. Thermal effects on aquatic organisms. ORNL/EIS-73/28. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 183 pp.

Coutant, C. C., and H. A. Pfuderer. 1973. Thermal effects. Journal of the Water Pollution Control Federation 45(6):1331-1369.

Rochelle, J. M., and C. C. Coutant. 1973. Temperature sensitive ultrasonic fish tag, Q-5099. ORNL/TM-4438. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 26 pp.

Coutant, C. C. 1974. Physiology for the fishery ecologist. Ecology 55(3):686-687.

Coutant, C. C., H. M. Ducharme, Jr., and J. R. Fisher. 1974. Effects of cold shock on vulnerability of juvenile channel catfish (Ictalurus punctatus) and largemouth bass (Micropterus salmoides) to predation. Journal of the Fisheries Research Board of Canada 31(3):351-354.

Coutant, C. C., and H. A. Pfuderer. 1974. Thermal effects. Journal of the Fisheries Research Board of Canada 46(6):1476-1540.

Coutant, C. C., H. A. Pfuderer, and B. N. Collier. 1974. Thermal effects on aquatic organisms: An annotated bibliography of 1973 literature. ORNL/EIS-74/28. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 241 pp.

Goodyear, C. P., C. C. Coutant, and J. R. Trabalka. 1974. Sources of potential biological damage from once-through cooling systems of nuclear power plants. ORNL/TM-4180. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 43 pp.

Rochelle, J. M., and C. C. Coutant. 1974. Ultrasonic tag for extended temperature monitoring from small fish. Underwater Telementry Newsletter 4(1):1, 4-7.

Coutant, C. C. 1975. Responses of bass to natural and artificial temperature regimes. pp. 272-285. IN R. H. Stroud and H. Clepper (edsitors), Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Coutant, C. C. 1975. Temperature and organisms. Ecology 56(2):499.

Coutant, C. C. 1975. Evaluation of entrainment effect. pp. 1-10. IN L. D. Jensen (editor), 2nd Entrainment and Intake Screening Workshop. The Johns Hopkins University Water Research Project Report No. 15. Baltimore, Maryland.

Coutant, C. C. 1975. Temperature selection by fish -- A factor in power-plant impact assessments. pp. 575-597. IN Environmental Effects of Cooling Systems at Nuclear Power Plants. IAEA-SM-187/11. International Atomic Energy Aqency, Vienna, Austria.

Coutant, C. C. 1975. Effects of power plants (book review). Science 189:132-133.

Coutant, C. C., and R. J. Kedl. 1975. Survival of larval striped bass exposed to fluid-induced and thermal stresses in a simulated condenser tube. ORNL/TM-4695. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 37 pp.

Coutant, C. C., and S. S. Talmage. 1975. Thermal effects: A review of the literature of 1974 on wastewater and water pollution control. Journal of the Water Pollution Control Federation 47(6):1656-1711.

Coutant, C. C., S. S. Talmage, R. F. Carrier, and B. N. Collier. 1975. Thermal effects on aquatic organisms -- Annotated bibliography of the 1974 literature. ORNL/EIS-75/28. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 168 pp.

Coutant, C. C. 1976. Physical and ecological consequences of power plant cooling. Working draft paper for UNESCO International Hydrological Programme - Man and the Biosphere Working Group Meeting, Paris. 23-26 March 1976.

Coutant, C. C. 1976. Syntheses of recommendations. pp. 23-34. IN Sigma Research, Inc. (editor), Workshop on the Impact of Thermal Power Plant Cooling Systems on Aquatic Environments. Special Report 38, Vol. I. Working Group Results. Electric Power Research Institute, Palo Alto, California.

Coutant, C. C. 1976. Impact of power plants on aquatic systems: A social perspective. pp. 14-20. IN Sigma Research, Inc. (editor), Workshop on the Impact of Thermal Power Plant Cooling Systems on Aquatic Environments. Special Report No. 38, Vol. II. Electric Power Research Institute, Palo Alto, California.

Coutant, C. C. 1976. Thermal effects on fish ecology. pp. 891-896. IN Encyclopedia of Environmental Engineering, Volume 2. W & G. Baird, Ltd., Northern Ireland.

Coutant, C. C. 1976. How to put waste heat to work. Environmental Science and Technology 10(9):868-871.

Bowles, R. R., C. C. Coutant, and J. S. Griffith. 1976. Effects of water velocity on activity of juvenile striped bass. ORNL/TM-5368. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 73 pp.

Coutant, C. C., and D. K. Cox. 1976. Growth rates of subadult largemouth bass at 24 to 35.5°C. pp. 118-120. IN G. W. Esch and R. W. McFarlane (editors), Thermal Ecology II. CONF-750425 U. S. Atomic Energy Commission. National Technical Information Service, Springfield, Virginia.

Coutant, C. C., and S. S. Talmage. 1976. Thermal effects. Journal of the Water Pollution Control Federation 48(6):1487-1544.

Coutant, C. C., S. S. Talmage, R. F. Carier, B. N. Collier, and N. S. Dailey. 1976. Thermal effects on aquatic organisms. Annotated bibliography of the 1975 literature. ORNL/EIS-88, Oak Ridge National Laboratory, Oak Ridge, Tennessee. 323 pp.

Coutant, C. C., D. K. Cox, and K. W. Moored, Jr. 1976. Further studies of cold shock effects on susceptibility of young channel catfish to predation. pp. 154-158. IN G. W. Esch and R. W. McFarlane (editors), Thermal Ecology II. CONF-750425 U. S. Atomic Energy Commission. National Technical Information Service, Springfield, Virginia.

Cox, D. K., and C. C. Coutant. 1976. Acute cold-shock resistance of gizzard shad. pp. 159-161. IN G. W. Esch and R. W. McFarlane (editors), Thermal Ecology II. CONF-750425 U. S. Atomic Energy Commission. National Technical Information Service, Springfield, Virginia.

Kedl, R. J., and C. C. Coutant. 1976. Survival of juvenile fishes receiving thermal and mechanical stresses in a simulated power plant condenser. pp. 394-400. IN G. W. Esch and R. W. McFarlane (editors), Thermal Ecology II. CONF-750425 U. S. Atomic Energy Commission. National Technical Information Service, Springfield, Virginia.

Wolters, W. R., and C. C. Coutant. 1976. The effect of cold shock on the vulnerability of young bluegill (Lepomis macrochirus) to predation. pp. 162-164. IN G. W. Esch and R. W. McFarlane (editors), Thermal Ecology II. CONF-750425 U. S. Atomic Energy Commission. National Technical Information Service, Springfield, Virginia.

Coutant, C. C. 1977. Representative species concept. pp. 149-154. IN R. K. Ballentine and L. J. Guawaia (editors), The Integrity of Water. U. S. Environmental Protection Agency, Washington, D.C.

Coutant, C. C. 1977. Physiological considerations o future thermal aditions for aquatic life. pp. 251-266. IN M. Marois (editor), World Conference Towards a Plan of Actions for Mankind, Volume 3, Biological Balance and Thermal Modifications. Pergamon Press, Oxford.

Coutant, C. C. 1977. Ecological successes of the freshwater black basses (book review). Ecology 58(1):218.

Coutant, C. C. 1977. The Connecticut River ecological study: The impact of a nuclear power plant (book review). Transactions of the American Fisheries Society 106(1): 115-116.

Coutant, C. C. 1977. Cold shock to aquatic organisms - Guidance for power plant siting, design, and operation. Nuclear Safety 18(3):329-342.

Coutant, C. C. 1977. Compilation of temperature preference data. Journal of the Fisheries Research Board of Canada 34:739-745.

Beall, S. E., C. C. Coutant, M. Olszewski, and J. S. Suffern. 1977. Energy from cooling water. Industrial Water Engineering 14(6):8-14.

Coutant, C. C., and S. S. Talmage. 1977. Thermal effects. Journal of the Water Pollution Control Federation 49(6):1369-1425.

Stevens, A. R., R. L. Tyndall, C. C. Coutant, and E. Willaert. 1977. Isolation of the etiologic agent of primary amoebic meningoencephalitis from artificially heated waters. Journal of Applied Environmental Microbiology 34(6): 701-705.

Coutant, C. C. 1978. Determining the ecological effects of power plant cooling. pp. 173-200. IN Fifth FAO/SIDA Workshop on Aquatic Pollution in Relation to Living Resources. TF-RAS 34 (SWE), Suppl. 1. Food and Agricultural Organization of the United Nations, Rome, Italy.

Coutant, C. C. 1978. A working hypothesis to explain mortalities of striped bass, *Morone saxatilis*, in Cherokee Reservoir. ORNL/TM-6534. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 36 pp.

Coutant, C. C., C. S. Wasserman, M. S. Chung, D. B. Rubin, and M. Manning. 1978. Chemistry and biological hazard of a coal ash seepage stream. Journal of the Water Pollution Control Federation 50(4):747-753.

Olszewski, M., J. S. Suffern, C. C. Coutant, and D. K. Cox. 1979. An overview of waste heat utilization research at the Oak Ridge National Laboratory. pp. 2299-2320. IN S. S. Lee and S. Sengupta (editors), Waste Heat Management and Utilization. Hemisphere Publishing Corporation, Washington, D.C.

Schubel, J. R., C. C. Coutant, and P. M. J. Woodhead. 1978. Thermal effects of entrainment. pp. 19-93. IN J. R. Schubel and B. C. Marcy (editors), Power Plant Entrainment. A Biological Assessment. Academic Press, New York, New York.

Suffern, J. S., S. M. Adams, B. G. Blaylock, C. C. Coutant, and C. A. Guthrie. 1978. Growth of monosex hybrid Tilapia in the laboratory and sewage oxidations ponds. pp. 65-82. IN Symposium on Culture of Exotic Fishes. Fish Culture Society, American Fisheries Society, Auburn, Alabama. 257 pp.

Talmage, S. S., and C. C. Coutant. 1978. Thermal effects. Journal of the Water Pollution Control Federation 50(6):1514-1553.

Tyndall, R. L., E. Willaert, A. R. Stevens, and C. C. Coutant. 1978. Isolation of pathogenic Naegleria from artificially heated waters. pp. 117-123. IN Symposium on Microbiology of Power Plant Thermal Effluents. University of Iowa Press, Iowa City, Iowa.

Coutant, C. C. 1979. Count kilowatts for fun, profit. Nuclear Division News (Union Carbide Corporation) 10(13):3,81.

Coutant, C. C. 1979. Chapter III. A conceptual format for cooling system environmental impact assessment projects. pp. 53-67. IN W. Majewski and D. C. Miller (editors), Predicting Effects of Power Plant Once-through Cooling on Aquatic Systems. Technical Papers in Hydrology 10, UNESCO, Paris, France.

Coutant, C. C. 1979. Chapter IX. Beneficial uses of discharge heat. pp. 146-155. IN W. Majewski and D. C. Miller (editors), Predicting Effects of Power Plant Once-through Cooling on Aquatic Systems. Technical Papers in Hydrology 10, UNESCO, Paris, France.

Coutant, C. C., R. B. McLean, and D. L. DeAngelis. 1979. Influence of physical and chemical alterations on predator-prey interactions. pp. 57-68. IN R. H. Stroud and H. Clepper (editors), Predator-Prey Systems in Fisheries Management. Sport Fishing Institute, Washington, D.C.

Coutant, C. C., D. S. Vaughan, and H. McLain. 1979. Scientific review, analysis and critique of section 316(a) thermal demonstrations and section 316(b) intake demonstrations. For Public Service of Indiana, Cayuga and Wabash Generating Stations. Oak Ridge National Laboratory, Oak Ridge, Tennessee for U.S. Environmental Protection Agency, Region V, Chicago, Illinois. 38 pp.

Coutant, C. C., and J. S. Suffern. 1979. Temperature influences on growth of aquatic organisms. pp. 113-124. IN S. S. Lee and S. Sengupta (editors), Waste Heat Management and Utilization. Hemisphere Publishing Corp., Washington, D.C.

DeAngelis, D. L., and C. C. Coutant. 1979. Growth rates and size distributions of first-year smallmouth bass populations: Some conclusions from experiments and a model. Transactions of the American Fisheries Society 108:137-141

DeAngelis, D. L., D. K. Cox, and C. C. Coutant. 1979. Cannibalism and size dispersal in young-of-the-year largemouth bass: Experiment and model. Ecological Modelling 8:133-148.

Majewski, W., D. C. Miller, and C. C. Coutant. 1979. Chapter I. Introduction. pp. 13-19. IN W. Majewski and D. C. Miller (editors), Predicting Effects of Power Plant Once-through Cooling on Aquatic Systems. Technical Papers in Hydrology 10, UNESCO, Pari s, France .

Miller, D. C., and C. C. Coutant. 1979. Chapter II. Potential and observed ecological effects of once-through cooling systems. pp. 20-52. IN W. Majewski and D. C. Miller (editors), Predicting Effects of Power Plant Once-through Cooling on Aquatic Systems. Technical Papers in Hydrology 10, UNESCO, Paris, France.

Miller, D. C., and C. C. Coutant. 1979. Chapter VII. Preoperational cooling system impact assessment: Physical and biological information requirements. pp. 118-136. IN W. Majewski and D. C. Miller (editors), Predicting Effects of Power Plant Once-through Cooling on Aquatic Systems. Technical Papers in Hydrology 10, UNESCO, Paris, France.

Miller, D. C., and C. C. Coutant. 1979. Chapter VIII. Operational monitoring of cooling system impacts. pp. 137-145. IN W. Majewski and D. C. Miller (editors), Predicting Effects of Power Plant Once-through Cooling on Aquatic Systems. Technical Papers in Hydrology 10, UNESCO, Paris, France.

Talmage, S. S., and C. C. Coutant. 1979. Thermal effects. Journal of the Water Pollution Control Federation 51(6):1517-1554.

Coutant, C. C. 1980. Critical choices: Energy conservation in power plant cooling. pp. 188-190. IN Environmental Effects of Cooling Systems, Technical Reports Series No. 202, International Atomic Energy Agency, Vienna, Austria.

Coutant, C. C. 1980. Adaptation capability. pp. 134-141. IN Environmental Effects of Cool ing Systems. Technical Reports Series No . 202 . International Atomic Energy Agency, Vienna, Austria.

Coutant, C. C. 1980. Pathogenic amoeba. pp. 121-124. IN Environmental Effects of Cooling Systems. Technical Reports Series No. 202, International Atomic Energy Agency, Vienna, Austria.

Coutant, C. C. 1980. Beneficial uses of reject heat. pp. 190-192. IN Environmental Effects of Cooling Systems. Technical Reports Series No. 202, International Atomic Energy Agency, Vienna, Austria.

Coutant, C. C. 1980. Abortive tagging makes sense. Underwater Telemetry Newsletter 10(1):13.

Coutant, C. C. 1980. Environmental quality for striped bass. pp. 179-187. IN H. Clepper (editor), Marine Recreational Fisheries 5, Sport Fishing Institute, Washington, D.C.

Coutant, C. C., and D. S. Carroll. 1980. Temperatures occupied by ten ultrasonic-tagged striped bass in freshwater lakes. Transactions of the American Fisheries Society 109: 195-202 .

Coutant, C. C., H. R. Waddle, and B. A. Schaich. 1980. Temperature and habitat selection by striped bass. Underwater Telemetry Newsletter 10(1):1, 3 -4 .

Schaich, B. A., and C. C. Coutant. 1980. A biotelemetry study of spring and summer habitat selection by striped bass in Cherokee Reservoir, Tennessee, 1978. ORNL/TM-7127. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 226 pp.

Spigarelli, S., and C. C. Coutant. 1980. Ecosystem stress and cooling systems. pp. 175-184. IN Environmental Effects of Cooling Systems, Technical Reports Series No. 202, International Atomic Energy Agency, Vienna, Austria.

Talmage, S. S., and C. C. Coutant. 1980. Thermal effects. Journal of the Water Pollution Control Federation 52(6) :1575-1615.

Van Winkle, W., C. C. Coutant, J. W. Elwood, S. G. Hildebrand, J. S. Mattice, and R. B. McLean. 1980. Comparative reservoir research at Oak Ridge National Laboratory. pp. 1432-1447. IN Symposium on Surface Water Impoundments. Paper No. 7-23. American Society of Civil Engineers, Minneapolis, Minnesota.

Waddle, H. R., C. C. Coutant, and J. L. Wilson. 1980. Summer habitat selection by striped bass, *Morone saxatilis*, in Cherokee Reservoir, Tennessee, 1977. ORNL/TM-6927. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Coutant, C. C. 1981. Foreseeable effects of C02-induced climate change: Freshwater concerns. Environmental Conservation 8(4):285-297.

Cox, D. K., and C. C. Coutant. 1981. Growth dynamics of juvenile striped bass as functions of temperature and ration. Transactions of the American Fisheries Society 110:226-238.

Coutant, C. C. 1982. Effects of C02-induced climate change on freshwater ecosystems. IN Report by American Association for the Advancement of Science on the C02 Problem. U.S. Department of Energy, Washington, D.C.

Coutant, C. C. 1982. Evidence for upstream dispersion of adult caddisflies (Trichoptera:Hydropsychidae) in the Columbia River. Aquatic Insects 4(2):61-66.

Coutant, C. C. 1982. Positive phototaxis in first instar Hydropsyche cockerelli banks. Aquatic Insects 4(1):55-59.

Conway, L., G. Chapman, C. C. Coutant, E. Crecelius, B. Jaslow, L. Thorne, and R. Vocke. 1982. Environmental mobility of toxic substances released from photovoltaic-associated processes: Aquatic systems. pp. 139-161. IN G. R. Hendrey, P. D. Maskowitz, D. Patten, W. Berry, and H. L. Conway (editors), Potential Environmental Problems of Photovoltaic Energy Technology. BNL-51431, Brookhaven National Laboratory, Upton, New York.

DeAngelis, D. L., and C. C. Coutant. 1982. Genesis of bimodal size distributions in species cohorts. Transactions of the American Fisheries Society 111:384-388.

Coutant, C. C. 1983. Striped bass and the management of cooling lakes. pp. 389-396. IN S. S. Lee and S. Sengupta (editors), Waste Heat Utilization and Management. Hemisphere Publishing Corp., Washington, D.C.

Cheek, T. E., M. J. Van den Avyle, and C. C. Coutant. 1983. Distribution and habitat selection of adult striped bass, *Morone saxatilis* (Walbaum), in Watts Bar Reservoir, Tennessee. ORNL/TM-8447. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 288 pp.

Coutant, C. C. 1983. Thermal pollution by power plants. pp. 846-868. IN Encyclopedia of Chemical Technology. Vol. 22, Third Edition. John Wiley & Sons, Inc., New York.

Coutant, C. C., and D. L. DeAngelis. 1983. Comparative temperature-dependent growth rates of largemouth and smallmouth bass fry. Transactions of the American Fisheries Society 112:416-423.

Coutant, C. C., and W. Van Winkle. 1983. Paradox of the striped bass: ORNL fishes for answers. ORNL Review 16(3):2-10. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Wetzel, R. G., J. B. Grace, E. A. D. Allen, J. W. Barko, S. Beer, G. Bowes, M. Briston, C. C. Coutant, B. G. Drake, J. E. Hobble, O. Holm-Hanse, H. B. A. Prins, and J. H. Peverley. 1983. Aquatic plant communities. pp. 223-280. IN E. R. Lemon, (editor) C02 and Plants: The Response of Plants to Rising Levels of Atmospheric Carbon Dioxide. A AAAS Symp. No. 84. Westview Press, Boulder, Colorado.

Coutant, C. C., K. L. Zachmann, D. K. Cox, and B. L. Pearman. 1984. Temperature selection by juvenile striped bass in laboratory and field. Transactions of the American Fisheries Society 113:666-671.

Patterson, M. R., R. J. Sworski, A. L. Sjoreen, M. G. Browman, C. C. Coutant, D. M. Hetrick, B. D. Murphy, R. J. Raridon. 1984. A user's manual for UTM-TOX, the Unified Transport Model. ORNL-6064. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Weller, D. E., D. J. Anderson, D. L. DeAngelis, and C. C. Coutant. 1984. Rates of heat exchange in largemouth bass: Experiment and model. Physiological Zoology 57:413-427.

Coutant, C. C. 1985. Striped bass, temperature, and dissolved oxygen: A speculative hypothesis for environmental risk. Transactions of the American Fisheries Society 114(1):31-61.

Coutant, C. C. 1985. Striped bass: Environmental risks in fresh and salt water. Transactions of the American

Fisheries Society 114:1-2.

Cheek, T. E., M. J. Van den Avyle, and C. C. Coutant. 1985. Influences of water quality on distribution of striped bass in a Tennessee River impoundment. Transactions of the American Fisheries Society 114(1):67-76.

Coutant, C. C., and G. F. Cada. 1985. Analysis and development of a project evaluation process. Bonneville Power Administration, DOE/BP-391, Portland, Oregon.

Coutant, C. C. 1986. Thermal niches of striped bass. Scientific American 254(8):98-104.

Coutant, C. C. 1987. Thermal preference: When does an asset become a liability? Environmental Biology of Fishes 18(3) :161-172.

Coutant, C. C. 1987. Poor reproductive success of striped bass from a reservoir with reduced summer habitat. Transactions of the American Fisheries Society 116(2):154-160.

Coutant, C. C., and D. L. Benson. 1988. Linking estuarine water quality and impacts on living resources: Shrinking striped bass habitat in Chesapeake Bay and Albermarle Sound. U.S. Environmental Protection Agency, EPA 503/3-88-001, Washington, D.C.

Coutant, C. C., and C. L. Heckman. 1988. A review of state regulations that exceed those of the Federal Resource Conservation and Recovery Act (RCRA). DOE/HWP-40, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sale, M. J., S. F. Railsback, S. Y. Chang, C. C. Coutant, R. E. Spath, and G. H. Taylor. 1989. Balancing hydropower development in thc Ohio River basin. pp. 886-896 in A. J. Eberhardt (editor), Proceedings of an International Conference on Hydropower. American Society of Civil Engineers, New York.

Coutant, C. C. 1990. Temperature-oxygen habitat for freshwater and coastal striped bass in a changing climate. Transactions of the American Fisheries Society 119:240-253.

Railsback, S. F., C. C. Coutant, and M. J. Sale. 1990. Improving the effectiveness of fisheries agencies in developing hydropower mitigation. Fisheries (Bethesda) 15:3-8.

Coutant, C. C., and D. L. Benson. 1990. Summer habitat suitability for striped bass in Chesapeake Bay: reflections on a population decline. Transactions of the American Fisheries Society 119:757-778.

Coutant, C. C. 1990. Microchemical analysis of fish hard parts for reconstructing habitat use: Practice and promise. American Fisheries Society Symposium 7:574-580.

Coutant, C. C. 1992. Testing the Waters. Electric Perspectives 16(4):32-40.

Coutant, C. C., and C. H. Chen. 1993. Strontium microstructure in scales of freshwater and estuarine striped bass (*Morone saxatilis*) detected by laser ablation mass spectrometry. Canadian Journal of Fisheries and Aquatic Sciences 50: 1318-1323.

Rose, K. A., J. H. Cowan, jr., E. D. Houde, and C. C. Coutant. 1993. Individual-based modelling of environmental quality effects on early life stages of fishes: a case study using striped bass. American Fisheries Society Symposium 14:125-145.

Sale, M. J., and C. C. Coutant. 1994. Hydropower: licensed to protect the environment (edited interview). ORNL Review 26(3/4):2-19.

Coutant, C. C., T. W. H. Backman, G. R. Bouck, E. M. Dawley, L. E. Fidler, and W. Krise. 1994. Panel on Gas Bubble Disease. Working Group Meeting June 21-22, 1994. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Coutant, C. C., T. W. H. Backman, E. M. Dawley, W. J. Ebel, L. E. Fidler, A. Nebeker, and R. G. White. 1995. Panel on Gas Bubble Disease. Second Working Group Meeting November 1-3, 1994. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Coutant, C. C. 1995. Thermal Pollution, Power Plants. Pages 2607-2620. IN: Encyclopedia of Energy Technology and the Environment, John Wiley & Sons, New York.

Coutant, C. C., T. W. H. Backman, G. R. Bouck, E. M. Dawley, W. J. Ebel, L. E. Fidler, J. O. T. Jensen, W. Krise, and R. G. White. 1996. Summary Report. Panel on Gas Bubble Disease. Third Working Group Meeting February 1-3, 1996. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Coutant, C. C. 1996. Comment: Effects of instream brush on juvenile coho salmon. Transactions of the American Fisheries Society 125:150-151.

Stanford, J. A., J. V. Ward, W. J. Liss, C. A. Frissell, R. N. Williams, J. A. Lichatowich, and C. C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers: Research and Management 12:391-413.

Dickerman, J., and C. C. Coutant. 1996. Oceans, energy, and environmental policy: a primer. Oak Ridge National Laboratory for U. S. Department of Energy, Washington, DC.

Coutant, C. C. 1996. A new year! Fisheries (Bethesda) 21(9): 24.

Coutant, C. C. 1996. Interfaces. Fisheries (Bethesda) 21(10): 40.

Coutant, C. C. 1996. Let's talk. Fisheries (Bethesda) 21(11): 32.

Coutant, C. C. 1996. Can we afford it? Fisheries (Bethesda) 21(12):26.

Coutant, C. C., P. A. Bisson, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, J. A. Stanford, and R. N. Williams. 1997. Review of the National Marine Fisheries Service' "1996 Annual Report to the Oregon Department of Environmental Quality" related to waiver of dissolved gas standard. ISAB-97-1, Independent Scientific Advisory Board, Northwest Power Planning Council and National Marine Fisheries Service, Portland, Oregon.

Williams, R. N., L. D. Calvin, C. C. Coutant, M. W. Erho, jr., J. A. Lichatowich, W. J. Liss, W. E. McConnaha, P. R. Mundy, J. A. Stanford, R. R. Whitney, D. L. Bottom, and C. A. Frissell. 1996. Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem. Northwest Power Planning Council, Portland, Oregon.

Coutant, C. C. 1996. Juvenile migration. Chapter 6 in R. N. Williams, L. D. Calvin, C. C. Coutant, M. W. Erho, jr., J. A. Lichatowich, W. J. Liss, W. E. McConnaha, P. R. Mundy, J. A. Stanford, R. R. Whitney, D. L. Bottom, and C. A. Frissell. Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem. Northwest Power Planning Council, Portland, Oregon.

Coutant, C. C. 1996. Monitoring and evaluation. Chapter 9 in Williams, R. N., L. D. Calvin, C. C. Coutant, M. W. Erho, jr., J. A. Lichatowich, W. J. Liss, W. E. McConnaha, P. R. Mundy, J. A. Stanford, R. R. Whitney, D. L. Bottom, and C. A. Frissell. Return to the River: Restoration of Salmonid Fishes in the Columbia River Ecosystem. Northwest Power Planning Council, Portland, Oregon.

Cada, G. F., C. C. Coutant, and R. R. Whitney. 1997. Development of biological criteria for the design of advanced hydropower turbines. DOE/ID-10578. U. S. Department of Energy, Idaho Falls, Idaho.

Williams, R. N., P. A. Bisson, Coutant, C. C., D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, J. A. Stanford and R. R. Whitney. 1997. Report of the Independent Scientific Advisory Board regarding a research proposal for inclusion in the 1997 Smolt Monitoring Program. Comparative Survival Rate Study of Hatchery PIT Tagged Chinook. ISAB-97-2, Northwest Power Planning Council and National Marine Fisheries Service, Portland, Oregon.

Coutant, C. C. 1997. What do we believe? Fisheries (Bethesda) 22(1):30.

Coutant, C. C. 1997. Who's in charge here? Fisheries (Bethesda) 22(2):28.

Williams, R. N., P. A. Bisson, Coutant, C. C., D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, J. A. Stanford and R. R. Whitney. 1997. Ecological impacts of the flow provisions of the Biological Opinion for endangered Snake River salmon on resident fishes in the Hungry Horse and Libby systems in Montana, Idaho, and British Columbia. ISAB 97-3, Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon, and the National Marine Fisheries Service, Seattle, Washington.

Williams, R. N., P. A. Bisson, Coutant, C. C., D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, J. A. Stanford and R. R. Whitney. 1997. Report of the Independent Scientific Advisory Board regarding a research proposal for inclusion in the Columbia River Basin Fish and Wildlife Program: Lake Pend Oreille Fishery Recovery Project. ISAB 97-4, Northwest Power Planning Council and National Marine Fisheries Service, Portland, Oregon.

Coutant, C. C. 1997. An interface: Council of Aquatic Sciences. Fisheries (Bethesda) 22(3):33.

Williams, R. N., P. A. Bisson, Coutant, C. C., D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, J. A. Stanford, R. R. Whitney and S. S. Hanna. 1997. Review of a draft programmatic environmental impact statement: Impacts of Artificial Salmon and Steelhead Production Strategies in the Columbia River Basin. ISAB Report 97-5. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Coutant, C. C. 1997. When is artificial good? Fisheries (Bethesda) 22(4):36.

Coutant, C. C. 1997. Do we have it all together? Fisheries (Bethesda) 22(5):28.

Coutant, C. C. 1997. Taken for Granted. Fisheries (Bethesda) 22(6):32.

Coutant, C. C. 1997. Dumber every day: Fighting the stupidity complex. Fisheries (Bethesda) 22(7):24.

Coutant, C. C. 1997. Thermal Pollution. Pages 963-984, In: Kirk-Othmer Encyclopedia of Chemical Technology, Fourth Edition, Volume 23. John Wiley and Sons, Inc.

Williams, R. N., J. A. Lichatowich, P. A. Bisson, Coutant, C. C., R. Francis, D. Goodman, N. Huntly,L. McDonald, B. Riddell, J. A. Stanford, and S. S. Hanna. 1997. Review of the Columbia River Basin Fish and Wildlife Program as directed by the 1996 amendment to the Power Act. ISRP Report 97-1, Report of the Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

Van Winkle, W., C. C. Coutant, H. I. Jager, J. S. Mattice, D. J. Orth, R. G. Otto, S. F. Railsback, and M. J. Sale. 1997. Essay--Uncertainty and instream flow standards: Perspectives based on hydropower research and assessment. Fisheries (Bethesda) 22(7):21-22.

Mulholland, P. J., G. R. Best, C. C. Coutant, G. M. Hornberger, J. L. Meyer, P. J. Robinson, J. R. Stenberg, R. E. Turner, F. Vera-Herrera, and R. G. Wetzel. 1997. Effects of climate change on freshwater ecosystems of the Southeastern United States and the Gulf Coast of Mexico. Hydrological Processes 11:949-970.

Coutant, C. C., P. Bisson, and P. Brouha. 1997. Management audit gives AFS headquarters good marks, makes suggestions for improvements. Fisheries (Bethesda) 22(8):16-18.

Coutant, C. C., L. D. Calvin, M. W. Erho, Jr., J. A. Lichatowich, W. J. Liss, W. E. McConnaha, P. R. Mundy, J. A. Stanford, R. R. Whitnery, R. N. Williams, D. L. Bottom, and C. A. Frissell. 1997. The normative river: an ecological vision for the recovery of the Columbia River salmon. Pages 50-59, *in* D. J. Mahoney, editor. Waterpower '97. Proceedings of the 1997 International Conference on Hydropower. American Society of Civil Engineers, New York.

Whitney, R. R., L. D. Calvin, M. W. Erho, Jr., and C. C. Coutant. 1997. Downstream passage for salmon at hydroelectric projects in the Columbia River Basin: Development, installation, and evaluation.

ISAB 97-15, Independent Scientific Advisory Board, Northwest Power Planning Council and National Marine Fisheries Service, Portland, Oregon.

Coutant, C. C. 1998. What is "Normative" for fish pathogens? A perspective on the controversy over interactions between wild and cultured fish. Journal of Aquatic Animal Health 10:101-106.

Williams, R. N., P. A. Bisson, C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, J. A. Stanford, and R. R. Whitney. 1997. Review of the August 8, 1997 Draft of the Snake River Salmon Recovery Plan. ISAB Report 97-6, Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Williams, R. N., P. A. Bisson, C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, J. A. Stanford, and R. R. Whitney. Review of the National Marine Fisheries Services' "1997 Draft Annual Report to the Oregon Department of Environmental Quality" Related to Waiver of Dissolved Gas Standard. Report ISAB 97-7. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Williams, R. N., P. A. Bisson, C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, J. A. Stanford, and R. R. Whitney. 1998. Review of the 1998 Work plan for the Comparative Survival Rate Study of Hatchery PIT Tagged Chinook. ISAB Report 98-1. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Coutant, C. C. 1998. Expert Review of Thermal Effects of Richard B. Russell Pumped Storage Project on Striped Bass in J. Strom Thurmond Reservoir. Report for U.S. Department of Justice, Washington, DC. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

C. C. Coutant, R. Best, P. Bloom, D. Boesch, J. Grassle, D. Grigal, R. Houghton, J. Klopatek, W. Lewis, H. Regier, T. Sharik, and D. Sprugel. 1998. Review of U. S. Environmental Protection Agency's National Health and Environmental Effects Research Laboratory Western Ecology Division. Unnumbered report. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Williams, R. N., P. A. Bisson, C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, J. A. Stanford, and R. R. Whitney. 1998. Response to Questions of the Implementation Team Regarding Juvenile Salmon Transportation in the 1998 Season. ISAB Report 98-2. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Williams, R. N., P. A. Bisson, C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, J. A. Stanford, and R. R. Whitney. 1998. Independent Scientific Advisory Board 1997 Annual Report. ISAB Report 98-3. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Williams, R. N., P. A. Bisson, C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, and R. R. Whitney. 1998. The Scientific Basis for Juvenile Fish Passage Improvements in the Federal Columbia River Power System: John Day Dam Extended Length Turbine Intake Screens and Bonneville Dam Bypass System Outfalls. First Report: The ISAB Corps Capital Construction Project Review. ISAB Report 98-4. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Bisson, P. A., C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, R. R. Whitney, and R. N. Williams. 1998. Recommendation for Stable Flows in the Hanford Reach During the Time When Juvenile Fall Chinook are Present Each Spring. Report ISAB 98-5. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Bisson, P. A., C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, R. R. Whitney, and R. N. Williams. 1998. Independent Scientific Advisory Board Review of "Development of a Regional Framework for Fish and Wildlife Restoration in the Columbia River Basin". Report ISAB 98-6. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Bisson, P. A., C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, R. R. Whitney, and R. N. Williams. 1998. Report of the Independent Scientific Advisory Board Review of the U.S. Army Corps of Engineers' Capital Construction Program. Part II. A. Development and Testing of Surface Bypass. Report ISAB 98-7. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Bisson, P. A., C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, R. R. Whitney, and R. N. Williams. 1998. Report of the Independent Scientific Advisory Board Review of the U.S. Army Corps of Engineers' Capital Construction Program. Part II. B. Dissolved Gas Abatement Program. Report ISAB 98-8. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Williams, R. N., J. A. Lichatowich, P. A. Bisson, C. C. Coutant, R. Francis, D. Goodman, N. Huntly, L. McDonald, B. Riddell, and S. Hanna. 1998. Review of the Columbia River Basin Fish and Wildlife Program for Fiscal Year 1999 as Directed by the 1996 Amendment of the Northwest Power Act. ISRP Report 98-1. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

Coutant, C. C. 1998. Fisheries Delegation to the People's Republic of China. Citizen Ambassador Program of People to People International, Spokane, Washington.

Independent Scientific Group (R. N. Williams, chair; P. A. Bisson; D. L. Bottom; L. D. Calvin; C. C. Coutant; M. W. Erho, jr.; C. A. Frissell; J. A. Lichatowich; W. J. Liss; W. E. McConnaha; P. R. Mundy; J. A. Stanford; and R. R. Whitney). 1998. Return to the River: An ecological vision for the recovery of the Columbia River salmon. Environmental Law 28(3):503-518.

Coutant, C. C. 1998. Turbulent Attraction Flows for Juvenile Salmonid Passage at Dams. ORNL/TM-13608. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Coutant, C. C., M. S. Bevelhimer, and W. Van Winkle. 1998. Brayton Point Station Section 316(a) and 316(b) Review. Prepared for Region 1, U.S. Environmental Protection Agency, Boston, Massachusetts by Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Independent Scientific Group (R. N. Williams, chair; P. A. Bisson; D. L. Bottom; L. D. Calvin; C. C. Coutant; M. W. Erho, jr.; C. A. Frissell; J. A. Lichatowich; W. J. Liss; W. E. McConnaha; P. R. Mundy; J. A. Stanford; and R. R. Whitney). 1999. Scientific Issues in the restoration of salmonid fishes in the Columbia River. Fisheries 24(3):10-19.

Coutant, C. C. 1999. Think like a fish! Emphasizing the behavior in behavioral guidance systems. Hydro Review 18(3) :18-24.

Coutant, C. C. 1999. Perspectives on temperature in the Pacific Northwest's fresh waters. ORNL/TM-1999/44. Report for U.S. Environmental Protection Agency, Region 10, Seattle, Washington. Oak Ridge National Laboratory , Oak Ridge, Tennessee.

Coutant, C. C., D. Goodman, S. S. Hanna, N. Huntly, D. Lettenmaier, J. Lichatowich, L. McDonald, B. Riddell, W. Smoker, R.R. Whitney, and R. N. Williams. 1999. Review of the BPA Reimbursable Account Programs in the Columbia River Basin as Requested in the Senate-House Conference Report on FY99 Energy and Water Development Appropriations Bill. Report ISRP-99-1. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

Coutant, C. C., D. Goodman, S. S. Hanna, N. Huntly, D. Lettenmaier, J. Lichatowich, L. McDonald, B. Riddell, W. Smoker, R.R. Whitney, and R. N. Williams. 1999. Review of the Columbia River Basin Fish and Wildlife Program for Fiscal Year 2000 as Directed by the 1966 Amendment of the Northwest Power Act. A Report of the Independent Scientific Reviw Panel for the Northwest Power Planning Council. (2 volumes). Report ISRP 99-2. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

Coutant, C. C., D. Goodman, S. S. Hanna, N. Huntly, D. Lettenmaier, J. Lichatowich, L. McDonald, B. Riddell, W. Smoker, R.R. Whitney, and R. N. Williams. 1999. Response review of fiscal year 2000 proposals. Report ISRP 99-4. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

Bisson, P. A., C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, R. R. Whitney, and R. N. Williams. 1999. ISAB Review of "1998 Draft Annual Report to the Oregon

Department of Environmental Quality" (December 1, 1998). Report ISAB 99-1. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Bisson, P. A., C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, R. R. Whitney, and R. N. Williams. 1999. Report of the Independent Scientific Advisory Board Review of the U.S. Army Corps of Engineers' Capital Construction Program. Part I. Adult Passage. Report ISAB 99-2. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Bisson, P. A., C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, R. R. Whitney, and R. N. Williams. 1999. Independent Scientific Advisory Board Work-In-Progress Report: Looking for Common Ground: Comparison of Recent Reports Pertaining to Salmon Recovery in the Columbia River Basin. Report ISAB 99-3. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Bisson, P. A., C. C. Coutant, D. Goodman, J. A. Lichatowich, W. J. Liss, L. McDonald, P. Mundy, B. Riddell, R. R. Whitney, and R. N. Williams. 1999. Report of the Independent Scientific Advisory Board Review of the U.S. Army Corps of Engineers' Capital Construction Program. Part III. Overview of the U.S. Army Corps of Engineers' Capital Construction Program. Report ISAB 99-4. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Bisson, P. A., C. C. Coutant, D. Goodman, R. Gramling, J. Lichatowich, E. Loudenslager, W. Liss, L. McDonald, D. Phillip, B. Riddell, and R. R. Whitney. 2000. Review of studies of fish survival in spill at The Dalles Dam. Report ISAB 2000-1. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Bisson, P. A., C. C. Coutant, D. Goodman, R. Gramling, J. Lichatowich, E. Loudenslager, W. Liss, L. McDonald, D. Phillip, and B. Riddell. 2000.Review of the draft performance standards and indicators for artificial production in the Northwest Power Planning Council's Artificial Production Review. Report ISAB 2000-2. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Bisson, P. A., C. C. Coutant, D. Goodman, R. Gramling, J. Lichatowich, E. Loudenslager, L. McDonald, D. Phillip, and B. Riddell. 2000. The Columbia River Estuary and the Columbia River Basin Fish and Wildlife Program. Report ISAB 2000-5. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISAB. 2000. Consistency of the Council's artificial production policies and implementation strategies with multi-species framework principles and Scientific Review Team guidelines. Report ISAB 2000-3. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISRP (Independent Scientific Review Panel). 2000. Review of Coeur d'Alene Tribe trout production facility master plan. Report ISRP 2000-1. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2000. Review of the Tucannon River captive broodstock Master Plan. Report ISRP 2000-2. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2000. Review of databases funded through the Columbia River Basin Fish and Wildlife Program. Report ISRP 2000-3. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2000. Review of "Restoration plan for Pacific lamprey (Lampetra tridentata) in the Umatilla, River, Oregon." Report ISRP 2000-4. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2000. Review of the master plan for feasibility assessment of a white sturgeon 'put and take" consumptive fisheries in Oxbow and Hells Canyon reservoirs, Snake River. Report ISRP 2000-6, Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP 2000. Final review of fiscal year 2001 project proposals for the Columbia River Gorge and Intermountain provinces. Report ISRP 2000-9. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

Coutant, C. C. 2000. Cool refuges for big striped bass: Twenty years of testing the thermal squeeze hypothesis. Proceedings of the Gulf Coast Striped Bass Management Workshop (Nov. 1998). U.S. Fish and Wildlife Service, Mobile, Alabama.

Coutant, C. C. 2000. What is 'normative' at cooling water intakes? Defining normalcy before judging adverse. Environmental Science & Policy 3:S37-S42.

Coutant, C. C., and R. R. Whitney. 2000. Fish behavior in relation to passage through hydropower turbines: a review. Transactions of the American Fisheries Society 129:351-380.

Coutant, C. C., and M. S. Bevelhimer. 2000. Technical evaluation of the utility of intake approach velocity as an indicator or potential adverse environmental impact under Clean Water Act Section 316(b). Technical Report 1000731. EPRI, Palo Alto, California.

Bisson, P. A., C. C. Coutant, D. Goodman, R. Gramling, D. Lettenmaier, J. Lichatowich, E. Loudenslager, W. Liss, L. McDonald, D. Phillip, and B. Riddell. 2000. Model synthesis report. An analysis of decision support tools used in Columbia River Basin salmon management. Report ISAB 2001-1. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISAB. 2001. Research and monitoring in a low-flow year. Report ISAB 2001-2. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISAB. 2001. Hatchery surplus review. Report ISAB 2001-3. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISAB. 2001. Recommendations on Council staff's draft issue paper "Analysis of 2001 Federal Columbia River Basin System Operations on Fish Survival." Report ISAB 2001-4. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISAB. 2001. Review of Lower Snake River flow augmentation studies. Report ISAB 2001-5. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISAB. 2001. Review of the Biological Objectives in the 2000 Fish and Wildlife Program. Report ISAB 2001-6. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Coutant, C. C. (editor). 2001. Behavioral technologies for fish guidance. American Fisheries Society Symposium 26. Bethesda, Maryland.

Coutant, C. C. 2001. Turbulent attraction flows for guiding juvenile salmonids at dams. Pages 45-65. In C. C. Coutant, editor. Behavioral technologies for fish guidance. American Fisheries Society Symposium 26. Bethesda, Maryland.

Coutant, C. C. 2001. Integrated, multi-sensory behavioral guidance systems for fish diversions. Pages 105-113. In C. C. Coutant, editor. Behavioral technologies for fish guidance. American Fisheries Society Symposium 26. Bethesda, Maryland

Committee on Environment and Natural Resources, National Technology Council. 2000. From the Edge: Science to support restoration of Pacific salmon. Office of Science and Technology Policy, Washington, DC. (C. C. Coutant, principal author).

Independent Scientific Group. 2000. Return to the River 2000. Restoration of salmonid fishes in the Columbia River ecosystem. Report 2000-12. Northwest Power Planning Council, Portland, Oregon.

ISAB. 2001. A review of salmon recovery strategies for the Columbia River Basin. Report ISAB 2001-7. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISRP. 2001. Review of FY High Priority proposals for the Columbia River Basin Fish and Wildlife Program. Report ISRP-2001-1. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2001. Preliminary review of FY 2002 project proposals for the Mountain Columbia Province. Report ISRP-2001-2. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2001. Final review of FY 2002 project proposals for the Mountain Columbia Province. Report ISRP-2001-3. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2001. Preliminary review of fiscal year 2002 project proposals for the Columbia Plateau province. Report ISRP-2001-6. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2001. Review of Fiscal Year 2001 Action Plan proposals. Report ISRP-2001-7. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2001. Final review of Fiscal Year 2001 Action Plan proposals including responses to ISRP comments. Report ISRP-2001-7a. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2001. Final review of Fiscal Year 2002 proposals for the Columbia Plateau Province. Report ISRP-2001-8. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2001. Preliminary review of the United States Army Corps of Engineers' Bonneville Decision Document Juvenile Fish Passage Recommendation October 2001. Report ISRP-2001-11. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISAB. 2002. Review of Giorgi et al. report: "Mainstem Passage Strategies in the Columbia River System: Transportation, Spill, and Flow Augmentation." Report ISAB-2002-1. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISRP. 2002. ISRP comments on Corps' response to Document ISRTP 2001-11. Report ISRP-2001-11a. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Final review: Arrowleaf/Methow River Conservation Project. Report ISRP-2002-1. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Preliminary review of Fiscal Year 2003 proposals for the Upper and Middle Snake, Columbia Cascade, and Lower Columbia and Estuary provinces. Report ISRP-2002-2. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Review of protocols for the inventory and monitoring of fish, wildlife, and their habitats in the Pacific Northwest; statement of work by David H. Johnson, Washington Department of Fish and

Wildlife. Report ISRP-2002-3. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Review of Council staff's draft research plan for fish and wildlife in the Columbia River basin. Report ISRP-2002-4. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Review of March 27, 2002 Draft Guidelines for Action Effectiveness Research Proposals for FCRPS Offsite Mitigation Measures. Report ISRP-2002-5. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Review of 2002 Innovative Proposals. Report ISRP-2002-8. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Review of revised Moses Lake Recreational Facility proposal. Report ISRP-2002-9. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Review of project 200101500 – Echo Meadow Project. Report ISRP-2002-10. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Final review of Fiscal Year 2003 proposals for the Upper and Middle Snake, Columbia Cascade, and Estuary provinces. Report ISRP-2002-11. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Preliminary review of Fiscal Year 2003 Mainstem and Systemwide proposals. Report ISRP-2002-13. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Final review of Fiscal Year 2003 Mainstem and Systemwide proposals. Report ISRP-2002-14. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISRP. 2002. Review of criteria for evaluating proposals to secure tributary water. Report ISRP-2002-15. Independent Scientific Review Panel for the Northwest Power Planning Council, Portland, Oregon.

ISAB. 2003. Review of flow augmentation: update and clarification. Report ISAB-2003-1. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISAB. 2003. Review of strategies for recovery of tributary habitat. Report ISAB-2003-2. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

ISAB. 2003. Review of salmon and steelhead supplementation. Report ISAB-2003-3. Independent Scientific Advisory Board for the Northwest Power Planning Council, Portland, Oregon and the National Marine Fisheries Service, Seattle, Washington.

Williams, M. A., and C. C. Coutant. 2003. Modification of schooling behavior in larval atherinid fish *Atherina mochon* by heat exposure of eggs and larvae. Transactions of the American Fisheries Society 132:638-645.

ISRP. 2003. Summary of ISRP reviews and interactions with the Action Agencies' RM&E effort. Report ISRP-2003-2. Independent Scientific Review Panel for the Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2003. Review of draft Clearwater Subbasin Plan. Report ISRP-2003-3. Independent Scientific Review Panel for the Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2003. Review of BPA's draft Request for Proposals for RM&E. Report ISRP-2003-4. Independent Scientific Review Panel for the Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2003. Review of revised mainstem/systemwide proposals for research, monitoring and evaluation. Report ISRP-2003-6. Independent Scientific Review Panel for the Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2003. Review of proposals for BPA's request for studies on RPAs 182 and 184. Report ISRP-2003-7. Independent Scientific Review Panel for the Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2003. Final review of proposals submitted in response to Bonneville Power Administration's March 14, 2003 request for studies for Reasonable and Prudent Alternative Actions 182 and 184 of the 2000 Federal Columbia River Power System Biological Opinion. Report ISRP-2003-9. Independent Scientific Review Panel for the Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2003. Review of the Umatilla Fish Hatchery monitoring and evaluation project (19900500) document, "Comprehensive Assessment of Salmonid Restoration and Enhancement Efforts in the Umatilla River Basin." Report ISRP-2003-10. Independent Scientific Review Panel for the Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2003. Review of protocols for counting salmonids, resident fish, and lampreys in the Pacific Northwest. Report ISRP-2003-11. Independent Scientific Review Panel for the Northwest Power and Conservation Council, Portland, Oregon.

Bevelhimer, M. S., and C. C. Coutant. 2003. Impacts of volumetric flow rate of water intakes on fish populations and communities. Technical Report 1005178. EPRI, Palo Alto, California.

Coutant, C. C., and M. S. Bevelhimer. Submitted. Light tags for observing behavior of migrating salmonids. American Fisheries Society Symposium XX (proceedings of 2002 bioengineering symposium held at AFS annual meeting, Baltimore, MD).

Coutant, C. C. 2004. A riparian habitat hypothesis for successful reproduction of white sturgeon. Reviews in Fisheries Science 12:23-73.

Coutant, C. C., D. Goodman, S. Hanna, L. McDonald, B. Riddell, N. Huntly, W. Liss, W. Smoker, R. R. Whitney, R. Williams, R. Bilby, P. A. Bisson, E. J. Loudenslager, and D. P. Philipp. 2004. A Joint ISAB and ISRP Review of the Draft Research, Monitoring & Evaluation Plan for the NOAA Fisheries 2000 Federal Columbia River Power System Biological Opinion. Independent Scientific Advisory Board and Independent Scientific Review Panel Report ISAB & ISRP 2004-1. Northwest Power and Conservation Council, Northwest Indian Tribes, and NOAA Fisheries, Portland, Oregon. 66 pages.

Bilby, R. E., P. A. Bisson, C. C. Coutant, D. Goodman, S. Hanna, E. Loudenslager, L. McDonald, D. Philipp, and B. Riddell. 2003. ISAB Comments on Draft NOAA Technical Recovery Team Documents Identifying Independent Salmonid Populations Within Evolutionarily Significant Units. Independent Scientific Advisory Board Report ISAB 2003-4. NOAA Fisheries, Northwest Indian Tribes, and Northwest Power and Conservation Council, Portland, Oregon. 12 pages.

Coutant, C. C., S. Hanna, N. Huntly, W. Liss, L. McDonald, B. Riddell, W. Smoker, R. Whitney, R. N. Williams, J. D. McIntyre, T. Poe, and E. Merrill. 2004. Final Review of the United States Army Corps of Engineers' Anadromous Fish Evaluation Program for Fiscal Year 2004. Independent Scientific Review Panel Report ISRP 2004-8. Northwest Power and Conservation Council, Portland, Oregon. 106 pages.

Coutant, C. C., S. Hanna, N. Huntly, W. Liss, L. McDonald, B. Riddell, R. R. Whitney, R. N. Williams, J. Griffith, and R. White. 2004. Review of Draft Clearwater Subbasin Plan (November 2003 version). Independent Scientific Review Panel Report ISRP 2004-4. Northwest Power and Conservation Council, Portland, Oregon. 33 pages.

Coutant, C. C., S. Hanna, N. Huntly, W. Liss, L. McDonald, B. Riddell, W. Smoker, R. Whitney, R. N. Williams, J. D. McIntyre, T. Poe, and E. Merrill. 2003. Review of Fiscal Year 2004 Pre-proposals for the United States Army Corps of Engineers' Anadromous Fish Evaluation Program. Independent Scientific Review Panel Report ISRP 2003-14. Northwest Power and Conservation Council, Portland, Oregon. 47 pages

Coutant, C. C., D. Goodman, S. Hanna, L. McDonald, B. Riddell, N. Huntly, W. Liss, W. Smoker, R. R. Whitney, R. Williams, R. Bilby, P. A. Bisson, E. J. Loudenslager, and D. P. Philipp, R. Aldridge, S. Gregory, J. Griffith, L. Hardesty, J. Karr, J. Lichatowich, J. McIntyre, T. Poe, D. Scarnecchia, B. Ward, E. Merrill, D. Spear, and E. Schrepel. 2004. Scientific Review of Subbasin Plans for the Columbia River Basin Fish and Wildlife Program. Independent Scientific Review Board and Independent Scientific Advisory Board Report 2004-13, NOAA Fisheries, Northwest Indian Tribes and Northwest Power and Conservation Council, Portland Oregon. 152 pages.

ISAB. 2004. ISAB Findings from the Reservoir Operations / Flow Survival Symposium. Report ISAB 2004-2. Northwest Power and Conservation Council, Portland, Oregon.

ISAB. 2005. Review of the Pacific Northwest Aquatic Monitoring Partnership's "Study Design for Comparing Monitoring Protocols". Report ISAB 2005-1. Northwest Power and Conservation Council, Portland, Oregon.

ISAB. 2005. Viability of ESUs Containing Multiple Types of Populations. Report ISAB 2005-2. Northwest Power and Conservation Council, Portland, Oregon.

ISAB. 2005. Recommendation to Study Effects of Load Following on Juvenile Salmon Migratory Behavior and Survival. Report ISAB 2005-3. Northwest Power and Conservation Council, Portland, Oregon.

ISAB. 2005. Report on Harvest Management of Columbia River Salmon and Steelhead. Report ISAB 2005-4. Northwest Power and Conservation Council, Portland, Oregon.

ISAB. 2005. Review of the All-H Analyzer (AHA). Report ISAB 2005-5. Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2004. Review of Captive Propagation Program Elements: Programmatic Issue 12 for the Mountain Snake and Blue Mountain Provinces. Report ISRP 2004-14. Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2004. Estuary and Lower Columbia Habitat Monitoring and RME Plan Reviews. Report ISRP 2004-16. Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2004. Review of Umatilla RM&E Plan. Report ISRP 2004-17. Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2005. Review of Criteria and Checklist for Evaluating Proposals to Secure Riparian Easements to Protect Tributary Habitat. Report ISRP 2005-1. Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2005. Combined Step Review for Re-introduction of Lower Columbia River Chum Salmon into Duncan Creek. Report ISRP 2005-3. Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2005. Review of Select Area Fishery Evaluation Project. Report ISRP 2005-8. Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2005. Review of Updated Proposed Action (UPA) Habitat Projects to Improve Survival of Upper Columbia River Spring Chinook and Steelhead. Report ISRP 2005-9. Northwest Power and Conservation Council, Portland, Oregon.

ISRP and ISAB. 2005. Preliminary Review of Draft Research Plan. Report ISRP/ISAB 2005-13. Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2005. Retrospective Report 1997-2005. Report ISRP 2005-14. Northwest Power and Conservation Council, Portland, Oregon. 150 pages.

ISAB. 2006. Review of the 2005 Comparative Survival Studies' Annual Report and Applicability of Comparative Survival Studies' Analysis Results. Report ISAB 2006-3. Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2006. Preliminary Review of FY 2007-09 Proposals for the Columbia River Basin Fish and Wildlife Program. Report ISRP 2006-4. Northwest Power and Conservation Council, Portland, Oregon.

ISRP. 2006. ISRP Final Review of Proposals Submitted for Fiscal Year 2007-2009 Funding Through the Columbia River Basin Fish and Wildlife Program. Report ISRP 2006-6. Northwest Power and Conservation Council, Portland, Oregon.

Coutant, C. C., R. Mann, and M. J. Sale. 2006. Reduced Spill at Hydropower Dams: Opportunities for More Generation and Increased Fish Protection. Report ORNL/TM-2005/179. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Publications Summary: 322 as of September 15, 2004.

Notes:
1. Some ISAB and ISRP reports are listed as ISAB or ISRP authorship, without all names. ISRP reports are listed only when I was a coauthor; other ISRP numbered reports did not include me as part of the review team. Short letter reports are not included.
2. Proprietary consulting reports are not included.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of ENTERGY NUCLEAR INDIAN POINT 2, LLC, ENTERGY NUCLEAR INDIAN POINT 3, LLC, and ENTERGY NUCLEAR OPERATIONS, INC. (Indian Point Nuclear Power Station)	Docket Nos. 50-247, 50-286

DECLARATION OF WEBSTER VAN WINKLE, PH.D. IN OPPOSITION TO RIVERKEEPER CONTENTION EC-1 AND STATE OF NEW YORK CONTENTION 31

I, Webster Van Winkle, Ph.D., declare as follows:

QUALIFICATIONS

1. I have extensive and varied experience in assessing environmental impacts of energy technologies in freshwater, estuarine, and marine environments. I have particular depth and expertise regarding assessments, under NEPA, Clean Water Act §316(b), and analogous state law, of the potential impacts of cooling water withdrawals, including entrainment and impingement. I have served as an expert scientific consultant for federal and state agencies and the owners of various power plants.

2. I have conducted extensive research and assessments with regard to Hudson River fish populations and communities, specifically with regard to the impacts of cooling water withdrawals on these populations and communities. My involvement with power plants on the Hudson River started in 1972 with work in support of the U.S. Department of Energy's ("DOE") Oak Ridge National Laboratory's ("ORNL") evaluation of the then-proposed operation of Indian Point Units 2 and 3. My work related to power plants located on the Hudson River has been a part of my professional career for the past 35 years.

3. Prior to founding Van Winkle Environmental Consulting Co. in 1998, I spent 26 years in the Environmental Sciences Division at ORNL. At ORNL, I served as Principal Investigator, Group Leader, and Section Head. In this capacity, I led or participated in numerous environmental research, assessment, and management projects involving small streams to rivers, reservoirs, lakes, estuaries, and coastal ocean, and a range of potential stressors to these water bodies including temperature, mercury, radioisotopes, and acid rain.

4. I am a Fellow of the American Association for the Advancement of Science and the American Institute of Fishery Research Biologists. I hold a Ph.D. degree in Zoology from Rutgers University (1967), and a Bachelor of Arts degree in History from Oberlin College (1961). As an Assistant Professor in the Biology Department at the College of William and Mary, I taught courses in biometry, experimental design, and comparative animal physiology and advised students (1967-1970). I was an NSF Science Faculty Fellow and Public Health Service Postdoctoral Fellow in the Biomathematics Program, North Carolina State University, Raleigh, North Carolina, during which I focused on research, publishing, and additional course work in biomathematics (1970-1972). My curriculum vitae, including a list of my peer reviewed scientific publications, is attached hereto as **Attachment 1**.

BACKGROUND

5. I understand that this proceeding ("Proceeding") before the Nuclear Regulatory Commission ("NRC" or the "Commission") concerns the May 2007 application by Entergy Nuclear Operations, Inc. ("Entergy") to renew, for a period of 20 years, the operating licenses for Entergy Nuclear Indian Point 2, LLC ("IP2") and Entergy Nuclear Indian Point 3, LLC ("IP3"), nuclear power generating units located in Buchanan, New York. 72 Fed. Reg. 26,850 (May 11, 2007). I understand that Riverkeeper, Inc. ("Riverkeeper") and the New York Attorney General ("AG") have filed petitions ("Petitions") to intervene in this license renewal proceeding, in which they specifically request a hearing before the NRC with respect to certain issues that they maintain are not adequately addressed in Entergy's license renewal application ("LRA").

6. I have reviewed the contentions related to the issues of entrainment and impingement – Riverkeeper Contention EC-1 and NYS Contention 31 (the "EI Contentions"). I have reviewed the declarations of Drs. Richard Seaby and Peter Henderson in support of Riverkeeper's Contention EC-1, and accompanying reports co-authored by Drs. Seaby and Henderson entitled *Status of Fish Populations and the Ecology of the Hudson River* ("Pisces Hudson Report") and *Analysis of Entrainment, Impingement, and Thermal Impacts at Indian Point Power Station* ("Pisces EI Report"). I have also reviewed the declaration of Roy A. Jacobson in support of NYS Contention 31.

7. This Declaration is submitted in support of Entergy's response to the EI Contentions.

AEI REPORT

8. Together with Drs. Lawrence W. Barnthouse of LWB Environmental Services, Inc.; Douglas F. Heimbuch of AKRF, Inc.; and John Young of ASA Analysis and Communications, Inc., I have prepared a report, entitled *Entrainment and Impingement at IP2 and IP3: A Biological Impact Assessment* (Jan. 2008) ("AEI Report"). The AEI Report is attached as **Attachment 2** to the Barnthouse Declaration and is incorporated herein by reference. To the best of my knowledge, the factual

statements in the AEI Report are true and accurate, and the opinions expressed therein are based on my best professional judgment.

RESPONSE TO PISCES EI REPORT, PISCES HUDSON REPORT, AND JACOBSON DECLARATION

9. I have reviewed the Pisces EI Report, the Pisces Hudson Report, and Jacobson Declaration. Below, I reply in part to these documents. I disagree with many of the opinions offered in these documents. The fact that I do not specifically address a particular opinion or contention in this Declaration does not mean that I agree with such opinions or contentions.

Pisces Hudson Report

10. The Pisces Hudson Report addresses the larger and general Hudson River ecosystem without regard to IP2 and IP3 (or even any mention of it). Therefore, the Pisces Hudson Report does not permit any inferences to be made regarding the possible effects of Indian Point's operations on the ecosystem.

11. Together with Drs. Young, Barnthouse and Heimbuch, I examined several fish community metrics to assess changes in the juvenile (Age 0) fish community sampled by the Hudson River Monitoring Program. To determine whether a metric had changed, we divided the dataset into two equal time periods constituting the first half of the dataset ("Period 1") and the second half of the dataset ("Period 2"). Standard community level metrics were calculated using data from Period 1 and compared to the same metrics calculated using data from Period 2. Because sampling gear used in the shorezone, benthic, and water column habitats differ, metrics were calculated for each habitat.

12. The metrics calculated were: (1) species richness – calculated by summing the total number of species found in samples in a given year; (2) the percent of total abundance comprised of dominant species – a dominant species being defined as a species contributing 10% or more to the total abundance of Age 0 fish; (3) species turnover – the number of species whose abundance changed sufficiently that they could be considered to have entered or left the fish community; (4) total abundance – the mean catch per sample of all Age 0 fish in a given year; and (5) species density – mean number of species per sample collected in the HRMP in a given year. These metrics were calculated using the BSS and FSS datasets utilized in the AEI Report and described above.

13. Species richness did not change significantly from the first half of the dataset to the second. In the first half of the dataset, the average number of species collected in the shorezone, benthic, and water column habitats were 44, 31 and 18 respectively in Period 1, and 44, 30, and 19 respectively in Period 2.

	Species Richness	
Habitat	Period 1	Period 2
Shorezone	44	44
Benthic	31	30
Water Column	18	19

14. The community was dominated by a few abundant species in all three habitats in both periods, with little change in the percent of total abundance made up by the dominant species.

	Percent of Individuals from Dominant Species	
Habitat	Period 1	Period 2
Shorezone	67	67
Benthic	76	74
Water Column	95	94

15. Eleven different species were abundant enough to be considered dominant in at least one habitat in one year. Of the 171 instances in which a species comprised more than 10% of the total abundance in a habitat in a year, 150 (or 87.7%) of those instances were due to the presence of the 8 species analyzed in the AEI Report (the "8 RIS").

16. Very few species increased to the point of entering the fish community (initially missing or rare and becoming relatively common), and similarly, very few species decreased to the point of leaving the fish community (changing from relatively common to missing or rare). Atlantic croaker and channel catfish were not collected during the earlier years but have since increased in abundance. Conversely, goldfish, rainbow smelt and rough silverside have decreased in abundance over time and are now rarely collected (or not collected at all) in the HRMP. Considering that the total number of species of Age 0 fish in the river exceeds 75, this level of species turnover is not ecologically significant.

17. The total abundance of Age 0 Fish declined by approximately 20% between Period 1 and Period 2 (all three habitats combined). *See* Figure 1 for results by individual habitat. When the 8 RIS are removed from the analysis, the total abundance of all remaining species did not change significantly from Period 1 to Period 2. *See* Figure 2 for results by individual habitat, and note that abundance of non-RIS in the shorezone approximately doubled between Period 1 and Period 2. Thus, excluding the 8 RIS accounts for the shift in results from a 20% decrease in total abundance to an increase or no change from Period 1 to Period 2.

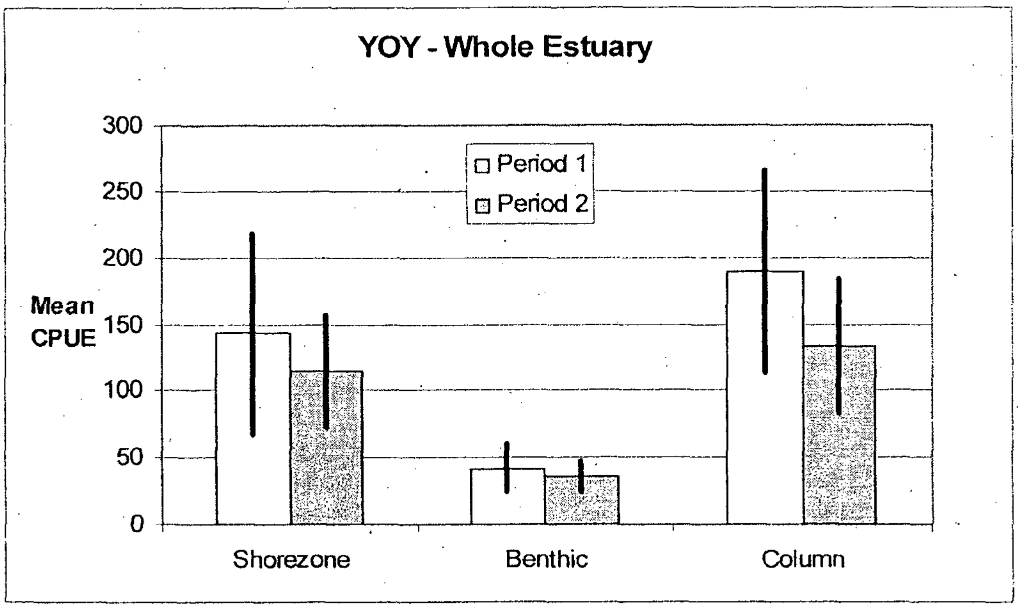


Figure 1.

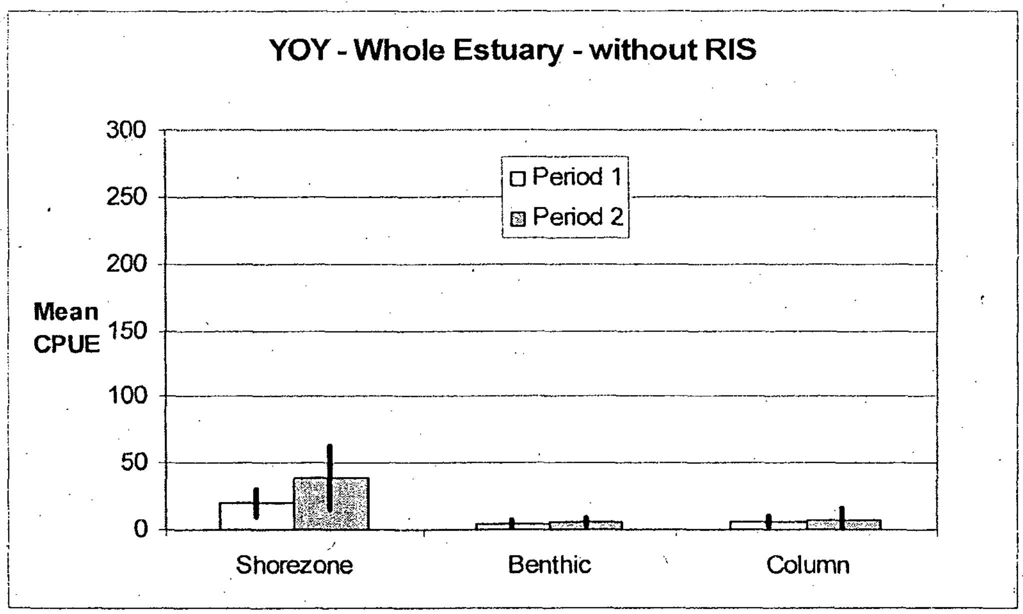


Figure 2.

18. Species density, the total number of species caught per sample, declined by approximately 10% between Period 1 and Period 2 (all three habitats combined). *See* Figure 3 for results by individual habitat. When the 8 RIS are removed from the analysis, there was no significant change in species density among the remaining species for any of the three habitats as indicated by the overlapping error bars (Figure 4). Thus, as with

total abundance of Age 0 Fish, excluding the 8 RIS accounts for the shift in results from a 10% decrease in species density to no significant change from Period 1 to Period 2.

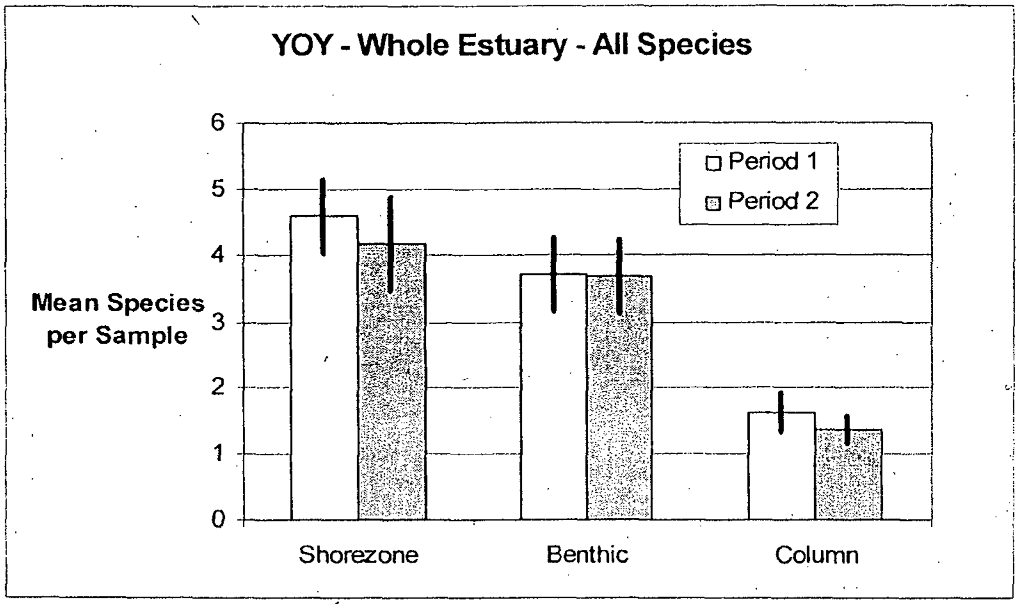


Figure 3.

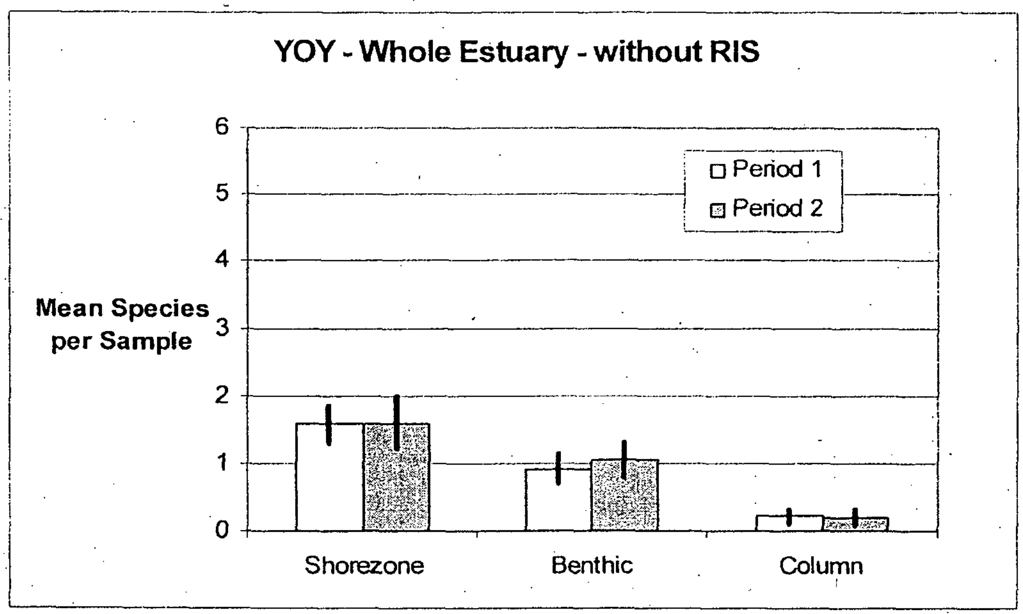


Figure 4.

19. The AEI Report evaluated the changes in the 8 RIS in detail and concluded, in each case, that the change in abundance of each RIS was unrelated to impingement and entrainment at Indian Point. Furthermore, results for the total

abundance and species density metrics, with RIS excluded, indicate no significant changes. Because impingement and entrainment at Indian Point is not related to the changes in abundance of the 8 RIS (as discussed in the AEI Report), it is also not related to the changes in the two community metrics showing declines, namely total abundance and species density. Thus, the results of these analyses in conjunction with the conclusions of the AEI Report are inconsistent with an impact hypothesis that impingement and entrainment at Indian Point is having an adverse effect on the Age 0 fish community in the Hudson River estuary.

CONCLUSION

20. In my professional opinion, nothing in the Pisces Reports or Jacobson Declaration undermines the conclusion set forth in the AEI Report that entrainment and impingement of individual fish by the IP cooling-water intake structures have not caused an adverse environmental impact on specific fish populations or the fish community in the Hudson River estuary.

Signed this 18th day of January, 2008.

Webster Van Winkle

Webster Van Winkle, Ph.D.
Van Winkle Environmental Consulting Co.

ATTACHMENT 1

Dr. Webster Van Winkle
Van Winkle Environmental Consulting Co.
5163 N. Backwater Ave., Boise, Idaho 83714
Resume, January 2008

Consulting Activities From 1998-Present

(1) Idaho Power Company (IPC), Boise, ID. As part of FERC re-licensing activities of IPC's hydropower facilities, I participate in meetings, workshops, and field trips; give presentations; and contribute to open-literature publications, reports and other documents for four projects: (a) White Sturgeon Populations from Shoshone Falls to Lower Granite Dam—continuing; (b) Centrarchid Populations in Brownlee Reservoir—completed; (c) Trout in the Malad River—completed; (d) Threatened and Endangered Snails in the Mid-Snake River. 1998—continuing.
(2) Hudson River Utilities (Dynegy Northeast Generation, Newburgh, NY). With Drs. Larry Barnthouse & Chuck Coutant, evaluated evidence concerning impacts of cooling water withdrawals (Barnthouse et al. 2001) and participated in meetings. 2000-2002.
(3) EPRI (Electric Power Research Institute), Palo Alto, CA. As part of EPRI'S 316(a&b) Fish Protection Issues Program, participated in meetings, workshops, and site visits; gave presentations; and contributed to open-literature publications, reports and other documents for four projects: (a) comments on EPA's proposed Section 316(b) regulations; (b) co-authored two EPRI reports relating to Section 316(b); (c) chaired American Fisheries Society symposium and publication on Biology, Management, and Protection of Sturgeon; and (d) served as EPRI's representative on Atlantic States Marine Fisheries Commission Power Plant Panel.
(4) Dominion Nuclear Connecticut, Inc., Waterford, CT. Participated in workshops/meetings and reviewed documents associated with assessing potential entrainment and impingement impacts at the Millstone Nuclear Power Plant. 1998-2000.

Previous Positions

Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN (1972-retired Oct 1998). Broad range of experiences in research, assessment, and management as Principal Investigator, Group Leader, and Section Head.

NSF Science Faculty Fellow and Public Health Service Postdoctoral Fellow, Biomathematics Program, North Carolina State University, Raleigh, North Carolina, 1970-1972.

Assistant Professor, Department of Biology, College of William and Mary, Williamsburg, Virginia, 1967-1970. Taught undergraduate and graduate courses in biometry, experimental design, and comparative animal physiology.

Research Associate and On-Site Director, Shellfish Research Laboratory, Rutgers University, Monmouth Beach, New Jersey, 1966-1967.

Education

Ph.D.	Rutgers University, New Brunswick, NJ	Zoology	1967
B.A.	Oberlin College, Oberlin, Ohio	History	1961

Relevant Previous Activities & Honors

Member, Review Panel, Western Division of American Fisheries Society, Review of the Recovery Program for the Endangered Pallid Sturgeon in the Upper Missouri River Basin. 2003-2004.

Co-organized and co-chaired symposium on Biology, Management, and Protection of North American Sturgeon at the American Fisheries Society Annual Meeting, St. Louis, MO, August 2000. Lead editor for AFS Symposium 28 (2002) with same title.

Member, Atlantic States Marine Fisheries Commission Power Plant Panel, 2001-2004. A co-author of report on Cumulative Impacts of Power Plant Impingement and Entrainment: a Case Study for Atlantic Menhaden.

Organized and co-chaired session on *Density-Dependent (Compensation) Processes* for the EPRI Conference on Power Generation Impacts on Aquatic Resources, Atlanta, GA, April 1999.

Principal Investigator, EPRI project on Compensatory Mechanisms in Fish Populations (CompMech), 1987-1998. Funding level: $400,000 - $1,000,000/yr.

Member, Scientific Advisory Group for the Interagency Ecological Studies Program, California Department of Water Resources, Sacramento, CA, 1996-1998.

Member, Technical Advisory Group and reviewer for U.S. Army Corps of Engineers, Rock Island District, Rock Island, IL, 1993–1995; and 1998–1999. Objective: to evaluate field, laboratory, and modeling studies relating to impacts on fish populations of increased navigation traffic in the Upper Mississippi River.

Member, Technical Advisory Committee for NOAA's South Atlantic Bight Recruitment Experiment (SABRE), 1991-1995.

Associate Editor (for modeling and statistics), Editorial Board, American Fisheries Society, 1982-1984.

Fellow, American Institute of Fishery Research Biologists, 1989.

Fellow, Biological Sciences Section, American Association for the Advancement of Science (AAAS), 1983.

Publications

A. Peer-reviewed Journal Articles, Book Chapters, and Books

1. Senior Author

Van Winkle, W. 1968. The effects of season, temperature, and salinity on the oxygen consumption of bivalve gill tissue. Comp. Biochem. Physiol. 26:69-80.

Van Winkle, W. 1970. Effect of environmental factors on byssal thread formation. Mar. Biol. 7:143-148.

Van Winkle, W. 1972. Ciliary activity and oxygen consumption of excised bivalve gill tissue. Comp. Biochem. Physiol. 42A:473-485.

Van Winkle, W., D.C. Martin, and M.J. Sebetch. 1973. A home-range model for animals inhabiting an ecotone. Ecology 54:205-209.

Van Winkle, W. 1975. Comparison of several probablitistic home-range models. J. Wildlife Management 39:118-123.

Van Winkle, W. 1975. Problems in establishing the relationship between pumping rate and oxygen consumption rate in the hard clam, *Mercenaria mercenaria*. Comp. Biochem. Physiol. 50A:657-660.

Van Winkle, W. and C.P. Mangum. 1975. Oxyconformers and oxyregulators: a quantitative index. J. Exptal. Mar. Biol. Ecol. 17:103-110.

Van Winkle, W., S.Y. Feng, and H.H. Haskin. 1976. Effect of temperature and salinity on extension of siphons of *Mercenaria mercenaria*. J. Fish. Res. Board Canada 33:1540-1546.

Van Winkle, W., S.W. Christensen, and J.S. Mattice. 1976. Two roles of ecologists in defining and determining the acceptability of environmental impacts. Internatl. J. Environ. Studies 9:247-254.

Van Winkle, W. (ed.) 1977. Assessing the effects of power-plant-induced mortality on fish populations. Pergamon Press, New York. 380 p.

Van Winkle, W., D.L. DeAngelis, and S.R. Blum. 1978. A density-dependent function for fishing mortality rate and a method for determining elements of a Leslie matrix with density-dependent parameters. Trans. Am. Fish. Soc. 107(3):395-401.

Van Winkle, W., B.L. Kirk, and B.W. Rust. 1979. Periodocities in Atlantic coast striped bass (*Morone saxatilis*) commercial fisheries data. J. Fish. Res. Board Canada 36:54-62.

Van Winkle, W., D.S. Vaughan, L.W. Barnthouse, and B.L. Kirk. 1981. An analysis of the ability to detect reductions in year-class strength of the Hudson River white perch (*Morone americana*) population. Can. J. Fish. Aquatic Sci. 38(6):627-632.

Van Winkle, W., S.W. Christensen, and J.E. Breck. 1986. Linking laboratory and field responses of fish populations to acidification. Water, Air and Soil Pollution 30:639-648.

Van Winkle, W., K.D. Kumar, and D.S. Vaughan. 1988. Relative contributions of Hudson River and Chespeake Bay striped bass stocks to the Atlantic Coast population vary substantially among year classes. pp. 255-266. IN L.W. Barnthouse, R.J. Klauda, and D.S. Vaughan (eds.). Proc. Symposium on Advancing the Science of Assessment: Technical Lessons from the Hudson River Power Plant Case. Am. Fish. Soc. Monogr.

Van Winkle, W., K.A. Rose, R. C. Chambers. 1993. Individual-based approach to fish population dynamics: An overview. Trans. Amer. Fish. Soc. 122:397-404.

Van Winkle, W., K.A. Rose, K.O. Winemiller, D.L. DeAngelis, S.W. Christensen, and R.G. Otto. 1993. Linking life history theory and individual-based modeling to compare responses of different fish species to disturbance. Trans. Amer. Fish. Soc. 122:459-466.

Van Winkle, W., B.J. Shuter, B.D. Holcomb, H.I. Jager, J.A. Tyler, and S.Y. Whitaker. 1996. Regulation of energy acquisition and allocation to respiration, growth, and reproduction: simulation model and example using rainbow trout. pp. xxx-xxx. IN R.C. Chambers and E.A. Trippel (eds.). Early Life History and Recruitment in Fish Populations. Chapman & Hall, New York.

Van Winkle, W., K.A. Rose, B.J. Shuter, H.I Jager, and B.D. Holcomb. 1997. Effects of climatic temperature change on growth, survival, and reproduction of rainbow trout: predictions from a simulation model. Canadian J. Fish. & Aquatic Sciences 54:2526-2542.

Van Winkle, W., C.C. Coutant, H.I. Jager, J.S. Mattice, D.J. Orth, R.G. Otto, S.F. Railsback, and M.J. Sale. 1997. Uncertainty and instream flow standards: perspectives based on research and assessment experience. Fisheries 22: 21-22.

Van Winkle, W., H.I. Jager, S.F. Railsback, B.D. Holcomb, T.K. Studley, and J.E. Baldrige. 1998. Individual-based model of sympatric populations of brown and rainbow trout for instream flow assessment: model description and calibration. Ecological Modelling 110:175-207.

Van Winkle, W., and V. H. Dale. 1998. Model interactions: a reply to Aber. Bulletin of the Ecological Society of America 79(4):169-170.
Van Winkle, W. 2000. A perspective on power generation impacts and compensation in fish populations. Environmental Science and Policy 3: S425-S431.

2. Coauthor

Barnthouse, L.W., J. Boreman, S.W. Christensen, C.P. Goodyear, W. Van Winkle, and D.S. Vaughan. 1984. Population biology in the courtroom: The lesson of the Hudson River controversy. Bioscience 34:14-19.
Barnthouse, L.W., W. Van Winkle, D.S. Vaughan. 1983. Impingement losses of white perch at Hudson River power plants: Magnitude and biological significance. Environ. Manag. 7(4):355-364.
Breck, J.E., D.L. DeAngelis, W. Van Winkle, and S.W. Christensen. 1988. Potential importance of spatial and temporal heterogeneity in pH, Al, and Ca in allowing survival of a fish population: A model demonstration. Ecological Modeling 41:1-16.
Christensen, S.W., J.E. Breck, and W. Van Winkle. 1988. Predicting acidification effects on fish populations, using laboratory data and field information. Environ. Toxicol. Chem. 7:735-747.
Christensen, S.W., W. Van Winkle, L.W. Barnthouse, and D.S. Vaughan. 1981. Science and the law: Confluence and conflict on the Hudson River. Environ. Impact Assessment Review 2(1):63-68.
Dale, V. H., and W. Van Winkle. 1998. Models provide understanding, not belief. Bulletin of the Ecological Society of America 79(2):129-130.
DeAngelis, D.L., L.W. Barnthouse, W. Van Winkle, and R.G. Otto. 1990. A critical appraisal of population approaches in assessing fish community health. J. Great Lakes Research 16(4):576-590.
Elwood, J.W., J.D. Newbold, R.V. O'Neill, and W. Van Winkle. 1983. Resource spirally: An operational paradigm for analyzing lotic ecosystems. pp. 3-27. IN R.D. Fontaine and S.M. Bartell (eds.). The Dynamics of Lotic Ecosystems. DOE Symposium Series, Ann Arbor Science Publishers, Ann Arbor, Michigan.
Feng, S.Y., and W. Van Winkle. 1975. The effect of temperature and salinity on the heart rate of the oyster *Crassostrea virginica*. Comp. Biochem. Physiol. 50A:473-476.
Gross, L.J., K.A. Rose, E.J. Rykiel, W. Van Winkle, and E. E. Werner. 1992. Individual-based modeling: summary of a workshop. pp. 511-522. IN D.L. DeAngelis and L.J. Gross (eds.). Populations, communities and ecosystems: a perspective from modeling at the level of individual organisms. Routledge, Chapman & Hall, New York.
Heimbuch, D.G., E. Lorda, D.S. Vaughan, L.W. Barnthouse, J. Uphoff, W. Van Winkle, A. Kahnle, B. Young, J.R. Young, L. Kline, G. White, and P. Kilduff. 2008(?). Assessing coastwide effects of power plant entrainment and impingement on fish populations: Atlantic menhaden example. North American Journal of Fisheries Management (in press).
Jager, H.I., D.L. DeAngelis, M.J. Sale, W. Van Winkle, D.D. Schmoyer, M.J. Sabo, D.J. Orth, and J.A. Lukas. 1993. An individual-based model for smallmouth bass reproduction and young-of-year dynamics in streams. Rivers 4:91-113.
Jager. H.I., H.E. Cardwell, M.J. Sale, M.J. Bevelhimer, C.C. Coutant, and W. Van Winkle. 1997. Modelling the linkages between flow management and salmon recruitment in streams. Ecological Modelling 103:171-191.
Jager, H.I., W. Van Winkle, and B.D. Holcomb. 1999. Would hydrologic climate changes in Sierra-Nevada streams influence trout persistence? Trans. Amer. Fish. Soc. 128:222-240.
Jager, H.I., W. Van Winkle, K. Lepla, J. Chandler, and P. Bates. 2000. Population viability analysis of riverine fishes. Species issue of the J. Environ. Science & Policy 3:S483-489.
Jager, H.I., W. Van Winkle, K. Lepla, and J. Chandler. 2001. A theoretical study of river fragmentation by dams and its effects on white sturgeon populations. Environ. Biol. Fishes 60:347-361.
Jager, H.I., W. Van Winkle, K.A. Lepla, J.B. Chandler, P. Bates, and T.D. Counihan. 2002. Factors controlling white sturgeon recruitment in the Snake River. pp. 127-150. IN W. Van Winkle, P.J. Anders, D.H. Secor, and D.A. Dixon (eds.). Biology, Management, and Protection of Sturgeon, Amer. Fisheries Society Symposium 28, Amer. Fish. Society, Bethesda, MD.
Mangum, C.P., and W. Van Winkle. 1973. Responses of aquatic invertebrates to declining oxygen conditions. Amer. Zool. 13: 529-541.
Newbold, J.D., J.W. Elwood, R.V. O'Neill, and W. Van Winkle. 1981. Nutrient spiralling in streams: The concept and its field measurement. Can. J. Fish. Aquatic. Sci. 38:860-863.
Newbold, J.D., R.V. O'Neill, J.W. Elwood, and W. Van Winkle. 1982. Nutrient spiraling in streams: Implications for nutrient limitation and invertebrate activity. Amer. Nat. 120(5): 628-652.

O'Neill, R.V., R.H. Gardner, S.W. Christensen, W. Van Winkle, J.H. Carney, and J.B. Mankin. 1981. Some effects of parameter uncertainty in density-independent and density-dependent Leslie models for fish populations. Can. J. Fish. Aquatic Sci. 39(5):782-785.

Vaughan, D.S., and W. Van Winkle. 1982. Corrected analysis of the ability to detect reductions in year-class strength of the Hudson River white perch (*Morone americana*) population. Can. J. Fish. Aquatic Sci. 39(5):782-785.

B. Proceedings

1. Senior Author

Van Winkle, W., B.W. Rust, and C.P. Goodyear. 1974. A striped-bass population model and computer program. pp. 532-549. IN R. Crosbie and P. Luker (eds.). Summer Computer Simulation Conference, 1974. Simulation Councils, Inc., La Jolla, CA.

Van Winkle, W. 1976. The application of computers in an assessment of the environmental impact of power plants on an aquatic ecosystem. pp. 85-108. IN S. Fernbach and H.M. Schwartz (eds.). Proc. Conf. Computer Support of Environ. Science and Analysis. CONF-750706. Prepared by the Lawrence Livermore Laboratory, Univ. Calif., Livermore, CA, at the request of the USERDA.

Van Winkle, W. 1977. Conclusions and recommendations for assessing the effects of power-plant-induced mortality on fish populations: The optimist, the pessimist, and the realist. Pp. 366-373. IN W. Van Winkle (ed.). 1977. Assessing the effects of power-plant-induced mortality on fish populations. Pergamon Press, New York. 380 p.

Van Winkle, W. 1981. Population level assessments should be emphasized over community/ecosystem-level assessments. pp.63-66. IN L.D. Jensen (ed.). Fifth National Workshop on Entrainment and Impingement. EA Communications, Melville, NY.

Van Winkle, W., C.C. Coutant, J.W. Elwood, S.G. Hildebrand, J.S. Mattice, and R.B. McLean. 1981. Comparative reservoir research at Oak Ridge National Laboratory. pp. 1432-1447. IN H.G. Stefan (ed.). Proc. Sympos. Surface Water Impoundments. Amer. Soc. Civi. Engin., New York.

Van Winkle, W., and Kadvany, J. 2003. Modeling fish entrainment and impingement impacts: bridging science and policy. pp. 46-69. IN V. H. Dale, editor. Ecological Modeling for Resource Management, Springer, New York, NY.

Van Winkle, W., W.P. Dey, S.M. Jinks, M.S. Bevelhimer, and C.C. Coutant. 2003. A blueprint for the problem formulation phase of EPA-type ecological risk assessments for 316(b) determinations. IN D.A. Dixon, J.A. Veil, and J. Wisniewski, editors. Defining and Assessing Adverse Environmental Impact from Power Plant Impingement and Entrainment of Aquatic Organisms. A.A. Balkema Publishers, Lisse, The Netherlands.

2. Coauthor

Barnthouse, L.W., W. Van Winkle, and B.L. Kirk. 1981. The direct impact of impingement on the Hudson River white perch population. pp. 199-205. IN L.D. Jensen (ed.). Fifth National Workshop on Entrainment and Impingement. EA Communications, Melville, NY.

Breck, J.E., D.L. DeAngelis, and W. Van Winkle. 1986. Simulating fish exposure to toxicants in a heterogeneous body of water. pp. 451-455. IN R. Crosbie and P. Luker (eds.). Summer Computer Simulation Conference, 1974. Simulation Councils, Inc., La Jolla, CA.

Christensen, S.W., W. Van Winkle, and J.S. Mattice. 1976. Defining and determining the significance of impacts: concepts and methods. pp. 191-219. IN R.K. Sharma, J.D. Buffington, J.T. McFadden (eds.). Proc. Workshop Biol. Significance of Environ. Impacts. NR-CONF-002. U.S. Nuclear Regulatory Commission, Washington, D.C.

Jager, H.I., M.J. Sale, M.J. Sabo, D.D. Schmoyer, W. Van Winkle, and D.L. DeAngelis. 1994. Spatial simulation of smallmouth bass in streams. pp. xxx-xxx. WaterPower '93.

C. Selected Reports

1. Senior Author

Van Winkle, W., B.W. Rust, C.P. Goodyear, S.R. Blum, and P. Thall. 1974. A striped bass population model and computer program. Oak Ridge National Laboratory, Oak Ridge, TN. ORNL/TM-4578. ESD-643.

Van Winkle, W., S.W. Christensen, and G. Kauffman. 1976. Critique and sensitivity analysis of the compensation function used in the LMS Hudson River striped bass models. ORNL, Oak Ridge, TN. ORNL/TM-5437. ESD-944.

Van Winkle, W., S.W. Christensen, and J.S. Suffern. 1979. Incorporation of sublethal effects and indirect mortality in modeling population-level impacts of stress, with an example involving power-plant entrainment and striped bass. ORNL, Oak Ridge, TN ORNL/NUREG/TM-288. ESD-1295.

Van Winkle, W., L.W. Barnthouse, B.L. Kirk, and D.S. Vaughan. 1980. Evaluation of impingement losses of white perch at the Indian Point Nuclear Station and other Hudson River power plants. ORNL, Oak Ridge, TN. NUREG/CR-1100. ORNL/NUREG/TM-361. ESD-1932.

Van Winkle, W., R.W. Counts, J.G. Dorsey, J.W. Elwood, V.W. Lowe, R. McElhaney, S.D. Schlotzhaurer, F.G. Taylor, and R.R. Turner. 1982. Mercury contamination in East Fork Popular Creek and Bear Creek. ORNL, Oak Ridge, TN. ORNL/TM-8894. ESD-2051.

Van Winkle, W., and K.D. Kumar. 1982. Relative stock composition of the Atlantic Coast striped bass population—further analysis. ORNL, Oak Ridge, TN. NUREG/CR-2563. ORNL/TM-361. ESD-1988.

Van Winkle, W., Richter, T.J., and J.A. Chandler. 2002. Relative Potential Consequences of Alternative Operational Scenarios for Centrarchid Populations in Brownlee Reservoir. Idaho Power Company, Hells Canyon Complex Hydroelectric Project, Technical Report, Appendix E.3.1-5, Chapter 4, Boise, Idaho.

Van Winkle W. 2003. Comments for EPRI on EPA's Notice of Data Availability, Clean Water Act Section 316(b)—National Pollution Discharge Elimination System—Proposed Regulations for Cooling water Intake Structures at Phase II Existing Facilities. Submitted to EPA as Appendix D of EPRI's submission.

2. Coauthor

Barnthouse, L.W., and 12 other authors. 1977. A selective analysis of power plant operation on the Hudson River with emphasis on the Bowline Point generating station. ORNL, Oak Ridge, TN. ORNL/TM-5877 (Vol. 2). ESD-1156.

Barnthouse, L.W., S.W. Christensen, B.L. Kirk, K.D. Kumar, W. Van Winkle, and D.S. Vaughan. 1980. Methods to assess impacts on Hudson River striped bass. Annual report to the Nuclear Regulatory Commission. ORNL, Oak Ridge, TN. NUREG/CR-1243. ORNL/NUREG/TM-374. ESD-1493.

Barnthouse, L.W., B.L. Kirk, K.D. Kumar, W. Van Winkle, and D.S. Vaughan. 1980. Methods to assess impacts on Hudson River white perch. Annual report to the Nuclear Regulatory Commission. ORNL, Oak Ridge, TN. NUREG/CR-1242. ORNL/NUREG/TM-373. ESD-1492.

Barnthouse, L.W., and W. Van Winkle. 1980. Modeling tools for ecological impact evaluation. pp. 271-313. IN F.S. Sanders (ed.). Development document for strategies for ecological effects monitoring at DOE energy production facilitieis. ORNL, Oak Ridge, TN. ORNL /TM-373. ESD-1639.

Barnthouse, L.W., W. Van Winkle, J. Golumbek, G.F. Cada, C.P. Goodyear, S.W. Christensen, J.B. Cannon, and D.W. Lee. 1982. Impingement impact analyses, evaluation of alternative screening devices, and critiques of utility analyses relating to density-dependent growth, the age structure of the Hudson River striped bass population, and the LMS real-time life-cycle model. Vol. II of the impact of entrainment and impingement on fish populations in the Hudson River estuary. ORNL, Oak Ridge, TN. ORNL/NUREG/TM-385/V2. ESD-1791.

Barnthouse, L.W., W. Van Winkle, B.L. Kirk, and D.S. Vaughan. 1982. The impact of impingement on the Hudson River white perch population: Final report. ORNL, Oak Ridge, TN. ORNL/NUREG/TM-7975. ESD-1842.

Bevelhimer, M., Y. Jager, and W. Van Winkle. 2001. Malad River Trout Model: Simulations of the Effects of Minimum Flow, Entrainment, and Passage. Idaho Power Company, Upper and Lower Malad River Hydroelectric Project, Technical Report, Appendix E.3.1-B, Status, Habitat, and Limiting Factors for Rainbow Trout, Boise, ID.

Boreman, J., L.W. Barnthouse, D.S. Vaughan. C.P. Goodyear, S.W. Christensen, K.D. Kumar, B.L. Kirk, and W. Van Winkle. 1982. *Entrainment impact estimates of six fish species inhabiting the Hudson River estuary.* Vol. I of the impact of entrainment and impingement on fish populations in the Hudson River estuary. ORNL, Oak Ridge, TN. ORNL/NUREG/TM-385/VI. ESD-1790.

Christensen, S.W., D.S. Vaughan, W. Van Winkle, L.W. Barnthouse, D.L. DeAngelis, K.D. Kumar, and R.M. Yoshiyama. 1982. Methods to assess impacts on Hudson River striped bass: Final report. ORNL, Oak Ridge, TN. NUREG/CR-2674. ORNL/TM-8309. ESD-1978.

DeAngelis, D.L., W. Van Winkle, S.W. Christensen, S.R. Blum, B.L. Kirk, B.W. Rust, and C. Ross. 1978. A generalized fish life-cycle population model and computer program. of the impact of entrainment and impingement on fish populations in the Hudson River estuary. ORNL, Oak Ridge, TN. ORNL/ TM-6125. ESD-1128.

Dey, W., S. Jinks, and W. Van Winkle. 2002a. Evaluating the Effects of Power Plant Operations on Aquatic Communities: Guidelines for Selection of Assessment Methods. EPRI Report 1005176, Palo Alto, CA. May 2002.

Dey, W., S. Jinks, and W. Van Winkle. 2002b. Evaluating the Effects of Power Plant Operations on Aquatic Communities: An Ecological Risk Assessment Framework for Clean Water Act Section 316(b) Determinations. EPRI Report 1005337, Palo Alto, CA. July 2002.

Eraslan, A.H., R.D. Sharp, and W. Van Winkle. 1982. User's manual for STRIPE: A computer simulation model for the striped bass young-of-the-year population in the Hudson River. ORNL, Oak Ridge, TN. NUREG/CR-1830. ORNL/NUREG/TM-423. ESD-1646.

Eraslan, A.H., W. Van Winkle, R.D. Sharp, S.W. Christensen, C.P. Goodyear, R.M. Rush, and W. Fulkerson. 1976. A computer stimulation model for the striped bass young-of-the-year population in the Hudson River. ORNL, Oak Ridge, TN. ORNL/NUREG-8. ESD-766.

Heimbuch, D.G., E. Lorda, D.S. Vaughan, L.W. Barnthouse, J. Uphoff, W. Van Winkle, A. Kahnle, B. Young, J.R. Young, L. Kline, G. White, and P. Kilduff. 2005. Cumulative impacts of power plant entrainment and impingement: a case study for Atlantic menhaden. Report to the Management and Science Committee, Atlantic States Marine Fisheries Commission, Washington, DC.

Mount, D.R. (ed.), M.D. Marcus (ed.), H.L. Berman, J.E. Breck, S.W. Christensen, W.A. Gern, C.G. Ingersoll, D.G. McDonald, B.R. Parkhurst, W. Van Winkle, C.M. Wood, and H.L. Bergman. 1989. Physiological, toxicological, and population responses of brook trout to acidification. An interim report of the Lake Acidification and Fisheries Project, EPRI RP-2346. Electric Power Research Institute, Palo Alto, California.

Turner, R.S., D.W. Johnson, J.W. Elwod, W.Van Winkle, R.B. Clapp, and J.O. Reuss. 1986. Factors affecting response of surface waters to acidic deposition. ORNL, Oak Ridge, TN. ORNL/TM-9787. ESD-2596.

Yoshiyama, R.M., W. Van Winkle, B.L. Kirk, and D.E. Stevens. 1981. Regression analyses of stock-recruitment relationships in three fish populations. ORNL, Oak Ridge, TN. NUREG/CR-1836. ORNL/NUREG/TM-424. ESD-1645.

D. Written Testimony and Environmental Impact Assessments

1. Senior Author

Van Winkle, W. 1977. Supplemental testimony of NRC staff in response to Board comments on aquatic impact analysis. Testimony before the Atomic Safety and Licensing Board in the matter of Consolidated Edison Company of New York, Inc., Indian Point Station, Unit No. 2.

Van Winkle, W., and L.W. Barnthouse. 1979. Evaluation of impingement losses of white perch at Hudson River power plants. Testimony prepared for the U.S. Environmental Protection Agency, Region II, in the matter of National Pollutant Discharge Elimination System Permits for Central Hudson Gas & Electric Corporation (Roseton Generating Station) et al.

Van Winkle, W., and S.W. Christensen. 1979. Incorporation of sublethal effects and indirect mortality in modeling population-level impacts of power-plant entrainment. Testimony prepared for the U.S. Environmental Protection Agency, Region II, in the matter of National Pollutant Discharge Elimination System Permits for Central Hudson Gas & Electric Corporation (Roseton Generating Station) et al.

2. Coauthor

Barnthouse, L.W., and W. Van winkle. 1979. Impingement impact estimates for seven Hudson River fish species. Testimony prepared for the U.S. Environmental Protection Agency, Region II, in the matter of National Pollutant Discharge Elimination System Permits for Central Hudson Gas & Electric Corporation (Roseton Generating Station) et al.

Christensen, S.W., W. Van Winkle, and P.C. Cota. 1975. Effect of Summit Power Station on striped bass populations. Testimony presented to the Nuclear Regulatory Commission in the matter of Summit Power Station, Units 1&2, Delmarva Power & Light Co. and Philadelphia Electric Co.

Golumbek, J., W. Van Winkle, and C.P. Goodyear. 1979. A critical evaluation of the LMS 2-dimensional real-time life cycle model of the Hudson River striped bass population. Testimony prepared for the U.S. Environmental Protection Agency, Region II, in the matter of National Pollutant Discharge Elimination System Permits for Central Hudson Gas & Electric Corporation (Roseton Generating Station) et al.

Richmond, C.R., and S.I. Auerbach. 1983. Summary of actions and activities related to mercury releases in the Oak Ridge area from DOE/UCC-ND operated facilities. Testimony at a joint hearing of the subcommittee on Energy Research and Production and the Subcommittee on Investigations and Oversight of the U.S. House Science and Technology Committee on the Impact of Mercury Releases at the Oak Ridge Complex. (Note: WVW not identified as an author.)

Spore, R., and W. Van Winkle. 1977. Testimony of NRC staff on the relative benefits and costs associated with applicant's request for extension of operation with once-through cooling at Indian Point No. 2. Testimony before the Atomic Safety and Licensing Board in the Matter of Consolidated Edison Company of New York, Inc., Indian Point Station, Unit No. 2.

3. Corporate Authored

Final environmental statement related to operation of Indian Point Nuclear Generating Plant, Unit No. 3, Consolidated Edison Company of New York. 1975. U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation. (Responsible for sections on aquatic ecology).

Draft environmental statement related to operation of Indian Point Nuclear Generating Plant, Unit No. 1, Consolidated Edison Company of New York. 1975. U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation. (Responsible for sections on aquatic ecology).

Final environmental statement for facility license amendment for extension of operation with once-through cooling for Indian Point Nuclear Generating Plant, Unit No. 2, Consolidated Edison Company of New York. 1976. U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation. (Responsible for sections on aquatic and terrestrial ecology).

Draft environmental statement for the Susitna Hydroelectric project, Alaska Power Authority. Federal Energy Regulatory Commission. (With C.C. Coutant, responsible for sections on fish population dynamics, fisheries, and aquatic ecology.)

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of ENTERGY NUCLEAR INDIAN POINT 2, LLC, ENTERGY NUCLEAR INDIAN POINT 3, LLC, and ENTERGY NUCLEAR OPERATIONS, INC. (Indian Point Nuclear Power Station)	Docket Nos. 50-247, 50-286

**DECLARATION OF JOHN R. YOUNG, PH.D.
IN OPPOSITION TO RIVERKEEPER CONTENTION EC-1 AND
STATE OF NEW YORK CONTENTION 31**

I, John R. Young, Ph.D., declare as follows:

QUALIFICATIONS

1. I am a Senior Scientist at ASA Analysis & Communication, Inc. ("ASA"), an environmental consulting firm founded in December 1995. ASA provides technical and management services in support of the regulatory compliance needs of private and public sector clients throughout the United States. I provide technical direction for ASA's applied statistics and environmental monitoring services.

2. I have extensive experience in designing, conducting, and directing environmental research programs, management, and collection of data. My experience encompasses nearly 20 years in environmental consulting, including 7 years with ASA, and 13 years in the environmental department at Consolidated Edison Company ("ConEd"). As a consultant, my work has centered on Clean Water Act ("CWA") §316(b) and water quality issues.

3. I have extensive, first-hand experience assessing the Hudson River ecology. I first worked on the Hudson River fish community in 1976, when I became a member of the technical staff with Texas Instruments' (TI) Environmental Services Division. At that time, TI was conducting the riverwide field program for the Roseton, Bowline, and Indian Point power plants. At TI, I provided technical oversight of the striped bass mark-recapture program and was technical coordinator of the 1978 Year Class Report. In 1980, I moved to Ecological Analysts, where I managed and provided technical direction of entrainment programs at Indian Point 2 and 3 nuclear power generating units located in Buchanan, New York, and other stations on the Hudson. I accepted employment with Consolidated Edison in 1987, where I was a staff biologist with responsibility for the technical aspects of the Hudson River monitoring program,

and provided management oversight of contractors working on the program. While at ConEd, I coordinated the completion of the 1999 Draft Environmental Impact Statement ("DEIS") associated with the applications for renewal of State Pollutant Discharge Elimination System ("SPDES") permits for, among others, Indian Point 2 and Indian Point 3. In 2000, I joined ASA and continued to be involved in the Hudson River monitoring program as a consultant to the new owners of the Hudson River power stations. I have also provided technical services related to impact assessments for other power stations in New York, Pennsylvania, New Jersey, and other east coast states.

4. I hold a Ph.D. in biology from the City University of New York, a Master of Science in applied statistics and operations research from Union College, a Master of Science in ecology from the Pennsylvania State University, and a Bachelor of Arts degree in biology from Washington University. My curriculum vitae, including a list of my peer reviewed scientific publications, is attached hereto as **Attachment 1**.

BACKGROUND

5. I understand that this proceeding ("Proceeding") before the Nuclear Regulatory Commission ("NRC" or the "Commission") concerns the May 2007 application by Entergy Nuclear Operations, Inc. ("Entergy") to renew, for a period of 20 years, the operating licenses for Entergy Nuclear Indian Point 2, LLC ("IP2") and Entergy Nuclear Indian Point 3, LLC ("IP3"), nuclear power generating units located in Buchanan, New York. 72 Fed. Reg. 26,850 (May 11, 2007). I understand that Riverkeeper, Inc. ("Riverkeeper") and the New York Attorney General ("NYS") have filed petitions ("Petitions") to intervene in this license renewal proceeding, in which they specifically request a hearing before the NRC with respect to certain issues that they maintain are not adequately addressed in Entergy's license renewal application ("LRA").

6. I have reviewed the contentions related to the issues of entrainment and impingement – Riverkeeper Contention EC-1 and NYS Contention 31 (the "EI Contentions"). I have reviewed the declarations of Drs. Richard Seaby and Peter Henderson in support of Riverkeeper's Contention EC-1, and accompanying reports co-authored by Drs. Seaby and Henderson entitled *Status of Fish Populations and the Ecology of the Hudson River* ("Pisces Hudson Report") and *Analysis of Entrainment, Impingement, and Thermal Impacts at Indian Point Power Station* ("Pisces EI Report"). I have also reviewed the declaration of Roy A. Jacobson in support of NYS Contention 31.

7. This Declaration is submitted in support of Entergy's response to the EI Contentions.

AEI REPORT

8. Together with Drs. Lawrence W. Barnthouse of LWB Environmental Services, Inc.; Douglas F. Heimbuch of AKRF, Inc.; and Webster Van Winkle of Van Winkle Environmental Consulting, I have prepared a report, entitled *Entrainment and Impingement at IP2 and IP3: A Biological Impact Assessment* (Jan. 2008) ("AEI

Report"). The AEI Report is attached as **Attachment 2** to the Barnthouse Declaration and is incorporated herein by reference. To the best of my knowledge, the factual statements in the AEI Report are true and accurate, and the opinions expressed therein are based on my best professional judgment.

DATASETS USED IN AEI REPORT

9. The analyses conducted in the AEI Report are based on empirical data collected under the direction and oversight of the New York Department of Environmental Conservation ("NYSDEC") for a period of over 30 years spanning the period of commercial operations for IP2 and IP3. For a detailed description of the collection and processing of field samples, please see the Declaration of Mark T. Mattson, Ph.D., ¶¶9-26 (Jan. 2008) (the "Mattson Declaration").

10. The datasets underlying the AEI Report have been used in numerous publications in peer reviewed scientific journals or subjected to other types of review.

11. The Longitudinal River Ichthyoplankton Survey ("LRS"), the Longitudinal River Beach Seine Survey ("BSS"), the Longitudinal River Fall Shoals Survey ("FSS") and the Tomcod Survey ("TS"), each described in detail in the Mattson Declaration, are the primary datasets used in the AEI Report to assess the effects of impingement and entrainment at IP2 and IP3.

12. These four datasets were selected as the primary datasets for the analyses conducted in the AEI Report, because they have been conducted continuously since the mid-1970s. They cover nearly all of the period of commercial operation of IP2 (1973 startup) and all of the period of commercial operation of IP3 (1976 startup).

13. These four datasets provide the most comprehensive and consistent data, subjected to extensive quality control measures, for the estimation of long-term trends in the abundance of multiple life stages of important Hudson River fish populations.

14. A variety of other programs, conducted by the generators, NYSDEC, and federal resource management agencies provide additional information that can be used to evaluate the validity of data collected from these four primary programs. These secondary datasets include:

a) *Striped Bass Mark-Recapture Program.* This program was initiated in 1984, to estimate the contribution of the Hudson River striped bass hatchery (established as a condition of the Hudson River Settlement Agreement) to the Hudson River population. The program targets 1-year-old and 2-year-old striped bass, and is conducted from November through March. Data from this program are used to estimate the numbers of striped bass >150 mm in length overwintering in the lower estuary. Growth and survival rate estimates are also obtained from this program.

b) *NYSDEC Beach Seine Survey.* Since 1976, the NYSDEC Division of Marine Resources has conducted a beach seine survey in the lower

Hudson River estuary. The program focuses on the Tappan Zee and Haverstraw Bay. It samples juvenile fish using a method similar, but not identical to, the generators' beach seine survey

c) *Juvenile Alosid Survey.* NYSDEC conducts a beach seine survey in the middle and upper regions of the estuary (above River Mile 55) to estimate the relative abundance of YOY American shad and other juvenile fishes. This program was initiated in 1980 and continues to the present.

d) *Western Long Island Survey.* DEC conducts a survey for subadult striped bass in the bays around western Long Island Sound. Sampling is conducted using a 200-ft. beach seine. The program was initiated in 1984 and is continuing, although it has been modified over time.

e) *Spawning Stock Assessment.* DEC conducts a haul seine survey in the Hudson River to provide information on length, age and sex distribution, and mortality rates for adult American shad and striped bass. The program was initiated in 1982 and continues to the present.

f) *Commercial Fishery Monitoring.* NYSDEC monitors the commercial gill net fishery for American shad. The objective of the program is to determine the relative abundance and age structure of the commercial catch of American shad.

15. As shown in Appendix A to the AEI Report, indices of abundance of various life stages of Hudson River fish species derived from these secondary datasets are strongly correlated with indices derived from the four primary datasets. These strong correlations support the use of the primary datasets in the AEI Report.

16. Based on my education and training, expertise, experience, and professional judgment, the datasets described above and used to perform the analyses and draw the conclusions set forth the AEI Report are the best available for evaluating long-term trends in fish species abundance.

ADDITIONAL QUALITY CONTROL MEASURES

17. Due to the large number of samples collected in the Hudson River Monitoring Program, particularly in the LRS, and the strict QC program for laboratory analysis described in the Mattson Declaration, it typically takes at least six months after collection of the last sample before the laboratory analysis is complete. After the laboratory analysis has been completed, the data are converted to electronic format and delivered to ASA to undergo additional checks for completeness and validity of variable values. During this phase, suspect values may be checked against field data sheets and log books, and laboratory-derived data may be rechecked. Once the data have successfully passed this phase, they are summarized in the "Year Class Report," which provides a basic summary of abundance and distribution of selected species based upon

the data collected in that year. At this point, the data are considered suitably validated and ready for more detailed analysis, such as that performed in the AEI Report.

RESPONSE TO PISCES EI REPORT, PISCES HUDSON REPORT, AND JACOBSON DECLARATION

18. I have reviewed the Pisces EI Report, the Pisces Hudson Report, and Jacobson Declaration. Below, I reply in part to these documents. I disagree with many of the opinions offered in these documents. The fact that I do not specifically address a particular opinion or contention in this Declaration does not mean that I agree with such opinions or contentions.

Pisces EI Report

19. I would like to bring special attention to an inherent flaw in the Pisces EI Report. In Section 3.1 of the Pisces EI Report, Drs. Seaby and Henderson provide a table containing the numbers entrained at Indian Point as a measure of actual entrainment mortality. This is not correct.

20. Entrainment survival refers to the ability of small fish and invertebrates to pass through the cooling system unharmed. In the early 1970s, conventional wisdom held that few, if any, fish or invertebrates would survive entrainment. Studies done on the Hudson River, particularly at Indian Point, were instrumental in disproving this view, and were accepted by federal and state regulatory agencies.

21. Both the U.S. Environmental Protection Agency ("USEPA") (in its Phase II rule) and NYSDEC (in the Danskammer SPDES proceeding) have recognized the value of site-specific studies of entrainment survival, provided the studies are carefully designed and executed. In the Danskammer SPDES proceeding, NYSDEC accepted the studies conducted at the Danskammer Point station in the 1970s as being of sufficient rigor and scientific validity to use in setting a site-specific performance standard.

22. The studies of entrainment survival conducted at IP2 and IP3, particularly those conducted in 1980 and 1988, are both more recent and more advanced (in terms of sampling gear) than the Danskammer studies. The IP2 and IP3 entrainment survival data demonstrate that survival of entrained ichthyoplankton can be substantial for some species.

23. Therefore, discussions of potential entrainment impacts in the Pisces EI Report that fail to account for entrainment survival are not scientifically valid and overstate potential mortality due to entrainment.

Pisces Hudson Report

24. The Pisces Hudson Report addresses the larger and general Hudson River ecosystem without regard to IP2 and IP3 (or even any mention of it). Therefore, the Pisces Hudson Report does not permit any inferences to be made regarding the possible effects of Indian Point's operations on the ecosystem.

25. Together with Drs. Van Winkle, Barnthouse and Heimbuch, I examined several fish community metrics to assess changes in the juvenile (Age 0) fish community sampled by the Hudson River Monitoring Program. To determine whether a metric had changed, we divided the dataset into two equal time periods constituting the first half of the dataset ("Period 1") and the second half of the dataset ("Period 2"). Standard community level metrics were calculated using data from Period 1 and compared to the same metrics calculated using data from Period 2. Because sampling gear used in the shorezone, benthic, and water column habitats differ, metrics were calculated for each habitat.

26. The metrics calculated were: (1) species richness – calculated by summing the total number of species found in samples in a given year; (2) the percent of total abundance comprised of dominant species – a dominant species being defined as a species contributing 10% or more to the total abundance of Age 0 Fish; (3) species turnover – the number of species whose abundance changed sufficiently that they could be considered to have entered or left the fish community; (4) total abundance – the mean catch per sample of all Age 0 Fish in a given year; and (5) species density – mean number of species per sample collected in the HRMP in a given year. These metrics were calculated using the BSS and FSS datasets utilized in the AEI Report and described above.

27. Species richness did not change significantly from the first half of the dataset to the second. In the first half of the dataset, the average number of species collected in the shorezone, benthic, and water column habitats were 44, 31 and 18 respectively in Period 1, and 44, 30, and19 respectively in Period 2.

	Species Richness	
Habitat	Period 1	Period 2
Shorezone	44	44
Benthic	31	30
Water Column	18	19

28. The community was dominated by a few abundant species in all three habitats in both periods, with little change in the percent of total abundance made up by the dominant species.

	Percent of Individuals from Dominant Species	
Habitat	Period 1	Period 2
Shorezone	67	67
Benthic	76	74
Water Column	95	94

29. Eleven different species were abundant enough to be considered dominant in at least one habitat in one year. Of the 171 instances in which a species comprised more than 10% of the total abundance in a habitat in a year, 150 (or 87.7%) of those were due to the presence of the 8 species analyzed in the AEI Report (the "8 RIS").

30. Very few species increased to the point of entering the fish community (initially missing or rare and becoming relatively common) and, similarly, very few species decreased to the point of leaving the fish community (changing from relatively common to missing or rare). Atlantic croaker and channel catfish were not collected during the earlier years but have since increased in abundance. Conversely, goldfish, rainbow smelt and rough silverside have decreased in abundance over time and are now rarely collected (or not collected at all) in the HRMP. Considering the total number of species of Age 0 fish in the river exceeds 75, this level of species turnover is not ecologically significant.

31. The total abundance of Age 0 Fish declined by approximately 20% between the first half of the dataset and the second half of the data set (all three habitats combined). *See* Figure 1. When the 8 RIS are removed from the analysis, the total abundance of all remaining species did not change significantly. *See* Figure 2. Abundance of non-RIS in the shorezone approximately doubled between Period 1 and Period 2. Thus, the change in abundance in the 8 RIS account for the change in overall abundance of Age 0 Fish.

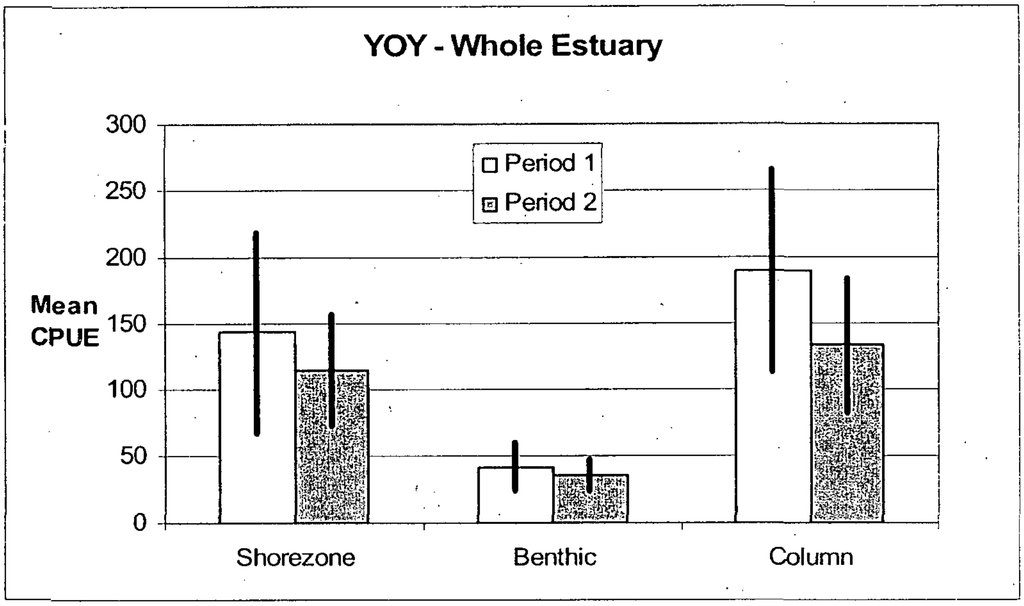


Figure 1.

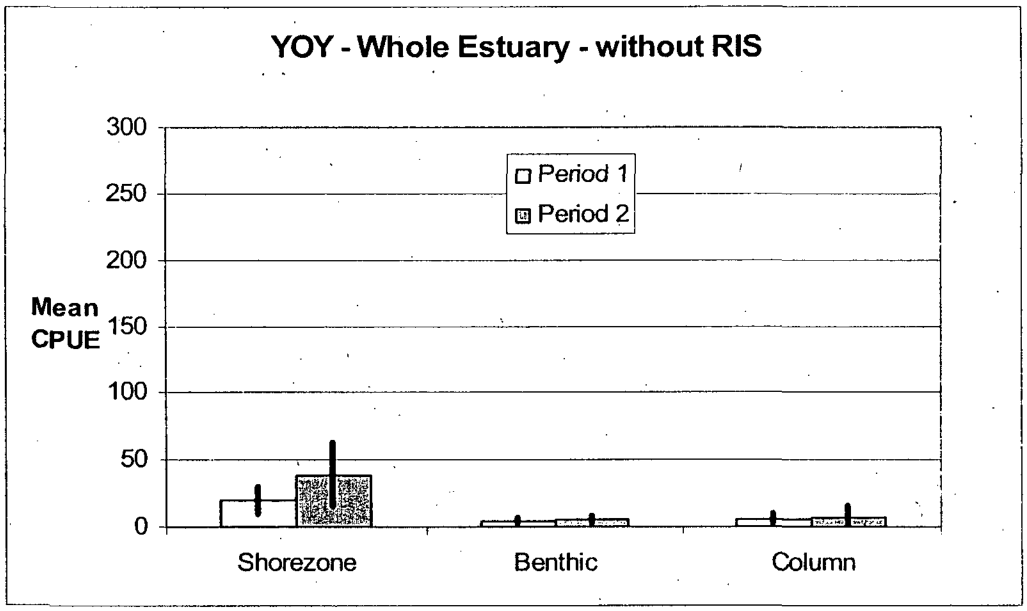


Figure 2.

32. Species density, the total number of species caught per sample, declined by approximately 10% between Period 1 and Period 2 when all species are included in the analysis. *See* Figure 3. When the 8 RIS are removed from the analysis, there was no significant change in species density among the remaining species. *See* Figure 4. Thus, as with total abundance of Age 0 Fish, the 8 RIS account for the change in overall species density.

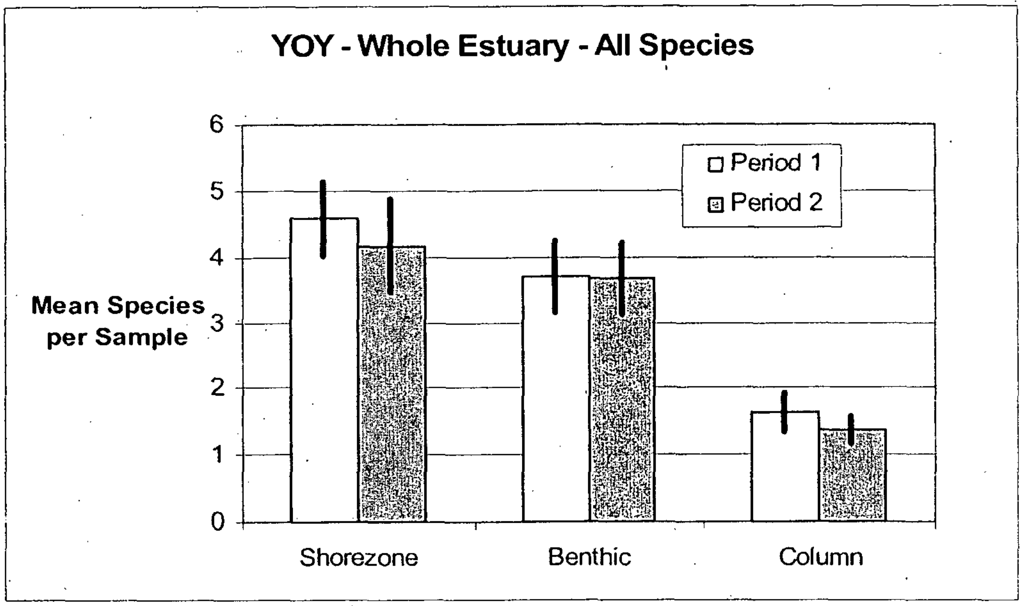


Figure 3.

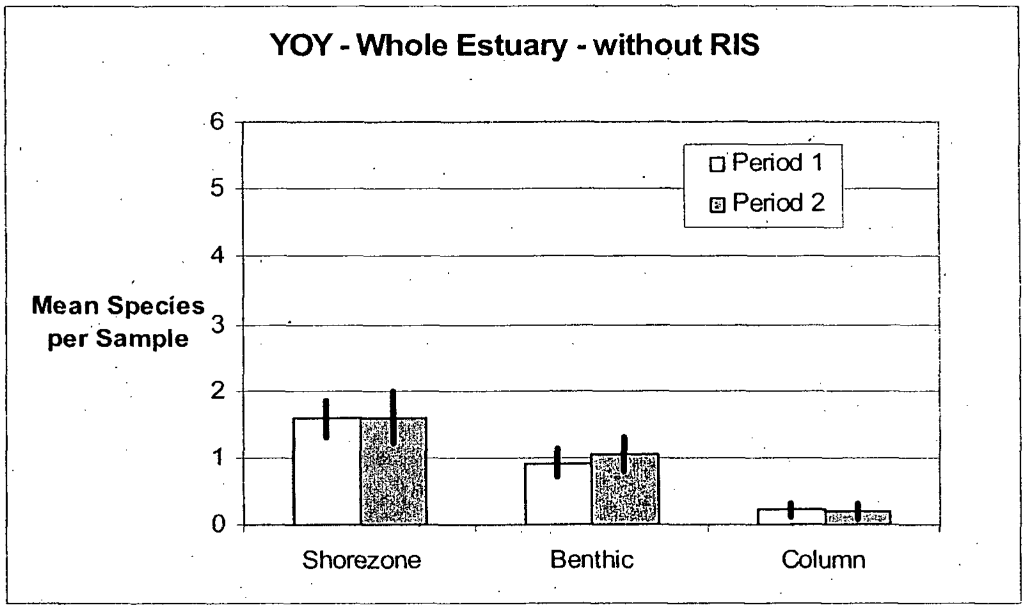


Figure 4.

33. The AEI Report evaluated the changes in the 8 RIS in detail and concluded, in each case, that the change in abundance of each RIS species was unrelated to impingement and entrainment at Indian Point. Furthermore, results for the species density and total abundance metrics, with RIS excluded, indicate no significant changes. Because impingement and entrainment at Indian Point is not related to the changes in abundance of the 8 RIS, it is also not related to the changes in the two community metrics

showing declines, namely total abundance and species density. Thus, the results of these analyses in conjunction with the conclusions of the AEI Report are inconsistent with an impact hypothesis that impingement and entrainment at Indian Point is having an adverse effect on the Age 0 fish community in the Hudson River estuary.

Jacobson Declaration

34. Mr. Jacobson, like Pisces, does not argue that changes in the fish community, cited to Waldman (2006), are caused by impingement and entrainment at Indian Point. Waldman, however, does offer an opinion on the primary threats to biodiversity in the Hudson: commercial and recreational fishing ("greatest stress on New York's marine fishes"), habitat alteration and degradation, contamination of chemical pollutants, introduction of exotic species such as zebra mussels, and climate change.

CONCLUSION

35. In my professional opinion, nothing in the Pisces Reports or Jacobson Declaration undermines the ER, or alters the conclusion set forth in the AEI Report that entrainment and impingement associated with Indian Point's respective cooling-water intake structures does not adversely impact Hudson River fish populations. Therefore, as a matter of science, the Pisces Reports and Jacobson Declaration do not alter the conclusion that the operation of those CWIS has not caused harm to the Hudson River ecology, and also therefore that closed-cycle cooling would not improve the Hudson River ecology.

Signed this 18 day of January, 2008.

John R. Young, Ph.D.
ASA Analysis & Communication, Inc.

ATTACHMENT 1

John R. Young
Senior Scientist/Associate

Dr. Young has more than 30 years of experience in aquatic impact assessments and ecological studies in marine, estuarine, and freshwater aquatic habitats. He has worked both as a consultant and within the utility industry. He recently coordinated a Draft Environmental Impact Statement for renewal of discharge permits at four power plants located on a tidal estuary in the Northeast. He has also served as issue manager for human health effects of electromagnetic fields and dredge project permitting.

Education

Ph.D.; City University of New York; Biology (Ecology, Evolution & Behavior Subprogram); 1999
M.S.; Union College; Applied Statistics & Operations Research; 1988
M.S.; Pennsylvania State University; Ecology; 1979
A.B.; Washington University; Biology; 1973

Professional Affiliations

American Fisheries Society • Hudson River Environmental Society
Associate editor for the North American Journal of Fisheries Management

Experience

Ecological Risk and Impact Assessment— Participated in long-term study of effects of power generation on fish populations of the Hudson River estuary in various capacities while employed as consultant and as a utility scientist. Directed mark-recapture studies to estimate population sizes and movement patterns for anadromous and estuarine species. Supervised technical staff in completion of interpretive reports on multi-year multi-plant impacts. Project manager for studies of entrainment abundance and through-plant survival using state-of-the-art equipment and study designs. As a utility scientist, provided technical direction for all aspects of the long-term (30+ years) monitoring program. Coordinated multi-plant, multi-company environmental impact statement for renewal of discharge permits. Participated in discharge permit renewals for power plants located on Delaware Bay, Hackensack River. Performed data analysis and provided expert testimony on 316(b) compliance of power plant discharge permit conditions.

Aquatic Ecology—Technical and management oversight of estuary-wide study of the dynamics of larval and early juvenile fish populations to determine the effects of natural and human-induced stresses on factors such as mortality and growth rates, and subsequent year-class success. Directed ecological study of aquatic ecology of Long Island Sound in the vicinity of a nuclear power station, and in the tidal portions of the Hackensack River, New Jersey. Used data from ecological studies to assess fish life history characteristics.

Aquatic Toxicology—As part of doctoral research, developed new statistical techniques for analysis of fluctuating asymmetry, a method of detecting population stress from contaminants. Used the new techniques to reassess past studies of fluctuating asymmetry in fish populations with respect to sample sizes, metrics, and data quality. Examined multi-year trends in fluctuating asymmetry in east coast striped bass populations. Participated in analysis of effects of PCB contamination on Hudson River striped bass population using long-term monitoring program data.

Modeling and Biometrics- Participated in the development and implementation of stochastic single- and multi-age structural models for the quantitative assessment of the effects of power plant entrainment and impingement on fish populations. Evaluated density-dependent and stock recruitment functions for the assessment of long-term power plant impact. Examined alternative management options for Atlantic sturgeon and sandbar sharks using age-structured models. Participated in development of individual-based models for striped bass and bay anchovy with Oak Ridge National Laboratory scientists. Used operations research techniques to develop a model for optimizing entrainment mitigation measures at 6 generating units. Developed stochastic simulation model to evaluate mark-recapture estimators for migratory fish populations. Taught SAS programming for data analysis in graduate level biometrics course.

Water Quality Assessments—Analyzed long-term trends in water temperature and freshwater inflow in the Hudson River in relation to fish life history characteristics. Coordinated modeling of thermal plume compliance with water quality regulations. Assessed regulatory compliance of nuclear reactor upgrades with discharge temperature limits. Performed literature review and provided testimony for hearings on state thermal criteria for streams. Designed program to establish alternative numerical criteria for rate of temperature change.

Regulatory Requirements—Experienced in various regulatory environmental exhibits such as 316(a) and (b) demonstrations, FERC exhibits, natural resource damage assessments, wetlands permits, dredging permits, and pesticide use. Participated in utility industry efforts to assist EPA with development of 316(b) regulations. Provided advice and taught in-house course on compliance with pesticide, fish & wildlife, regulations, marine construction permitting, and dredging. Assisted utility clients in response to proposed numerical limits on rate of temperature change. Conducted literature review of thermal shock and evaluated possible study design elements to develop alternative numerical criteria for rate of temperature change.

Data Management and Analysis—Directed in-house staff and consultants involved in data management and analysis activities. Proficient in use of wide variety of computer data management, analysis and graphics software including SAS, Lotus 1-2-3, APL, Freelance, Excel, Word, WordPerfect.

Selected Publications and Presentations

Young, J. 2007. Establishing alternative criteria for thermal shock. Poster presentation at The Second Thermal Ecology and Regulation Workshop. Sponsored by EPRI and Tri-State Generation. Denver, CO.

Young, J. R. 2007. Removing bias for fluctuating asymmetry in meristic characters. Journal of Agricultural, Biological and Environmental Statistics 12(4):485-497.

Heimbuch, D. G., E. Lorda, D. Vaughan, L. W. Barnthouse, J. Uphoff, W. Van Winkle, A. Kahnle, B. Young, J. Young, and L. Kline. 2007. Assessing coastwide effects of power plant entrainment and impingement on fish populations: Atlantic menhaden example. North American Journal of Fisheries Management 27(2):569-577.

Young, J. 2006. Estimating Baseline for a "Non-baseline" Intake. Presented at EPRI/UWAG Symposium on Technologies and Techniques for §316(b) Compliance. Atlanta, GA.

Young, J. 2006. Resurrecting Entrainment Survival. Presented at EPRI/UWAG Symposium on Technologies and Techniques for §316(b) Compliance Symposium. Atlanta, GA.

Dey, W., J. Young, and I. Strand. 2006. Evaluating Uncertainty in Benefits Valuation under the Phase II

Rule. Presented at EPRI/UWAG Symposium on Technologies and Techniques for §316(b) Compliance. Atlanta, GA.

Schultz, E. T., K. M. M. Lwiza, J. R. Young, K. J. Hartman, and R. C. Tipton. 2006. The dynamics of bay anchovy in the Hudson River Estuary: Process-oriented studies and long-term changes. American Fisheries Society Symposium 51: 197-213.

Schultz, E. T., J. Young, J. M. Martin, and K. M. M. Lwiza. 2005. Tracking cohorts: Analysis of migration in the early life stages of an estuarine fish. Estuaries 28(3):394-405.

Young, J., W. Dey, S. Jinks, N. Decker, M. Daley, and J. Carnright. 2005. Evaluation of variable pumping rates as a means to reduce entrainment mortalities. Pages 101-110 in USEPA. 2005. Proceedings Report: Symposium on Cooling Water Intake Technologies to Protect Aquatic Organisms. EPA 625-C-05-002

Barnthouse, L. W., D. Glaser, and J. Young. 2003. Effects of historic PCB exposures on reproductive success of the Hudson River striped bass population. Environmental Science & Technology 37:233-238.

Young, J. R. and W. P. Dey. 2002. Uncertainty and Conservatism in Assessing Environmental Impact under §316(b): Lessons from the Hudson River Case. The Scientific World Journal, 2(S1):30-40.

Cowan, J. H. Jr., K. A. Rose, E. D. Houde, S. Wang, and J. Young. 1999. Modeling effects of increased larval mortality on bay anchovy population dynamics in the mesohaline Chesapeake Bay: Evidence for compensatory reserve. Marine Ecology Progress Series 185:133-146.

Waldman, J. R., J. R. Young, B. P. Lindsay, R. E. Schmidt, and H. Andreyko. 1999. A comparison of alternative approaches to discriminate larvae of striped bass and white perch. North American Journal of Fisheries Management 19:470-481.

Young, J. R., R. G. Keppel, and R. J. Klauda. 1992. Quality assurance and quality control aspects of the Hudson River ecological study. In Smith, C. L. (ed.) Estuarine Research in the 1980's: Proceedings of the Seventh Symposium of the Hudson River Environmental Society.

Wells, A. W. and J. R. Young. 1992. Long-term variability and predictability of Hudson River physical and chemical characteristics. In Smith, C. L. (ed.) Estuarine Research in the 1980's: Proceedings of the Seventh Symposium of the Hudson River Environmental Society.

Heimbuch, D. G., D. J. Dunning, and J. R. Young. 1992 Post yolk-sac larvae abundance as an index of year class strength of striped bass in the Hudson River. In Smith, C. L. (ed.) Estuarine Research in the 1980's: Proceedings of the Seventh Symposium of the Hudson River Environmental Society.

Wells, A. W., D. M. Randall, D. J. Dunning, and J. R. Young. 1991. Dispersal of young-of-the-year hatchery striped bass in the Hudson River. North American Journal of Fisheries Management 11:381-392.

Young, J. R. and W. L. Kirk. 1989. Optimal entrainment mitigation strategies for several Hudson River power plants using dynamic programming. Presented at Edison Electric Institute Biologist's Task Force Annual Meeting. Chicago, IL.

Young, J. R., R. J. Klauda, and W. P. Dey. 1988. Population estimates for juvenile striped bass and white perch in the Hudson River Estuary. American Fisheries Society Monograph 4: 89-101.

Muessig, P. H., J. R. Young, D. S. Vaughan, and B. A. Smith. 1988. Advances in field and analytical methods for estimating entrainment mortality factors. American Fisheries Society Monograph 4:124-132.

McLaren, J. B., J. R. Young, T. B. Hoff, I. R. Savidge, and W. L. Kirk. 1988. Feasibility of supplementary stocking of Age-0 striped bass in the Hudson River. American Fisheries Society Monograph 4: 286-291.

Young, J. R., T. B. Hoff, W. P. Dey, and J. G. Hoff. 1988. Management recommendations for a Hudson River Atlantic sturgeon fishery based on an age-structured population model. Pages 353-365. In Smith, C. L. (ed.) Fisheries Research in the Hudson River. State University of New York Press, Albany.

Lauer, G. L., J. R. Young, and J. S. Suffern. 1981. The best way to assess environmental impacts is through the use of generic and site-specific data. Pages 21-33 In Jensen, L. D. (ed.) Issues associated with impact assessment. EA Communications. Sparks, MD

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of ENTERGY NUCLEAR INDIAN POINT 2, LLC, ENTERGY NUCLEAR INDIAN POINT 3, LLC, and ENTERGY NUCLEAR OPERATIONS, INC. (Indian Point Nuclear Power Station)	Docket Nos. 50-247, 50-286

DECLARATION OF MARK T. MATTSON, PH.D.
IN OPPOSITION TO RIVERKEEPER CONTENTION EC-1 AND
NEW YORK ATTORNEY GENERAL CONTENTIONS 31-32

I, Mark T. Mattson, Ph.D., declare as follows:

QUALIFICATIONS

1. I am a Vice President and Principal Aquatic Ecologist with Normandeau Associates, Inc. ("Normandeau"), a professional consulting firm that specializes in ecological, environmental, and natural resources management services. My general expertise is in aquatic ecology, particularly fisheries, and the application of field sampling design and analytical methods to evaluate anthropogenic influences on population and community dynamics of aquatic ecosystems.

2. I have particular depth and expertise in assessing the potential aquatic impacts of power-plant operations under Clean Water Act, §316(a) and (b), and equivalent state law. I have supervised at least twelve (12) site-specific assessments of potential impacts from power plant thermal discharges or cooling water intakes on aquatic ecosystems, and have participated in at least thirty (30) such assessments performed by Normandeau, over the past 30 years, mostly in the northeastern United States.

3. I have extensive, first-hand experience assessing the Hudson River ecology. It began with my post-graduate professional career in October 1979, working on the Hudson River Biological Monitoring Program ("HRBMP"). I have continued to remain involved in one or more aspects of this monitoring program in each of the past thirty (30) years from 1979 to present. My three decades of fisheries work on the Hudson River and New York Harbor also includes numerous cooling water intake studies performed for Indian Point, Bowline, Lovett, Danskammer Point, Roseton, and Albany Steam Stations. My 30 years of fisheries work on the Hudson River also includes several studies performed for the New York State Department of Environmental Conservation

("NYSDEC"), including two annual creel surveys, a river herring stock assessment, and a survey of biological samples for tissue contaminants. I am the author or co-author of seventeen (17) peer-reviewed scientific publications on various aspects of Hudson River fish populations, and have been a peer-reviewer for numerous other publications.

4. I have served on the Board of Directors for the Hudson River Environmental Society annually since 2000, including four years as the Vice President (2002-2006). The Hudson River Environmental Society is a non-advocacy environmental group with a mission of disseminating timely technical information for use in decision making about environmental policy in the Hudson River watershed to both the public and research community through conferences, seminars, a newsletter, and peer-reviewed publications.

5. I hold Master of Science and Ph.D. degrees in Zoology from the University of New Hampshire, and a Bachelor of Arts degree in Biology from the University of Connecticut. I am an active member of the American Society of Limnology and Oceanography, the International Limnology Society, and the American Fisheries Society. My current curriculum vitae, including a list of my peer reviewed scientific publications and professional society presentations, is attached hereto as Attachment 1.

THIS PROCEEDING

6. I understand that this proceeding before the Nuclear Regulatory Commission ("NRC" or the "Commission") concerns the May 2007 application by Entergy Nuclear Operations, Inc. ("Entergy") to renew, for a period of 20 years, the operating licenses for Entergy Nuclear Indian Point 2, LLC ("IP2") and Entergy Nuclear Indian Point 3, LLC ("IP3"), nuclear power generating units located in Buchanan, New York. 72 Fed. Reg. 26,850 (May 11, 2007). I understand that Riverkeeper, Inc. ("Riverkeeper") and the New York Attorney General ("NYS") have filed petitions ("Petitions") to intervene in this license renewal proceeding, in which they specifically request a hearing before the NRC with respect to certain issues that they maintain are not adequately addressed in Entergy's license renewal application ("LRA").

7. I have reviewed Riverkeeper Contention EC-1 and NYS Contentions 31-32 (the "EI and ESA Contentions"). I have reviewed the declarations of Dr. Richard Seaby and Dr. Peter Henderson in support of Riverkeeper's Contention EC-1, and accompanying reports co-authored by Drs. Seaby and Henderson entitled *Status of Fish Populations and the Ecology of the Hudson River* ("Pisces Hudson Report") and *Analysis of Entrainment, Impingement, and Thermal Impacts at Indian Point Power Station* ("Pisces EI Report") (together, the "Pisces Reports"). I have also reviewed the declaration of Roy A. Jacobson in support of NYS Contentions 31-32. A list of the scientific documents that I refer to in this Declaration is attached hereto as Attachment 2.

8. This Declaration is submitted in support of Entergy's response to the EI and ESA Contentions.

HUDSON RIVER BIOLOGICAL MONITORING PROGRAM AND THE AEI REPORT

9. Since 1966, a continuing and extensive annual biological monitoring program has been performed to assess potential impacts of cooling water withdrawals from electric power generating stations (including IP2 and IP3) on the Hudson River ecology.

10. These programs have been developed under the oversight, and with the input, of regulators, including the New York State Department of Environmental Conservation ("NYSDEC") and the environmental community, including Riverkeeper. To my knowledge, the HRBMP is the most extensive continuous fisheries monitoring program of its type performed in the United States. This statement is corroborated by Dr. John Waldman, formerly with the Hudson River Foundation for Science and Environmental Research, Inc. (the "Hudson River Foundation"), an independent foundation dedicated to research on the Hudson River ecosystem, and now on the faculty of Queens College, who stated in the introduction to his peer reviewed publication titled "The Hudson River Environment and its Dynamic Fish Community" that "[i]ndeed, the Hudson is one of the most scientifically studied rivers in the world" (Waldman et al. 2006). Presently and historically (since 1974), the core fisheries monitoring program has entailed the following six field and laboratory surveys:

- Ichthyoplankton Survey, often referred to as the Longitudinal River Ichthyoplankton Survey,
- Fall Juvenile Fish Survey, often referred to as the Longitudinal River Fall Shoals Survey,
- Beach Seine Survey for juvenile fish, often referred to as the Longitudinal River Beach Seine Survey,
- Water Quality Survey, often referred to as the Longitudinal River Water Quality Survey,
- Striped Bass Winter Population Survey, often referred to as the Striped Bass Survey, and
- Atlantic Tomcod Spawning Stock Survey, often referred to as the Tomcod Survey.

11. The primary objective of the Longitudinal River Ichthyoplankton Survey is to determine the seasonal occurrence, abundance, and distribution of eggs and larvae of fish found along the 152 mile portion of the Hudson River estuary between Battery Park and the Troy Dam above Albany. This survey is the ichthyoplankton complement of the Longitudinal River Fall Shoals Survey. The present Ichthyoplankton Survey is a massive biological monitoring program that, based on my experience, is unprecedented in the combined within-year temporal, spatial and geographic extent for the number of

consecutive years of sampling. Annually, the Ichthyoplankton Survey collects about 3,650 samples per year; 87,317 samples were collected and 54,516 of these were analyzed in the laboratory during the 1979-2006 period. The ichthyoplankton survey began during 1973 and has continued annually to present, with sampling performed during typically 10 to 20 consecutive weeks beginning in March and continuing through July of each year. The first three surveys are performed during the day, and the remaining surveys are at night, with about 200 samples per week collected at randomly selected tow paths allocated among 13 geographic regions, and three depth strata. The pelagic stratum is sampled with a 1 m^2 x 8 m long Tucker trawl equipped with a 500 micron mesh net. The shoal (river bottom found in 10-20 ft of depth) and bottom (river bottom found at depths >20 ft) are both sampled with a 1 m^2 epibenthic sled equipped with a 1 m^2 x 8 m long net of 500 micron nitex mesh. Sample volumes are determined using flume-calibrated flowmeters, and standard deployment practices for each 5-minute tow insure a sample volume of about 300 m^3 +10%. All field samples are preserved with 10% buffered formalin, and approximately 75% of the samples collected are analyzed in the laboratory. Standardized subsampling and quality control re-inspection of 10% or more of the samples insure consistent laboratory sorting, identification and enumeration. All ichthyoplankton eggs and larvae in the selected samples are identified to the lowest possible taxon (generally species), enumerated, and representative subsamples of several key species of larvae (striped bass, white perch, American shad, Atlantic tomcod, and bay anchovy) are randomly selected and measured for total length. The accuracy of the laboratory methods used to discriminate between two similar and abundant species of Hudson River fish larvae that are often difficult to distinguish (striped bass and white perch) has been validated in a peer reviewed publication (Waldman et al. 1999).

12. The primary objective of the Longitudinal River Fall Shoals Survey is to determine the seasonal occurrence, abundance, and distribution of young of the year fish in the 152 mile portion of the Hudson River estuary between Battery Park at the southern tip of Manhattan and the Troy Dam above Albany. The survey began during 1973 and has continued annually to present, with sampling performed during 8 to 12 alternate weeks spread between early July and late October of each year. Sampling is at night, with about 200 samples per week collected at randomly selected tow paths allocated among 13 geographic regions, and three depth strata. The present Fall Juvenile Fish Survey is a massive biological monitoring program that, based on my experience, is unprecedented in the combined within-year temporal, spatial and geographic extent for the number of consecutive years of sampling. Annually, the Fall Juvenile Fish Survey collects about 2,050 samples per year; 52,543 samples were collected and analyzed during the 1979-2006 period. The pelagic (channel) stratum is sampled with a 1 m^2 Tucker trawl equipped with a 3 mm mesh net. The shoal (river bottom found in 10-20 ft of depth) and bottom (river bottom found at depths >20 ft) were sampled with a 1 m2 epibenthic sled (3 mm mesh net) prior to 1985 and with a 1 m x 3 m beam trawl (1.3 mm stretch mesh cod end) beginning in 1985 and continuing to present. Sample volumes are determined using flume-calibrated flowmeters, and standard deployment practices for each 5-minute tow insure a variation in sample volume of less than 10%. All fish caught are identified to species and enumerated without subsampling into length classes representative of young of the year, yearling and older age categories. Representative subsamples of key species of fish are randomly selected and measured for total length.

13. The primary objective of the Longitudinal River Beach Seine Survey is to determine the seasonal occurrence, abundance, and distribution of young of the year fishes in the shore zone (<10 ft. deep) along the 142 mile portion of the Hudson River estuary between Yonkers (GW Bridge) and the Troy Dam above Albany. The survey began during 1974 and has continued annually to present, with sampling performed during typically 10 alternate weeks spread between early July and late October of each year. All sampling is during the day, with 100 randomly selected beaches sampled per week among 12 geographic regions. The present Beach Seine Survey is a massive biological monitoring program that, based on my experience, is unprecedented in the combined within-year temporal, spatial and geographic extent for the number of consecutive years of sampling. Annually, the Beach Seine Survey collects about 2,000 samples per year; 31,497 samples were collected and analyzed during the 1979-2006 period. A 100 ft x 8 ft. bag seine is fished with 1.9 cm stretch mesh in the wings and 0.9 cm stretch mesh netting in the bag. Standard deployment practices for each seine haul insure a sampling area swept of about 450 m^2 +10%. All fish caught are identified to species and enumerated without subsampling into length classes representative of young of the year, yearling, and older age categories. Water temperature, dissolved oxygen, and conductivity are measured and recorded one foot below the surface of each beach location. All fish caught are identified to species and enumerated without subsampling into length classes representative of young of the year, yearling and older age categories. Representative subsamples of key species of fish are randomly selected and measured for total length.

14. The primary objective of the Longitudinal River Water Quality Survey is to determine from grab-type samples the longitudinal and vertical distribution of water temperature, dissolved oxygen and conductivity measured along the 152 mile portion of the Hudson River estuary between Battery Park and the Troy Dam above Albany. This survey is run concurrently with the Ichthyoplankton and Fall Juvenile Surveys described above. The Water Quality Survey began during 1973 and has continued annually to present. Prior to 1982, water quality measurements were taken at depth associated with each sample, resulting in measurements taken at about 100 to 200 station and depth combinations during each week of sampling. Beginning in 1982, and continuing to present, water quality measurements were disassociated with each sample, and spread among 60 fixed stations at approximately 3 mile intervals along the 152 miles of river, resulting in measurements taken at 182 station and depth combinations during each week of sampling. Water quality measurements were taken from a total of 110,255 depth, station and date combinations for the Longitudinal River Water Quality Survey, and an additional 31,497 water quality samples were collected from the Long River Beach Seine Survey during the 1979-2006 period. At each water quality station, near-surface, mid-depth and near-bottom measurements are taken and recorded, except in shallow (shoal) areas where just near-surface and near bottom measurements are taken. At each location and depth, water temperature is measured and recorded to the nearest 0.1 degrees Celsius (°C), dissolved oxygen is measured and recorded to the nearest 0.1 milligrams per liter (mg/l), and conductivity is measured and recorded in microsiemens per centimeter (μS/cm) to the nearest scaling factor. Water quality instrumentation is subjected to daily calibration and quality control calibration against known standards.

15. The primary objective of the Striped Bass Winter Population Survey is to sample the immature striped bass (typically between 150 mm and 500 mm in total length) by trawling in the lower Hudson River and New York Harbor habitat to obtain mark-recapture estimates of the total number of Age 1 and Age 2 fish in this over-wintering population. The Striped Bass Survey is presently performed from November through April of each year for at least 24 consecutive weeks of field sampling. This survey began in 1984 and has continued annually to present, excluding winters of 1984-85 and 1986-87. Fishing gear, deployment, tagging, and sampling weeks have been standard from the winter survey of 1987-88 to present. The Striped Bass Survey has caught, tagged and released more than 300,000 fish to date (about 10,000 per year), tag recoveries within the survey are typically 50 to 655 fish per year, and all of these recaptured fish are released again after recording the tag data. Tags are also recovered from anglers by a cooperative program run through the Hudson River Foundation at a rate of about 300 to1400 per year and used to make a second mark/recapture population estimate.

16. The primary objectives of the Atlantic Tomcod Spawning Stock Survey is to sample the mid-winter spawning population of Atlantic tomcod in the Hudson River to describe biological characteristics (age, growth, gender, fecundity) and obtain mark-recapture estimates of the total adult population size. Tomcod are caught, marked, and released from box traps fished in the Hudson River at nearshore sites between the George Washington Bridge in upper Manhattan and Mid-Hudson Bridge in Poughkeepsie from December through February (13 weeks) of each year. Marked fish are recaptured in the Striped Bass survey trawling effort described above. The Tomcod Survey has been performed annually from the winter of 1982-83 to present, excluding 1984-85 and 1986-87, using standard gear, deployment and sampling weeks throughout this period. Tomcod were marked by finclips prior to the winter of 1987-88, and were marked with Visual Implant (VI) Tags from 1987-88 to present. More than 400,000 tomcod have been marked, released or recaptured to date.

17. Normandeau has been managing one or more aspects of the HRBMP since 1974 (from 1974-1979, as Texas Instruments, Inc.), except for 1980 and 1981, and continues to do so. I have personally supervised or conducted studies pursuant to the HRBMP annually since October 1979 (except for 1980-1981).

18. In addition to the HRBMP described above, I have supervised and participated in CWA §316(b) cooling water intake structure ("CWIS")-related studies that Normandeau has performed at IP2 and IP3 since October 1979. These CWIS studies include a statistical evaluation of the reliability of impingement sampling designs at IP2 and IP3 based on historical (1976-1979) impingement data, routine impingement monitoring at IP2 and IP3 (1984-1986, and 1989-1991), IP2 and IP3 Ristroph screen and return sluice impingement survival studies (1985-1993), IP3 fish guidance studies using underwater acoustic devices (1986-1990), relative probability of entrainment study at IP2 and IP3 (1989), and IP2 and IP3 entrainment studies (1981-1982; 1986-1987).

19. Normandeau annually prepares and implements a Quality Assurance (QA) Program for each of the six field and laboratory surveys performed for the HRBMP that is based on application of a 10% average outgoing quality limit (AOQL) for all biological

measurement parameters and a 1% AOQL for all data files used in calculations, data tables and figures in the final reports. This QA program is designed to meet or exceed the guidance criteria of the U.S. Environmental Protection Agency and be consistent with the intent of federal regulations (10 CFR 50).

20. I am unaware in my professional experience of any biological monitoring program of this magnitude that applies industrial quality control and quality assurance procedures to the acquisition of fisheries data and has done so consistently and annually since 1974. This QA Program has been the subject of three peer-reviewed publications (Geoghegan et al. 1990; Young et al. 1992; and Geoghegan 1996), and, in my professional opinion, represents the desired environmental consulting industry standard.

21. Normandeau's QA program for the HRBMP comprised two systems: a Quality Control (QC) system and a Quality Assurance (QA) system. The function of the QC system is to continually monitor the reliability and validity (accuracy, precision, and completeness) of data produced on a daily basis. The function of the QA system is to independently verify that the QC system is implemented and is functioning as specified in the program QA Manual. The foundation of the QA and QC system for the HRBMP is the QA Manual, referred to as the Standard Operating Procedures or "SOP." A SOP is prepared annually before the onset of each of the six field and laboratory surveys comprising the HRBMP. Each SOP describes the methods used in the survey for sampling, laboratory analysis, QC, and QA, and is provided to the NYSDEC for their review and acceptance prior to the onset of annual field sampling activities. The principal strengths of this QA Program are the functional independence of the systems and the common collection and interpretation point for quality related information, the Quality Assurance Director. The QC system is managed by the Program Manager and is conducted by program personnel. The QA system is managed by Normandeau's corporate Quality Assurance Director and used project-independent technical personnel during performance and system audits.

22. For the HRBMP performed by Normandeau and its predecessor (Texas Instruments) that generated the data presented in the AEI Report a QC plan was implemented that subjected all sample processing tasks involving the sorting, fish identification, and enumeration to a standard and appropriate quality assurance/quality control review based on a Military Inspection Standard (MIL-STD) inspection plan derived from MIL-STD 1235 Single and Multiple Level Continuous Sampling Procedures (10 December 1981) and Tables for Inspection by Attributes to achieve a 10% AOQL. A 1% AOQL QC lot sampling plan was applied to all data files used in calculations, data tables and figures in the final AEI Report. QC inspection of laboratory samples was accomplished by random re-inspection of at least 10% of the samples independently by a qualified QC biologist to confirm the data generated from sample processing meets the accuracy standards specified in the QA Manual. An AOQL of 10% for sample processing means that 10% or fewer of the samples would be outside of the established measurement error for variables specified in the SOP for each of the six surveys. Similarly, a 1% AOQL means that the data files produced from Normandeau's sampling and sample processing activities and used in calculations, data tables and figures in the AEI Report was certified by statistical inspection to document that less than

one record (line of data) out of every 100 records was outside of the established error specified in the SOP. For both sample processing and data processing tasks, any errors that were discovered during QC inspection were corrected, thus providing a data set with a quality level better than the specified AOQL.

23. A QA Program was also implemented for each of the impingement and entrainment monitoring programs performed by Normandeau at IP2 and IP3 that was consistent with the QA Program for the HRBMP as described above.

24. In short, based upon my work described above:

- I am well-versed in the Hudson River ecology in the vicinity of IP2 and IP3 through my participation in the HRBMP, through other studies performed by Normandeau in the Hudson River, and through my review of the work of other Hudson River researchers.

- I am directly aware of the principles and methods used to obtain biological data for the HRBMP and for the impingement and entrainment studies performed by Normandeau relating to the IP2 and IP3 CWIS.

- I have first-hand knowledge of the quality of the HRBMP and for the impingement and entrainment studies performed by Normandeau relating to the IP2 and IP3 CWIS.

25. I have reviewed the report, entitled *Entrainment and Impingement at IP2 and IP3: A Biological Impact Assessment* (Jan. 2008) ("AEI Report"), attached as Attachment 2 to the Declaration of Lawrence W. Barnthouse, Ph.D.

26. In my professional opinion, the HRBMP dataset on which the AEI Report relies is unique in its breadth, and is robust and validated under a strict QA program.

RESPONSE TO PISCES REPORTS AND JACOBSON DECLARATION

27. I have reviewed the Pisces Reports and the Jacobson Declaration. Below, I reply in part to the Pisces Reports and the Jacobson Declaration. I disagree with many of the opinions offered in these documents. The fact that I do not specifically address a particular opinion or contention in this Declaration does not mean that I agree with such opinions or contentions.

Ristroph Screens and Impingement Holding Mortality

28. The Pisces EI Report asserts that impingement mortality at IP2 and IP3 is in the order of "hundreds of thousands of fish" annually. Pisces EI Report, at 1. The Pisces EI Report acknowledges, however, that "[t]he installation of Ristroph screens and fish return systems at Indian Point between 1990 and 1991 reduced this mortality for some species." *Id.* at 11. Similarly, the Jacobson Declaration asserts that "data demonstrate that impingement figures are significant," Jacobson Decl. ¶ 17, but acknowledges that Ristroph-modified screens play a role in survival, *see id.* ¶¶ 18, 22.

Nevertheless, both the Pisces EI Report and the Jacobson Declaration question whether survival rates from fish return systems using Ristroph screens could be overestimated as a result of the eight hour post-impingement observation period used to represent survival rates. *See* Pisces EI Report, at 12-19; Jacobson Decl. ¶¶ 18, 22.

29. Beginning in January 1985, to address impingement, the IP2 and IP3 CWIS were retrofitted with Ristroph modified traveling screens (referred to as Royce Version 1 or Version 2 traveling screens) manufactured by the Royce Equipment Company of Houston, Texas. Evaluations to optimize the performance of these Ristroph modified traveling screens occurred annually until the present screens and fish return systems were installed at IP3 in 1991 and IP2 in 1992. The customized Ristroph screen technology for Indian Point was developed and designed under the direction of Riverkeeper's then-consultant, Dr. Ian Fletcher, a well-regarded fisheries expert acting as the technical expert for Riverkeeper. At the time it was developed and installed, IP2 and IP3's Ristroph screen technology was considered state of the art, and it is my understanding that this technology is still considered state of the art intake screening technology today.

30. Following the initial installation of one Ristroph screen (Royce Version 1) at IP2, fish survival studies were conducted daily throughout 1985 (beginning on 16 January) by comparing the survival of fish impinged on the Ristroph screen with the survival of fish impinged on the conventional traveling screens simultaneously operating in screenwells 21-25. Ristroph screen evaluations continued annually through November 1994, testing the fish survival, the debris handling characteristics, and the interaction between fish survival and debris handling for various modifications to the Ristroph screen mesh panels, spray headers, spray header alignment, and fish transfer bucket system. Beginning in 1989 and continuing into 1991, a full scale mockup of the fish return sluice system for the IP2 and IP3 CWIS was built near the quarry adjacent to the Indian Point site. This full scale return sluice system was tested to determine the best configuration of pipes and sluice flow to minimize the mortality of impinged fish that would be transferred from the Ristroph screens into this return sluice when both were installed at IP2 and IP3. After the installation of the present Ristroph modified traveling screens at IP3 in 1991 and IP2 in 1992, testing of the installed full scale sluice system continued through 1993 to determine the best configuration to minimize the recirculation and re-impingement of surviving fish that were released back into the Hudson River near the IP2 and IP 3 CWIS.

31. In 1985, Normandeau first performed impingement survival studies for the IP2 and IP3 Ristroph screens. These survival studies determined survival at 0, 6, 12, 24, 36, 48, 60, 72, 84 and 96 hours after impingement. In 1986, additional impingement survival studies were conducted to compare Royce Version 1 and Version 2 screens using mortality observations at time 0 and after eight hours of holding time. The change from a 96-hour holding time to an 8-hour holding time was selected by Riverkeeper's then-technical expert, Dr. Fletcher. Publications by Fletcher (1986; 1990) selected eight hour estimates as the most reliable time period for quantifying survival rates of impinged fish at IP2 and IP3 without the potential confounding effects of control mortality. I understand that the 1985 impingement survival studies for IP2 and IP3 provided the basis

for Dr. Fletcher's selection of eight hours as the appropriate latent mortality holding time, because no mortality was observed in the first 12 hours for control fish that were simultaneously held in aquaria to observe subsequent (i.e., latent) mortality along with test fish collected from the Ristroph screen (Con Edison 1985, Figure 3-1). It should be noted that control fish are those subjected to collection, handling and holding conditions for the initial and all latent survival observations, but were not exposed to impingement from the Ristroph screens. For example, striped bass held as controls during 1985 experienced no handling mortality at the 0, 6 and 12 hour observation periods, however some (about 1%) mortality was observed at 24 hours, and holding mortality continued to increase to about 15% through 96-hours of holding reflecting the stress of conditions in the holding facility. Subsequent morbidity tests of additionally modified Ristroph screens conducted by Dr. Fletcher (Royce Version 2; Fletcher 1986; 1990) were therefore based on mortality observations at initial (time = 0) and after 8-hours (latent) of holding in aquaria with full knowledge of the results of the Royce Version 1 tests.

32. Therefore, to the best of my knowledge and based on personal conversations with Dr. Fletcher at the time, suggestions in the Pisces EI Report and the Jacobson Declaration that survival rates from fish return systems using Ristroph screens could be overestimated as a result of the eight hour post-impingement observation period used to represent survival rates were specifically considered and rejected by Dr. Fletcher in his scientific evaluation of the Ristroph screens and fish return system at IP2 and IP3.

Threatened and Endangered Species

33. In his declaration, Mr. Jacobson argues that IP2 and IP3 "harm" a federally and New York State listed endangered species (shortnose sturgeon) and a candidate threatened species (Atlantic sturgeon) by impinging them on the water intake screens or entraining them through the cooling water systems." Jacobson Decl. ¶ 26; *see also id.* ¶¶ 27-32. This assertion is unfounded based on the biology and status of the populations of these two species in the Hudson River.

Shortnose Sturgeon

34. As NYSDEC is aware, shortnose sturgeon are rarely found in the vicinity of IP2 and IP3, and are therefore not susceptible to impingement or entrainment at the CWIS.

- From late fall to early spring, adult shortnose sturgeon concentrate in a few overwintering areas (Dovel et al. 1992, Geoghegan et al. 1992, Bain 1997). Spawning adults concentrate in deep, channel habitats considerably upstream from IP2 and IP3 near Kingston (RM 94) and another group of juveniles and adults that will not be in reproductive condition the following spring concentrate in brackish water downstream between RM 33-38 in Haverstraw Bay (Bain 1997). In the spring, these non reproductive fish migrate upstream and disperse throughout the tidal portion of the river in deep, channel habitats. When water temperatures reach approximately 8°C, typically in early to mid-April, reproductively active adults begin a rapid migration from their overwintering areas near Kingston upstream in the channel to spawning grounds from Coxsackie (RM 125) to the Federal Dam in Troy (RM 151) and thus are not exposed to water withdrawal at IP2 and IP3 located at RM 42. Spawning typically occurs in the upstream spawning grounds until water temperatures reach 15°C (late April through May) after which adults disperse down throughout their broad summer range in deep channel habitats from approximately RM 27 to RM 112. The deep channel waters and the turbulent spawning reach just downriver of the Federal Dam in Troy are beyond the sphere of influence of IP2 or IP3.

- Shortnose sturgeon eggs adhere to solid objects on the river bottom and newly hatched embryos remain on the bottom near their upriver spawning grounds and are therefore not typically exposed to entrainment at IP2 or IP3. Larvae gradually disperse downstream and occur in deep water, channel areas with strong currents (Bain 1997) and are therefore not likely to be entrained along the shoreline at IP2 and IP3 because they generally avoid shoreline habitats where the CWIS is located. Figure 1 demonstrates that early life stages of shortnose sturgeon, those most susceptible to entrainment and impingement, are rarely observed in the vicinity of IP2 and IP3, and primarily occur upriver. In fact, only one larval shortnose sturgeon and one unidentified larval sturgeon (probably an Atlantic sturgeon) were observed in the Indian Point nearfield region among 11,051 Long River Ichthyoplankton Survey samples collected there from 1979 through 2006. Age 1 and older shortnose sturgeon are distributed throughout the river in the summer, however their relatively large size and strong swimming ability, and pronounced preference for deep, channel areas considerably reduces their exposure risk to impingement at IP 2 and IP3. Furthermore, the complex migration patterns described above demonstrate that shortnose sturgeon are transient seasonal residents in the vicinity of IP2 and IP3, passing through this portion of the Hudson River only during the late spring through early fall as juveniles and adults disperse from upstream habitat to the lower tidal portions of the River.

35. NYSDEC specifically discontinued the annual impingement monitoring program at IP2 and IP3 as soon as the Ristroph screens and fish return system were installed and operating (i.e., 1992). I recall a conversation with Mr. Edward Radle of NYSDEC on site at Indian Point at that time during which Mr. Radle explained that a reason for stopping annual impingement sampling was that a state of the art fish screening and return system was just installed, which has been demonstrated to provide good survival of impinged fish that are returned to the Hudson River alive. No additional fish would be saved by sampling them, and in fact, many would be killed due to the additional handling required to process them in the impingement samples (e.g., measure, weigh, identify, count). So Mr. Radle's preference was that the fish be returned to the Hudson River and given a chance to survive rather than requiring IP2 and IP3 to continue annual sampling.

36. Lastly, Mr. Jacobson's stated concern about shortnose sturgeon is not well-founded. The Hudson River shortnose sturgeon population has been increasing since the 1990s. Mark-recapture population estimates performed for the National Marine

Fisheries Service (NMFS) indicate a late 1990s shortnose sturgeon population of about 60,000 fish with adults comprising more than 90% of the population (Bain et al. 2007). Compared to population estimates in the late 1970s, the Hudson population has increased by more than 400% (Bain et al. 2007). Independent analysis of data from a mark-recapture program and from the HRBMP (Fall Juvenile Fish Survey) and analyzed by Dr. David Secor and Mr. Ryan Woodland (2005) also indicate more than a four fold increase in abundance over this time period (confirming the usefulness of the HRBMP as an index of shortnose sturgeon abundance in the Hudson River ecosystem). This information indicates that the Hudson River supports by far the largest population of shortnose sturgeon throughout its range, and that the current population is expanding (Bain et al. 2007).

37. Although the shortnose sturgeon currently is listed as a federally endangered species, the National Oceanic and Atmospheric Administration ("NOAA") has concluded that a shortnose sturgeon population composed of 10,000 spawning adults is large enough to be at a low risk of extinction and adequate for delisting under the U.S. Endangered Species Act (NOAA 1996). Following the criteria used by NOAA for shortnose sturgeon, the total and spawning population estimates in the Hudson River exceed the safe level established by NOAA by more than 500%, clearly indicating that this population merits designation as "recovered" and qualifies for delisting from the U.S. Endangered Species Act protection (Bain et al. 2007).

38. Mr. Jacobson is either unaware of or inappropriately omits this more recent and relevant Hudson River specific information regarding the large, stable and healthy population of approximately 60,000 shortnose sturgeon.

39. Atlantic sturgeon is currently under consideration to determine whether listing as threatened or endangered under the federal Endangered Species Act is warranted. It is not presently listed as endangered, threatened, or a species of special concern by New York. Atlantic sturgeon are anadromous; spawning occurs in freshwater, but adults reside for many years in marine waters outside the Hudson River. Spawning females enter the Hudson River in mid-May and migrate along deep channel areas directly to freshwater spawning grounds upriver near Hyde Park (RM 81) and Catskill (RM 113, Bain 1997). Females return to marine waters quickly after spawning. Atlantic sturgeon are unlikely to spawn in the Indian Point region because Atlantic sturgeon eggs, embryos and larvae are intolerant of saline conditions and some significant length of river habitat is needed downstream of a spawning site to accommodate dispersal of embryos and larvae (Bain 1997). This observation is supported by empirical data obtained from the Longitudinal River Surveys (Figure 2) which demonstrates that Atlantic sturgeon eggs, larvae and young of the year rarely occur below the West Point region (RM 47) which is consistent with their limited salinity tolerance. In fact, only one young of the year Atlantic sturgeon and one unidentified larval sturgeon (probably an Atlantic sturgeon) were observed in the Indian Point nearfield region among 11,051 Long River Ichthyoplankton Survey samples collected there from 1979 through 2006.

40. Spawning male Atlantic sturgeon enter the Hudson River starting in April and some may remain as long as November. During their upstream migration, male sturgeon reside in channel areas in water greater than 25 ft (Dovel and Berggren 1983, Bain 1997). Juvenile Atlantic sturgeon are distributed over much of the Hudson River from July through September and they use deep channel habitats as in other life intervals (Bain 1997). The largest numbers of juveniles appears to be located from RM 39 to 87 (Bain 1997) thus there is some overlap with the Indian Point region at the downriver extent of their range. Figure 2 demonstrates that some Atlantic sturgeon juveniles occur from the Tappan Zee (RM 24) to the Indian Point (RM 46) regions, however the greatest numbers occur from the West Point (RM 47) region upriver to Saugerties (RM 106). In the fall, juveniles overwinter in brackish water between RM 12-46, however they remain in deep, channel areas and the majority of the population is therefore not expected to be exposed to impingement at IP2 or IP3.

41. Based on this analysis, the Jacobson Declaration's suggestion that the operation of IP2 and IP3's respective CWIS harms shortnose sturgeon or Atlantic sturgeon populations is contradicted by both the peer-reviewed, published scientific literature and from empirical observations from the HRBMP.

Entrainment and Impingement

42. The Pisces EI Report repeatedly argues that impingement and entrainment at IP2 and IP3 have caused an impact responsible for observed trends in fish populations and changes in the fish community. These arguments are speculative and reflect only a superficial understanding of the Hudson River ecosystem as described by the HRBMP. Moreover, the Pisces EI Report presents its arguments without any clear definition of ecological significance, adverse impact, or the criteria used for assessment, and without establishing testable hypotheses of cause and effect related to impingement or entrainment.

43. The Pisces EI Report examines the numbers of fish impinged and entrained at IP2 and IP3, and states that the annual number of fish entrained during 1981-1987 for American shad, bay anchovy, river herring, striped bass, and white perch were "very large," totaling over 1.2 billion individuals for these species combined. Pisces EI Report, at 3. The terms "large" and "very large" used by the Pisces EI Report are unscientific and meaningless without context or reference point.

44. The Pisces EI Report states that impingement and entrainment mortality due to IP2 and IP3 is typically measured on just a few of the 140 fish species found in the Hudson River, and that the impact on other species is "un-quantified and may be significant." Pisces EI Report, at 4. These statements reveal a lack of understanding about the ecology of north-temperate estuarine systems like the Hudson River, which are controlled primarily by physical processes in which most of the fish community biomass is in relatively few fish species, precisely those species considered by the AEI Report.

45. The Pisces EI Report suggests that CMR estimates of 12.04% for Atlantic tomcod and 10.38% for bay anchovy in the ER support a finding of "large" entrainment

impacts by IP2 and IP3. Pisces EI Report, at 11). Contrary to Pisces' assertions, however, the ER does not support the conclusion that "high" CMR estimates equate to "large" entrainment impacts on the Hudson River populations.

Fish Community Stability

46. The Pisces Hudson Report addresses the larger and general Hudson River ecosystem without regard to IP2 and IP3 (or even any mention of it). Therefore, the Pisces Hudson Report does not permit any inferences to be made regarding the possible effects of Indian Point's operations on the ecosystem.

47. The Pisces Hudson Report attempts to make the case that the fish community in the Hudson River is not stable and appears to be declining in stability over time. Significantly, the Pisces Hudson Report ignores the ecological tenet that species adapted to changing environments that change as a result of dynamic physical conditions like the temperature, salinity and flow regime experienced in north temperate estuaries such as the Hudson River are adapted to wide variations in these environmental parameters and are therefore more robust and less vulnerable to changes.

48. The Pisces Hudson Report refers to a number of multivariate methods besides the principal component analysis ("PCA") that Pisces presents in support of its contention that "apparent stability" in the fish community structure since 1985 "hides" great changes in the Hudson River fish community. However, the Pisces Hudson Report never defines "apparent stability," and it should be recognized that the concept of stability in ecosystems has been one of much controversy and research resulting in little agreement among researchers as to what stability means since 1969. It is cavalier at best, and scientifically flawed at worst, to use this phrase in the context of a scientific discussion of fish community dynamics without defining it. Furthermore, the Pisces Hudson Report only presents the results of one multivariate method, PCA, and no other multivariate method is described or presented.

49. The Pisces Hudson Report states that the PCA analysis reveals a clear pattern of change in the fish community sampled in the 1980s, 1990s, and 2000s. The Pisces Hudson Report supports that contention by examining a linear equation based on PC#1. However, the Report does not point out another apparent pattern in the data revealed by a tight grouping of components that occurs irrespective of years that remains unnoticed and therefore unexplained by the authors of this report. It is unscientific to selectively interpret patterns in the analytical results that support some preconceived notion of how the community is changing while ignoring (not explaining) other patterns apparent in the data.

50. Therefore, in my professional opinion, the Pisces Hudson Report sets forth conclusions that are poorly described, speculative, and reflect a superficial understanding of the Hudson River ecosystem as described by the HRBMP.

CONCLUSIONS

51. Based on my education and training, expertise, first-hand experience and professional judgment:

- the principles and methods used to obtain the data in the AEI Report and to perform the analyses and draw the conclusions presented AEI Report are tested and accepted within the disciplines of aquatic ecology, field sampling design, aquatic ecosystem population and community dynamics, and limnology, and comport with the standards of the environmental consulting industry as I understand them.

- The work undertaken to prepare the AEI Report reliably applied such principles and methods.

- The data and methods used in the AEI Report were evaluated through rigorous and documented quality assurance/quality control assessments that meet or exceed USEPA guidance for environmental programs.

52. Thus, in my professional opinion, the AEI Report is worthy of the highest degree of confidence.

53. In contrast, based on my education and training, expertise, first-hand experience and professional judgment, the principles and methods used to perform the analyses and draw the conclusions presented in the Pisces Reports and the Jacobson Declaration, are poorly described, speculative, and reflect only a marginal understanding of the Hudson River ecosystem as described by the HRBMP. Moreover, the Pisces EI Report presents its arguments without any clear definition of ecological significance, adverse impact, or the criteria used for assessment, and without establishing testable hypotheses of cause and effect related to impingement or entrainment at IP2 and IP3, and therefore do not comport with environmental consulting industry standards.

Signed this 18th day of January, 2008.

Mark T. Mattson

Mark T. Mattson, Ph.D.
Normandeau Associates, Inc.
Vice President & Principal Aquatic Ecologist

FIGURES

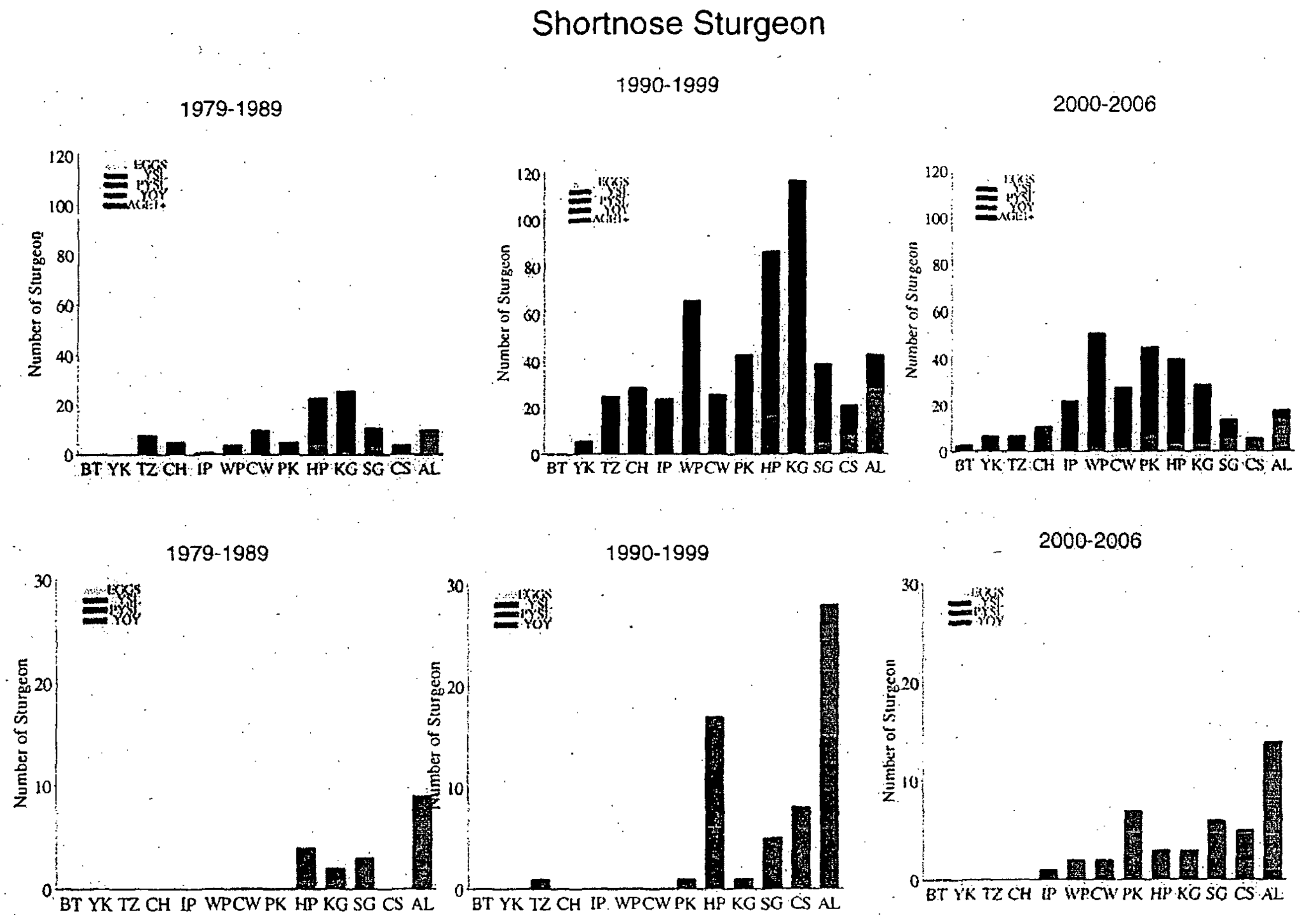


Figure 1. Number of shortnose sturgeon caught in the Hudson River by decade (1979-1989, 1990-1999, 2000-2006) in each of 13 geographic regions sampled between the Battery (BT) at New York City and Albany (AL) by the Hudson River Biological Monitoring Program (171,357 total samples). Note that the Indian Point region where IP2 and IP3 are located is labeled "IP", and is represented by 16,948 samples collected and examined for shortnose sturgeon from 1979 through 2006.

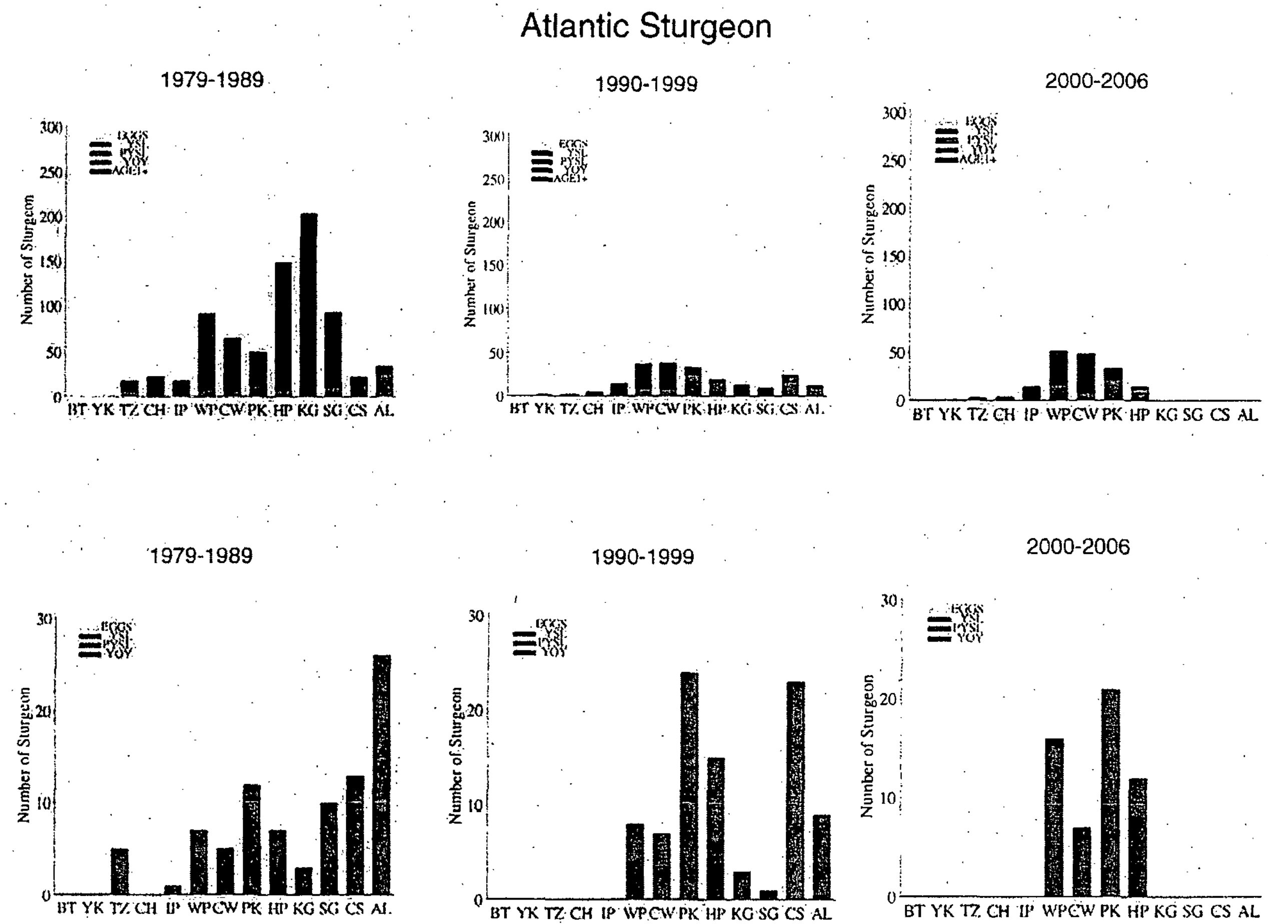


Figure 2. Number of Atlantic sturgeon caught in the Hudson River by decade (1979-1989, 1990-1999, 2000-2006) in each of 13 geographic regions sampled between the Battery (BT) at New York City and Albany (AL) by the Hudson River Biological Monitoring Program (171,357 total samples). Note that the Indian Point region where IP2 and IP3 are located is labeled "IP", and is represented by 16,948 samples collected and examined for Atlantic sturgeon from 1979 through 2006.

ATTACHMENT 1

NORMANDEAU ASSOCIATES, INC.

MARK T. MATTSON, Ph.D.
Vice President/Principal Aquatic Ecologist

Dr. Mattson is a Vice President and Principal Aquatic Ecologist at Normandeau who has supervised or conducted more than 45 fisheries and aquatic ecology projects over the past 28 years. He is a specialist in aquatic ecology/ fisheries field sampling design and in the application of population and community level statistics to measure anthropogenic effects on aquatic ecosystems. Dr. Mattson has also presented testimony on the development and application of periphyton and benthic macroinvertebrate community biocriteria to narrative water quality classification for several projects in Maine and Connecticut.

EDUCATION

Ph.D. 1979, Zoology (Limnology), University of New Hampshire
M.S. 1975, Zoology, University of New Hampshire
B.A. 1973, Biology, University of Connecticut

PROFESSIONAL EMPLOYMENT HISTORY

1981-Present	Normandeau Associates, Inc.
1979-1981	Texas Instruments Inc., Ecological Services

PROFESSIONAL AFFILIATIONS

American Society of Limnology and Oceanography
International Limnological Society
American Fisheries Society

SELECTED PROJECT EXPERIENCE

Entergy Nuclear Northeast, Inc. (2006-Present) – Provided technical assistance in the areas of fisheries and aquatic ecology for the Nuclear Regulatory Commission (NRC) Environmental Report and Environmental Site Audit for the re-licensing of the James A. FitzPatrick Nuclear Power Plant located on Lake Ontario (NY). Project Manager.

Entergy Nuclear Northeast, Inc. (2006-Present) – Provided technical assistance in the areas of fisheries and aquatic ecology for the Nuclear Regulatory Commission (NRC) Environmental Report and Environmental Site Audit for the re-licensing of the Indian Point Nuclear Power Plant located on the Hudson River (NY). Project Manager.

Entergy Nuclear Northeast, Inc. (2005-Present) - Preparation of a Clean Water Act Section 316(b) Proposal for Information Collection (PIC) and Comprehensive Demonstration Study (CDS) in compliance with the Phase II Rule regulating the cooling water intake structure at the James A. FitzPatrick Nuclear Power Plant located on Lake Ontario (NY). Project Manager and Report Author.

Entergy Nuclear Vermont Yankee, Inc. (2005-Present) - Preparation of a Clean Water Act Section 316(b) Proposal for Information Collection (PIC) and Comprehensive Demonstration Study (CDS) in compliance with the Phase II Rule regulating the cooling water intake structure at the Vermont Yankee Nuclear Power Generating Station located on the Connecticut River (VT). Project Manager and Report Author.

Entergy Nuclear Northeast, Inc. (2005-Present) - Preparation of a Clean Water Act Section 316(b) Proposal for Information Collection (PIC) and Comprehensive Demonstration Study (CDS) in compliance with the Phase II Rule regulating the cooling water intake structure at the Pilgrim Nuclear Power Station located on the Atlantic Ocean (Cape Cod Bay) (MA). Project Manager and Report Author.

MARK T. MATTSON, Ph.D.
Vice President/Principal Aquatic Ecologist

SELECTED PROJECT EXPERIENCE (Continued)

Public Service Company of New Hampshire, Inc. (2005-Present) - Preparation of a Clean Water Act Section 316(b) Proposal for Information Collection (PIC) and Comprehensive Demonstration Study (CDS) in compliance with the Phase II Rule regulating the cooling water intake structure at Merrimack Station located on the Merrimack River (NH). Report Author.

Public Service Company of New Hampshire, Inc. (2005-Present) - Preparation of a Clean Water Act Section 316(b) Proposal for Information Collection (PIC) and Comprehensive Demonstration Study (CDS) in compliance with the Phase II Rule regulating the cooling water intake structure at Newington Station located on the Piscataqua River (Great Bay Estuary) (NH). Report Author.

Public Service Company of New Hampshire, Inc. (2005-Present) - Preparation of a Clean Water Act Section 316(b) Proposal for Information Collection (PIC) and Comprehensive Demonstration Study (CDS) in compliance with the Phase II Rule regulating the cooling water intake structure at Schiller Station located on the Piscataqua River (Great Bay Estuary) (NH). Report Author.

Public Service Company of New Hampshire (1994-1996; 2003-Present) - Bow Station hydrothermal demonstration in support of NPDES requirements for accessing potential impacts on yellow perch, American shad and Atlantic salmon. Project Biologist.

Entergy Nuclear Vermont Yankee, Inc. (2002-Present) – Preparation of a Clean Water Act Section 316(a) Demonstration in support of a request for increased discharge temperatures at the Vermont Yankee Nuclear Power Generating Station (VT). Project Manager and Report Author.

Entergy Nuclear Vermont Yankee, Inc. (2002-Present) - Environmental support services for NPDES, indirect discharge, solid waste and biological monitoring programs at the Vermont Yankee Nuclear Power Generating Station (VT). Project Manager.

Entergy Nuclear Operations, Inc. (2001-Present) - Hudson River Striped Bass Program (NY). Project Manager.

Entergy Nuclear Operations, Inc. (2001-Present) - Hudson River Atlantic tomcod Program (NY). Project Manager.

Entergy Nuclear Operations, Inc. (2001-Present) - Hudson River Ichthyoplankton and Juvenile Fish Surveys field and laboratory services (NY). Corporate Officer.

New York Department of Environmental Conservation (NY) (1998-2006) - Hudson River Herring Spawning Stock Assessment. Technical Director.

Covanta Mid-Connecticut, Inc. (2003-2005) – Connecticut Resource Recovery Authority generating station evaluation of existing and proposed new Clean Water Act Section 316(b) rules for existing facilities – an entrainment and impingement evaluation (CT). Project Manager.

Somerset Operations (MA) (2001-2004) – Two-year evaluation of impingement, entrainment and the thermal plume at this existing generating station. Corporate Officer.

MARK T. MATTSON, Ph.D.
Vice President/Principal Aquatic Ecologist

SELECTED PROJECT EXPERIENCE (Continued)

New York Power Authority (NY) (2001-2003) -- Charles Poletti Power Plant Effects of Entrainment and Impingement Program. Ichthyoplankton, Juvenile Fish Trawl Surveys; Cunner and Tautog Mark-Recapture Program in Long Island Sound, New York Harbor, and the Hudson River. Project Manager and Technical Director.

Pratt and Whitney East Hartford (CT) (2000 - 2003) -- Two-year evaluation of impingement, entrainment and the thermal plume at the Wilgoos facility on the Connecticut River (CT). Project Manager.

Bridgeport Energy LLC Facility (CT, Bridgeport Harbor) (2000 - 2003) – Two-year evaluation of impingement, entrainment and the thermal plume at this new generating station. Corporate Officer.

Vermont Yankee Nuclear Power Corporation (VT) (1996-2002) - Environmental support services for NPDES, indirect discharge, solid waste and biological monitoring programs at the Vermont Yankee Nuclear Power Generating Station. Project Manager.

Shering-Plough Corporation (NJ) (1999-2001) - Biological assessment of the endangered Dwarf Wedge Mussel (Alasmidonta heterodon) in the Paulins Kill River (Sussex Co., NJ). Project Manager.

New York Department of Environmental Conservation (NY) (1999-2001) - Aquatic Biological sample collections for contaminants analysis from New York Harbor and the Hudson River. Corporate Officer.

New York Power Authority (1984-1994; 1997-2001) - Hudson River Striped Bass Stock Assessment Program (NY). Project Manager.

New York Power Athority. (1982-1994; 1997-2001) - Hudson River Atlantic Tomcod Spawning Stock Survey (NY). Project Manager.

Consolidated Edison Company of New York, Inc. (1988-1989, 1991-2001) - Hudson River Ichthyoplankton Laboratory Program (NY). Corporate Officer.

Consolidated Edison Company of New York, Inc. (1984-1989, 1991-2001) - Hudson River Ichthyoplankton and Juvenile Surveys (NY). Corporate Officer.

Pratt and Whitney Middletown (CT) (2000) -- Cooling water intake screen evaluation to determine applicability of Best Management Practices (BMP) to demonstrate the use of Best Technology Available (BTA) with respect to impingement and entrainment at the Middletown manufacturing facility on the Connecticut River (CT). Project Manager.

Public Service Electric & Gas Company (1996-2000) - Salem Station (NJ) Delaware Bay-wide monitoring fisheries studies for the Estuarine Enhancement Program. Corporate Officer.

Public Service Electric & Gas Company (1996-1998) - Hudson Station (NJ) supplemental 316(a) and 316(b) biological studies. Project Manager.

Eckenfelder, Inc. (1995-1998) - Phase II RFI studies for adjacent surface water sediments AOC for the Ciba-Geigy site located on the Hudson River in Glens Falls (NY). Project Manager.

MARK T. MATTSON, Ph.D.
Vice President/Principal Aquatic Ecologist

SELECTED PROJECT EXPERIENCE (Continued)

Wisconsin Public Service Corporation (1996) - Oconto Electric Hydroelectric Project (WI) Fish Entrainment and Turbine Mortality Study. Project Manager.

Dairyland Power Reservoir Productivity Study (1995-1996) - Reservoir productivity study in support of hydropower relicensing on the Flambeau River (WI). Project Manager.

Wisconsin Public Service Corporation (1994-1995) - Wausau Hydroelectric Project (WI) Fish Entrainment and Turbine Mortality Studies. Project Manager.

Wisconsin Public Service Corporation (1992-1994) - Grand Rapids Hydroelectric Project (WI) Fish Entrainment and Turbine Mortality Studies. Project Manager.

Great Northern Paper Co. (1986-1992) - Penobscot Mills and Ripogenus Dam Hydropower Relicensing Projects (ME). Project Aquatic Ecologist.

Empire State Electric Energy Research Corp. (1990-1991) - Demonstration of an Acoustic Fish Deterrence System at the James A. Fitzpatrick Nuclear Power Plant Cooling Water Intake (NY). Project Manager.

Niagara Mohawk Power Corp. (1990-1991) - Fish Guidance Study at Albany Steam Station (NY). Project Manager/Technical Advisor.

Central Hudson Gas and Electric Corp. (1989-1991) - Roseton and Danskammer Point Stations Impingement Monitoring Program (NY). Project Manager.

Consolidated Edison Company of New York, Inc. (1984-1986, 1989-1991) - Indian Point Impingement Studies (NY). Project Manager.

Consolidated Edison Company of New York, Inc. (1985-1991) - Indian Point Nuclear Generating Station Ristroph Screen Impingement Mitigation Study (NY). Project Manager.

Wisconsin Public Service Corporation (1990) - Nine Hydroelectric Facilities (WI) Fish Turbine Entrainment/Mortality Study Plans. Project Manager.

New York Power Authority (1990) - Indian Point Unit 3 Nuclear Power Plant Zebra Mussel Monitoring Project. Project Manager.

Central Hudson Gas & Electric Corp. (1990) - Zebra Mussel Monitoring at Roseton and Danskammer Point Stations. Project Manager.

Central Hudson Gas & Electric Corp. (1990) - Survey of Hudson River Marinas for the Presence of Zebra Mussels. Project Manager.

The Upjohn Company (1982, 1987-1990) - Quinnipiac River Study (CT). Project Aquatic Ecologist.

New York Power Authority (1986-1990) - Indian Point Fish Deterrence Studies (NY). Corporate Officer/Technical Reviewer.

Consolidated Edison Company of New York, Inc. (1989) - Relative Probability of Entrainment Study for Indian Point Station (NY). Project Manager.

Consolidated Central Hudson Gas and Electric Corp. (1986-1988) - Danskammer Point Station Fine Mesh Fish Impingement Studies (NY). Project Manager.

MARK T. MATTSON, Ph.D.
Vice President/Principal Aquatic Ecologist

SELECTED PROJECT EXPERIENCE (Continued)

Consolidated Edison Company of New York, Inc. (1986-1987) - Special Studies to Examine Fish Abundance in Unsampled Areas of the Hudson River (NY). Project Manager.

Consolidated Edison Company of New York, Inc. (1986-1987) - Indian Point Entrainment Abundance Studies (NY). Technical Advisor.

Consolidated Edison Company of New York, Inc. (1984-1985) - 1982 and 1983 Year Class Reports for the Hudson River Monitoring Program (NY). Technical Reviewer.

Orange and Rockland Utilities, Inc. (1983-1985) - Hudson River White Perch Stock Assessment Study (NY). Project Manager.

Great Northern Paper Company (1981-1985) - Hydroelectric Development Project (ME). Project Aquatic Ecologist.

New York Power Authority (1980-1985) - Hudson River Gear Evaluation Studies (NY). Project Manager.

Bangor Hydro Basin Mills Hydroelectric Project (ME) (1983-1984) - Project Aquatic Ecologist.

Consolidated Edison Company of New York, Inc. (1981-1984) - Sampling Design Evaluation for Indian Point Fish Impingement Programs (NY). Project Manager.

Metropolitan District Commission (1982-1983) - Water Supply Alternatives (MA). Project Aquatic Ecologist.

Bangor Hydro Telos Dam Reconstruction Project (ME) (1982) - Project Aquatic Ecologist.

Consolidated Edison Company of New York, Inc. (1981-1982) - Indian Point Juvenile Fish Entrainment Study (NY). Project Manager.

Chicopee Falls Hydropower Project (MA) (1981) - Project Aquatic Ecologist.

Town of Concord (MA) (1981) - Water Supply Study. Project Aquatic Ecologist.

SPECIAL TRAINING

U.S. Fish and Wildlife Instream Flow Incremental Methodology Negotiations and Strategies, 1981; Conducting Field Studies, 1984
NAUI Certified SCUBA diver

SELECTED PRESENTATIONS AND PUBLICATIONS

Dunning, D.J., J.R. Waldman, Q.E. Ross and M.T. Mattson. 2006. Dispersal of age 2+ striped bass out of the Hudson River. Pages 287-294 in J.R. Waldman, K.E. Limburg, and D.L.Strayer, editors. Hudson River fishes and their environment. American Fisheries Society, Symposium 51. Bethesda, Maryland.

Dunning, D.J., Q.E. Ross, M.T. Mattson, and D.G. Heimbuch. 2006. Distribution and abundance of bay anchovy eggs and larvae in the Hudson River and nearby waterways. Pages 215-226 in J.R. Waldman, K.E. Limburg, and D.L.Strayer, editors. Hudson River fishes and their environment. American Fisheries Society, Symposium 51. Bethesda, Maryland.

MARK T. MATTSON, Ph.D.
Vice President/Principal Aquatic Ecologist

SELECTED PRESENTATIONS AND PUBLICATIONS (Continued)

Smith, J.D., M.T. Mattson, and V. Thompson. 2006. Using computational fluid dynamics to determine the hydraulic zone of influence for ichthyoplankton and juvenile fish sampling areas in the vicinity of the James A. FitzPatrick Plant cooling water intake structure in Lake Ontario. Presentation at the EPRI and UWAG conference on 316(b) issues, to be held in Atlanta, Georgia, 6-7 September 2006.

Mattson, M.T., M.L. Hutchins, P.L. Harmon, and C.J. Swanson. 2004. Probability-based impact assessment for a §316(a) demonstration: an example from Entergy Nuclear Vermont Yankee. Chapter 13 *in* Proceedings from the EPRI Workshop on 316(a) Issues: Technical and Regulatory Considerations: October 16-17 2003, EPRI Palo Alto, CA and American Electric Power Company, Columbus, OH: 2004. 1008476.

Mattson, M.T. and D.J. Dunning. 2004. Mitigation value of a striped bass hatchery in the Hudson River Estuary. Presentation at the Symposium on Ecological Restoration under Section 316(b) of the Clean Water Act: Issues in Implementation. 134th Annual Meeting of the American Fisheries Society, Madison, Wisconsin, 22-26 August 2004.

Mattson, M.T. J.R. Young, K.A. Hattala, and A. Kahnle. 2003. Abundance index trends in alewife and blueback herring populations of the Hudson River Estuary. Presentation at: Hudson River Fishes & Their Environment. Hudson River Environmental Society conference held 20-21 March 2003 at Marist College, Poughkeepsie, NY.

Mattson, M.T. J.R. Young, and Q.E. Ross. 2002. Atlantic tomcod in the Hudson River Estuary. Presentation at the Symposium on Hudson River Fisheries. 132th Annual Meeting of the American Fisheries Society, Baltimore, Maryland, August 2002.

Dunning, D.J., J.R. Waldman, Q.E. Ross and M.T. Mattson. 1997. Use of Atlantic Tomcod and other prey species by striped bass in the lower Hudson River estuary during winter. Trans. Am. Fish, Soc. 236(5): 857-861.

Dunning, D.J., Q.E. Ross, W.L. Kirk, J.R. Waldman, D.G. Heimbuch and M.T. Mattson. 1992. Post juvenile striped bass studies after the settlement agreement. In: C.L. Smith ed., Estuarine Research in the 1980s. State University of New York Press. p.338-347.

Geoghegan, P., M.T. Mattson, J.J. Reichle and R.G. Keppel. 1992. Influence of salt front position on the occurrence of uncommon marine fishes in the Hudson River Estuary. Estuaries 15(2): 251-254.

Geoghegan, P., M. T. Mattson, and R. Keppel. 1992. Distribution of the shortnose sturgeon in the Hudson River Estuary, 1983-1988. In: C.L. Smith ed., In: C.L. Smith ed., Estuarine Research in the 1980s. State University of New York Press. p. 217-227.

Mattson, M.T., P. Geoghegan, D.J. Dunning. 1992. Accuracy of catch per unit effort indices of Atlantic tomcod in the Hudson River. In: C.L. Smith ed., In: C.L. Smith ed., Estuarine Research in the 1980s. State University of New York Press. p. 323-338.

Waldman, J. R., D. J. Dunning, and M. T. Mattson. 1991. Long-term retention of anchor tags and internal anchor tags by striped bass. North American Journal of Fisheries Management, 11: 232-234.

MARK T. MATTSON, Ph.D.
Vice President/Principal Aquatic Ecologist

SELECTED PRESENTATIONS AND PUBLICATIONS (Continued)

Humphreys, M., M. T. Mattson, R.E. Park, J.J. Reichle, D.J. Dunning and Q.E. Ross. 1990. Stocking checks on scales for identifying hatchery striped bass in the Hudson River. American Fisheries Society Symposium 7: 78-83.

Waldman, J. R., D. J. Dunning, Q. E. Ross, and M. T. Mattson. 1990. Range dynamics of Hudson River striped bass along the Atlantic coast. Transactions of the American Fisheries Society 119: 910-919.

Waldman, J. R., D. J. Dunning and M. T. Mattson. 1990. A morphological explanation for size-differential anchor tag loss in Hudson River striped bass. Transactions of the American Fisheries Society 119: 920-923.

Mattson, M.T., J.R. Waldman, D.J. Dunning, and Q.E. Ross. 1989. Abrasion and protrusion of internal anchor tags in Hudson River striped bass. American Fisheries Society Symposium 7:121-126.

Dunning, D.J., Q.E. Ross, M.T. Mattson, P. Geoghegan, and J.R. Waldman. 1989. Reducing mortality of striped bass captured in seines and trawls. North American Journal of Fisheries Management, 9(2): 171-176.

Geoghegan, P., M.T. Mattson, D.J. Dunning and Q.E. Ross. 1989. Improved data through quality control and quality assurance in a large scale striped bass tagging program. American Fisheries Society Symposium 7: Fish Marking Techniques.

Mattson, M.T., D.J. Dunning, Q.E. Ross and B.R. Friedman. 1989. Magnetic tag detection efficiency in a Hudson River striped bass hatchery evaluation program. American Fisheries Society Symposium 7: 267-277.

Mattson, M.T., J.B. Waxman and D.A. Watson. 1988. Reliability of impingement sampling designs: an example from Indian Point Station. American Fisheries Society Monograph 4:161-169.

Dunning, D.J., Q.E. Ross, J.R. Waldman, and M.T. Mattson. 1987. Tag retention and tagging mortality in Hudson river striped bass. North American Journal of Fisheries Management, 8(4): 535-538.

Geoghegan, P., M. T. Mattson, D. J. Dunning and Q. E. Ross. 1986. Effects of water temperature, collection gear, and tag type on handling mortality of striped bass. Presented at the 1986 Northeast Fish and Wildlife Conference, Hershey, Pennsylvania USA.

Mattson, M. T., D. J. Dunning and Q. E. Ross. 1985. Relative catch efficiency of a 3 m beam trawl, 6.2 m high-rise trawl and 1.0 m epibenthic sled for sampling young of the year striped bass and other fishes in the Hudson River Estuary. American Fisheries Society, August 1985.

Mattson, M. T. and J. B. Waxman. 1985. Movements of spawning Atlantic tomcod (Microgadus tomcod) in the Lower Hudson River, Northeast Fish and Wildlife Conference; May 1985.

Mattson, M. T. 1980. Diel and seasonal horizontal movements in a population of the predatory cladocean *Polyphemus pediculus*. American Society of Limnology and Oceanography, December 1980.

MARK T. MATTSON, Ph.D.
Vice President/Principal Aquatic Ecologist

SELECTED PRESENTATIONS AND PUBLICATIONS (Continued)

Mattson, M. T. and J. F. Haney. 1980. Factors influencing intrazooplankton predation by Polyphemus pediculus, Research Report No. 29. Water Resources Research Center, University of New Hampshire, Durham, NH. 149 pp.

In addition, Dr. Mattson has contributed to over 30 technical reports in the areas of aquatic ecology and sampling design.

ATTACHMENT 2

REFERENCES

Bain, M.B. 1997. Atlantic and shortnose sturgeons of the Hudson River: common and divergent life history attributes. Environmental Biology of Fishes 48:347-358.

Bain, M.B., Haley, N., Peterson, D.L., Arend, K.K., Mills, K.E. and P.J. Sullivan. 2007. Recovery of a US endangered fish. PLoS ONE 2(1): e168. doi:10.1371/journal.pone.0000168

Barnthouse, L.W., Heimbuch, D.G., Van Winkle, W., and J.Young. 2008. Entrainment and impingement at IP2 and IP3: A biological impact assessment.

Consolidated Edison Company of New York, Inc. 1985. Biological evaluation of a Ristroph screen at Indian Point unit 2. June 1985. 50 pages plus Appendix A.

Dovel, W.L., and Berggren, T.J. 1983. Atlantic sturgeon of the Hudson Estuary, New York. New York Fish and Game Journal 30(2):142-172.

Dovel, W.L., Pekovitch, A.W. and T.J. Berggren. 1992. Biology of the shortnose sturgeon (*Acipenser brevirostrum*) in the Hudson River estuary, New York. Pp. 187-216. *In*: C.L.

Fletcher, R.I. 1986. On the reconfiguration and empirical evaluation of a prototype screening device at Indian Point Nuclear Unit 2. Final Report to Hudson River fishermen's Association. 1 December 1986. 56 pages.

Fletcher, R.I. 1990. Flow dynamics and fish recovery experiments: water intake systems. Transactions of the American Fisheries Society 119: 393-415.

Geoghegan, P. Mattson, M.T., Dunning, D.J., and Q.E. Ross. 1990. Improved data quality in a tagging program through quality assurance and quality control. American Fisheries Society Symposium 7: 714-719.

Geoghegan, P., Mattson, M.T., and R.G. Keppel. 1992. Distribution of the shortnose sturgeon in the Hudson River Estuary, 1984-1988. Pages 217-227 *in* C.L. Smith, ed. Estuarine research in the 1980's. Hudson River Environmental Society seventh symposium on Hudson River ecology. State University of New York Press, Albany.

Geoghegan, P. 1996. The management of quality control and quality assurance systems in fisheries science. Fisheries 21 (8): 14-18.

NOAA National Marine Fisheries Service. 1996. Status review of shortnose sturgeon in the Androscoggin and Kennebec Rivers. Gloucester (Massachusetts): Northeast Regional Office, National Marine Fisheries Service.

Seaby, R.M. and P.A. Henderson. 2007. Entrainment, Impingement and Thermal Impacts at Indian Nuclear Power Station. Pisces Conservation, Ltd. November 2007. 49 pp.

Seaby, R.M. and P.A. Henderson. 2007. The Status of Fish Populations and the Ecology of the Hudson. Pisces Conservation, Ltd. November 2007. 37 pp.

Secor, D. H. and R.J. Woodland. 2005. Recovery and status of shortnose sturgeon in the Hudson River. Final Report to Hudson River Foundation for Science and Environmental Research, Inc. August 2005. 108 pages.

Waldman, J.R., Young, J.R., Lindsay, B.J., Schmidt, R.E., and H. Andreyko. 2006. A comparison of alternative approaches to discriminate larvae of striped bass and white perch. North American Journal of Fisheries Management 19: 470-481.

Waldman, J.R., Limburg, K.E. and D.L. Strayer. 2006. The Hudson River environment and its dynamic fish community. Pp. 1-7 *In* Hudson River fishes and their environment (Waldman, J.R., Limburg, K., and D. Strayer eds.). American Fisheries Society Symposium 51.

Waldman, J.R., Lake, T.R. and R.E. Schmidt. 2006. Biodiversity and zoogeography of the fishes of the Hudson River watershed and estuary. Pp. 129-150 *In* Hudson River fishes and their environment (Waldman, J.R., Limburg, K., and D. Strayer eds.). American Fisheries Society Symposium 51.

Young, J.R., Keppel, R.G., and R.J. Klauda. 1992. Quality assurance and quality control aspects of the Hudson River utilities environmental studies. Pages 303-322 *in* C.L. Smith, ed. Estuarine research in the 1980's. Hudson River Environmental Society seventh symposium on Hudson River ecology. State University of New York Press, Albany.

Copy 1

W-00-03

316 (b)

Comments, 1, 73

NOV 9 2000

933 East Pine Hill Drive
Schenectady, NY 12303-5559
November 9, 2000

(U. S. Mail)
Cooling Water Intake Structure (New Facilities)
Proposed Rule Comment Clerk--W-00-03, Water Docket,
Mail Code 4101, EPA, Ariel Rios Building
1200 Pennsylvania Ave., N.W.,
Washington, DC 20460

(e-mail)
ow-docket@epa.gov

RE: Docket Number W-00-03, Proposed Rule, National Pollutant Discharge Elimination System--Regulations Addressing Cooling Water Intake Structures for New Facilities, Federal Register Vol. 65, No. 155, Aug. 10, 2000, p. 49060-49121.

Dear Environmental Protection Agency:

This letter will provide first some summary comments and then extensive detailed comments and discussion arranged by issue.

First, the proposed rule is good, but does not go far enough in setting a technology standard that minimizes adverse impact, as required by law. I believe that the final rule eliminate the lesser degrees of protection proposed for "outside the littoral zone" and "less than 50 meters outside the littoral zone." I object to the lesser degrees of protection and believe they violate EPA's antidegradation policy and guidance for "Aquatic Life/Wildlife Uses," which states:

> *"Water Quality should be such that it results in* ***no mortality*** *and no significant growth* ***or reproductive impairment of resident species****. Any lowering of water quality below this full level of protection is not allowed."*[1] (Emphasis added)

Furthermore, I object to the lesser degrees of protection because, if promulgated, they would infringe upon state's rights and state law. If EPA implements lesser standards in the non-littoral zone it would be "permitting" clearly avoidable fish mortality in violation of state fish and wildlife laws. These fish and wildlife resources belong to the respective States, and EPA has no authority to allocate the killing or taking of these animals contrary to appropriate State laws. Furthermore, EPA's economic data shows that the cost of additional protection is affordable with the total national annualized compliance cost of $16.4 million.[2] Therefore, EPA should eliminate the lesser degrees of protection in order to correct this problem.

Second, several definitions need to be added or modified. EPA's proposed definition of "cooling water intake structure" is inadequate, as it does not even include the pumps that cause the actual in-taking of water and which physically cause much of the impingement and entrainment mortality. I provide a more comprehensive definition for EPA's consideration. I also provide a structure of definitions to clarify the meaning of "adverse," "adverse impact," "adverse environmental impact," and "minimize adverse

---

[1]USEPA. 1994. Water quality standards handbook:2nd ed.EPA-823-B-94-005a, p. 4-5.

[2]Proposed Rule page 49103 paragraph 2.

27pt 1ATT(3p)

environmental impact, " plus others. I also feel that excluding "ponds" from the rest of the lentic water standards is unacceptable and I recommend that it be grouped with "Standards for CWISs located in a lake or reservoir." I also propose a definition for ponds.

Third, EPA requests comments on alternative numeric criteria. I provide these.

Fourth, and very importantly, I make extensive comments on the numerous alternate approaches offered under "What Constitutes Adverse Environmental Impact Under This Proposed Rule?" commencing on page 49074. I am very concerned that EPA to is taking what should be a simple concept and turning it into an unlawful, arcane, and unworkable regulatory schemes. Many of the proposed alternatives are inconsistent with the technology-based standards of Sections 301, 304, and 306 of the Clean Water Act (33 USC 1311, 1314, 1316).

It is fundamental to the Clean Water Act that technology-based limitations are to protect the best uses of the water. Water-quality based limitations are to correct problems where the best uses are yet to be attained. Sections 301 and 304 drive the use of better and better technology to reduce pollution. Section 306 mandates technology for new facilities, which have the most flexibility to incorporate new, better, technology at an efficient cost. Section 302 provides for more stringent standards when, despite these measures, water quality standards and designated uses are still not attained. Section 303 provides further back-up through setting Total Maximum Daily Loads and Antidegradation protection measures. EPA's rulemaking must comply with and implement these principles.

Instead, many of the alternate approaches offered by EPA in the "Supplementary Information" take the reverse approach, and avoid implementing any technology-based limits until after aquatic life/wildlife uses are violated. This is inconsistent with the law and contrary to EPA's own antidegradation guidance. Therefore, New York subscribes to the approach EPA refers to as "a third alternative" on the last paragraph on page 49074, and I commend that approach to EPA. I strongly urge EPA to consider my general and technical comments carefully, and again offer my proposed, plain-English definition "adverse impact" for EPA's consideration.

Fifth, I offer my comments on requiring dry condenser cooling as Best Technology Available for new facilities. I believe this would be a simple, effective standard that would minimize or eliminate discharge of pollutants, consistent with the goals of the Act in 33 USC 1251(a)(1), and would encourage locating facilities away from major water bodies. However, it would be folly to discourage alternate technologies which achieve mortalities of fish, shellfish, and wildlife as low, or lower than that achieved by a dry condenser cooling design. Therefore, I endorse such an exemption for alternate technologies that meet or exceed the same level of protection as dry condensers.

Finally, I offer numerous other technical comments. All of my specific comments follow on the subsequent attached pages.

Should you have any questions or follow-up please contact me by e-mail at sarbello@nycap.rr.com or by mail at the above address

Sincerely,

William Sarbello

William Sarbello
B. S., M. S., Certified Wildlife Biologist

25 page attachment

Personal Comments of William Sarbello, 11/09/2000

Comments on proposed rule, Cooling Water Intake Structures for New Facilities; National Pollutant Discharge Elimination System; 40 CRF Parts 9, 122, 123, et al., Federal Register, Vol. 65, No. 155, Thurs. Aug. 10, 2000, pp.49060-49121

****

Issue 1: General Comment: While this rule is generally good, it does not go far enough in setting National Minimum Standards for 316(b). (Draft rule § 125.80(c), p. 49115.)

Recommendation 1: I will recommend strengthening language for this important National rule, to apply to all states, territories, tribes, and interstate authorities, in order to protect inter-jurisdictional stocks of fish, shellfish, and wildlife from unnecessary, avoidable mortality.

Discussion 1: This rule affects migratory stocks of fish, shellfish, and wildlife, and stocks in border waters whose movements cross political boundaries. It is not enough that an individual state may adopt stronger rules for itself; EPA must set strong standards that apply to all 500+ jurisdictions. While my state may have stronger standards than other states, that does not protect "our" striped bass (or summer flounder, rainbow smelt, turtles, or blue crabs) from getting killed in the waters of other states having less stringent standards. Only EPA rulemaking can make an adequate level of protection the "law of the land."

Also, having strong, uniform standards Nationwide would preclude corporations from fleeing to the state or political subdivision with the weakest rules. With cross-border electric power sales happening every hour, cross-border migration of fish stocks must not result in greater numbers of entrainment mortalities. Unless EPA establishes rigorous national standards, states with stricter standards will suffer economically for their efforts, and the effectiveness of their measures will be undercut by cross-border polluters bound by less rigorous standards.

****

Issue 2: 25% exclusion, Who is covered under this proposed rule? (Sup. Inf. P. 49066, V. A.; draft rule § 125.83 *"Cooling Water Intake Structure"*, p. 49116)

Recommendation 2: Eliminate this exclusion or, at the very least, make it a very small percentage, like "less than 1%." If limited to the choices offered by EPA on p. 49067 paragraph 4, I would choose the smallest, 5%.

Discussion 2: There are two issues here, a) a 25% exclusion is unreasonably large, and b) screening technology that reduces/eliminates mortality should be applied to any intake.

a) Under this exclusion, intakes drawing 8 MGD or more (up to 2 MGD cooling water comprising 25% or less of total intake volume) would not be required to take any mitigative. In the Hudson River at Athens (a tidal river under the proposed definition), an 8 MGD intake volume would be expected to kill annually (for the life of the facility) 3,549,107 alewife+blueback herring, 46,690 American shad, 44,442 white perch, 2,366 striped bass, and numerous other fish that were not characterized. (Extrapolations based on volumes from Commissioner's Interim Decision, Athens Generating Company, LP, SPDES No.: NY-0261009, June 2, 2000, p. 13, footnote 10.) Such levels of mortality are unacceptable, as they could be readily minimized by a variety of means, and would not constitute applications of the best technology available.

b) If any portion of the water is used for cooling the whole intake should be mitigated, at least through simple screening techniques, to reduce impingement and entrainment impacts. For example, the 8 MGD intake cited above could be readily mitigated by adding a 2 mm wedgewire screen designed to provide a through-slot velocity of less than 0.5 fps under conditions of 25% screen fouling, and be equipped with an air blast cleaning system and pressure differential sensor to detect fouling and initiate automatic cleaning. Such a screen configuration is a standard design, and would greatly reduce entrainment or impingement mortalities from both the process water and cooling water intake cycles.

I note that on p. 490067, second paragraph, that it was EPA's intention "...to ensure that almost all cooling water withdrawn from the waters of the U.S. are addressed by the requirements of this proposal for minimizing adverse environmental impact." I believe lowering the threshold as I have suggested will best accomplish EPA's stated objective.

****

Issue 3: 2 MGD Exclusion, Only cooling water intakes drawing more than 2 MGD are subject to this rule. (Draft rule § 125.81, p. 49116; Sup. Inf. V. A. p 49066.)

Recommendation 3: Lower this exclusion to 1 MGD. I reject the alternate thresholds of 5, 10, 20, 25, and 30 MGD as resulting in fish mortalities beyond acceptable levels.

Discussion 3: It is easier to mitigate the impacts of the small water withdrawals. I note that with the EPA-suggested 25% rule, even a 1 MGD cooling water intake could be part of a 4 MGD intake that would not be subject to today's rule. Such an intake would still kill millions of fish over the life of the intake. (See Discussion 2, and divide the numbers per species in half.) However, combining my proposed 1 MGD exclusion with my Recommendation 2 would still provide an exclusion for small cooling water withdrawals, while assuring full mitigation of more significant ones.

The consequences of EPA's proposed higher thresholds, at new plants, which have ultimate flexibility to employ the best technology would be unacceptable mortalities. For example, the 30 MGD threshold proposed, if applied at the Athens Generating Station, would needlessly kill:

13,309,150 river herring (alewife+blueback herring)
175,086 American shad
166,657 white perch, and
8,871 striped bass,

each year, every year, for the life of the facility (probably at least 40 years). **This is 175 times more impact than what My home state certified as Best Technology Available for such a facility.** I note that this 1,080 MW facility has been permitted and will be built without the excessively permissive conditions that EPA's 30 MGD exemption would have permitted.

EPA is concerned that a 25 MGD threshold would relieve 35% of the chemical industry from complying with the rule. However, the impact of the unmitigated intake upon the biological integrity of the waters is just as harmful whether the water is going to a chemical plant or an electric power plant. The fish killed are the property of the People of the State, not EPA and not the industry. I oppose EPA causing additional impacts upon the People's public trust resources in order to give a "break" to a specific industry. I favor a level-playing field where all industries are required maintain the biological, chemical, and physical integrity of U.S. waters. Therefore, I recommend that EPA select a 1 MGD threshold.

****

Issue 4: Definition of "Cooling Water Intake Structure" (Draft rule § 125.83, p. 49116; Sup. Inf. V. C. p 49066.)

Recommendation 4: This definition is insufficient; it should be modified to say, "*The entire physical structure and mechanism used for withdrawing and conveying water, from the waters of the U. S. to the heat exchanger, plus structures and discharges associated with its maintenance and operation. The cooling water intake structure shall include, but not be limited to, any associated constructed waterway, pipe, fissure, or other conveyance, porous dikes, fabric filters, barrier nets, all associated screens, perforated plates, fish return systems, trash buckets, fish troughs, fish return pipes (sluices, canals, etc.), pressure washes, backflushing mechanisms, air sparging mechanisms, pumps, manifolds, cleaning mechanisms, bar racks, trash conveyors, screen enclosures, traveling screen mechanisms and controllers, and any conveyance for passing discharge water to a point upstream from a heat exchanger.*"

Discussion 4: EPA's proposed definition excludes the most essential part of a water intake, the pumps, and does not include many important features for reducing aquatic organism mortality. This is especially critical, as this definition will doubtlessly apply to existing cooling water intake structures as well as new cooling water intake structures.

The pumps are the most critical part of the cooling water intake, regulating cooling water capacity, and should not be excluded. First, there would be no "intake" of water without the operation of pumps to withdraw water from the source water body, so to exclude them is unreasonable and illogical. Second, as a component of the cooling water intake, they are a major source of mortality for entrained aquatic organisms. For example, when the cooling water system is operated WITHOUT THE DISCHARGE OF HEAT, mechanical forces result in the mortality of virtually 100% of entrained bay anchovies are killed, and nearly 100% of entrained alewife and blueback herring. Studies done at the Connecticut Yankee nuclear power station (CT), and similar studies done in plants on the Hudson River (NY) that indicate this.

Indeed, one important method of mitigating once-through cooling system impacts is to reduce the quantity of water withdrawn by shutting off some of the pumps, or installing and operating variable-speed pumps. Not including the pumps as part of the cooling water intake excludes from regulation one of the most important tools for avoiding or minimizing the impacts and is unacceptable.

Further, EPA's proposed definition excludes key parts of what I consider cooling water intake structures, and parts that have a great influence on reducing impingement/entrainment mortality. I recommend including those structures explicitly. My proposal would include in-waterbody structures through which intake cooling water flows, like barrier nets and "gunderbooms." It would also include fish return systems, which are crucial to the survival of impinged organism, and the mitigation of intake structure impacts. Controlling the location, design, construction, capacity, and operation of low- and high-pressure screen washes, fish troughs on traveling screens, the pipes and sluices through which fish are returned, and the specialized low-impact pumps (helical or Archimedes screw-type) for returning the fish with minimum injuries should also be regulated as part of this rule.

Also, common devices that kill fish at intakes should be regulated under this rule, such as trash conveyors like the "aquaguard" which re-handle and re-injure. Fish survival can be improved by careful attention to the smoothness of pipe surfaces, their size, the radius of turns, and the velocity of flows.

****

Issue 5: EPA is considering adding language to preclude cooling water withdrawals that exceed 1% of the mean annual flow or volume of the water body. The language is proposed on p. 49068 paragraph 8, and would be inserted at the end of § 125.81.

Recommendation 5: I support this 1% limit; if anything it is quite generous. I suggest considering 0.1% or 0.05%. EPA's higher suggested levels, which go up to 20%, are unreasonably excessive. I believe a percentage limit, whatever it is, makes more sense than adding an absolute minimum flow threshold to avoid overwhelming smaller water bodies.

Discussion 5: I made approximate calculations for a tidal estuary in New York City (the East River) in the vicinity of a proposed new power plant at Astoria. The 1% flow calculation yielded a flow limitation of 924 MGD for that site, which is a very large quantity of water. This is much more water than is needed for the proposed NYPA Astoria facility (1.4 to 6.1 MGD for a closed-cycle-cooled, mechanical-draft evaporative tower, 500 MWe combined-cycle facility). Indeed, the 924 MGD representing 1% of the flow was adequate to supply the needs of 50 out of 56 steam-electric facilities in New York State with state NPDES permits. (For example, the once-through-cooled 1,200 MWe Bowline 1 & 2 Station is permitted for a maximum 912 MGD, the dry-condenser cooled 1,080 MWe Athens station is permitted at 0.18 MGD.)

In this example a 0.1% limitation would be 92.4 MGD, 0.05% would be 18.5 MGD.

****

Issue 6: Should BTA requirements or conditions be inserted into a general stormwater NPDES permit, or should a site-specific NPDES stormwater permit be required? (p. 49068 Sup. Inf. V. E., second paragraph.)

Recommendation 6: I support that an individual NPDES stormwater permit should be required.

Discussion 6: An individual permit would be simpler, and would also permit mitigating other impacts, such as those relating to a Clean Water Act Section 404 permit or Section 401water quality certificate.

****

Issue 7: Regulation of cooling water intakes upstream of a new facility that supply the new facility with water.

Recommendation 7: For other industrial facilities, the upstream facility should be required to meet the new source performance standards, no matter how small the percentage of flow for the new facility. For municipal water supply utilities that serve a larger community, the "more-than-one-half" rule suggested by EPA seems reasonable.

Discussion 7: Industrial facilities, must avoid using an existing facility to preclude compliance with new facility performance standards. I support EPA's interpretation that this is analogous to their General Counsel Opinion No. 43 (6/11/76). In New York State one facility requested authorization to use the existing intake of a once-through-cooling electric power plant as the intake for a new electric power plant, and, alternatively, the discharge of the once-through power plant as the intake to the new power plant.

I have required a separate and distinct intake for the new power plant. If the effluent of the existing power plant was to be used as input water to the new power plant, I would require that the intake of the existing power plant should meet new-plant standards.

For municipal water supply intakes, I propose not requiring new cooling water intake standards. Under most circumstances, the municipal intake will be mitigated under the terms of the state water supply permit and other laws. I support EPA's proposal that, if more than 50% of the municipal water supply utility is used to provide cooling water, it should comply with 316(b) standards. This would prevent the ruse of creating a municipal water supply district for the primary purpose of supplying industrial cooling water.

****

Issue 8: Proposal not to regulate facilities that discharge to a publicly-owned treatment works (POTW).

Recommendation 8: I believe that this is reasonable only for facilities that draw water from a municipal water supply utility, as regulated in Issue 7. I do not believe it is reasonable for cooling water intakes where cooling water is taken directly from the waters of the U.S., nor where water is taken from a second facility that withdraws water from the waters of the U.S.

Discussion 8: When water is taken from a municipal water supply utility and discharged to a POTW I agree that limits imposed by both public facilities will limit the quantity of water involved. My experience is that facilities that qualify are either small closed-cycle evaporative cooling electric power plants, electric power plants serving as a steam host to industry or supplying a municipal steam systems, and sometimes employ dry condenser cooling.

However, facilities taking cooling water directly from waters of the U.S. or from a secondary facility that withdraws cooling water from waters of the U.S. should be subject to the new facility performance standards. One example is the S. A. Carlson facility in Jamestown, NY. While not a new facility, it was withdrawing cooling water from a small stream (Chadakoin River), and returning discharges to the stream at temperatures in excess of 100° F. After mitigation, the facility (which still withdrew cooling water from waters of the U.S.) installed closed-cycle cooling, greatly reduced its intake flow, and sent its blowdown to the municipal POTW. This is a reasonable arrangement, but it would not be if the improved intake and closed-cycle cooling were not required.

As stated previously, setting up an intermediate company to withdraw the water should not excuse an intake system from meeting new facility performance standards; the impacts are the same no matter which company is doing the withdrawing.

****

Issue 9: Environmental impacts associated with Cooling Water Intake Structure (p.

49071-49074, Supp. Info. Sections A, B, and C only.

Recommendation 9: The text is good, but omits (and should add) a critical, additional discussion focusing on limits to the volume if intake waters.

Such a section should discuss the following considerations for weighing environmental impacts:

1. The negative environmental impacts of cooling water intake structures killing susceptible aquatic life increase in direct proportion to increases in the volume of water used (capacity).
2. Once-through cooling typically uses 100 times more water, and has 100 times the impact on aquatic life, than evaporative closed-cycle cooling, a readily-available pollution control measure.
3. Once-through cooling uses more than 2,200 times more water, and has more than 2,200 times the impact on aquatic life, than dry condenser cooling, another readily-available pollution control measure.
4. Unlike closed-cycle recalculating cooling systems (which treat the pollutant *heat* and minimize the discharge of this pollutant to the waters of the U.S.), once-through cooling systems take in vast quantities of waters for the sole purpose of dilution instead of treatment, of the pollutant *heat.*
5. Given the direction of regulation and the ability to incorporate existing mitigative technologies, once-through cooling at new facilities should be considered inconsistent with the goals of the Clean Water Act at 33 USC 1251(a)(1) and (6), pollution discharge elimination procedures at 33 USC 1314(c), and the standard of performance definition under 33 USC 1316(a)(1).

Discussion 9: To elaborate on the recommendation, ***Heat*** is explicitly listed as a named "pollutant" in the definitions at 33 USC 1362(6). More specifically, 150° F heat, the temperature of steam in a power plant condenser, meets the definition of "toxic pollutant" at 33 USC 1362(13), as it would kill and/or injure organisms.

Closed-cycle recirculating cooling systems treat the pollutant and minimize the discharge to waters of the U.S. The volume of water they use, and hence the capacity of their cooling water intake, is 100 to 2,200 times less than once-through cooling, with 100 to 2,200 times less impact on the propagation and survival of aquatic life in the waters of the U. S.

Once-through cooling systems simply dilute the pollutant before discharge, a practice that is permitted for no other pollutant. Even for transient pollutants like BOD or dissolved chlorine gas, treatment is required to reduce or remove the pollutant, and mere dilution is never permitted as an in-plant "process." (That is, digestion or de-chlorination would typically be required, respectively.) But for once-through cooling systems associated with a thermal discharge, dilution instead of treatment has been permitted, with huge effects on aquatic life. It is the taking of this huge volume of dilution water that is responsible for the very large capacity requirements of once-through cooling water intake; which in turn results in injury to or death of many billions of organisms every year.

These avoidable impacts, and this relationship of volume:mortality/morbidity, need to be added to this section.

****

Issue 10: Permitting once-through cooling for new facilities.

Recommendation 10: Once-through cooling systems should not be permitted for any waters of the U.S. unless an affirmative showing is made that the location, design, construction, and capacity of such system minimizes adverse environmental impacts to the same or greater extent than dry condenser cooling with the most effective screening, such as "Gunderboom."

Discussion 10: I believe that the low impingement/entrainment mortality levels that dry condenser cooling serves as the starting point Best Technology Available assessment for all competing technologies at new facilities, including evaporative and once-through cooling. I believe alternate technologies which meet or exceed the dry cooling level could be approved as BTA.

It is potentially possible that a once-through cooling system could meet such a standard. For example, a once-through system that used processed sewage for cooling might kill no fish, wildlife, or shellfish and consume less energy than closed-cycle cooling options. If it additionally met all water quality standards for the discharge it could potentially meet my proposed "alternative technology exemption"--demonstrating that it minimized adverse environmental impacts to the same or greater extent than would have been achieved by dry condenser cooling.

A Gunderboom marine life exclusion system is another potential alternative technology that might meet the standard. Studies would have to show that it did not impinge, injure, or kill eggs, larvae or fish from its through-fabric water velocity, and that seals and seams effectively prevented organisms from passing around the boom.. My experience indicates that the gunderboom would have to be sized large enough so that the target through-fabric velocity was 0.01 ft/sec to protect the eggs and larvae of striped bass. This is a 50 times lower velocity than EPA's proposed limit of 0.5 ft/sec. The applicant would have to demonstrate that injury and mortality to organisms was less than or equal to that expected from a dry cooling system to meet the "alternative technology exemption."

****

Issue 11: What Constitutes Adverse Environmental Impact Under This Proposed Rule (Part 1of 10) – Discussion of problems under 1977 316(b) draft guidance. (p. 49074, Supp. Info. VII. D., paragraphs 1 and 2)

Recommendation 11: I concur with EPA's assessment in paragraphs 1 & 2 of Supp. Info. VII. D., p. 49074. and recommends as a solution New York's approach outlined as the "second alternative" toward the end of Page 49704

Discussion 11: While the 1977 guidance had a good definition that "[a]dverse aquatic environmental impacts occur whenever there would be entrainment or impingement damage as a result of the operation of a specific cooling water intake structure," it errs by not requiring that adverse environmental impacts be minimized.

****

Issue 12: What Constitutes Adverse Environmental Impact Under This Proposed Rule (Part 2of 10) – EPA is not proposing language today defining adverse environmental impact, but may do so in the final rule (p. 49074, Supp. Info. VII. D. paragraphs 3 and 4)

Recommendation 12: The regulation must define this phrase, it is critical for understanding and implementing 316(b). I propose that EPA adopt the following definitions:

- **"Adverse environmental impact"** shall mean any harmful, unfavorable, detrimental or injurious effect on individual organisms of fish, wildlife or shellfish or their eggs or larvae; or the water, land, or air resources of the U.S., its states, territories, or possessions; or on human health, welfare, or safety; or on the human enjoyment of those resources.

- **"Minimize"** shall mean to reduce to the smallest possible amount, extent, size, or degree.

- **"Minimize adverse environmental impact"** shall mean to reduce to the smallest possible amount, extent, size, or degree the adverse environmental impacts in the following order of priority:

    - **First:** To comply with federal environmental laws and fish and wildlife laws, especially the Clean Water Act and Clean Air Act, and the rules, regulations, standards, criteria, orders, classifications, limitations, certifications, antidegradation policies, etc. there under. In addition for delegated Section 402 or 404 programs, all applicable environmental and fish and wildlife laws, rules, regulations, standards, criteria, orders, classifications, limitations, certifications, antidegradation policies, etc. of the state or other political subdivision to which the delegation has been made.

- **Second:** To take any additional measures necessary to restore the chemical, physical, and biological integrity of the waters of the U.S., in order to comply with the policies of 33 USC 1251, and in the case of a delegated permit program, any similar, no less protective policy contained in the laws of such delegated state or other political subdivision.

- **Third:** Among any remaining adverse environmental impacts, as determined pursuant to the National Environmental Policy Act or applicable equivalent state environmental impact assessment law, to avoid and minimize those impacts to the extent practicable, consistent with social, economic and other considerations.

Discussion 12: I believe that not having a simple, clear definition of "adverse environmental impact" hinders the advancement of the goals of the Clean Water Act. I continue to stress that EPA's emphasis should be placed on minimizing adverse environmental impact through the many, readily available pollution control techniques. Attempting to set higher thresholds for "adverse" will perpetuate debates over measurement and interpretation while fish mortalities continue without sufficient mitigation efforts. Instead the emphasis should be on avoidance and minimization.

****

Issue 13: What Constitutes Adverse Environmental Impact Under This Proposed Rule (Part 3of 10) – EPA's "potential alternative 1" Entraining 1% or more of the aquatic organisms in the near-field area in a 1-year study would constitute an adverse environmental impact. (p. 49074, Supp. Info. VII. D. paragraphs 5 and 6.)

Recommendation 13: As proposed, I believe this approach is **not** consistent with the water-quality-based quality programs within EPA , the Endangered Species Act, nor state fish and wildlife laws. ~~Those~~ EPA's water-quality-based programs specifically assure that all commercial, recreational, and socially important species (like endangered/threatened species) are 100% protected ,and protect 99% of all other species. "Potential alternative 1" does not. Under "potential alternative 1" there would be no determination of "adverse environmental impact" even if all endangered species were killed, as long as the grand total of organisms killed was less than 1% of the sum of near-field organisms comprised of all species. I recommend EPA drop this alternative as violating state and federal laws and the Clean Water Act antidegradation policy

Discussion 13: While attractive at first glance, this approach has many substantial and, I think, fatal problems. "Potential alternative 1" seeks to protect 99% of the organisms, whereas EPA's guidance in water quality-based programs is to protect 99% of the species, plus all socially, recreationally, and commercially important species. This is very different, and "Potential alternative 1" is far less protective than what I believe the law requires.

First, "potential alternative 1" treats all organisms the same regardless of species, so a rapidly-reproducing *Daphnia sp.* is accorded the same weight as an endangered sea turtle or a young striped bass for the purpose of counting 1% of the near-field organisms. This is insufficiently sensitive. Further, it is clearly inconsistent with EPA's guidance for setting action levels in water quality-based programs. Typically in such programs the species are arrayed by sensitivity, from most sensitive to least. The first cut-off line is set to protect 99% of the species. However, if any socially, commercially, or recreationally-important species lie within that 1%, the cut-off line is moved to assure the protection of such important species. This may result in protecting 99.999% of the species to properly implement the guidance. "Potential alternative 1" has no such provision and does not look at species. If it did, it would find in most situations that a great many socially, commercially, or recreationally-important species are susceptible and are indeed being killed by impingement/entrainment in the near-field.

Second, a 1-year study, which will doubtlessly involve sampling and sampling bias, might not be sufficiently accurate to portray all the species and the variability of their numbers to be encountered over the 50-year life of the facility associated with the cooling water intake.

A third difficulty is defining the extent of the near-field area, especially in dynamic systems like tidal rivers.

A fourth difficulty is that rather than minimizing adverse impact, this approach would permit the unnecessary killing of endangered, threatened, commercially important, and recreationally important game and protected species. These species are a public trust resource, and usually protected by State and federal fish and wildlife laws. Rather than minimize mortality to the lowest levels, EPA is essentially establishing an entitlement for cooling water intake operators to kill these protected species in violation of state and federal laws. Besides the usual important fish species in my home state we have had canvasback and redhead ducks killed in power plant intakes, EPA sites endangered sea turtles in Florida, and I know seals have been killed by drowning when entrained in the water intake tunnel of the Seabrook plant in New Hampshire.

Fifth, some states have species-specific water quality standards, such as salmon propagation or anadromous fish passage. Permitting avoidable mortality to occur would appear to violate such a water quality standard. Even where a higher attained use is not designated, any impairment could be a violation of the antidegradation policy.

I feel this approach is erroneous, and in some circumstances may be unlawful, and I urge EPA not to promulgate it.

****

Issue 14: What Constitutes Adverse Environmental Impact Under This Proposed Rule (Part 4of 10) – EPA's "Potential Alternative 2" – Impingement and entrainment would constitute an adverse environmental impact, however EPA would develop additional guidance to define when the magnitude is great enough to be deemed adverse. (p. 49074, Supp. Info. VII. D. paragraphs 8.)

Recommendation 14: This approach is still problematic and inconsistent with the requirements of technology-based standards, new source performance standards, and antidegradation policy of the Clean Water Act. Rather than simply striving to minimize adverse impact, some degree of reasonably avoidable mortality would be O.K., although impingement and entrainment are adverse environmental impacts they are at the same time not adverse environmental impact. This is "Catch-22" logic, and I urge EPA to instead select "Potential Alternative 3."

Discussion 14: I am very concerned that EPA to is taking what should be a simple concept and turning it into an unlawful, arcane, and unworkable regulatory schemes. Many of the proposed alternatives are inconsistent with the technology-based standards of Sections 301, 304, and 306 of the Clean Water Act (33 USC 1311, 1314, 1316).

It is fundamental to the Clean Water Act that technology-based limitations are to protect the best uses of the water. Water-quality based limitations are to correct problems where the best uses are yet to be attained. Sections 301 and 304 drive the use of better and better technology to reduce pollution. Section 306 mandates technology for new facilities, which have the most flexibility to incorporate new, better, technology at an efficient cost. Section 302 provides for more stringent standards when, despite these measures, water quality standards and designated uses are still not attained. Section 303 provides further back-up through setting Total Maximum Daily Loads and Antidegradation protection measures. EPA's rulemaking must comply with and implement these principles.

Instead, many of the alternate approaches offered by EPA in the "Supplementary Information" take the reverse approach, and avoid implementing any technology-based limits until after aquatic life/wildlife uses are violated. This is inconsistent with the law and contrary to EPA's own antidegradation guidance. Therefore, I subscribe to the approach EPA refers to as "a third alternative" on the last paragraph on page 49074, and I commend that approach to EPA. I strongly urge EPA to consider my general and technical comments carefully, and again offer my proposed, plain-English definition "adverse impact" for EPA's consideration.

See also Recommendation 11 and Discussion 11.

****

Issue 15: What Constitutes Adverse Environmental Impact Under This Proposed Rule (Part 5of 10) – EPA's "Potential Alternative 3" – "Adverse environmental impact" defined as "any impingement or entrainment of aquatic organisms" similar to the State of New York approach. (p. 49074, Supp. Info. VII. D. paragraphs 9.)

Recommendation 15: I wholeheartedly support this approach. After 25 years of experience implementing the delegated NPDES program under a water quality standard that parallels 316(b), my home state's natural resource agency has found this approach works. I commend to EPA the draft language I provided in Recommendation 12.

Discussion 15: I feel this approach is most consistent with the purposes of the Clean Water Act, with protecting species under federal and state Endangered Species Acts, and minimizing mortality on protected public trust fish and wildlife resources. I do not believe that any of the other potential alternatives identified by EPA meet the responsibilities under these laws.

****

Issue 16: What Constitutes Adverse Environmental Impact Under This Proposed Rule (Part 6 of 10) – EPA's "Potential Alternative 4" – Defines adverse environmental impact in relation to reference site similar to biocriteria like the "Index of Biological Integrity."

Recommendation 16: As I mentioned in my submission to the 316(b) workshops, I believe this approach is unworkable because 1) There are no pristine, un-impacted sites to serve as a baseline, and 2) rather than avoiding the impacts in the first instance, the project would operate, kill organisms, and only then measure what was lost against a reference site, if such existed.

Discussion 16: Most cooling water intakes and associated power generation or industry are located near other population and industrial centers where the environment has been altered by human activity and pollution for decades, if not centuries. For example, most estuaries like the Hudson River have been altered by centuries of environmental injuries.. Other similar estuaries have been similarly impacted from domestic and industrial pollution, dredging, upland erosion, interception of fish passage by dams, loss of littoral habitat by bulkheading and fill, loss of wetland systems, alteration of flow by river regulating reservoirs and hydropower dams upstream, legal and illegal harvest, municipal water supply withdrawals and out-of-basin transfers, toxic sediments, introduced exotic species, and the cumulative impact of decades of multiple, very large cooling water intakes. What could one possibly use as a "base case" for a pristine version of the Hudson River for an Index of Biological Integrity (IBI)? How could an agency apportion observed changes to decide what was caused by cooling water IBI withdrawals, and what was caused by any of the many other simultaneous anthropogenic and natural impacts?

There is a role for sharing data from one site to close-by sites on the same water body as an indicator of species abundance and as a predictor of potential species impingement/entrainment for proposed facilities. But this must be done very cautiously, as nearby sites may have very different physical characteristics that can affect the composition of the biological community. Without more details I am very skeptical that an IBI-type approach would not work, or at best could only measure what was lost by not employing the Best Technology Available in the first instance.

****

Issue 17: What Constitutes Adverse Environmental Impact Under This Proposed Rule (Part 7 of 10) – "Potential Alternative 5" EPA requests comment on a definition of adverse environmental impact that would focus on (1) the protection of threatened, endangered, or otherwise listed species; (2) protection of socially, recreationally, and commercially important species; and (3) protection of community integrity, including structure and function.

Recommendation 17: This alternative would fail to implement appropriate goals and policies under the Clean Water Act. If EPA continues to pursue this policy it will continue to foster what it *says* it wants to end:

> *"The initial determination of environmental impact has often relied on population modeling, which* ***given its inherent complexity, has yielded ambiguous or debatable results. One result has been*** *that many section 316(b) permitting* ***decisions have predominantly focused on determining whether a cooling water intake structure is causing an adverse environmental impact.*** *Given that both the methods for making such determinations and the standard regarding what constitutes an "adverse" environmental impact were not precisely defined,* ***permitting authorities have had to*** *exercise significant judgment and* ***focus significant time and effort to determine what requirements should be imposed*** *under section 316(b)."* (p. 49074, **emphasis added.)**

Rather than creating a common-sense definition of "adverse," or issuing meaningful national standards, this alternative would be continuing "ANALYSIS PARALYSIS." Such studies will always yield debatable results in the short term, it would be more reasonable and cost effective for dischargers to invest in preventing or minimizing impacts. See my discussion for an elaboration.

I recommend that EPA accept the definitions I have offered in Issue 12 of these comments, minimize the impacts, and effectively administer the public resource, consistent with its duties under sections 316(b), 304(c) and 306 of the Clean Water Act (33 USC 1326(b), 1314(c), and 1316).

Discussion 17: In New York's Hudson River, regulated dischargers, conservation groups, an endowed research foundation, and the State have spent millions of dollars and more than 25 years trying to characterize **a subset** of the issues EPA would require for determining whether or not the impacts would constitute "adverse impact." The state agency, regulated parties, and citizen conservation groups **still disagree on the interpretation**, despite probably the best data set on the planet, full agreement on sampling design, data collection, certain analysis techniques, and many aspects of modeling. This alternative would repeat this impossible "ANALYSIS PARALYSIS" approach for every NEW thermal discharger, instead of requiring pollution control equipment be installed before the plant is built.

(The work sited has been carried out under the Hudson River Settlement of 1981 for the State PDES permit for Bowline, Roseton, and Indian Point generating stations, which created, among other things, cooperative in-river and at-plant monitoring of aquatic organisms, and created the independent Hudson River Foundation to carry out river research.)

****

Issue 18: What Constitutes Adverse Environmental Impact Under This Proposed Rule (Part 8 of 10) – "*Potential Alternative 6*"-- *The EPA may consider definitions to be* submitted by the Utility Water Action Group measures for assessing when adverse impact is occurring by water body type. (p. 49075, paragraph 3).

Recommendation 18: Section 303 of the Clean Water Act (33 USC 1313) Congress gives the States, EPA, interstate agencies, territories, and tribes the authority to adopt water quality standards after due process. States and other qualifying jurisdictions have the prime responsibility for classifying waters according to their best use, setting standards to maintain their biological, chemical, and physical integrity to meet those designated uses, and to implement antidegradation policies to protect higher attained uses. Industry groups have not been given authority ~~to participate~~ in this regulatory process.

Discussion 18: I appreciate that this might be a good-will gesture; however, industry-driven waterbody classifications are likely to be overly self-serving, resulting in inconsistent use designations, and unacceptable alteration of the antidegradation policy.

In New York State, classes "E" (industrial use) and "F" (sewage conveyance) were eliminated in 1967, so that all perennial waters must support fish propagation and survival. I also call to EPA's attention that New York State has just added 152 miles of the Hudson River to its 305(b) Priority Water Bodies list as "impaired" for "aquatic life propagation" due to the cumulative impacts of multiple once-through cooling water intakes of thermal dischargers. This is based on 24 years of data quantifying the impact of these cooling water intakes in reducing the September 1 young-of-year population of several important species of fish.

The UWAG proposal is troublesome, and I request that a with a copy under the Freedom of Information Act.

****

Issue 19: What Constitutes Adverse Environmental Impact Under This Proposed Rule (Part 9 of 10) "Potential Alternative 7"– Should EPA define adverse environmental impact more broadly and consider non-aquatic adverse environmental impacts as well? (p. 49075, paragraph 4).

Recommendation 19: See my suggested definitions at Recommendation 12. Yes, adverse environmental impact is broader. However, a panoply of environmental laws and regulations already exist to address these impacts. These laws and regulations have already balanced public need, public health and welfare, risk, costs to the public and the regulated parties, etc. EPA should simply require compliance with these laws and regulations. A "wholly disproportionate cost" test could be employed, but only after there has been compliance with the standards of all applicable laws. In my experience to date is that the loss in efficiency is not wholly disproportionate to the benefits of reduced flows and concomitant reduction in impact; for new plants the loss in efficiency averages between 0.5 to 2% for a 100- to 2,000 times reduction in water consumption and impact.

Discussion 19: Adding a pollution control device to an industrial process will almost invariably cause some decrease in process efficiency and internalization of costs versus externalizing costs of environmental impacts.

The pollution control devices that reduce cooling water intake volume, and reduce the mortality of aquatic life probably cause some decreases in efficiency and increases in cost to the discharger versus unfettered operation, but that is completely consistent with the concept of "polluter pays." Our mutual concern should not be with maximizing the profit for the discharger, but assuring that all environmental and fish and wildlife laws are met.

Using evaporative closed cycle cooling reduces the volume of water used (capacity) by a thermal discharger, and proportionally the aquatic impacts, by about 100 times, compared to once-through cooling, dry evaporative closed-cycle cooling with about 2,200 times reduction in capacity and impact. A recent application for a new combined-cycle power plant in New York City (Keyspan Ravenswood, 250 MW) compared the loss of electric production for 2 forms of closed-cycle cooling against a once-through cooling base-case. **The loss in efficiency was less than 1% for plume-abated mechanical draft evaporative cooling towers under all conditions for a 100-times reduction in impact.** (%MW reduction compared to once-through vs. air temp. in °F: **0.76%**, 90°; **0.68%**, 55° [annual average temp]; and **0.64%**, 20°.) The numbers for a 2,200 times reduction in water volume and impact with dry cooling is 3.9%, 90°; 1.2%, 55°, and 1.0%, 20°. A couple of percent cost to meet environmental standards is a relatively marginal expense, which should not determine whether or not a project should be permitted or built.

****

Issue 20: What Constitutes Adverse Environmental Impact Under This Proposed Rule (Part 10 of 10) "Potential Alternative 8"– *EPA is taking comments on whether to alter* the 316(b) standard of "best technology available" to conform with the 316(a) of "balanced indigenous population" standard.

Recommendation 20: Such a shift would weaken public policy, and would result in environmental damage and "analysis paralysis" instead of preventing the pollution in the first place. It may also be contrary to the intent of the Clean Water Act and case law. EPA should impose reasonable nationwide pollution. I am concerned that such a change would be inconsistent with Clean Water Act antidegradation requirements and guidance in the EPA Water Quality Standards Handbook.

Discussion 20: My home state has evidence that many once-through cooling water intake structures impair fish propagation. To gather the detailed information that follows took 24 years and millions of dollars of monitoring, research, and analysis. Each new cooling water intake structure should not have to repeat the mistakes of the past.

Here are the statistics for the 152-miles of Hudson River from the southern tip of Manhattan to the head of tide at the Federal dam at Troy, NY. The figures indicate the percentage reduction in the September 1 young-of-year population due to the mortality caused by the cumulative impact of the major once-through cooling intakes; the lower end of the range makes certain assumptions about through-facility survival of entrained organisms, the high end of the range assumes 100% mortality. The years presented are those with the highest reduction for that species of the 24 years of data:

- 25-79% reduction in spottail shiner (1977)
- 27-63% reduction in striped bass (1986)
- 52-65% reduction in American shad (1992)
- 44-53% reduction in Atlantic tomcod (1985)
- 39-45% reduction in alewife and blueback herring combined (1992)
- 30-44% reduction for white perch (1983), and
- 33% reduction for bay anchovy (1990)

This conditional mortality rate data shows population in an unbalanced state compared to the native or "indigenous" state without cumulative cooling water withdrawal impacts. However, it is fair to predict that industry representatives are ready and willing to argue that this does not indicate an unbalanced population.

This alternative would create more opportunities for endless delay and debate. EPA should adopt the plain language presented by My in Recommendation 12, and should prevent pollution nationally through good standards for all new intakes. Employing the 316(a) standard for 316(b) would amount to backsliding.

I am concerned that a change from "Best Technology Available to minimize adverse impact" to "balanced indigenous population" would be inconsistent with Clean Water Act antidegradation requirements and guidance in the EPA Water Quality Standards Handbook. Antidegradation requires protecting designated uses and higher attained uses. In particular, the guidance for "Aquatic Life/Wildlife Uses" states:

> *"Water quality should be such that it results in **no mortality** and no significant growth **or reproductive impairment of resident species.** Any lowering of water quality below this full level of protection is not allowed"* (Emphasis added, Water quality standards handbook: second edition. EPA-823-B-94-005a, page 4-5. USEPA 1994.)

However, this proposed change would lower the water quality standard from "minimization" to permitting large levels of mortality, which seems inconsistent with antidegradation. I note that 316(a) applies to a discretionary variance that should not become a universal mandatory requirement that supercedes the plain language of 316(b).

****

Issue 21: Proposed Section 316(b) New Facility Regulatory Framework (1 of 5)–**Grouping water bodies into 4 categories**. (p. 49076 paragraph 2 through p. 49178 paragraph 1)

Recommendation 21: I support EPA's identification and grouping of water bodies into 4 categories for purposes of assigning protection requirements pertinent to each. However, I strongly disagree with the sub-categorization based on littoral zone (See Recommendation 24). The definition for "lake" should be broadened to include "pond," which is similar to a lake but has no wave-swept beach free of vegetation. The "pond" classification should be included with the "lake" and "reservoir" categories, so it would read, "lake, reservoir, or pond."

Discussion 21: The categories seem reasonable, with the addition noted.

****

Issue 22: Proposed Section 316(b) New Facility Regulatory Framework (2 of 5)–

Capacity requirements, (p. 49077 to 49078)

Recommendation 22: I support EPA's proposed capacity requirements. I strongly support the river and stream limitation of "no more than the more stringent of 5% of the source water mean annual flow or 25% of the source water 7Q10" and would recommend adding this important concept to the regulatory framework. The lake-reservoir-pond requirement is essential to preserving the ecology of ponded waters, and agree that the "[t]otal design intake flow must not upset the natural stratification of the source water." (EPA might consider whether the phrase should read, ...natural *thermal* stratification... .) And, while new, I think the proposed estuary-tidal river requirement is logical, and I support it.

Discussion 22: Good work!

****

Issue 23: Proposed Section 316(b) New Facility Regulatory Framework (3 of 5)– **Maximum intake velocity cap of 0.5 feet per second (fps)** (p. 49077 to 49078).

Recommendation 23: I strongly support this maximum velocity limitation as a means of reducing fish mortality. However, to be effective it should be coupled with an exclusionary screen. Unless fish are physically excluded, or have a barrier that they can perceive and swim away from, they will be entrained even at these low velocities. I therefore strongly urge that screening be made part of this requirement.

Discussion 23: Without a physical barrier, fish will not perceive any danger, and will be entrained into the plant. I have found that some fish, fully capable of swimming out against the intake velocity, often do not do so. I do have at least one existing electric generating plant in my home state that uses no intake screens (Milliken Station, Lansing, NY). They periodically reverse flows through their condensers in order to backflush out all the dead fish that accumulate and clog their condenser tubes.

I have studies to show this velocity works effectively with 2 mm-spaced wedgewire-type screen. This velocity may be too high for finer-mesh screens, which will impinge fish eggs and larvae. And for gunderboom-type barriers, 0.05 fps is the maximum velocity that does not impinge eggs. I anticipate that, for finer screens, lower velocities could be imposed as a condition under §125.84(f) and (g).

****

Issue 24: Proposed Section 316(b) New Facility Regulatory Framework (4 of 5)– **Differing degrees of protection for intakes within the littoral zone, outside the littoral zone, and within 50 meters of the littoral zone** (p. 49077 to 49078).

Recommendation 24: I strongly support the measures EPA has proposed for intakes within the littoral zone and in estuaries and tidal rivers as a good national standard of performance.

However, I strongly feel that the level of protection suggested for littoral zones should be applied to non-littoral zones as well. I am concerned that the lesser degree of protection is inconsistent with applicable antidegradation requirements for protecting aquatic life and wildlife uses. I urge EPA to drop the lesser degrees of protection for non-littoral areas and have the stronger standards apply, irrespective of light intensity.

Discussion 24: The littoral zone approach is problematic. First, life in the deep water areas is no less valuable, less important, or any less a public trust resource than that found in shallower littoral waters. It should be afforded the same degree of protection.

Second, these deep waters are critical habitats for many important species and no less worthy of full protection . For example, in the deep, oligotrophic Finger Lakes of New York these areas are the home of the mysid shrimp, *Mysis relicta*, an important food for the lake trout, rainbow smelt, and alewives, found at that depth because of the low light levels.

In marine waters, deep waters these are the areas where juvenile winter flounder have been entrained by offshore dredging projects. These are areas of important surf clam beds, and both the food for these clams and the spawn of the clams would be subject to entrainment by cooling water intakes. They are also important feeding areas for endangered sea turtles, and a variety of finfish and zooplankton spawn at depth in these areas. Also, these are areas where many species migrate parallel to the shoreline.

Third, fewer requirements could result in new power plants and other thermal dischargers preferentially selecting these site, concentrating their impacts there. Instead, to avoid negative impacts, I recommend the same high level of protection for all sites.

Fourth, the littoral zone changes with time, and can be expected to change over the life of the facility. Efforts to clean up lakes have increased light penetration and the size of the littoral zone. I have seen secci disc readings in Lake Erie go from several inches in the 1960's, to more than 40 feet in the 1990's. Other effects have resulted in increased light penetration, such as acidification from acid rain, and increases in filter-feeding bivalve populations.

For this and other reasons I feel that the "zone of rooted aquatics" does not delimit the only area worthy of maximum protection, all areas should receive the degree of protection recommended for the littoral areas.

I am concerned that the lesser degree of protection is inconsistent with applicable antidegradation requirements for protecting aquatic life and wildlife uses. EPA's "Water

Quality Standards Handbook: Second Edition provides guidance for antidegradation that apply to "Aquatic Life/Wildlife Uses" (page 4-5) states:

> *"Water quality should be such that it results in **no mortality** and no significant growth **or reproductive impairment of resident species.** Any lowering of water quality below this full level of protection is not allowed"* (Emphasis added).

I believe this antidegradation requirement would apply to this current rulemaking effort. I interpret that the lesser protection proposed for non-littoral areas would not meet the antidegradation policy. I therefore urge EPA to afford the degree of protection afforded to the littoral zone, estuaries, and tidal rivers to all areas.

****

Issue 25: Proposed Section 316(b) New Facility Regulatory Framework (5 of 5)– General comment on approach (p. 49079, paragraph 1 through 3).

Recommendation 25: I strongly support nationwide application of the concept of minimum technology requirements for use in section 316(b) determinations, including the velocity cap, capacity requirements, screening requirements, plus additional requirements that may be imposed by the director.

I believe, however, that the level of protection required for the "littoral zone" should apply for the non-littoral zone in each of the 4 categories of waters in the proposed rule.

I also recommend an additional alternative that could permit once-through cooling under certain circumstances that may do a better job of avoiding and minimizing adverse environmental impacts and meet all applicable laws and water quality standards. I believe it will work better than the "non littoral zone" concept.

I recommend an exemption to permit alternate technologies which achieve the same degree of fish, wildlife, and shellfish protection as the new facility technology-based standard for Best Technology Available. Such an exception could be worded as follows:

> Equivalent-performing alternate technology exception – An alternate technology that kills fewer aquatic organisms, meets all legal requirements, and minimizes adverse environmental impact [see definition offered in Recommendation 12] may, at the discretion of the Director, be substituted as equal to BTA.

Such an exception could permit once-through cooling from public treatment works wastewater, or from fishless waters, or potentially from very fine-pore filters with exceptionally low velocities, like gunderbooms or porous dikes, BUT only if they work as well or better than closed cycle cooling with all the additional requirements.

With these strengthened provisions, I believe EPA has an outstanding approach that would simplify permitting, increase certainty, eliminate "analysis paralysis" from needlessly complex criteria, level the playing field nationally among states, and assure equal protection of migratory stocks that cross state lines.

I further believe this is a more efficient use of applicant and government agency resources. Money would be spent on pollution prevention, instead of lengthy, and often ambiguous studies, analysis, disagreement, debate and deliberation, while mortalities continue.

<u>Discussion 25:</u> None.

****

<u>Issue 26:</u> Requiring dry cooling systems (p. 49080, paragraph 18 and following)

<u>Recommendation 26:</u> I support requiring dry condenser cooling as Best Technology Available for new facilities. I believe this would be a simple, effective standard that would minimize or eliminate discharge of pollutants, consistent with the goals of the Act in 33 USC 1251(a)(1), and would encourage locating facilities away from major water bodies. However, it would be folly to discourage alternate technologies that achieve mortalities of fish, shellfish, and wildlife as low, or lower than that achieved by a dry condenser cooling design. Therefore, I endorse such an exemption for alternate technologies that meet or exceed the same level of protection as dry condensers.

<u>Discussion 26:</u> See wording for alternate technology exemption in Discussion 25. In this case it would state that best technology available is dry condenser cooling, and alternatives that achieve the same level of protection as dry condenser cooling may be substituted as equal to BTA.

****

<u>Issue 27:</u> Comments sought on requiring the BTA requirements EPA has proposed for estuaries and tidal rivers to apply to all facilities, regardless of their location. (Page 49082, second paragraph.)

<u>Recommendation 27:</u> NYSDSEC strongly endorses this alternative for numerous reasons, including that it is the only one that meets antidegradation and state fish, wildlife, and shellfish laws. Furthermore, EPA's economic data shows that the cost of additional protection is affordable with the total national annualized compliance cost of $16.4 million.

<u>Discussion 27:</u> See Issue 24 Recommendations and Comments.

****

Issue 28: Comments sought on alternate regulatory approach with 3 tiers of risk analysis and about 22 decision points before applying technology-based limits to the new facility (Page 49082, 4th paragraph.)

Recommendation 28: I am very concerned that EPA to is taking what should be a simple concept and turning it into an unlawful, arcane, and unworkable regulatory schemes. Many of the proposed alternatives are inconsistent with the technology-based standards of Sections 301, 304, and 306 of the Clean Water Act (33 USC 1311, 1314, 1316).

It is fundamental to the Clean Water Act that technology-based limitations are to protect the best uses of the water. Water-quality based limitations are to correct problems where the best uses are yet to be attained. Sections 301 and 304 drive the use of better and better technology to reduce pollution. Section 306 mandates technology for new facilities, which have the most flexibility to incorporate new, better, technology at an efficient cost. Section 302 provides for more stringent standards when, despite these measures, water quality standards and designated uses are still not attained. Section 303 provides further back-up through setting Total Maximum Daily Loads and Antidegradation protection measures. EPA's rulemaking must comply with and implement these principles.

Instead, many of the alternate approaches offered by EPA in the "Supplementary Information" take the reverse approach, and avoid implementing any technology-based limits until after aquatic life/wildlife uses are violated. This is inconsistent with the law and contrary to EPA's own antidegradation guidance. Therefore, I subscribe to the approach EPA refers to as "a third alternative" on the last paragraph on page 49074, and I commend that approach to EPA. I strongly urge EPA to consider my general and technical comments carefully, and again offer my proposed, plain-English definition "adverse impact" for EPA's consideration.

In addition this alternative is extremely information-hungry, and at each decision point there could be arguments about data collection, results, and interpretation. I strongly oppose this alternative.

Discussion 28: See Issues, Comments, and Recommendations 12 through 20.

****

Issue 29: Comments are sought on "state of the art studies and predictions" involving multiple decision points and 7 levels of analysis for multiple species, including cost-benefit analyses. (Page 49083, 2nd paragraph)

Recommendation 29: I strongly oppose this alternative, same recommendation and discussion as Issue 28. Additionally this alternative would violate state's rights and state fish and wildlife laws regarding killing of protected animals. I oppose the cost-benefit analysis proposed. It externalizes the costs to the public in killing public trust fish, wildlife, and shellfish resources (which are not the property of the intake operator) as the "cost," weighing it against the monetary savings of not installing pollution control technology, benefits that would accrue only to the intake operator. I object to this type of "public bears the costs for benefits to private polluters" as contrary to the principle of "polluter pays." I do not believe EPA has any right to allocate State public trust resources to be killed in this manner, especially when the means to minimize the mortality is readily available, and strongly recommend against this alternative.

Discussion 29: Same as Issue 28.

****

Issue 30: Comments are sought the suggestion on site-specific assessments as Issues 28 and 29 would not delay permitting or impose undue burden on state or federal permit writers (Page 49083, 5^{th} paragraph.)

Recommendation 30: My experience living in a state that has administered the state NPDES program since 1975 indicates that, on the contrary, this is a tremendous burden on program, staff, and state trust natural resources. EPA should instead implement the technology-based-standards approach required by the Clean Water Act. See issues, comments, and discussions 28, 12-20, and 29.

Discussion 30: See Discussion 20 for some of the impacts my home state has found in the Hudson River. After 24 years of data collection the results are still argued by the regulated parties, and New York has 152 miles of irreplaceable estuary impaired for fish propagation and survival.

****

Issue 31: Pages 49089-49091. "6. What is the role of restoration measures? ...Mandatory ...Discretionary ...Voluntary... ."

Recommendation 31: I strongly support the mandatory restoration approach as described in 6. a., which mitigates only for the adverse environmental impact that would remain after applying all other techniques for mitigating the location, design, construction, and capacity of the intake structure.

I do not support the voluntary restoration approaches listed in 6. c., where questionable mitigation may be substituted for technology-based water quality standards. Such mitigation is almost always an inadequate replacement of the species, functions, and values lost, and is inconsistent with the purposes and goals of the Clean Water Act, as explained previously.

For discretionary mitigation as described in 6. b. there is inadequate detail for us to decide its value or liability.

<u>Discussion 31:</u>

The staff of my State's natural resources agency usually address environmental impacts in the following hierarchy:

1) Avoid a negative impact to the extent practicable.
2) For those negative impacts that can't be avoided, minimize them to the extent practicable.
3) For the residual negative impact that can't be avoided or minimized, seek compensation, (replacement of function) in the following order of ranking:
    a) In-kind, on-site or as close to it as possible (same watershed).
    b) In-kind, off-site.
    c) Out-of-kind, on-site or as close to it as possible (same watershed).
    d) Out-of-kind, off-site.

This hierarchy is similar to Federal policies, (e.g. USFWS) having the common root of the Council on Environmental Quality, which oversees NEPA implementation.

****

END OF COMMENTS.

United States
Environmental Protection
Agency

Office of Water
(4305)

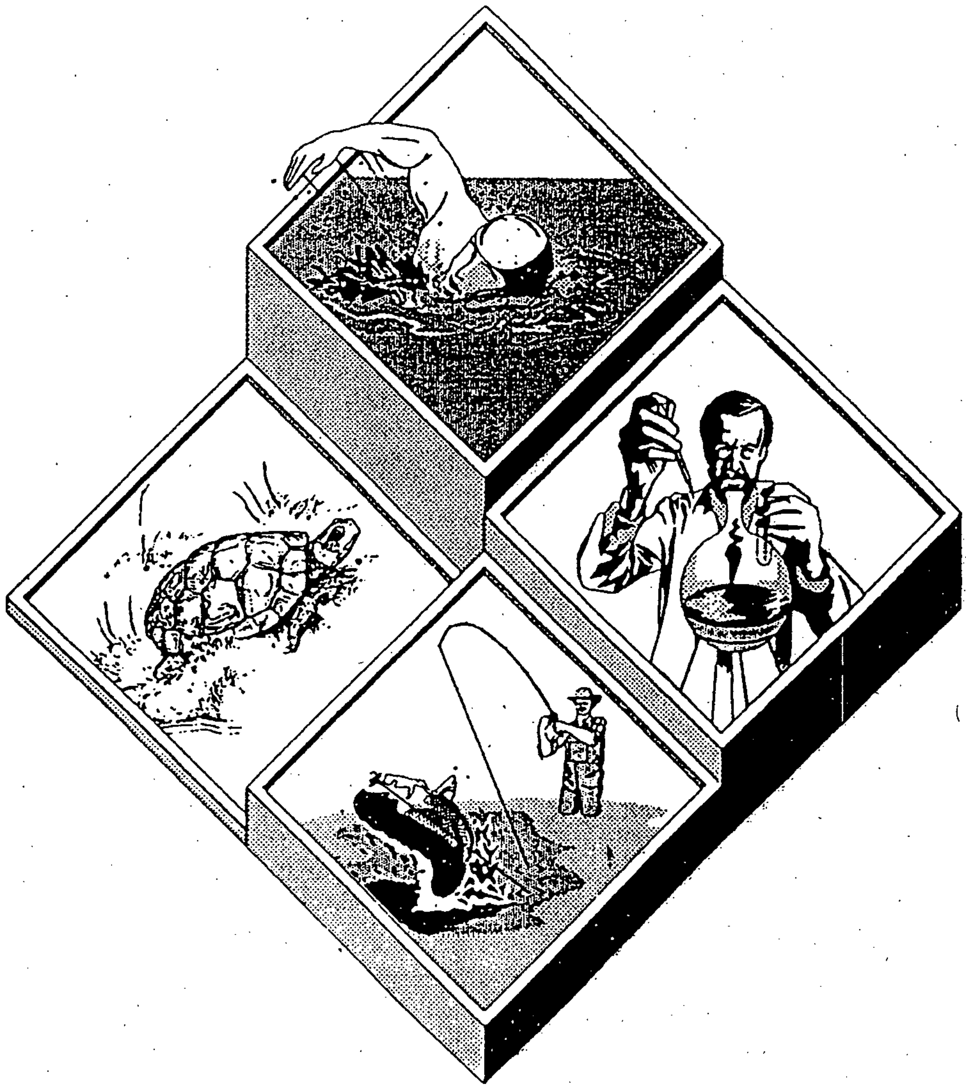
EPA-823-B-94-005a
August 1994

EPA

Water Quality Standards Handbook:

W-00-03
316(b)
Comments.1.73
ATT 1

Second Edition



"... to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."

Section 101(a) of the Clean Water Act

Contains Update #1
August 1994

3p

CHAPTER 4

ANTIDEGRADATION

(40 CFR 131.12)

Table of Contents

permit. EPA has the responsibility under CWA section 301(b)(1)(C) to determine what is needed to protect existing uses under the State's antidegradation requirement, and accordingly may define "existing uses" or interpret the State's definition to write that permit if the State has not done so. Of course, EPA's determination would be subject to State section 401 certification in such a case.

4.4.2 Aquatic Life/Wildlife Uses

No activity is allowable under the antidegradation policy which would partially or completely eliminate any existing use whether or not that use is designated in a State's water quality standards. The aquatic protection use is a broad category requiring further explanation. Non-aberrational resident species must be protected, even if not prevalent in number or importance. Water quality should be such that it results in no mortality and no significant growth or reproductive impairment of resident species. Any lowering of water quality below this full level of protection is not allowed.

A State may develop subcategories of aquatic protection uses but cannot choose different levels of protection for like uses. The fact that sport or commercial fish are not present does not mean that the water may not be supporting an aquatic life protection function. An existing aquatic community composed entirely of invertebrates and plants, such as may be found in a pristine alpine tributary stream, should still be protected whether or not such a stream supports a fishery.

Even though the shorthand expression "fishable/swimmable" is often used, the actual objective of the Act is to "restore and maintain the chemical, physical, and biological integrity of our Nation's waters" (section 101(a)). The term "aquatic life" would more accurately reflect the protection of the aquatic community that was intended in section 101(a)(2) of the Act.

Section 131.12(a)(1) states, "Existing instream water uses and level of water quality necessary to protect the existing uses shall be maintained and protected." For example, while sustaining a small coldwater fish population, a stream does not support an existing use of a "coldwater fishery." The existing stream temperatures are unsuitable for a thriving coldwater fishery. The small marginal population is an artifact and should not be employed to mandate a more stringent use (true coldwater fishery) where natural conditions are not suitable for that use.

A use attainability analysis or other scientific assessment should be used to determine whether the aquatic life population is in fact an artifact or is a stable population requiring water quality protection. Where species appear in areas not normally expected, some adaptation may have occurred and site-specific criteria may be appropriately developed. Should the coldwater fish population consist of a threatened or endangered species, it may require protection under the Endangered Species Act. Otherwise, the stream need only be protected as a warmwater fishery.

4.4.3 Existing Uses and Physical Modifications

A literal interpretation of 40 CFR 131.12(a)(1) could prevent certain physical modifications to a water body that are clearly allowed by the Clean Water Act, such as wetland fill operations permitted under section 404 of the Clean Water Act. EPA interprets section 131.12(a)(l) of the antidegradation policy to be satisfied with regard to fills in wetlands if the discharge did not result in "significant degradation" to the aquatic ecosystem as defined under section 230.10(c) of the section 404(b)(l) Guidelines.

The section 404(b)(1) Guidelines state that the following effects contribute to significant degradation, either individually or collectively:

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of ENTERGY NUCLEAR INDIAN POINT 2, LLC, ENTERGY NUCLEAR INDIAN POINT 3, LLC, and ENTERGY NUCLEAR OPERATIONS, INC. (Indian Point Nuclear Power Station)	Docket Nos. 50-247, 50-286

DECLARATION OF J. CRAIG SWANSON, PH.D. IN OPPOSITION TO RIVERKEEPER CONTENTION EC-1 AND NEW YORK ATTORNEY GENERAL CONTENTION 30

I, J. Craig Swanson, Ph.D., declare as follows:

QUALIFICATIONS

1. I am a Senior Principal at Applied Science Associates, Inc. ("ASA"), a consulting firm specializing in the development and application of computer models to investigate marine and freshwater environments, particularly hydrodynamic modeling. My business address is 70 Dean Knauss Drive, Narragansett, RI 02882.

2. I have over 30 years of experience developing, employing and assessing computer models that simulate environmental processes, including hydrodynamics and water quality, in marine and freshwater systems. I have designed a leading hydrodynamics model, BFHYDRO (as part of the WQMAP modeling system), used by regulators and regulated industry alike, to assess hydrodynamics as well as saline and thermal discharges in rivers, lakes, estuaries and coastal areas. Specifically, I have:

- directed the application of hydrodynamic models and associated field programs to evaluate many surface water processes, including those associated with thermal discharges from power plants into receiving waters, in numerous circumstances, including in estuaries and tidal rivers.
- investigated the behavior of thermal discharges from power plants on ambient temperature distributions in receiving waters, including in estuaries and tidal rivers.

3. I have first-hand experience modeling and assessing hydrodynamic conditions in the lower Hudson River as well as extensive first-hand experience modeling

and assessing hydrothermal dynamics in estuary and riverine ecosystems, particularly in New England and internationally.

4. I hold a Ph.D. degree in Ocean Engineering from the University of Rhode Island, which I received in 1986. I hold two Master of Science degrees, one in Ocean Engineering from the University of Rhode Island, which I received in 1976, and one in Mechanical Engineering from the University of Bridgeport, which I received in 1973. My Bachelor of Science degree, which I received in 1970, is in Mechanical Engineering from Purdue University. Among other organizations, I am a member of the American Society of Civil Engineers, the Water Environment Federation and the International Association for Hydraulic Research. My current curriculum vitae, including a list of my peer reviewed scientific publications and professional presentations, is attached hereto as **Attachment 1**.

THIS PROCEEDING

5. I understand that this proceeding ("Proceeding") before the Nuclear Regulatory Commission ("NRC" or the "Commission") concerns the May 2007 application by Entergy Nuclear Operations, Inc. ("Entergy") to renew, for a period of 20 years, the operating licenses for Entergy Nuclear Indian Point 2, LLC ("IP2") and Entergy Nuclear Indian Point 3, LLC ("IP3"), nuclear power generating units located in Buchanan, New York. 72 Fed. Reg. 26,850 (May 11, 2007). I understand that Riverkeeper, Inc. ("Riverkeeper") and the New York Attorney General ("NYS") have filed petitions (the "Petitions") to intervene in this Proceeding, in which they specifically request a hearing before the NRC with respect to certain issues that they maintain are not adequately addressed in Entergy's license renewal application ("LRA").

6. I have reviewed Riverkeeper Contention EC-1 and NYS Contention 30, with particular focus on assertions by Riverkeeper and NYS that thermal discharges under the New York State Department of Environmental Conservation ("NYSDEC")-approved thermal limits in IP2 and IP3's SPDES permit violate New York State criteria governing thermal discharges (the "Hydrothermal Contentions"). I have reviewed the following materials submitted by Riverkeeper and NYS in purported support of the Hydrothermal Contention: (i) the declarations of fisheries biologists Dr. Richard Seaby and Dr. Peter Henderson and accompanying reports co-authored by Drs. Seaby and Henderson entitled *Status of Fish Populations and the Ecology of the Hudson River* ("Pisces Hudson Report") and *Analysis of Entrainment, Impingement, and Thermal Impacts at Indian Point Power Station* ("Pisces EI Report"); and (ii) the declaration of Dr. David W. Dilks (the "Dilks Declaration"). The hydrothermal components of these materials shall be referred to herein collectively as the "Hydrothermal Reports."

7. This Declaration is submitted in support of Entergy's response to the Hydrothermal Contentions.

OVERVIEW OF HYDROTHERMO DYNAMICS PRINCIPLES

8. Hydrodynamics is a scientific or conceptual engineering term for the study of fluid flow which can be applied to liquids, such as water, based on fundamental engineering principles. Hydrothermal dynamics is a more specialized area that combines hydrodynamics and thermodynamics, which is a branch of physics that studies the flow of energy which can be applied to changes in temperature, pressure and volume in physical systems, such as waterbodies. Because this scientific terminology can be unfamiliar, I have tried in this Declaration to use non-scientific language where possible.

9. Scientists use hydrothermal dynamics to understand the effects, if any, of heated water, such as a thermal discharge from a power plant, on the ambient water in the ecosystem to which the discharge is made. Since heat dissipates over time and space, the essential question becomes how fast and over what area will the heat diminish. Imagine a glass of warm water left on a kitchen countertop; it will cool. Now imagine dumping that glass of warm water into a sink filled with cool water – the warm water will not stay warm in the sink (as it would not on the counter), but also will be rapidly incorporated into the sink water, dissipating in such a way that its temperature contribution to the water in the sink is diluted as it becomes mixed throughout the sink.

10. Hydrothermal dynamics allows us to evaluate the specifics of that cooling and dilution. Further, because thermodynamics rests on settled physics principles and laws, the process is capable of a high degree of precision and certainty.

PURPOSE, METHODOLOGY, AND SUMMARY OF CONCLUSIONS

11. I was asked by Entergy to conduct an independent review of the thermal modeling reported in Appendices VI-3-A and VI-3-B of the Draft Environmental Impact Statement ("DEIS") referenced at page 3-36 of Entergy's Environmental Report (the "1999 Hydrothermal Modeling"). The 1999 Hydrothermal Modeling was conducted on behalf of the owners of three generating stations on the Hudson River, including IP2 and IP3, who retained Lawler, Matusky & Skelly Engineers, LLP ("LMS"), hydrothermal modeling consultants, for this purpose.

12. NYSDEC required LMS to conduct the 1999 Hydrothermal Modeling and compare the model results, based upon conditions dictated by NYSDEC, to New York State criteria governing thermal discharges. The Hydrothermal Contentions take the results of the 1999 Hydrothermal Modeling and make inferences about IP2 and IP3's current compliance, not with the thermal criteria in Indian Point's current SPDES Permit, but with a numeric criterion in NYSDEC's thermal regulations – specifically that a minimum of one-third of the surface of the River not be raised more than four degrees Fahrenheit. *See* Dilks Decl., at ¶¶ 16-20.

13. In order to make defensible evaluations of compliance with regulatory criteria based upon hydrothermal modeling results, the modeled environmental conditions must represent conditions that actually could occur in the waterbody. I conducted my independent review of the 1999 Hydrothermal Modeling to determine whether that

modeling was based upon such conditions and whether it supports the suggested non-compliance, focusing on two components of the NYSDEC-directed modeling that were not in line with expected engineering, or hydrodynamic and hydrothermal, realities; specifically, the timing and duration of so-called "slack water conditions" (that is, the point during a tidal cycle at which there exists little or no current) in the river offshore of the discharge location.

14. As discussed in greater detail below and in the attached report entitled *Review of Thermal Modeling Relative to Discharge from Indian Point 2 and 3 to the Hudson River*, both the timing and duration of slack water conditions associated with the 1999 Hydrothermal Modeling are not realistic and, in fact, do not occur in the River offshore of Indian Point. Given these significant deviations from realistic conditions in the River near Indian Point, it is my opinion that the Hydrothermal Modeling results can not be used accurately to determine whether Indian Point has been, or currently is, in violation of applicable New York State thermal discharge criteria.

INDEPENDENT ANALYSIS OF 1999 HYDROTHERMAL MODELING

15. The Dilks Declaration alleges that Indian Point is not in compliance with a portion of 6 N.Y.C.R.R. §704.2(b)(5)(ii), specifically the requirement that "a minimum of one-third of the surface area as measured from water edge to water edge at any stage of tide shall not be raised more than four Fahrenheit degrees over the temperature that existed before the addition of heat of artificial origin." *See* Dilks Decl., at ¶ 19. Dr. Dilks asserts that, based upon the 1999 Hydrothermal Modeling, that the thermal plume extends "100% of the surface width" of the river "during certain tidal conditions." As discussed below, these tidal conditions do not actually occur in the river offshore of Indian Point. The Pisces EI Report speculates as to Indian Point's compliance with this same requirement. *See* Pisces EI Report, at 21 ("seems clear that Indian Point's thermal discharge does not meet applicable criteria." (emphasis supplied).

16. The basis for that allegation is the 1999 Hydrothermal Modeling, *see* Dilks Decl. at ¶ 17. Other than the 1999 Hydrothermal Modeling, Dr. Dilks does not provide any independent basis for his assertion that Indian Point is not in compliance with the above-referenced portion of 6 N.Y.C.R.R. § 704.2(b)(5)(ii). Similarly, Pisces does not offer any independent basis to support this allegation. *See* Pisces EI Report, at 21 (referencing 1999 Hydrothermal Modeling results).

17. While Dr. Dilks relies solely on the 1999 Hydrothermal Modeling, he severely criticizes the accuracy of the results of that modeling, stating that "[t]o the extent that real world conditions differ from these idealized conditions, CORMIX [i.e., one model used in the 1999 Hydrothermal Modeling] results may be accurate or may be completely inaccurate" and could "provide extremely wrong answers." Dilks Decl., at ¶ 23.

18. I agree that the 1999 Hydrothermal Modeling yields completely wrong answers as applied to the Hydrothermal Contentions because that modeling was not based on conditions that actually could occur in the river near Indian Point.

19. Two important deviations in the 1999 Hydrothermal Modeling from conditions that could actually occur in the river are the timing and duration of slack water conditions in the Hudson River offshore of Indian Point.

Timing of Slackwater Conditions

20. For purposes of the 1999 Hydrothermal Modeling, it was assumed that near slack water conditions occurred at a mean-low water condition in the River – that is, "low tide" when the river is at its average lowest water depth. In combination, these conditions (*i.e.*, slack water and low tide) are intended to represent the most conservative condition for hydrothermal modeling because the water in the river is assumed to be static and at its lowest volume. To model this condition, the 1999 Hydrothermal Modeling used a near slack water condition (actually the 10th percentile flood current speed) at mean low water, which means that the river is essentially motionless so that the heat will build up and with the smallest volume of water available for dilution. Although this condition may represent, in some circumstances, a conservative, but realistic, condition for assessing thermal dispersion in some waterbodies, each waterbody differs, and this condition cannot be assumed to be a realistic condition without proper assessment of the specific tidal dynamics of a given waterbody. It is important to identify the timing in the tidal cycle at which slack water conditions arise because higher river current speeds at minimum river volume and larger volumes at minimum speeds result in lower temperature increases in the river.

21. I undertook a specific assessment of River conditions near IP2 and IP3 to determine whether the slack water assumptions in the 1999 Hydrothermal Modeling represent a realistic condition, and determined it was not. In fact, slack water conditions occur near mid-tide, not at low tide.

22. Using commonly available computer software based on National Oceanic and Atmospheric Administration (NOAA) measured data, predicted tides and currents were made for Peekskill on the Hudson River, the closest station to the Indian Point site in the NOAA database. The slack water occurs closer to the time of mean tide rather than at the time of mean low water. The maximum flood currents occur on an average of 30 minutes before high tide and maximum ebb currents occur on an average 45 minutes before low tide. This is due to the nature of the tidal wave in the Hudson River.

23. It has been well documented that maximum flood currents occur at the same time as high tide and maximum ebb currents occur the same time as low tide at the Battery, essentially the mouth of the Hudson River at the southern tip of Manhattan Island,. At the George Washington Bridge, the maximum flood occurs 30 minutes before high tide and maximum ebb occurs 30 minutes before low tide. The slack water condition occurs closer to high and low waters only at Albany.

24. This changing relationship has been confirmed by measurements taken along the entire Hudson River that show maximum floods occur 15 minutes before high tide, while the maximum ebb occurs 45 minutes before low tide and the slack water occurs closer to the mid-tide at Peekskill.

25. The reason for the variation in the phasing between water level and currents is due to the fact that the tides are considered a progressive wave at the Battery, a standing wave in Albany, with variation between along the River. These tidal wave types are well explained by theory and occur in other water bodies besides the Hudson River including San Francisco Bay and Great South Bay on Long Island

26. The erroneous assumption that slack water conditions occur at mean low water is important because it corresponds to the lowest volume of water within the river and, therefore, a condition that overstates the effects of thermal discharges. Because slack water conditions occur at mid-tide, there is a greater amount of water located offshore of Indian Point and, therefore, greater mixing and cooling than in the condition assumed in the 1999 Hydrothermal Modeling. This leads to an overestimation of the distance the thermal plume travels across the river.

Duration of Slack Water Conditions

27. The duration of slack water conditions is also critical to any estimate of how far a thermal plume will travel across a river. Under slack conditions, the water is free to move directly across the river in response to the initial cooling water discharge whereas, during every other tidal condition, the water is forced up or down stream depending upon the prevailing current.

Time varying tidal currents can be analyzed to determine the likelihood that currents less than a particular speed will occur. The 1999 Hydrothermal Modeling presented 10th percentile current speeds that can be defined as the maximum current speed that occurs less than 10% of the time. This analysis was performed for other percentiles as well. Table 1 gives the current speed for the 10th, 25th, 50th, and 90th percentiles. In addition the duration or elapsed time for which the currents are less than or equal to the speeds shown is also given. The duration for the 100th percentile would be the total time of the flooding tide from slack to maximum or 3.25 hours.

Table 1 Duration and percentiles of current speeds during flooding

Percentiles	Current speeds m/s(fps)	Duration or Elapsed Time (hours)
10	0.106 (0.35)	0.25
25	0.260 (0.85)	1.0
50	0.460 (1.51)	1.5
90	0.610 (2.10)	2.5

28. The 1999 Hydrothermal Modeling utilized a steady state model called the CORMIX model. I reran a newer version of the model but used the same input data to determine how long it would take for the thermal plume to reach the opposite bank of the river – in other words, how long would steady state conditions have to persist in order for this condition to actually occur in the river world. The CORMIX model predicted that

the plume would occupy the whole width of the River if the 10th percentile flood current speed of 0.29 fps (0.088 m/s) (i.e., slack water conditions) were to last for 2.93 hours. However, as noted above, the 10th percentile current speeds last only for 15 minutes. Thus, the 1999 Hydrothermal Modeling vastly overstated the duration of slack water conditions offshore of Indian Point.

29. Dr. Dilks also recognized that the steady state assumption contained in the CORMIX model "is clearly inapplicable in a tidal system such as the Hudson, where currents are constantly changing in both magnitude and direction" and that "[t]he DEIS is correct that using a steady state model to approximate tidally varying conditions may overstate the peak temperature impact, for the individual snapshot in time that a simulation represents." Dilks Decl., at 9-10

30. This unrealistic duration of slack water conditions is important because, at lower tidal current speeds, the exit velocity of the plume (1.98 m/s (3.5 fps)) completely dominates the plume behavior and hence travels longer distances in the cross-river direction. The cross-river travel distance of the plume decreases from 1510 m to 51 m, as flood current speed increases from 0.29 fps (0.088 m/s) (10^{th} percentile) to 2.1 fps (0.61 m/s) (90^{th} percentile).The steady state assumption of 0.29 fps (0.088 m/s) constant flood current speed by the CORMIX model grossly overestimates the cross-river travel distance of the plume and hence is inaccurate

31. Based upon these two erroneous assumptions about actual River conditions, the 1999 Hydrothermal Modeling dramatically overstates the cross-river travel distance of the thermal plume and, therefore, cannot be used as a meaningful measure of whether Indian Point is, or has been, in noncompliance with the above-referenced elements of 6 N.Y.C.R.R. §704.2(b)(5)(ii). Because Dr. Dilks opinion about the extent of the thermal plume is based solely on the 1999 Hydrothermal Modeling, which even he agreed was not reliable, there is simply no scientifically valid opinion that the plume stretches all the way across the river or that Indian Point is not in compliance with 6 N.Y.C.R.R. §704.2(b)(5)(ii).

ADDITIONAL RESPONSE TO PISCES EI REPORT

32. The Pisces EI Report quotes various materials from the Final Environmental Impact Statement ("FEIS") and, in particular, provides an aerial photograph that purports to depict the extent of the thermal plume emanating from Indian Point's discharge canal. *See* Pisces EI Report, at 22. In my opinion, this photograph is not useful for evaluating the thermal discharge against applicable New York State thermal criteria because it does not provide a temperature scale and, therefore, it is not possible to discern from the photograph the extent to which ambient river temperatures have been increased by four Fahrenheit degrees or more (which is the operative change in temperature noted in the regulation).

RESPONSE TO PISCES HUDSON REPORT

33. The Pisces Hudson Report addresses the larger and general Hudson River ecosystem without regard to IP2 and IP3 (or even any mention of it). Therefore, the Pisces Hudson Report does not permit any inferences to be made regarding the possible effects of Indian Point's operations on thermal conditions in the river nor compliance with applicable thermal discharge criteria.

CONCLUSIONS

34. In my professional opinion, the 1999 Hydrothermal Modeling reflects the thermal influence of IP2 and IP3's operations under unrealistic conditions that do not occur offshore of Indian Point.

35. Therefore, it is my professional opinion that neither the 1999 Hydrothermal Modeling nor the materials presented in the Hydrothermal Reports demonstrate present or historic noncompliance with 6 N.Y.C.R.R. 704.2(b)(5)(ii) as alleged in the Hydrothermal Contentions.

Signed this 18TH day of January, 2008.

J. Craig Swanson
J. Craig Swanson, Ph.D.
Principal
Applied Science Associates, Inc.

ATTACHMENT 1

J. Craig Swanson **Senior Principal**

EDUCATION

Ph.D.	Ocean Engineering, University of Rhode Island	1986
M.S.	Ocean Engineering, University of Rhode Island	1976
M.S.	Mechanical Engineering, University of Bridgeport	1973
B.S.	Mechanical Engineering, Purdue University	1970

QUALIFICATIONS

Dr. Swanson specializes in the development and application of hydrodynamic, water quality and sediment transport and hazardous material spill computer models for rivers, lakes, estuarine, coastal and shelf use. He has directed the application of these models and associated field programs to solve many types of surface water problems. These applications include circulation studies for a large variety of problems in the United States and abroad. In addition he has assessed the potential impacts of suspended sediment plumes from construction of onshore and offshore LNG terminals and pipelines, impacts of thermal plumes from LNG terminal operations and the transport and fate of LNG spills on water. Dr. Swanson has investigated the environmental effects of proposed wind farms and the wave and current environment to which they will be exposed. He has also investigated the impacts of heated discharge from power plants on the temperature distributions in receiving waters, the impacts of waterfront construction on circulation and flushing, dredging and disposal activities on circulation and water quality, and combined sewer overflow design alternatives on water quality. Dr. Swanson has appeared as an expert witness in hydrodynamics and water quality before various agencies at quasi-judicial hearings and meetings as well as in legal proceedings. He has participated as a speaker in many conferences and has spoken often to various technical and lay audiences explaining project results and findings.

EXPERTISE

- Project and program management
- Numerical modeling of hydrodynamics, water quality and sediment transport in rivers, lakes, estuaries, and coastal regions
- Computational methods including finite difference, finite element, and boundary fitted coordinates
- Coastal physical oceanography
- Environmental impact assessments
- Environmental data collection and analysis
- Expert testimony
- Permitting assistance

HONORS AND AWARDS

- Member of the Scientific Advisory Committee to the Rhode Island Bays, Rivers, and Watersheds Coordination Team, appointed by the Governor of Rhode Island.
- University Fellowship, University of Rhode Island

PROFESSIONAL MEMBERSHIPS

- American Society of Civil Engineers
    - Former Chairman of the ASCE Task Committee on Microcomputer Applications in Coastal and Ocean Engineering
    - Former Member of the ASCE Tidal Hydraulics Committee
- Marine Technology Society
- American Meteorological Society
- American Association for the Advancement of Science

- American Geophysical Union
- American Water Resources Association
- Water Environment Federation
- International Association for Hydraulic Research
- National Society of Professional Engineers
- Rhode Island Society of Environmental Professionals
- Environmental Business Council of New England
  - Seving on Board of Directors
  - Chairman of the Rhode Island Chapter

EXPERIENCE

Applied Science Associates, Inc. **1979 to present**

Senior Principal

- Co-founded ASA in 1979 to provide marine science and engineering consulting services.
- As Director of Operations was responsible for company wide operations including staffing, planning, project oversight, and profitability.
- Responsible for management and participation in a wide variety of marine related science and engineering projects.

Project Principal, Project Manager or Senior Scientist in the following representative studies:

Hydrodynamics

- Directed a study to assess the effects on circulation, water quality and sedimentation of a proposed channel deepening project at Quonset Point, Rhode Island. The study included an extensive field program and application of models for a range of areas surrounding the site.
- Directed the application of a three dimensional boundary fitted baroclinic hydrodynamic model to Narragansett Bay and areas offshore from Buzzards Bay to Long Island Sound. The model is part of a larger real time data assimilation and forecasting system.
- Developed a general three-dimensional boundary-fitted coordinate finite difference hydrodynamic model. The model used a semi implicit solution technique to solve the hydrodynamic equations. Forcing included tides, wind, river flow and density differences.
- Directed a hydrodynamic and suspended sediment modeling study of the effects of the removal of bridge piers and abutments for the Sakonnet River Bridge in Rhode Island.
- Performed a study to evaluate hydraulic options to correct a restrictive connection between a salt pond and the ocean on Cape Cod.
- Directed a study to develop a hydrodynamic and pollutant transport model for Salem Sound in Massachusetts for use by state regulators. The model was applied to a wastewater treatment plant outfall to assess its effects on the sound.
- Directed a modeling study to estimate the circulatory and sediment effects of various bridge replacement configurations in Missisquoi Bay on Lake Champlain.
- Developed a three-dimensional finite difference hydrodynamic circulation model of the Gulf of Maine and Georges Bank region. The model used a finite difference, split mode, semi implicit solution technique. Forcing included tides, winds and longshore pressure gradient.
- Performed a hydrodynamic model study of the Onondaga Lake outlet in Syracuse, New York. A slightly saline lake and fresh river creates a two-layer structure in the outlet under certain conditions. A field program to determine causative factors and system response was conducted. A two-phase modeling approach using an analytical model of the outlet and a three dimensional model of the outlet and portions of the adjacent lake and river was used.
- Assessed the impacts of a restrictive bridge opening on the circulation and flushing in the Narrow River, Narragansett, RI. Analysis included and measurement program to determine the tidal characteristics of the estuary and application of analytical models to estimate changes with a new bridge.

- Assessed the impacts of a proposed dredging project in the Thames River, Groton, CT. The influence on circulation in the river was investigated using a series of analytical models to estimate longitudinal changes and a numerical model was employed to estimate lateral changes.

Alternative Energy Related Projects

- Directing a study of the environmental effects of proposed Cape Wind wind farm in Nantucket Sound. Studies included assessing the transport and fate of: a potential spill of insulating oil used in the turbines; estimating the recovery time of seabed scars from construction activities; predicting water column suspended sediment levels and bottom deposition patterns from jet plow burial of the connecting cables; assessing the cumulative effects of the turbine pile array on the waves, currents and sediment transport; and evaluating potential cable exposure from migrating sand waves.
- Directed a study of the expected wave conditions for a proposed wind farm off the south coast of Long Island, New York. Studies focused on establishing a consistent wave climatology based on disparate sources of wave information at other sites as well as predicting the wave environment from historical meteorological conditions
- Directed a study to acquire environmental data via a multi component field program and perform an environmental characterization of a site of a proposed wave energy system off the south coast of Rhode Island. An assessment was performed on the environmental impacts of the deployment and operation of the floating structure.

Liquefied Natural Gas (LNG) Related Projects

- Led the development of an LNG spill transport and fate model using ASA's proven spill modeling technology. LNGMAP includes a orifice discharge, pool spreading, vapor dispersion and thermal radiation submodels.
- Directed a feasibility study for a proposed LNG terminal offshore the U.S. coast. Tasks included identification of relevant environmental data, assessing potential data gaps and recommending necessary field studies.
- Directed a study to assess possible thermal effects of seawater heating from regasification facilities and sedimentation from pipeline construction as part of a team developing an Environmental Impact Statement for a proposed LNG project off the coast of Louisiana in the Gulf of Mexico.
- Directed a study to evaluate the potential biological effects of dredging a channel and turning basin for a proposed LNG facility in the Taunton River in Massachusetts. The study included a month-long field program and applications of a hydrodynamic model to predict the currents, a dredged sediment transport model to estimate water column sediment concentrations and deposition patterns, and a biological model to calculate doses and effects to categories of marine species and their life stages.

Thermal Effluent Related Projects

- Oversaw the study of thermal effects for a proposed upgrade to a power plant on Lake Maracaibo in Venezuela. The primary focus was to optimize the location of intake and discharge structures to minimize recirculation of heated effluent and to efficiently disperse the thermal plume to minimize environmental impacts.
- Directed a study to assess the thermal effects on a pool in the Connecticut River in Vermont from a cooling water discharge. The study included a field program to measure existing temperatures and included a three dimensional application of a hydrothermal model.
- Oversaw the study of the thermal effects of increasing flow from a power plant in Jubail Harbor, Saudi Arabia. The study included a thermal mapping survey to develop a model calibration data set and a modeling study to evaluate the extent of possible temperature increases in the harbor and surrounding waters.
- Directed a thermal mapping study of discharge from a jet engine testing facility on the Connecticut River in Hartford, CT in support of monitoring requirements for a discharge permit

renewal.

- Directed a thermal mapping and modeling study for a waste-to-energy plant on the Saugus River in Massachusetts in support of a possible upgrade and for a discharge permit renewal application.
- Critically reviewed the three-dimensional hydrothermal modeling performed in support of a permit for a New England electrical generating facility. The review was part of a due diligence study for a possible buyer.
- Directed a study analyzing the thermal effects of a large electrical generating plant on the circulation and thermal structure in Mt. Hope Bay, MA. The study included an extensive field program and a three-dimensional model application.
- Managed a study to evaluate the thermal impacts of a potential repowering of a former generating plant site on the Fore River in Weymouth, MA. The study examined various intake and discharge conceptual designs to minimize the environmental effects and associated mixing zone of the plant. A full three-dimensional model was used for the analysis.
- Directed the analysis of thermal impacts from a proposed expansion at an electrical generating facility located on the Cape Cod Canal, Sandwich, MA. The study included application and calibration of a three-dimensional model to the canal and adjacent waters to estimate the increase in plume size with greater heat discharge.

Wastewater Related Problems

- Directed a study to develop a hydrodynamic and pollutant transport model for Salem Sound in Massachusetts for use by state regulators. The model was applied to a wastewater treatment plant outfall to assess its effects on the sound.
- Oversaw a fecal coliform field and modeling study along the eastern shore of Outer New Bedford Harbor. Both dry and wet weather surveys were conducted and fecal sources were identified (human vs. non human).
- Directed a study to evaluate temporary ocean discharge from a barge of squid processing wastes into Rhode Island Sound while a facility upgrade was constructed.
- Directed a design of a dye study for a small wastewater treatment plant discharging to a small impoundment to establish a mixing zone for the facility.
- Developed a three-dimensional coliform dispersion model of upper Narragansett Bay to evaluate combined sewer overflow management alternatives.
- Performed a dispersion analysis of the Dartmouth, Massachusetts municipal sewage outfall off Salters Point in Buzzards Bay. Applied a hydrodynamic and pollutant transport model system to New Bedford Harbor and portions of Buzzards Bay.
- Directed a study analyzing characteristics of receiving water quality impacts of various combined sewer overflow design alternatives for Fall River, Massachusetts system. A hydrodynamic and pollutant transport model system was applied to Mt. Hope Bay and the lower Taunton River.
- Directed a study to evaluate the water quality benefits of a series of combined sewer overflow design alternatives for the Providence River and upper Narragansett Bay. The study included modeling of hypothetical load reductions for various alternatives and two one-year simulations of receiving water quality based on the preferred alternatives

Sediment Transport and Dredging Relating Problems

- Directed a modeling analysis to assess the sediment plume generated from dredging operations in Oakland Harbor in San Francisco Bay. The project included calibrating a hydrodynamic model of the Bay and applying a dredged material sediment transport model.
- Directed a study to evaluate the potential biological effects of dredging a channel and turning basin for a proposed LNG facility in the Taunton River in Massachusetts. The study included a month-long field program and applications of a hydrodynamic model to predict the currents, a dredged sediment transport model to estimate water column sediment concentrations and deposition patterns, and a biological model to calculate doses and effects to categories of marine species and their life stages.

- Managed a study in the Thames River to evaluate the environmental effects (elevated sediment and pollutant levels) from disposal of dredged material from a U.S. Navy submarine berth. Project used hydrodynamic, dredged sediment transport and pollutant transport models.
- Directed a study to assess the dredged material plume created from dredging operations for a berth deepening project at a pier in Sandy Hook Bay in New Jersey. The study included applications of a hydrodynamic model, a dredged sediment transport model and a pollutant transport model.
- Co-directed a study to estimate suspended sediment concentrations, deposition patterns and erosion potential along a proposed route from Connecticut to Long Island for a gas pipeline.
- Co-directed a multi phase study to estimate the deposition of suspended sediment from jet plow operations between Connecticut and Long Island for a proposed cable replacement project. The study also included a new cable installation to a different landfall on Long Island.
- Directed a modeling study to assess the suspended sediment and contaminant concentrations from disposal of dredged material taken from the channel in New Bedford Harbor.
- Co-directed a study to estimate the water column concentrations and deposition of suspended sediment from jet plow operations in the lower Hudson River for a proposed electrical cable crossing between New Jersey and Manhattan.
- Directed a modeling study to estimate the circulatory and sediment effects of various bridge replacement configurations in Missisquoi Bay on Lake Champlain.
- Directed a study of the deposition of suspended material from jet plow operations in New Haven Harbor for a proposed electrical cable to determine effects on adjacent leased oyster beds.
- Directed a modeling study of the plume from proposed dredging operations in the Providence River and upper Narragansett Bay. The purpose of the study was to estimate suspended sediment concentration levels in relation to biologically based environmental windows.
- Performed a modeling study of a proposed dredging project in Inner Boston Harbor. The analysis provided estimates of the resulting concentrations in Boston Harbor of suspended sediment.
- Directed a modeling study to evaluate changes in hydrodynamics due to disposal operation at a series of proposed dredged material disposal sites in central Narragansett Bay, RI for the Corps of Engineers.
- Directed a modeling study to assess the hydrodynamic environment at potential disposal sites in Narragansett Bay for the RI Coastal Resources Management Council.
- Directed a study to develop a PC-based dredged material management system for New York City. The system combines Corps of Engineer fates models with data display capabilities.
- Assessed the impacts of a proposed dredging project in the Thames River, Groton, CT. The influence on circulation in the river was investigated using a series of analytical models to estimate longitudinal changes and a numerical model was employed to estimate lateral changes.
- Managed the development of a PC-based dredged material management protocol for Essex County, Massachusetts. The protocol utilized a decision tree approach with sediment quality data and GIS information to evaluate potential dredging and disposal sites and GIS information.
- Developed a sediment quality data display system for the New England District Corps of Engineers to evaluate dredging projects. The system displays metals concentrations as bar graphs located on a map of Narragansett Bay from a sediment quality database.

Pollutant Transport and Water Quality

- Managed an integrated field program and hydro and pollutant transport modeling system application to identify the location and evaluate the distribution of bacteria sources responsible for closure of recreational shellfish beds in Southport Harbor, CT. Both forward and backward-in-time modeling was performed to establish likely pollutant sources.
- Directed a field and modeling study to assess the effects on the salinity structure in the Palmer

River of water withdrawal and brine discharge related to a desalinization facility for Swansea, MA.

- Co-directed a field study to assess water quality in the Madaket Harbor / Long Pond system on Nantucket Island. A hydrodynamic and flushing model was developed to determine flushing times for various components of the system.
- Directed a circulation and flushing study of a series of proposed marina designs in Yarmouth, MA assessing the configuration of the marina connection to the Parker River.
- Directed a field and modeling study of water withdrawal and brine discharge on the Taunton River in Dighton, MA for a proposed desalinization facility.
- Oversaw a modeling study in support of a nutrient TMDL for the Providence River in upper Narragansett Bay that included a baroclinic hydrodynamic model and a eutrophication model.
- Directed a field and modeling study to estimate flushing times in the Parker and Swan Rivers and Lewes Bay on Cape Cod as part of a larger study to estimate critical nutrient loading to the water bodies.
- Oversaw a modeling study in support of a nutrient and pathogen TMDL for Greenwich Bay in Rhode Island that included baroclinic hydrodynamic, pollutant transport and full eutrophication models
- Directed a study to develop a web-based model to forecast water level and nutrient concentrations in Miacomet Pond on Nantucket Island.
- Directed a simplified modeling study to estimate nutrient, pathogen and suspended sediment levels in the Ten Mile and Palmer Rivers in Massachusetts. The study evaluated present conditions and estimated future contaminant levels under different land use scenarios.
- Performed a modeling study using CORMIX to optimize the dilution of brine from a proposed desalinization facility submerged multiport diffuser to the Mediterranean Sea in Gaza.
- Oversaw a field and model data development study in support of an eventual TMDL for the lower Blackstone River in Rhode Island.
- Directed a study to evaluate the flushing of the Acushnet River Estuary. The study included measurements of the salinity distribution and a dye study and resulted in a comparison of flushing estimates by alternative techniques.
- Managed a study to develop conceptual design plans for a small brine discharge for a proposed desalinization project in the Sakonnet River. The study used CORMIX to optimize the design of a multiport submerged diffuser.
- Analyzed water quality effects of the proposed Rhode Island Central Energy Facility at Quonset Point, Rhode Island. Thermal and chemical impacts were analyzed for both the once-through cooling design and the stack emissions.
- Developed a simplified two-layer model for pollutant transport in Narragansett Bay for screening various pollution abatement alternatives.
- Analyzed the marine impacts of a proposed electrical generating facility at Arnold Point, which included in analysis of the once-through cooling system effects.
- Performed a marine environmental analysis of Weaver Cove, Portsmouth, Rhode Island in support of a proposed 550-slip marina.
- Performed a characterization study of the marine environment for a proposed development in Portsmouth, Rhode Island.
- Directed a field program and water quality modeling study of the Blackstone River, Rhode Island, to assess potential impacts of withdrawal of water for cooling of an electrical generating facility.
- Analyzed water quality data for the Thames River, Connecticut and recommended a research and modeling strategy to reduce eutrophication in the estuary.
- Developed a marina water quality management protocol for the State of Connecticut.

Expert Testimony

- Testified before the Vermont Environmental Court on modeling of the thermal effects of a cooling water discharge to the Connecticut River.

- Served as an expert witness in a legal suit to concerning discharge of hydrocarbons to a tidally influenced river in Maine.
- Testified before the Connecticut Siting Council on model-predicted deposition effects of sediment transport and deposition from jet plow technology to bury an electrical cable in New Haven Harbor.
- Directed an analysis of water quality effects of the proposed Rhode Island Central Energy Facility at Quonset Point, Rhode Island. Thermal and chemical impacts to Frys Pond and Narragansett Bay were analyzed from both the once-through cooling design and the stack emissions under dry and wet conditions. Provided expert testimony at Rhode Island Department of Environmental Management hearings on the technical aspects of the project.
- Assessed the water quality impacts of a large marina development at Weaver's Cove in Narragansett Bay, Portsmouth, RI. An analysis of flushing in the marina and the conceptual design of a breakwater were performed. Provided testimony before the Rhode Island Coastal Resources Management Council.
- Assessed the impacts to the Seekonk River from a proposed electrical generating facility in East Providence, RI. Provided expert testimony at public hearing.
- Assessed the impacts of three wastewater treatment plans on the Pawtuxet River in Rhode Island. Provided expert testimony at public hearing.

Data Management, Mapping and Analysis

- Directed a program of data management, products and computation for the South Atlantic Blake Plateau region. Data from current meters, air deployed XBT's, and various meteorological instruments were processed and archived.
- Developed a system to evaluate potential eelgrass restoration sites in Narragansett Bay, RI. The system displays bathymetry, bottom type, historical bed locations, wave energy exposure index, and light extinction data in a geographical context.
- Managed a large field and modeling program for Mt. Hope Bay, MA. Oversaw the quality control, data management and interaction of data use with models.

NASA Langley **1975-1976**

Geophysical Hydrodynamicist

- Participated in the development and application of new modeling techniques for coastal marine environments to be used as an aid in marine pollution management.

AVCO Lycoming **1970-1973**

Mechanical Design Engineer

- Provided conceptual design and analysis of mechanical components of gas turbine engines.
- Developed computer assisted design techniques for in-house applications.

PUBLICATIONS

Spaulding, M.L. and J.C. Swanson (in press). Circulation and transport dynamics in Narragansett Bay. Chapter in "Science for Ecosystem-based Estuarine Management: Narragansett Bay in the 21st Century, A. Desbonnet and B. A. Costa-Pierce (eds) Springer Series in Environmental Management.

Spaulding, M. L., J. C. Swanson, K. Jayko and N. Whittier, 2007. An LNG release, transport, and fate model system for marine spills. In J. of Hazardous Materials, LNG Special Issue – Dedicated to Risk Assessment and Consequence Analysis for Liquefied Natural Gas Spills, edited by W. J. Lehr, Vol 140, Issue 3, 488-503.

Swanson, C., H.-S. Kim, and S. Sankaranarayanan, 2006. Modeling of temperature distributions in Mount Hope Bay due to thermal discharges from the Brayton Point Station. In Natural and Anthropogenic Influences on the Mount Hope Bay Ecosystem, Northeastern Naturalist, Vol 13, Special Issue 4, 145-172.

Swanson, J.C., T. Isaji, M. Ward, B.H. Johnson, A. Teeter and D.G. Clarke, 2000. Demonstration of the SSFATE numerical modeling system. DOER Technical Notes Collection (TN DOER-E12). U.S. Army Engineer Research and Development Center, Vicksburg, MS. http: //www.wes.army.mil/el/dots/doer/pdf/doere12.pdf.

Odulo, A., C. Swanson, and D. Mendelsohn, 1997. The steady flow between reservoirs with different density and level through a contraction. Journal of Marine Research, 55, 31-55.

Odulo, A. and C. Swanson, 1998. The steady flow between reservoirs with different density and level through a channel with rectangular cross section and varying depth and width. Dynamics of Atmospheres and Oceans, 28, 39-61.

Odulo, A. and C. Swanson, 1997. The steady flow between reservoirs with different density and level over a sill. Continental Shelf Research, 17, 1561-1580.

Swanson, J.C., M. Spaulding, J-P. Mathisen and Oystein O. Jenssen, 1989. A three dimensional boundary fitted coordinate hydrodynamic model, Part I: development and testing. Dt. hydrog, Z.42, 1989, p. 169-186.

Mathisen, J-P., O.O. Jenssen, T. Utnes, J.C. Swanson and M.L. Spaulding, 1989. A Three Dimensional Boundary Fitted Coordinate Hydrodynamic Model, Part II: Testing and Application of the Model. Dt. hydrog, Z.42, 1989, p. 188-213.

Swanson, J.C., D. Mendelsohn and T. Isaji, 1987. Simulation of water quality impacts of a resource recovery facility, Marine Technology Society Journal, December, Vol. 21, No. 4.

Spaulding, M.L., M. Reed, E.L. Anderson, T. Isaji, J.C. Swanson, S.B. Saila, E. Lorda and H. Walker, 1985. Oil spill fishery impact assessment model: Sensitivity to spill location and timing. Estuarine, Coastal, and Shelf Science 20:41-53.

Spaulding, M.L., S.B. Saila, E. Lorda, H. Walker, E.L. Anderson and J.C. Swanson, 1983. Oil spill fishery impact assessment model: Application to selected Georges Bank fish species. Estuarine, Coastal and Shelf Science 16:511-541.

CONFERENCE PROCEEDINGS

Swanson, J.C, T. Isaji, and C. Galagan, 2007. Modeling the Ultimate Transport and Fate of Dredge-Induced Suspended Sediment Transport and Deposition. Presented at WODCON XVIII, 27 May - 1 June 2007, Orlando, FL.

Swanson, J. C. and M. L. Spaulding, 2006. A new approach to simulation of LNG spills in the ocean, Proceedings of OCEANS'06 MTS/IEEE, Boston, MA 18-21 September, 2006.

Swanson, J. C. C. Mueller and S. Barrett, 2006. Analysis of intake and discharge salinity regimes for a desalination plant, Proceedings of OCEANS'06 MTS/IEEE, Boston, MA 18-21 September, 2006.

Swanson, J. C. C. Galagan and T. Isaji, 2006. Transport and fate of sediment suspended from jetting operations for undersea cable burial, Proceedings of OCEANS'06 MTS/IEEE, Boston, MA 18-21 September, 2006.

Swanson, J.C, and T. Isaji, 2006. Modeling dredge-induced suspended sediment transport and deposition in the Taunton River and Mt. Hope Bay, Massachusetts. Presented at WEDA XXVI / 38th TAMU Dredging Seminar, June 25-28, San Diego, CA.

Zhang, H., C. Swanson, K. Streich, and M. Garren, 2005. Development of site-specific quality assurance project plan to support hydrodynamic and water quality modeling in Southport Harbor. Proceedings of the AWRA 2005 Annual Water Resources Conference, Seattle, Washington, 7 -10 November 2005.

Swanson, J. C., K. L. Streich, M. E. Garren, and H. X. Zhang, 2005. Locating potential bacterial sources using a computer modeling approach. Proceedings of theWater Environment Federation Annual Technical Exhibition and Conference, (WEFTEC05), Washington, DC, 29 October to 2 November 2005.

Swanson, C., M. E. Garren, H. X. Zhang, and K. L. Streich, 2005. Southport Harbor hydrodynamic and pollutant transport modeling study. Proceedings of the Water Environment Federation 2005 TMDL Conference, Philadelphia, Pennsylvania, 26-29 June 2005.

Spaulding, M.L., Howlett, E., Ward, M. and Swanson, C., 2004. COASTMAP: An integrated coastal ocean monitoring and modeling system for marine discharges. To be presented at MWWD 2004 -IEMES 2004 Conference, September 27-October 2, 2004 , Catania, Italy

Swanson,J.C, Isaji,T., Clarke, D., and Dickerson, C., 2004. Simulations of Dredging and Dredged Material Disposal Operations in Chesapeake Bay, Maryland and Saint Andrew Bay, Florida. Presented at WEDA XXIV / 36th TAMU Dredging Seminar, : July 7-9,2004, Orlando, Florida

Shahriar, E., Y. Mussalli, A. Pembroke, and J.C. Swanson. 2003. Environmental impact of heated seawater discharges in the Gulf. The 4th Middle East Refining and Petrochemicals Exhibition and Conference (Petrotech 2003), 29 September – 1 October 2003.

Swanson, J.C. and P. Hall, 2003. Using models to assess flushing in coastal water bodies. 8th Annual International Conference on Estuarine and Coastal Modeling (ECM 8), Monterey, CA, November 3-5, 2003.

Kim, H.-S. and J. C. Swanson, 2001. Modeling of double flood currents in the Sakonnet River. 7th Annual International Conference on Estuarine and Coastal Modeling (ECM 7), St. Pete Beach, Fl, November 5-7, 2001.

Swanson, C. and M. Ward, 2001. Linking landside nutrient loading and water quality models: application to Nantucket waters. 7th Annual International Conference on Estuarine and Coastal Modeling (ECM 7), St. Pete Beach, Fl, November 5-7, 2001.

Swanson, C., D. Mendelsohn, and M. Ward, 2000. Circulation and Pollutant Transport Modeling in Narragansett Bay. Oceans 2000 MTS/IEEE, Rhode Island Convention Center, Providence, RI, September 11-14, 2000.

Spaulding, M. L., D. Mendelsohn, and J. C. Swanson, 1999. WQMAP: An integrated three-dimensional hydrodynamic and water quality model system for estuarine and coastal applications, Marine Technology Society Journal, invited paper, Special issue on state of the art in ocean and coastal modeling, Vol. 33, No. 3, p. 38-54.

Swanson, J.C. and M. C. Ward 1999. Improving Coastal Model Predictions through Data Assimilation. In proceedings of The 6th International Conference on Estuarine and Coastal Modeling (ECM6), November 3-5, 1999, New Orleans, LA.

Spaulding, M., J.C. Swanson, D. Mendelsohn, 1999. Application of Quantitative Model – Data Calibration Measures to Assess Model Performance. Estuarine and Coastal Modeling 6 (ECM6), New Orleans, LA, 3-5 November 1999.

Opishinski, T., M. L. Spaulding, and C. Swanson, 1996. COASTMAP: An integrated system for environmental monitoring, modeling and management. Proceedings of the North American Water and Environment Congress 96, sponsored by ASCE, Anaheim, CA, 22-28 June 1996.

Howlett, E., D. Mendelsohn, C. Swanson, and M. Spaulding, 1996. An integrated water quality and oil spill model system. Proceedings of the North American Water and Environment Congress '96, sponsored by ASCE, Anaheim, CA, 22-28 June 1996.

Swanson, J. C., J. Grgin, and P. von Zweck, 1996. The integration of receiving water impacts in the evaluation process of alternative designs for CSO abatement in Providence, RI. Proceedings of the North American Water and Environment Congress 1996, sponsored by ASCE, Anaheim, CA, 22-28 June 1996.

Swanson, J. C. and D. Mendelsohn, 1996. Water quality impacts of dredging and disposal operations in Boston Harbor. Proceedings of the North American Water and Environment Congress 96, sponsored by ASCE, Anaheim, CA, 22-28 June 1996.

Swanson, J.C., D. Mendelsohn, 1995. BAYMAP: A simplified embayment flushing and transport model system. In Proceedings of the 4th International Conference on Estuarine and Coastal Modeling, October 26-28, 1995, San Diego, CA., Ed: M.L.Spaulding. Pub. American Society of Civil Engineers, pp. 570-582.

Mendelsohn, D., E. Howlett, and J.C. Swanson, 1995. WQMAP in a Windows Environment. In: Proceedings of the 4th International Conference on Estuarine and Coastal Modeling, October 26-28, 1995, San Diego, CA., Ed: M.L.Spaulding. Pub. American Society of Civil Engineers, pp. 555-569.

Swanson, J.C. and D.L. Mendelsohn, 1994. Application of a Water Quality Modeling, Mapping and Analysis System to Evaluate Effects of CSO Abatement Alternatives on Upper Narragansett Bay, Rhode Island. 1994 Water Environment Federation CSO Specialty Conference, Louisville, Kentucky, July 1994.

Swanson, J.C. and D. Mendelsohn, 1993. Application of WQMAP to Upper Narragansett Bay, Rhode Island. In Proceedings 3rd International Conference, Estuarine and Coastal Modeling, American Society of Civil Engineers, Oak Brook, IL, September 8-10, 1993, pp. 656-678.

Swanson, J.C., D. Mendelsohn, 1993. Application of WQMAP to upper Narragansett Bay, Rhode Island. Estuarine and Coastal Modeling III. Proceedings of the 3rd International Conference, sponsored by the Waterway, Port, Coastal and Ocean Division of the ASCE, Oak Brook, IL, September 8-10, 1993.

Spaulding, M.L, K. Jayko, T. Isaji, E.L. Anderson, E. Howlett, J.C. Swanson, D. Mendelsohn and S. Puckett, 1992. A model system for simulating larval entrainment on existing and remedial designs of seawater intakes. ASCE II, Water Forum 1992, Baltimore Convention Center and Hyatt Regency, Baltimore, MD, August 2-6, 1992.

Swanson, J.C., E. Howlett and D.L. Mendelsohn, 1992. A PC-based integrated water quality impact and analysis system. 2nd International Conference on Estuarine and Coastal Modeling, American Society of Civil Engineers, Tampa, Florida, 13-15 November 1991, pp. 489-500.

Mendelsohn, D.L. and J.C. Swanson, 1992. Application of a boundary fitted coordinate mass transport model. 2nd International Conference of Estuarine and Coastal Modeling, American Society of Civil Engineers, Tampa, Florida, November 13-15, 1991.

Reed, M. E. Anderson, S.S. Feng, D. French, E. Howlett, T. Isaji, K. Jayko, W., Knauss, D. Mendelsohn, S. Puckett, M. Spaulding and J.C. Swanson, 1991. Marine oil spills: Expert systems for emergency management and natural resource damage assessment. Proceedings: Reliability Engineering and Hazard Analysis, Rio de Janeiro, October 22-24, 1991.

Spaulding, M.L., and J.C. Swanson, 1990. Coastal ocean circulation modeling at Applied Science Associates, Inc. In: The Coastal Ocean Prediction Systems Program: Understanding and Managing Our Coastal Ocean, Volume II: Overview and Invited Papers, May 1990. Coastal Ocean Prediction Systems, Report of a Planning Workshop held 31 October to 2 November 1989 at the University of New Orleans.

Swanson, J.C. and M.L. Spaulding, 1990. Marina boat carrying capacity: An assessment and comparison of methodologies. Second National Marina Research Conference 12-14 January 1990, Clearwater Beach, Florida. Proceedings published by: International Marina Institute, Wickford, RI.

Swanson, J.C. and D.L. Mendelsohn, 1989. Dispersion Analysis of the Dartmouth, MA municipal sewage outfall Salters Point. ASCE Specialty Conference, Estuarine and Coastal Modeling, Proceedings of the Conference, 15-17 November 1989, Newport, R.I., pp. 60-81.

Swanson, J.C. and K. Jayko, 1988. Modeling the impacts of CSO treatment alternatives on Narragansett Bay, Rhode Island. Oceans 88, Baltimore, Maryland, October 31 - November 2.

Mathisen, M.P., O. Jenssen, M.L. Spaulding and J.C. Swanson, 1987. A three- dimensional numerical model for ocean currents where the horizontal grid spacing is varied using boundary fitted coordinates modeling the offshore environment. Society of Underwater Technology, London, England, April 1-2.

Swanson, J.C. and K. Jayko, 1987. Preliminary results from a simplified numerical model of Narragansett Bay, Rhode Island. Oceans 87, Halifax, Nova Scotia, September 28 - October 1.

Reed, M., V.J. Bierman, Jr., E.L. Anderson, M.L. Spaulding, T. Isaji and J.C. Swanson, 1983. A proposed ocean disposal site designation protocol: Document overview and workshop summary. Proceedings of Ocean Waste Management Symposium, NOAA/NOS/OAD, May 2-6, 1983 W. Alton Jones Campus, The University of Rhode Island.

Spaulding, M.L., M. Reed, S.B. Saila, E. Lorda, H. Walker, E.L. Anderson, T. Isaji and J.C. Swanson, 1982. Oil spill fishery impact assessment model: Sensitivity to spill location and timing. Symposium on physical processes related to oil movements in the marine environment. Symposium on physical processes related to oil movement in the marine environment, Ivarmine, Finland, November 23-25.

Cornillon, P., M. Reed, M.L. Spaulding and J.C. Swanson, 1980. The application of SEASAT-1 radar altimetry to continental shelf circulation modeling. 14th International symposium on remote sensing of environment, San Jose, Costa Rica, April.

Swanson, J.C. and M.L. Spaulding, 1978. Three-dimensional numerical model of vortex shedding from a circular cylinder. In: Symposium on non-steady fluid dynamics, ASME, New York.

Technical Reports

Yassuda, E., M.A. Corrêa, A.C.R. Lammardo, C.E. Simão, C. Swanson, and S. Subbayya, 2005.Hydrothermal Modeling of the Cooling Water Discharge from the Rafael Urdaneta Thermo Power Plant to the Maracaibo System. Prepared for Tecnoconsult S.A., Caracas, Venezulea, ASA Project 04-207, 49 p. plus appendices..

Swanson, C., D. French McCay, S. Subbayya, J. Rowe, P. Hall, T. Isaji, 2003. Modeling dredging-induced suspended sediment and the environmental effects in Mt. Hope Bay and the Taunton River for the proposed Weaver's Cove Energy, LLC, liquefied natural gas import terminal, Prepared for Weaver's Cove Energy, LLC, Fall River, Massachusetts, ASA Project 02-200, 91 p. plus appendices.

Swanson, C., T. Isaji, P. Hall, C. Webb, S. Whitin, 2003. Water quality assessment of Sconticut Neck, Fairhaven, Massachusetts and Outer New Bedford Harbor, Prepared for National Marine Fisheries Service, Habitat Conservation Division, Gloucester, MA, ASA Project 01-023, 50p. plus appendices.

Swanson, C., T. Isaji, H-S. Kim, P. Hall, 2003. Dredged material transport modeling analysis in New Bedford Harbor, Prepared for Maguire Group, Foxborough, MA and Massachusetts Coastal Zone Management, Boston, MA, ASA Project 01-100, 67p.

Swanson, J. C., H.-S. Kim, S. Subbayya, P. Hall, and J. Patel. 2003. Hydrothermal Modeling of the Cooling Water Discharge from the Vermont Yankee Power Plant to the Connecticut River, Prepared for Normandeau Associates, Inc., Bedford, NH, ASA Project 02-088, 63 p. plus appendices.

C. Swanson and T. Opishinski, 2002. Long-Term Monitoring of the Pratt & Whitney's Willgoos Facility Non-Contact Cooling System Outfall in the Connecticut River, Prepared for Normandeau Associates, Bedford, NH, ASA Project 2000-173.

Kim, H.-S., J. C. Swanson and J. Patel, 2002. Flushing analysis in the Acushnet River estuary. Prepared for New England Interstate Water Pollution Control Commission, Lowell, MA, March 2002, 59p. plus appendices.

PBR Consortium / Normandeau Associates, Inc., and Applied Science Associates, Inc. 2002. Environmental Impact Study of Seawater Cooling Discharges. Prepared for Royal Commission for Jubail and Yanbu, Jubail, Saudia Arabia, December 2002. 147p. plus appendices.

Swanson, C., Galagan, C. and Isaji, T., 2002. Simulations of sediment transport and deposition from electrical cable removal and placement between Norwalk, CT. and Northport, NY. Draft Report, March 2002, 32p.

Kim, H.-S., C. Swanson, 2001. Preliminary dredged material transport modeling in New Bedford Harbor. Draft Final Report prepared for Terry Whalen, Maguire Group Inc. Foxborough, MA, December 2001, 37 p. plus appendices.

Kim, H.-S., and C. Swanson, 2001. Fate and transport modeling of contaminants in Salem Sound. Report prepared for Marine Monitoring and Research Program, Massachusetts Coastal Zone Management, December 2001, 101p. plus appendices.

Kim, H.-S., and J. C. Swanson, 2001. Hydrodynamic and sediment transport modeling at the Sakonnet River Bridge. Report prepared for Marine Research, Inc., Falmouth, MA, May 2001, 69 p. plus appendices., ASA Report 99-175.

Swanson C., Chris Galagan, Tatsu Isaji, Hyun-Sook Kim, 2001. Simulations of sediment deposition from jet plow operations in New Haven Harbor. Submitted to Environmental Science Services, Inc. Providence, RI. ASA Project 01-083.

Swanson, C., C. Galagan, T. Isaji and H.-S. Kim, 2001. Simulations of sediment deposition from jet plow operations in New Haven Harbor. Draft Final Report to Environmental Science Services, July 2001, 13p.

Rines, H., T., Isaji, C. Swanson and D. Mendelsohn, 2001. Total nitrogen modeling of coastal embayments in Chatham, Massachusetts. Report prepared for Applied Coastal Research and Engineering, Inc., May 2001, 53p.

Swanson, C. and T. Isaji, 2001. Preliminary modeling of the RESCO facility thermal plume in the Saugus River. Report prepared for Environmental Strategic Systems, Inc., May 2001, 15 p.

Swanson C., Hyun-Sook Kim, Tatsu Isaji, Matthew Ward. 2001. Summary of hydrodynamic model results for Brayton Point Station simulations. Submitted to Meredith Simas PG&E National Energy Group, Somerset, MA. ASA Project 96-076

Ward, M., J. C. Swanson and C. Galagan. 2001. Shoreline and Benthic Erosion Potential Due to the Rt. 78 Missisquoi Bridge Reconfiguration. Prepared for Vanasse Hangen Brustlin, Inc., Bedford, NH, ASA Project 00-085.

Rines, H., T. Isaji and C. Swanson June 2000. Modeling the dispersion of squid processing waste. Submitted to Point Judith Fishermen's Company, Narragansett, RI.

Swanson, C.J., T. Isaji, and M. Ward, 2000. Dredged material plume for the Providence River and Harbor Maintenance Dredging Project. Prepared for New England District, U.S Army Corps of Engineers, Concord, MA, ASA Project 99-063.

Swanson, J.C. and D. Mendelsohn, 2000. Velocity estimates for candidate dredged material disposal sites in Narragansett Bay. Submitted to: SAIC, Newport, RI and New England District, USACE, Waltham, MA, ASA Project 97-059.

Swanson, C.J. and D. Mendelsohn, 2000. Canal station thermal plume modeling. Prepared for TRC Environmental Corporation, Lowell, MA, ASA Project 99-031.

Swanson, C.J., D. French, M. Ward, T. Isaji, C. Galagan, H. Schuttenberg, K. Sananikone, 1999. Supporting technical report for marine environmental impacts analysis of the proposed stakeholder port alternatives. ASA Project 97-001.

Isaji, T., D. Mendelsohn, H. Rines, J.C. Swanson, M. Ward, 1999. Mt. Hope Bay Winter 1999 field data and model confirmation. Submitted to PG & E Generating, Somerset, MA, ASA Project 96-076.

Swanson, J.C., D. Mendelsohn, H. Rines, and H. Schuttenberg, 1998. Mt. Hope Bay hydrodynamic model calibration and confirmation. Submitted to New England Power Company, Westborough, MA, ASA #96-076.

Anderson, Eric, Isaji, Tatsu and Swanson, J.C., 1995. MUDMAP simulations for selected release scenarios of hydrotest water. Submitted to British Gas Tunisia Limited, 1100 Louisiana, Suite 2500, Houston, Texas 77002, ASA #95-02.

Swanson, J.C. and D. Mendelsohn, 1995. Modeling results to assess water quality impacts from dredged material disposal operations for the Boston Harbor navigation improvement project. Report to Normandeau Associates, Bedford, NH, ASA #95-012, May.

Swanson, J.C. and H. Rines, 1995. Influence of the Middlebridge Road Bridge on circulation in the Narrow River. Report to Gordon R. Archibald, Inc., Pawtucket, RI, ASA #94-083, January.

Swanson, J.C. and H. Rines, 1994. Preliminary report of 1994 finfish monitoring in the Blackstone River. Report to Ocean State Power, Harrisville, RI, ASA #93-131, November.

Swanson, J.C., D. Mendelsohn and A. Odulo, 1994. Onondaga Lake Outlet hydrodynamic study. Report to Onondaga Lake Management Conference, Syracuse, NY, ASA #92-040. July.

Swanson, J.C., D.L. Mendelsohn, C. Galagan, and A.C. Turner, 1994. Field data collection and flushing model development of southwest Barnstable embayment system. ASA #93-040. Report to the Town of Barnstable, Hyannis, MA, May.

Swanson, J.C., D.L. Mendelsohn, S. Wright, C. Turner, H. Rines, C. Galagan, T. Isaji, 1993. Receiving water quality model for Narragansett Bay Commission combined sewer overflow facilities. Report to Louis Berger & Associates, Inc., Providence, RI, ASA #91-47.

Isaji, T. and J.C. Swanson, 1992. Water quality modeling of the Pawtuxet River using summer 1990 data. Report to Beta Engineering, Inc., Lincoln, RI; Garafalo and Associates, Warwick, RI; and Tutela Engineering Associates, Inc., Providence, RI, ASA #90-38.

Swanson, J.C., 1992. Marina water quality assessment. Report to Connecticut Department of Environmental Management, Hartford, CT, ASA #92-18.

Swanson, J.C., T. Isaji, D.L. Mendelsohn, and A.C. Turner, 1992. City of Fall River CSO phase II facilities plan receiving water quality modeling analysis. Report to Maguire Group, Inc., Foxborough, MA, ASA #90-24.

Swanson, J.C. and D.L. Mendelsohn, 1992. Flushing times for the Fords Landing project. Report to Vanesse Hangan Brustlin, Hayes, VA, ASA #90-31.

Applied Science Associates, Inc., 1991. Oil pollution risk assessment for seawater intakes along the Saudi Arabian Coast, Report to Stone & Webster, Houston, TX, ASA #91-39.

Applied Science Associates, Inc., 1991. Oceanographic data atlas - Northwest Gulf of Mexico. Report to Exxon Production Research Company, Houston, Texas, ASA #91-65.

Mendelsohn, D.L. and J.C. Swanson, 1991. Providence River hydrodynamic model transport calculations. Report to Narragansett Bay Project, Providence, RI, ASA #90-31.

French, D.P., J.C. Swanson and K. Jayko, 1990. Thames River estuary project screening model sensitivity study. Report to Thames River Advisor Committee, Southeastern Connecticut Regional Planning Agency (SCRPA), Norwich, Connecticut. ASA #89-09.

Spaulding, M.L. and J.C. Swanson, 1990. City of Fall River CSO Phase II facilities plan: Water quality issues, Mt. Hope Bay. Report to Maguire Group, Inc., Foxborough, MA.

Spaulding, M.L., J.C. Swanson and C. Turner, 1990. The new tides and tidal currents of Narragansett Bay. University of Rhode Island Marine Technical Report, 2nd Revision, November 1990.

Swanson, J.C., 1990. Analysis of flow obstruction from proposed breakwater at Weaver Cove. Report to Melville Marine Industries, Portsmouth, Rhode Island, ASA #89-88.

Swanson, J.C., 1990. Water quality impacts of the proposed Ragged Point Marina expansion. Report to Vanesse Hangen Brustlin, Inc., Hayes, Virginia, ASA #90-04.

Swanson, J.C., T. Isaji, D.L. Mendelsohn, and A.C. Turner, 1990. City of Fall River, CSO Phase II Facilities Plan receiving water quality modeling analysis. Report to Maguire Group, Inc., Foxborough, MA.

Swanson, J.C., D.L. Mendelsohn and A.C. Turner, 1990. Providence, Rhode Island CSO Study Area D receiving water quality analysis. Report to Greeley and Hansen, Philadelphia, PA., ASA #87-52.

French, D.P., J.C. Swanson, K. Jayko, V.M. Berounsky, S. Feng, 1989. Thames River estuary project data review and modeling strategy. Report to Thames River Advisory Committee, Southeastern Connecticut Regional Planning Agency (SCRPA), Norwich, CT, ASA #88-28, Final Report.

Swanson, J.C., K. Jayko, and S. Puckett, 1989. Estimated constituent concentrations from deposition and runoff loading to Omega Pond from stack emissions of the proposed Newbay cogeneration center. ASA #89-07.

Jayko, K. and J.C. Swanson, 1988. User's guide for a simplified box model. Report to Narragansett Bay Project, Rhode Island Department of Environmental Management, Providence, R.I., ASA #85-11.

Swanson, J.C., D.P. French and A.C. Turner, 1988. Assessment of potential impacts of Ocean State Power water withdrawal on metals levels in the Blackstone River. Report to Ocean State Power, Boston, MA., ASA #87- 53.

Swanson, J.C. and K. Jayko, 1988. A simplified estuarine box model of Narragansett Bay. Report to Narragansett Bay Project, R.I. Department of Environmental Management, Providence, R.I., ASA #85-11.

Swanson, J.C. and A.C. Turner, K. Jayko, and M. Reed, 1988. Estimated constituent concentrations from deposition and runoff loading to Frys Pond from stack emissions of the prepared Quonset Point Resource Recovery Facility, Report to Environmental Science Services, Providence, Rhode Island, ASA #87-35.

Swanson, J.C. and K. Jayko, 1988. Sensitivity analysis on water quality in Narragansett Bay using a simplified estuarine box model. Report to Narragansett Bay Project, R.I. Department of Environmental Management, Providence, R.I., ASA #85-11.

Swanson, J.C. and K. Jayko, 1988. Analysis of impacts of loads from CSO study area C on upper Narragansett Bay. Report to Camp Dresser & McKee, Boston, Massachusetts, ASA #85-32.

Swanson, J.C., 1987. Preliminary boat population assessment for a proposed marina at Weaver Cove, Portsmouth, Rhode Island. Report to Melville Marine Industries, Portsmouth, Rhode Island, ASA #87-23.

Swanson, J.C., D. Mendelsohn and T. Isaji, 1987. Estimated impacts of combined wet and dry deposition on Narragansett Bay from stack emissions of the proposed Quonset Point Resource Recovery Facility. Report to Environmental Science Services, Providence, Rhode Island, ASA #87-35.

Swanson, J.C., A.C. Turner and K. Jayko, 1987. CSO Study Area B, receiving water quality analysis. Appendices I in combined sewer overflow mitigation study, CSO Area B, Moshassuck River interceptor drainage basin. Report by O'Brien & Gere Engineers, Syracuse, New York and Narragansett Bay Commission, Providence, Rhode Island.

Swanson, J.C., D. Mendelsohn, 1987. Estimated impacts of stack emissions from the proposed Quonset Point Resource Recovery Facility on Narragansett Bay. Report to Thibault and Associates, Providence, Rhode Island, ASA #86- 41.

Swanson, J.C. and D. Mendelsohn, 1986. Numerical dispersion analysis of the Dartmouth (Massachusetts) municipal sewage outfall off Salters Point. Report to Jason M. Cortell and Associates, Waltham, Massachusetts.

Swanson, J.C. and M.L. Spaulding, 1986. A two-dimensional estuarine numerical water quality model: Application to the Providence River, Appendices B in water quality benefits of proposed CSO control projects for Providence, Rhode Island. Prepared by Metcalf and Eddy for EPA Region I under Contract 68-04-1009.

Han, G., C. Casagrande, T. Lee, L. Atkinson, J.C. Swanson, O. Brown, R. Evans, R. Calvert and F. Hotchkiss, 1985. Continuation of Blake Plateau current measurement study. Report to U.S.

Department of Interior, Minerals Management Service, Washington, D.C., Contract No. 14-12-0001-29202.

Spaulding, M.L., K. Jayko, T. Isaji, J.C. Swanson and J. Rosen, 1985. A two-dimensional laterally averaged estuarine numerical water quality model: Application to the Seekonk River, Appendices G in report to the Narragansett Bay Commission, Providence, Rhode Island on combined sewer overflows in CSO Area A. Report by Metcalf and Eddy, Woburn, Massachusetts to Narragansett Bay Commission, Providence, R.I.

Spaulding, M.L., J.C. Swanson, A.C. Turner and J. Rosen, 1985. Physical oceanography and water quality of the Seekonk River, Appendices F in report to the Narragansett Bay Commission, Providence, Rhode Island on combined sewer overflows in CSO Area A. Report by Metcalf and Eddy, Woburn, Massachusetts to Narragansett Bay Commission, Providence, Rhode Island.

Swanson, J.C., D. Mendelsohn, 1985. Analysis of water quality effects of the proposed Rhode Island Central Energy Recovery Facility at Quonset Point. Report to Thibault and Associates, Providence, Rhode Island and Blount Energy Resource Corp., Montgomery, Alabama, ASA #84-42.

Swanson, J.C. and M.L. Spaulding, 1985. The ASA/IKU three-dimensional boundary fitted coordinate hydrodynamic model, ASA #83-19, August.

Swanson, J.C. and M.L. Spaulding, 1985. The ASA/IKU three-dimensional boundary fitted coordinate hydrodynamic model: Documentation Manual, ASA #83-19, April.

Reed, M., T. Isaji, E.L. Anderson, J.C. Swanson and M.L. Spaulding, 1983. Characteristic wind, hydrodynamics and oil spill analyses for Georges Bank and the Gulf of Maine. Phase II report to U.S. Department of State, Canadian Maritime Boundary Dispute Task Force, 401 C Street NW, Washington, D.C.

Isaji, T., M.L. Spaulding and J.C. Swanson, 1982. A three-dimensional hydrodynamic model of wind and tidally-induced flows on Georges Bank, Appendices A, interpretation of the physical oceanography of Georges Bank. EG&G Final report, Bureau of Land Management, Contract #AA851-CT1-39.

Spaulding, M.L., S.B. Saila, M. Reed, J.C. Swanson, T. Isaji, E.L. Anderson, E. Lorda, V. Pigoga, K. Marti, J. Hoenig, H. Walker, F. White, R. Glazman and K. Jayko, 1982. Assessing the impact of oil spills on a commercial fishery - OCS Lease Sale No. 52, First interim report, July 1981; Second interim report, February 1982; Third interim report, July 1982, Final report, November 1982. Bureau of Land Management, New York OCS Office, Contract No. AA851-CTO-75. NTIS No. PB83-149104.

Swanson, J.C., 1978. Depth interpolation package. Department of Ocean Engineering, University of Rhode Island, Kingston, Rhode Island.

Swanson, J.C., 1978. Depth record banding and sorting package. Department of Ocean Engineering, University of Rhode Island, Kingston, Rhode Island.

Swanson, J.C. and M.L. Spaulding, 1978. Review of continental shelf circulation modeling. NASA Langley Research Center, Hampton, Virginia, Grant No. NSG 1495.

Swanson, J.C. and M.L. Spaulding, 1978. Wave refraction on Georges Bank: A preliminary investigation. Department of Ocean Engineering, University of Rhode Island.

Swanson, J.C. and M.L. Spaulding, 1977. Generation of tidal current and height charts for Narragansett Bay using a numerical model. Marine Technical Report 61, Ocean Engineering, NOAA Sea Grant.

Swanson, J.C. and M.L. Spaulding, 1977. Nearshore wave climate for Block Island Sound. Department of

Ocean Engineering, University of Rhode Island, Kingston, Rhode Island.

Swanson, J.C. and M.L. Spaulding, 1975. Three-dimensional numerical model of vortex shedding from a circular cylinder. Final report on Contract No. N66604-75-M-5606, Naval Underwater Systems Center, New London, Connecticut.

Swanson, J.C. and M.L. Spaulding, 1975. Numerical simulation of oil spreading on an ice surface. Department of Ocean Engineering, University of Rhode Island, Kingston, Rhode Island.

Spaulding, M.L. and J.C. Swanson, 1974. Tides and tidal currents of Narragansett Bay. Marine Technical Report 35, Ocean Engineering, NOAA Sea Grant.

White, F.M., J.C. Swanson, W. Lamb and R. Lamb, 1974. Flood tide currents in the vicinity of Tucker's Dock, Narragansett, Rhode Island. Department of Ocean Engineering, University of Rhode Island, Kingston, Rhode Island.

ATTACHMENT 2

Review of Thermal Modeling Relative to Discharge from Indian Point 2 and 3 to the Hudson River

Prepared by
J. Craig Swanson, PhD
Senior Principal

18 January 2008

asa
science. services. solutions.
Applied Science Associates, Inc.
70 Dean Knauss Drive
Narragansett, RI 02882

Introduction

Entergy Nuclear Operations, Inc. ("Entergy") submitted an application in 2007 to renew the operating licenses for two nuclear power generating units (Indian Point 2 and Indian Point 3) located in Buchanan, New York. These units use once-through cooling technology which results in a discharge of heated water to the adjacent Hudson River. Two potential intervenors, Riverkeeper, Inc. and the New York State Attorney General, have raised a series of contentions, some of which refer to the effects of the thermal discharges, the hydrothermal thermal modeling conducted by Lawler Matusky and Skelly Engineers (LMS) as contained in Appendices VI-3-A and VI-3-B of the Draft Environmental Impact Statement prepared in 1999 (the "1999 Hydrothermal Modeling") and the potential of violation New York State's thermal discharge criteria.

An independent review of 1999 Hydrothermal Modeling was performed. The primary focus was on the use of the CORMIX model to estimate the extent of the thermal plume in the river defined by the 4 °F rise above background conditions, with specific examination of the environmental data used as input to the model and the results based on that data.

Timing of the Tides in the Hudson River

The New York State Department of Environmental Conservation (NYSDEC) required LMS to perform CORMIX modeling based a tidal condition defined as near slack water condition (specifically the lowest 10^{th} percentile current during the flood tide) at mean-low water, considered to be the most conservative condition for thermal dispersion. However, near the Indian Point site, slack water conditions occur near mid tide and not at mean low water. Thus the tidal condition imposed by NYSDEC never occurs at this site.

Using the Tides and Currents software (Nobeltec, 2001), based on National Oceanic and Atmospheric Administration measured data, predicted tides and currents at various coastal locations in US can be made. Figure 1 shows the time variation of the tides and currents at Peekskill on the Hudson River, the closest station to the Indian Point site. It is seen that slack water occurs closer to the time of mean tide rather than at the time of mean low water. The maximum flood currents are seen to occur on an average of 30 minutes before high tide and maximum ebb currents occur on an average 45 minutes before low tide. This is due to the nature of the tidal wave in the Hudson River.

Blumberg and Hellweger (2006) note that at the Battery, essentially the mouth of the Hudson River at the southern tip of Manhattan Island, maximum flood currents occur at the same time as high tide and maximum ebb currents occur the same time as low tide. At the George Washington Bridge, they note that that the maximum flood occurs 30 minutes before high tide and maximum ebb occurs 30 minutes before low tide. The slack water condition occurs closer to high and low waters only at Albany.

This changing relationship is confirmed by measurements taken along the entire Hudson River by Schureman (1934) that show maximum floods occur 15 minutes before high tide, while the maximum ebb occurs 45 minutes before low tide and the slack water occurs closer to the mid-tide at Peekskill.

The reason for the variation in the phasing between water level and currents is due to the fact that the tides are considered a progressive wave at the Battery, a standing wave in Albany, with variation along the River.

In the case of progressive tidal waves, the tides and currents are in phase, with maximum flood currents occurring during high tide and maximum ebb currents occurring during low tide. Standing tidal waves can be considered as composed of two progressive tidal waves with same period, but traveling in opposite directions. The primary wave that enters the embayment from the open ocean and the secondary wave, caused by the reflection of the primary wave at the head of the embayment or at a dam, combine together to form a standing wave. In the case of standing tidal wave, the tides and currents are out of phase by about 3 hours, with slack currents occurring closer to high and low tides. The friction, cross-sectional geometry, and wave reflection influence whether progressive or standing tidal waves are formed in estuaries.

Although not typical, the tidal characteristics of the Hudson River are not unique. Many estuaries have similar conditions. For instance, in the eastern end of the central San Francisco Bay, the tides are standing waves due to reflection from the shore. The tides in San Pablo Bay, north of central San Francisco Bay, are nearly progressive with a 30-45 minute phase difference between the tides and currents (Cheng and Casulli, 1993). Wong (1993) showed that the tides and currents at the Fire Island Inlet in the New York Bight at the entrance to Great South Bay on Long Island are out of phase by 40 minutes, indicating a near progressive wave pattern. Wong's modeling results showed the phase difference between tides and currents inside Great South Bay to be 2.75 hours, with the wave characteristics changing from a progressive wave in Fire Island Inlet to a standing wave in Great South Bay. In the Hudson River, the tidal wave is progressive near the Battery and changes to standing in Albany, due to the reflection at the dam at Troy (Blumberg and Hellweger, 2006).

Duration of Tidal Conditions

Figure 2 shows the typical time varying tidal conditions in the Hudson River near the Indian Point site based on Tides and Currents (Nobeltec, 2001). Both the tidal elevation and tidal currents shown are similar to Figure 1 but at higher resolution. In addition, the current speeds have been divided into various percentiles, 10^{th}, 50^{th} and 90^{th}. The horizontal lines indicate the speeds that correspond to these percentiles, i.e. the 90^{th} percentile speed indicates that 90% of the speeds are less than or equal to the specified speed. Table 1 gives the current speed for the 10^{th}, 25^{th}, 50^{th}, and 90^{th} percentiles. In addition the duration or elapsed time for which the currents are less than or equal to the speeds shown is also given. The duration for the 100^{th} percentile would be the total time of the flooding tide from slack to maximum or 3.25 hours (from 11.75 to 14.5 hrs).

Table 1 Duration and percentiles of current speeds during flooding

Percentiles	Current speeds m/s(fps)	Duration or Elapsed Time (hours)
10	0.106 (0.35)	0.25
25	0.260 (0.85)	1.0
50	0.460 (1.51)	1.5
90	0.610 (2.10)	2.5

The CORMIX model was used by LMS to estimate the width of the thermal plume relative to the width of the Hudson River. Since the CORMIX model is steady state it cannot accept time varying current speeds as input. It assumes that whatever current is used is constant over time. The LMS results presented in DEIS Appendix VI-3-B using the NYSDEC required tidal conditions indicated that essentially the entire width (99-100%) of the Hudson River would exceed 4°F under the four summer months, June through September, modeled. The CORMIX results presented by LMS could not provide information on the time for the plume to travel from the discharge across the river based on the CORMIX version used (3.2). This information is critical since the plume will encounter significantly changing tidal currents in the river if it takes an appreciable amount of time to cross the river.

To determine the plume travel time, updated CORMIX runs were made using CORMIX-GI Version 4.1G, a newer version, using the same input parameters used by LMS in the DEIS. Figure 3 shows the plan view of the plume for a constant flood current speed of 0.29 fps (0.088 m/s), the June period. The updated CORMIX simulations predicted that the plume would occupy the whole width of the river <u>only if</u> the 10th percentile flood current speed of 0.29 fps (0.088 m/s) were to last for 2.93 hours, the travel time of the plume across the river. However the 10th percentile current speeds lasts less than 15 minutes as the flood tide starts from slack water, as seen in Figure 2. What will actually occur is that while the plume is traveling across the river it will encounter increasing currents as the flood tide increases.

Figure 4 shows the cross-river distance corresponding to 4°F (2.2°C) temperatures for different current speeds. It is seen that the cross-river travel distance of the plume decreases with increase in current speeds. At lower tidal current speeds, the exit velocity of the plume (1.98 m/s [3.5 fps]) completely dominates the plume behavior and hence travels longer distances in the cross-river direction. The cross-river travel distance of the plume decreases from 1510 m to 51 m, as flood current speed increases from 0.29 fps (0.088 m/s) (10th percentile) to 2.1 fps (0.61 m/s) (90th percentile).The steady state assumption of 0.29 fps (0.088 m/s) constant flood current speed by the CORMIX model grossly overestimates the cross-river travel distance of the plume and hence is inaccurate.

Conclusions

The relative timing of the tidal characteristics specified by NYSDEC for the 1999 Hydrothermal Modeling is purely hypothetical and not physically possible. These conditions therefore cannot be used to determine compliance with NYSDEC criteria. In addition the use of the steady state model cannot be used without analysis of the plume travel time. If the travel time is significant relative to the duration of the flood tide, as is the case here, then the results cannot be directly used.

Blumberg, A. F., and F. L. Hellweger (2006) "Hydrodynamics of the Hudson River Estuary",. In: *Hudson River Fishes and their Environment,* Waldman, J., K. Limburg, and D. Strayer, Eds. American Fisheries Society, Bethesda, Maryland, 51: 9-28, 2006.

Schureman, P. (1934) Tides and Currents in Hudson River, Coast and Geodetic Survey, USpecial Publication No., 189, .U.S. Department of Commerce, Washington.

Nobeltec (2001) Tides and Currents Pro for Windows, Version 3.0, Nautical Software Inc., Beaverton, Oregon.

Cheng, R. T., V. Casulli, and J. W. Gartner (1993) Tidal, Residual, Intertidal Mudflat (TRIM) Model and its Application to San Francisco Bay, California, Estuarine, Coastal and Shelf Science, Vol. 36, pp. 235-280.

Wong, K-C. (1993) Numerical simulation of exchange process within shallow bar-built estuary, Estuaries, Vol.16, No.2, pp. 335-345.

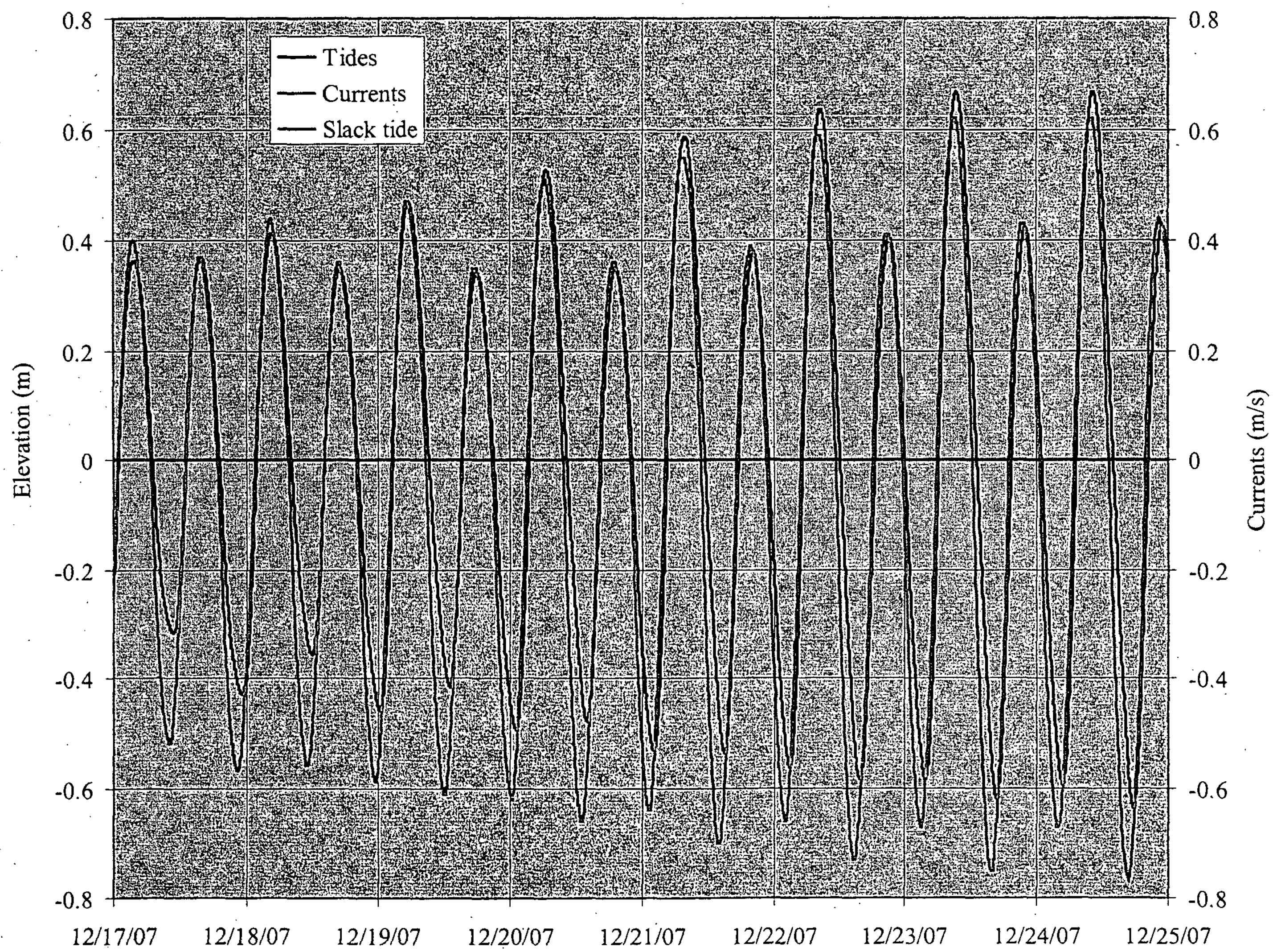


Figure 1 Tides and Currents at Peekskill predicted using Tides and Currents.

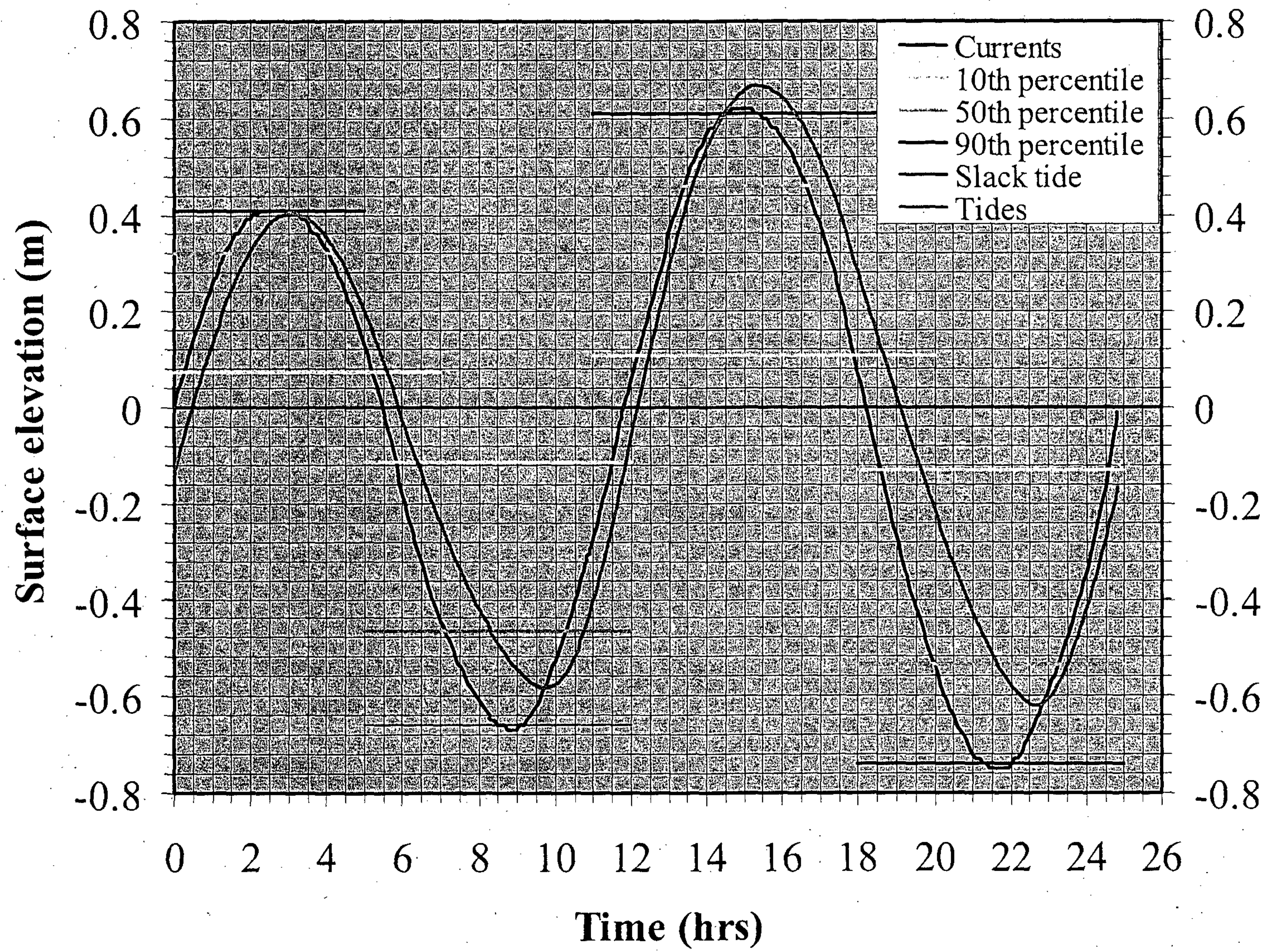


Figure 2 Tidal currents and its percentiles at Peekskill during one tidal cycle.

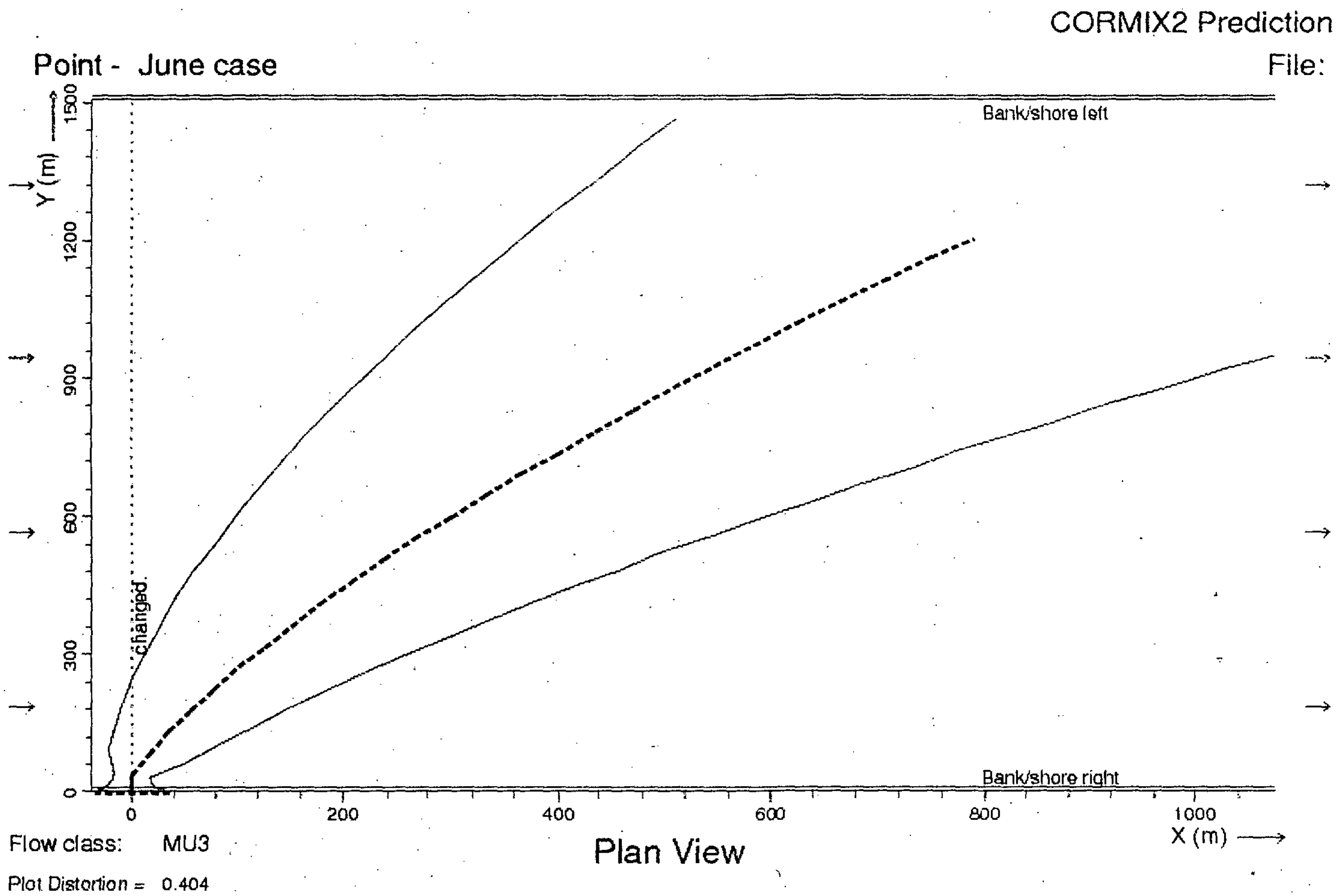


Figure 3. Plan view of the plume in the near-field for the 10 percentile steady current speed (0.09 m/s) using the same parameters as LMS.

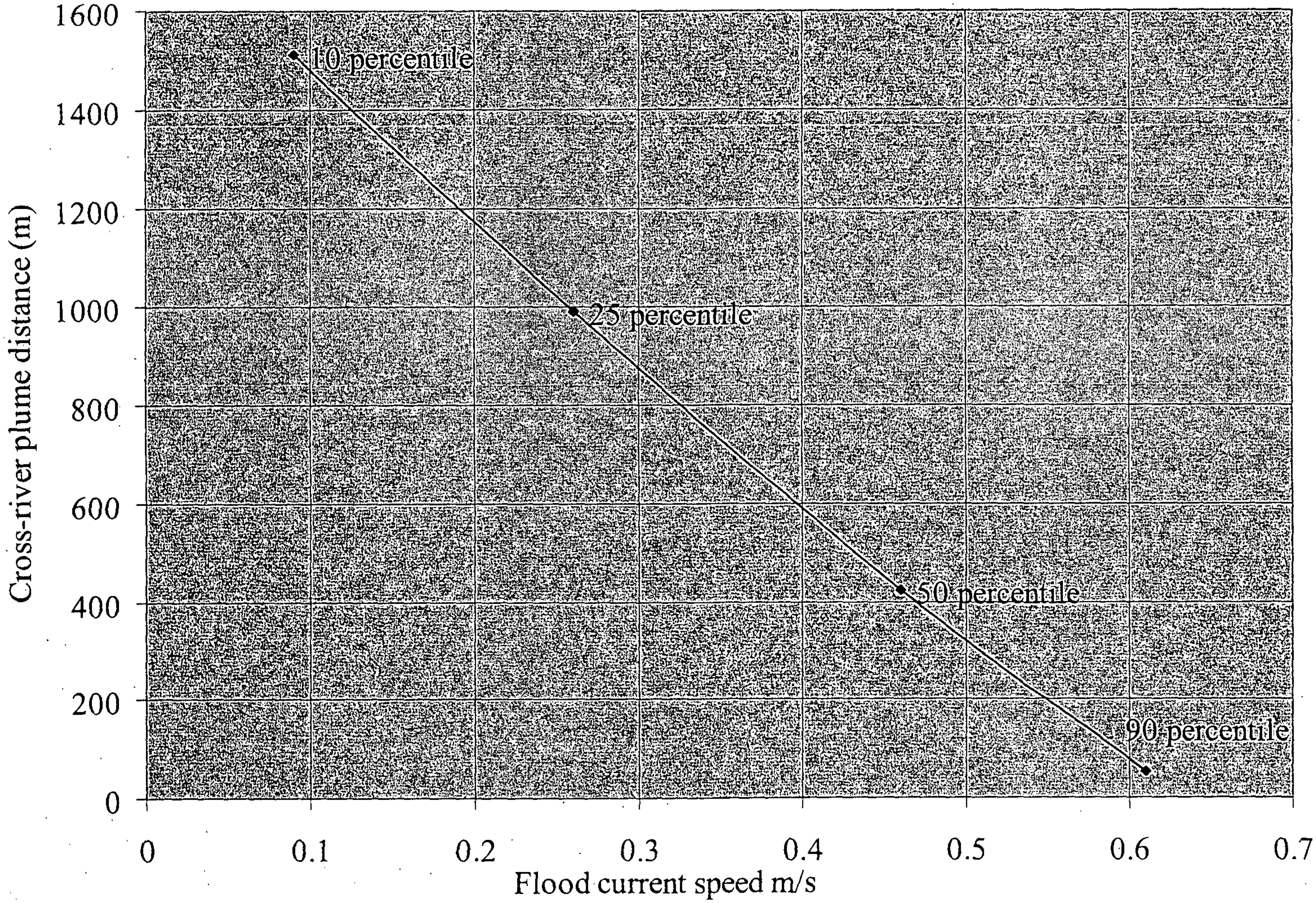


Figure 4 Cross-river plume distances for 4°F at different flood current speeds.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE SECRETARY

In the Matter of ENTERGY NUCLEAR INDIAN POINT 2, LLC, ENTERGY NUCLEAR INDIAN POINT 3, LLC, and ENTERGY NUCLEAR OPERATIONS, INC. (Indian Point Nuclear Power Station)	Docket Nos. 50-247, 50-286

DECLARATION OF CHARLES V. BECKERS, JR., P.E. IN OPPOSITION TO RIVERKEEPER CONTENTION EC-1 AND STATE OF NEW YORK CONTENTION 30

I, Charles V. Beckers, Jr., P.E., declare as follows:

1. I am a Senior Project Manager at Henningson, Durham & Richardson Architecture and Engineering, P.C. ("HDR"), a professional engineering consulting firm. I have over 30 years of experience in the development and application of multi-dimensional, time-variable hydrodynamic and water quality models.

2. Prior to the merger with HDR, I was employed by Lawler, Matusky & Skelly Engineers LLP ("LMS") for 15 years. LMS was merged into HDR in 2005. At LMS, I was the project manager and principal author for the engineering analyses contained in Appendix VI-3-A and Appendix VI-3-B of the Draft Environmental Impact Statement for State Pollutant Discharge Elimination System Permits for Bowline Point, Indian Point 2 & 3, and Roseton Steam Electric Generating Stations, dated December 1999 (the "DEIS").

3. I hold a Bachelor of Science in Physics and a Master of Science in Physical Oceanography. I am a member of the American Water Resources Association, the Water Environment Federation and affiliated New England Water Environment Association, and the American Water Works Association and affiliated New England Water Works Association.

4. I am a registered professional engineer in the State of Rhode Island and Providence Plantations.

5. I have conducted extensive research with regard to discharge of thermal effluent from power plants located on the Hudson River, including Indian Point Units 2 and 3, including the above-referenced analyses contained in the DEIS.

6. My curriculum vitae, including a list of my publications, is attached hereto as **Exhibit 1**.

7. I understand that this proceeding before the Nuclear Regulatory Commission ("NRC" or the "Commission") concerns the May 2007 application by Entergy Nuclear Operations, Inc. ("Entergy") to renew, for a period of 20 years, the operating licenses for Entergy Nuclear Indian Point 2, LLC ("IP2") and Entergy Nuclear Indian Point 3, LLC ("IP3"), nuclear power generating units located in Buchanan, New York. 72 Fed. Reg. 26,850 (May 11, 2007).

8. I understand that Riverkeeper, Inc. ("Riverkeeper") and the State of New York have filed petitions to intervene in this license renewal proceeding, in which they present contentions regarding alleged deficiencies in Entergy's application and characterize the conclusions reached from the analyses contained in Appendix VI-3-A and Appendix VI-3-B of the DEIS.

9. Attached hereto as **Exhibit 2** is a true and accurate copy of my correspondence to Ms. Elise N. Zoli, Esq., an attorney representing Entergy. I prepared this correspondence in response to an inquiry from Attorney Zoli into the history of the modeling efforts presented in the DEIS.

10. This Declaration is submitted in response to Riverkeeper Contention EC-1 and State of New York Contention 30. I understand that Entergy intends, under 10 C.F.R. §2.309(f), to contest whether Riverkeeper Contention EC-1 and State of New York Contention 30 are within the scope of this proceeding. I understand that if the NRC concludes that these contentions are not within the scope of this proceeding, then this Declaration will not be considered.

Signed this 19th day of December, 2007.

Charles V. Beckers, Jr., P.E.
Henningson, Durham & Richardson Architecture and Engineering, P.C.
Senior Project Manager

Exhibit 1

YEARS EXPERIENCE

37

EDUCATION

M.S., Physical Oceanography
University of Rhode Island, 1971

B.S., Physics
Union College, 1966

72 credits advanced study, Ocean Engineering
University of Rhode Island, 1969-1973

MEMBERSHIPS

Water Environment Federation and New England Water Environment Association
American Water Works Association and New England Water Works Association
American Water Resources Association

REGISTRATION

Registered Professional Engineer in the State of Rhode Island
United States Coast Guard Licensed Master, 100 Gross Tons, Near Coastal (200 nautical miles), Motor, Steam & Sail (Emergency Towing endorsement)

EXPERIENCE

HDR|LMS **2005-Present**
Lawler, Matusky & Skelly Engineers LLP **1990-2005**

Mr. Beckers is a Senior Project Manager for Mathematical Modeling in the Natural Resource Management and Permitting section at HDR|LMS (formerly Lawler, Matusky & Skelly Engineers LLP). He provides modeling analyses on a wide variety of environmental issues, ranging from the thermal impacts of power generation facilities to the availability of surface water supplies for public water systems. Mr. Beckers brings an extensive and diverse range of experience to projects, including not only water quality, hydrothermal, and hydrodynamic modeling, but also instrumentation, field survey, and marine operations experience.

Mr. Beckers joined LMS in 1990 as a project manager in the Mathematical Modeling Section and became a Senior Project Manager in 1993. From 1970 to 1986, he was employed in a similar capacity by Raytheon Oceanographic and Environmental Services. From 1986 to 1990, Mr. Beckers was employed by KVH Industries Inc. as project manager for electronic compass systems used by the U.S. Army, Navy and Marine Corps. During the 1980s he was also co-owner of East Passage Marine, Inc. and captain of the Tug HERCULES, which was engaged in marine salvage. Mr.

Beckers is a U.S. Coast Guard licensed master with experience in command of passenger, towing and salvage vessels. He continues to be active in the maritime industry on a part-time basis.

Mr. Beckers has authored more than 25 articles in the professional literature, ranging from a review of the revised "rules of the road" for vessel navigation to evaluation of the next generation tide gauge to complex, three-dimensional, time-variable mathematical modeling of water quality in a New York City water supply reservoir. He is experienced in dealing with governmental regulatory agencies on behalf of his clients and in making presentations at public hearings.

POWER GENERATION PROJECTS

Cromby Generating Station 316a Litigation, Exelon Corporation. Serving as Expert Witness with regard to thermal effects of Cromby Generating Station in Black Rock Pool, the Schuylkill River. Also providing review of engineering analyses and work products provided by other consultants regarding those effects.

Danskammer SPDES Permit Renewal Hearings, Dynegy Northeast Generation, Inc. Served as Expert Witness regarding Hudson River water temperatures and effects of the generating station on those temperatures.

Roseton Generating Station SPDES Permit Renewal, Dynegy Northeast Generation, Inc. Providing thermal plume analyses and expert testimony related to renewal of the New York State Pollution Discharge Elimination System permit.

316(b) Vulnerability Assessment and Action Plan, FirstEnergy Corp. Evaluation of the vulnerability of the Bay Shore and Eastlake generating stations to the requirements of the U.S. Environmental Protection Agency's Phase II 316(b) rules. Based on the assessment, he prepared an action plan for FirstEnergy's response to those requirements.

Bowline Point Generating Station SPDES Permit Renewal, Mirant Bowline LLC. Receiving waters characterization to the development of Supplement C for the New York State Pollutant Discharge Elimination System Permit renewal application for Bowline Point Generating Station. Supplement C addresses the characteristics of the receiving waters and the plume associated with each individual outfall, and is required for all industrial discharges to New York State estuaries.

Danskammer Point Generating Station Triaxial Survey, Dynegy Northeast Generation, Inc. Preparation of the survey protocol for a three-dimensional (triaxial) survey of the thermal plume associated with the Danskammer Point Generating Station cooling water discharges. The New York State Department of Environmental Conservation State Pollutant Discharge Elimination System Permit required submittal and approval of the protocol as an initial step in the performance of the triaxial survey.

Danskammer Point Generating Station SPDES Permit Renewal, Dynegy Northeast Generation, Inc. Management and contribution to Supplement C to the New York State Pollutant Discharge Elimination System Permit renewal application for Danskammer Point Generating Station. Supplement

C addresses the characteristics of each individual outfall from the facility and the characteristics of the receiving waters. He also performed preliminary CORMIX modeling of the thermal discharge plume.

Project Manager of Bay Shore Generating Station Thermal Mixing Zone Study, FirstEnergy Corp. The study consisted of a summer-long field survey program and a modeling analysis of the station cooling water discharge plume. The field survey consisted of two dozen moored temperature monitoring instruments, two moored current meters, and five mobile surveys. Each mobile survey measured surface water temperatures, vertical temperature profiles and water currents along pre-defined tracklines. All positioning and mapping was performed using Hypack survey software and GPS precision positioning. In a cooperative effort with the Ohio Environmental Protection Agency (OhioEPA), LMS used instrumentation provided by OhioEPA to measure vertical profiles of dissolved oxygen during the mobile surveys. In addition, the first mobile survey also included a bathymetric survey of the region immediately offshore of the cooling water discharge canal. The final report was submitted to the Ohio Environmental Protection Agency in fulfillment of a discharge permit requirement.

Bay Shore Generating Station Thermal Mixing Zone Plan of Study, FirstEnergy Corp. Provided the Plan of Study for the Thermal Mixing Zone Study required by the Ohio Environmental Protection Agency (OhioEPA) in the permit for the Bay Shore Generating Station cooling water discharge. The Plan was submitted to OhioEPA for review and approval prior to conduct of the Thermal Mixing Zone Study.

Project Manager of Empire State Newsprint Project Fisheries Impact Study, ENSR Corporation for BesiCorp & Epsilon Associates Inc. for BesiCorp. Estimation of the Conditional Mortality Rate and performed fish population modeling for Representative Important Species on the Hudson River near Albany, New York to evaluate the potential fish population impacts of a proposed newsprint recycling and electricity co-generation facility using both a river-water intake and grey water for cooling. His findings became part of submittals to cognizant regulatory agencies, including the New York State Board on Electric Generation Siting and the Environment, the New York State Department of Environmental Conservation, the U.S. Army Corps of Engineers and the National Fisheries Service. Subsequently, Mr. Beckers supported the owners in presenting the results of the evaluation to regulatory agencies and assisted in the preparation of additional permit application submittal materials.

Review of Proposed Phase II 316(b) Regulations, PG&E. Evaluation of the potential effects of the Phase II 316(b) regulations proposed by the U.S. Environmental Protection Agency (USEPA) on the Brayton Point Generating Station. Brayton Point was one of the models that USEPA used in developing its Phase II regulations, so it was important to the owners to have an understanding of how the USEPA had viewed their facility in framing the proposed rules. Used in preparation of comments on proposed rule.

Review of CORMIX Modeling of Brayton Point Generating Station Cooling Water Discharge PG&E. Review of CORMIX modeling of the cooling water discharge from Brayton Point Generating Station to provide a due diligence report on the results. The CORMIX modeling was performed by another consultant.

Project Manager Astoria Generating Station Repowering SPDES Permit and Article X Applications, Environmental Science Services Corporation for Orion Power. SPDES Permit and Article X applications for re-powering of the Astoria Generating Station. The LMS tasks included CORMIX modeling of the negatively buoyant cooling tower blowdown discharge, evaluation of the discharge impacts on aquatic biota, and evaluation of the cooling water intake impacts of fish populations. They also included a brief field survey to develop previously unavailable data on warer quality conditions at the site. Mr. Beckers provided the CORMIX modeling protocol for review by New York State Department of Environmental Conservation, performed the CORMIX modeling, evaluated the results, and provided additional analyses in response to questions raised by intervenor organizations.

Project Manager of Bridgeport Harbor Generating Station Low-Volume Discharge Modeling, Wisvest Connecticut LLC. Three-dimensional, time-variable model of Bridgeport Harbor and Long Island Sound, previously developed by LMS for the Bridgeport Wastewater Treatment Plant discharge, to evaluate the plume associated with a low-volume wastewater discharge from the Bridgeport Harbor Generating Station. The resulting report was submitted to Connecticut Department of Environmental Protection in satisfaction of a discharge permit requirement.

Bethlehem Energy Center Cooling Tower Blowdown Modeling Study, PSEG New York. Updating of the prior CORMIX plume modeling performed by LMS to evaluate the in-stream dilution of a mixed cooling tower and low-volume wastewater discharge to the Hudson River from the proposed combined cycle repowering of the Albany Steam Generating Station. The update reflected new engineering approaches to cooling tower design developed by new station owners. The discharge was to be made via the existing once-through cooling outfall. A specific concern was a river bank well field in close proximity downsteam. The resulting report was submitted as part of the updated SPDES permit and Article X applications for the repowering project.

Project Manager of Feasibility Studies – ABB Oak Point Energy Generating Facility, Black & Veach for ABB Energy Ventures. Response to New York State Department of Public Service comments on the client's Preliminary Scoping Statement, performed preliminary CORMIX modeling of the proposed cooling water discharge, evaluated relative cooling water intake and discharge locations to mininmize recirculation, proposed and evaluated active screen system based on Gunderboom filtration system, and aided in development of strategy for permitting of once-through cooling design for a proposed combined cycle generating facility at Oak Point on the East River.

Project Manager of Ravenswood Generating Station Cogeneration Project SPDES Permit andArticle X Applications, Burns & Roe Enterprises for KeySpan Energy. SPDES permit and Article X applications for addition of a heating steam/electricity cogenerating unit to the Ravenswood Generating Station. LMS provided the evaluation of the cooling water discharge for compliance with New York State thermal and 316(a) aquatic biota criteria, as well as the 316(b) cooling water intake evaluation. The CORMIX model was used to forecast the extent of the thermal plume under the existing plant configuration and the proposed plant configuration. Mr. Beckers coordinated the activities of these tasks with a parallel LMS project to gather additional entrainment and impingement data. He also performed additional CORMIX modeling to examine alternative discharge scenarios, in response to New York State Department of Environmental Conservation comments.

Albany Steam Generating Station Cooling Tower Blowdown Modeling Study, Niagara Mohawk Power Corporation. Application of CORMIX plume model to evaluate the in-stream dilution of a mixed cooling tower and low-volume wastewater discharge to the Hudson River from the proposed combined cycle repowering of the Albany Steam Generating Station. The discharge was to be made via the existing once-through cooling outfall. A specific concern was a river bank well field in close proximity downsteam. The resulting report was submitted as part of the SPDES permit and Article X applications for the repowering project.

FERC Relicensing Project , Consumers Power. Task manager of the following tasks performed by LMS in the FERC relicensing project for 11 hydropower impoundments owned by Consumers Power in Michigan: Bathymetric surveys, Conduct of a recreational use survey and development of a recreational use plan, and Conduct of a bank erosion study.

Salem Generating Station Cooling Water Discharge Permit Renewal, 316(a) and 316(b) Demonstration Studies (Third Renewal), Public Service Electric & Gas. Providing a review of the basis for calculation of the impacts of losses in lower trophic levels on equivalent adult organisms, primarily fish. Developing a recommendation to reconcile differences in calculations done for impingement/entrainment losses and restoration of salt marshes.

Salem Generating Station Cooling Water Discharge Permit Renewal and 316(a) Demonstration Study (Second Renewal), Public Service Electric & Gas. Coordination of the field surveys performed during the second permit renewal study for the Salem Generating Station. The field surveys included moored temperature monitoring instruments in Delaware River and Bay, moored and bottom-mounted current meters, tide gage, and mobile surveying. The mobile surveys included five vessels operating simultaneously to measure surface and vertical profiles of water temperature, salinity, currents and dye concentration. The sub-visible, fluorescent dye was injected into the cooling water discharge to develop dilution information for updated near- and far-field modeling. In addition, Mr. Beckers performed Response Temperature Modeling (RTM) to estimate the natural water temperatures that would have existed in the vicinity of Salem Generating Station in the absence of the cooling water discharge. The results of the field surveys and the RTM analyses became part of the application for renewal of the 316(a) variance and discharge permit.

Project Manager, Salem Generating Station Cooling Water Discharge Permit Renewal and 316(a) Demonstration Study (First Renewal), Public Service Electric & Gas. Mr. Beckers managed application of the RMA-10 and CORMIX models to the Salem thermal discharge for evaluation of compliance with New Jersey state thermal criteria and mixing zone requirements. Mr. Beckers applied the CORMIX model to evaluate the near-field conditions surrounding the outfall. The RMA-10 3-dimensional, time-variable model was applied to the Delaware River and Bay from the fall line at Trenton, New Jersey to the mouth at Lewis, Delaware. CORMIX model results were used to drive the far-field model. Mr. Beckers wrote the report that was incorporated into the renewal application in support of continuation of the 316(a).

Hudson River DEIS Thermal Modeling Study, Consolidated Edison Company for the Hudson River Utilities. As one element of the DEIS that LMS prepared for the thermal discharges from Roseton, Indian Point and Bowline Point generating stations, Mr. Beckers managed the task to model the combined thermal discharges from these and other electric generating station on the Hudson River. The study used a one-dimensional, time-variable model to evaluate the far-field effects of the cooling water discharges. Mr. Beckers performed CORMIX modeling of the three cooling water discharges. Working with Dr. John P. Lawler, Mr. Beckers developed and implemented a spreadsheet model that integrated the results of the near- and far-field model in a way that facilitated comparison with New York State thermal water quality criteria. Mr. Beckers documented the results of the modeling for subsequent incorporation in the DEIS prepared by others.

Manchester Street Generating Station Thermal Modeling Review, New England Power for Rhode Island Department of Environmental Management. In response to a requirement of the Rhode Island Department of Environmental Management, New England Power engaged the services of LMS to review the thermal modeling and aquatic biota impacts reports submitted by New England Power in support of their application for conversion of the Manchester Street Generating Station (Providence, Rhode Island) to combined cycle generation. Mr. Beckers performed the review of the thermal modeling and prepared a report on the findings.

Project Manager Hope Creek Generating Station Cooling Tower Blowdown Thermal Plume Study, Public Service Electric & Gas. Fluorescent dye survey to map the thermal plume associated with continuous cooling tower blowdown from the Hope Creek Generating Station. He used the CORMIX model to evaluate the dye survey results and a proposed change to the outfall configuration. Mr. Beckers prepared a report on the studies for submittal to New Jersey Department of Environmental Protection.

Burlington Generating Station Thermal Plume Modeling, Public Service Electric & Gas. Mr. Beckers conducted field surveying and modeling of the discharge from the existing facility and proposed alternative cooling options.

WATER SUPPLY PROJECTS

Safe Yield Guidance Manual, United Water New Jersey and Newark Department of Water and Sewer. Representing United Water New Jersey and Newark Water on the technical advisory panel for development of the New Jersey Department of Environmental Protection Reservoir Safe Yield Guidance Manual.

Technical Advisory Services for Water Allocation Permit Litigation, Newark Department of Water and Sewer. Providing technical advisory services related to on-going litigation between Newark and the New Jersey Department of Environmental Protection regarding aspects of the latest renewal of the water allocation permit for operation of Newark's water supply reservoirs in the Pequannock River watershed.

Technical Advisory Services for Renewal of Water Allocation Permit 5111, United Water New Jersey. Providing technical advisory services regarding the safe yield of the Hackensack River water supplies for renewal of Water Allocation Permit 5111 for diversion of water from Oradell Reservoir by United Water New Jersey.

Regional Water Supply Reliability Model Evaluation Project, Peace River/Manasota Regional Water Supply Authority. Evaluated nine modeling systems for use in evaluation of system reliability when new sources and interconnections are added to the Authority's system. Models evaluated included LMS-RMP, RiverWare, OASIS, WaterGems, EPANET, BESTSM, STELLA and custom software. STELLA was recommended as best meeting all the Authority's present and anticipated requirements.

Morris County Water Balance Modeling Project, Morris County (New Jersey) Planning Board. Developing the central water balance model that will integrate surface water modeling using the Stormwater Management Model (SWMM) and groundwater modeling using the MODFLOW model. The purpose of the water balance model is to assist the Board and its staff in evaluating the consequences of proposed changes in land use and water supply within the county.

Kensico Reservoir Water Quality Modeling Tasks, Kensico-City Tunnel Project, UTG Joint Venture for New York City Department of Environmental Projection. Providing technical guidance to HDR|LMS staff updating and applying the Kensico Water Quality Model for use in evaluating water quality associated with operation of a candidate reservoir outlet structures for the Kensico-City Tunnel.

Project Manager, Hackensack River Safe Yield Sensitivity Analysis, United Water New Jersey. Performed detailed review of elements included in most recent safe yield analysis to determine impact on safe yield. Elements reviewed included Oradell Reservoir hypsograph and dead storage, Lake Tappan release rules, and conformance of operating rules to requirements of the state Water Allocation Permit. Also evaluated safe yield impact of proposed increase in Wanaque South inter-basin transfer from Passaic River watershed.

Evaluation of Proposed Increase in Lake DeForest Storage on Safe Yield, United Water New York. Provided a technical memorandum on the potential effect on the safe yield of Lake DeForest Reservoir resulting from raising the height of the dam.

Project Manager of Newark Water Technical Support Project City of Newark, New Jersey, Department of Water and Sewer Utilities, Division of Water and Sewers. Support for the Newark Historical Water Database and the Newark Water and Sewer Budget Ledger systems previously provided by LMS, including recommendations regarding data rescue from an obsolete UNIX minicomputer. Development of an interface between the Newark Water Supply Management Program and the Newark Historical Water Database, both previously provided by LMS, to facilitate updating of the Management Program data set. Representation of Newark Water in the New Jersey Watershed Management Area program. Mr. Beckers attended Public Advisory Committee and Technical Advisory Committee meetings, and provided technical presentations to Watershed Management Area 3 public participants. Technical evaluation of the Water Allocation Permit renewal proposed by New Jersey Department of Environmental Protection. Mr. Beckers performed the evaluation, provided revised permit language, participated in meetings with the agency and is currently working with the City Attorney to support an adjudicatory hearing on the permit. He also "ghost wrote" a letter from the Newark mayor to the Department's Commissioner on the topic. Mr. Beckers also provided a plan for compliance with the State's proposed language, should that ultimately be required. Technical evaluation of the Pequannock Watershed Temperature TMDL. Mr. Beckers critiqued the thermal modeling employed by New Jersey Department of Environmental Protection in the TMDL, provided alternative language and participated in meetings with the Department on the TMDL. Mr. Beckers presented a paper on the topic to the Water Environment Federation TMDL 2005 Conference.

Project Manager Jersey City Reservoirs Bathymetry and Safe Yield Study, Jersey City Municipal Utilities Authority. Bathymetric surveys of Boonton and Splitrock reservoirs to determine if there have been any changes in the storage capacities used by Jersey City historically in managing their reservoirs. The surveys employed dual-frequency depth sounders, GPS positioning and HyPack data recording software. The surveys required reconciliation of the new survey results with historical data. The results were mapped using color-keyed contouring software. Determination of the safe yield of the Jersey City reservoir system, using the latest information on demand patterns, runoff, and bathymetry. Mr. Beckers updated and used the Jersey City Water Supply Management Program (JCWSMP), previously developed by LMS, to evaluate the safe yield. Mr. Beckers present the results of the project to the MUA Commission and is completing the final report. He will install the updated JCWSMP on the Jersey City computer system and provide training for their personnel.

Project Manager of Wanaque South and Alternative Sources Safe Yield Analysis, North Jersey District Water Supply Commission. On-going study of the safe yields of the Wanaque South Project, which includes the Monksville and Wanaque reservoirs, the Ramapo pump station and the Wanaque South pump station, and of the safe yields associated with alternatives to augment the existing system. Mr. Beckers has expanded the capability of the previously developed Wanaque South Management Program (WSMP) provided by LMS to include modeling of the effects of a hypothetical Regional Alternative Water Source. Mr. Beckers oversaw the extension of the WSMP database to include the latest river flow and storage data. Mr. Beckers is completing three separate reports emphasizing various aspects of the study for different audiences.

Project Manager of Hackensack River Reservoirs Safe Yield Study, United Water New Jersey. Study of the independent and combined safe yields of the four reservoirs on the Hackensack River and tributaries, along with supplementary water sources using inter-basin transfers. Mr. Beckers reviewed an existing Microsoft Access model of the system and managed improvements to the model, among other things adding automated safe yield calculation capability. Mr. Beckers performed the analyses using the model, presented the results to the client, and wrote the final report.

Potake Pond SEQR Services , LeBoeuf, Lamb, Greene & MacRae for United Water New York Providing modeling analyses of the impacts of proposed 110 million gallon additional diversion from Potake Pond to support flows in the Ramapo River during drought conditions. Mr. Beckers reviewed an existing Microsoft Excel spreadsheet model and added capabilities needed for the analysis. Mr. Beckers is using the model to evaluate the hydrological impacts of the additional diversion on Potake and Cranberry ponds, as well as the Beaver Pond Swamp, and the improvements to drinking water available from the Ramapo Valley Well Field. These evaluations will be part of the SEQR application for the proposed additional diversion. Mr. Beckers is also assisting in the evaluation of the hydraulic capacity of the Potake-Ramapo pipeline under the additional drawdown conditions.

Western Ramapo WWTP Environmental Assessment Support, Western Ramapo Engineering Team for Rockland County Sewer District No. 1. Providing model analyses of the impact on quality and flows in the Ramapo River, and operations at the Ramapo Valley Well Field resulting from the proposed discharge of highly treated wastewater to the Ramapo River.

Project Manager of Passaic River Nutrient TMDL Study, TRC OmniEnvironmental for New Jersey Department of Environmental Protection. On-going study to establish the phosphorus TMDL for the Passaic River. The focus of LMS' work is evaluation of appropriate phosphorus end points for the several water supply diversions in the Passaic watershed, as well as the impacts on water availability resulting from proposed phosphorus limits. LMS provided plans for conduct of a dye study to determine the interaction between the Two Bridges Sewer Authority discharge and the Wanaque South Pump Station drinking water intake, and is currently conducting a field study of the new Passaic Valley Water Authority filtration plant to estimate process impacts of phosphorus in the raw water.

Rockland County Water Reuse Alternatives Study, Stearns & Wheler for Rockland County Sewer District No. 1. Evaluated the impacts of proposed alternative locations for discharge of highly treated wastewater on the safe yield and raw water quality of affected water supply diversions. Mr. Beckers presented a paper on the project to a meeting of the American Water Resources Association.

Project Manager of Wanaque South Management Program Extension and Expansion Project North Jersey District Water Supply Commission. Incorporation of the latest stream flow and reservoir storage data in the Wanaque South Management Program, and add the ability to evaluate the effects of the Ramapo Valley Well Field on water availability at the Wanaque South Pump Station. Mr. Beckers oversaw the addition of the data to the database, and he wrote the new ObjectPAL computer programming necessary to add the well field impacts to the Paradox-based model.

Project Manager of Hudson River Diversion Study, United Water New York. Study of the potential for "flood skimming" to provide an additional source of potable water for Rockland County, New York during drought emergency conditions. Mr. Beckers wrote the final report on the study.

Water Allocation Permit Relocation Study, United Water New Jersey. Detailed report on the regulatory, environmental, and political constraints inherent in a proposal to relocate the diversion site for an existing New Jersey water allocation permit.

Project Manager of Newark Water Supply Management Program, Killam Associates for Newark (NJ) Department of Water and Sewer Utilities. Application of the LMS H_2*Online*[SM] Reservoir Management Program Version 2 (LMS-RMPv2) to the City of Newark, New Jersey, source water reservoirs. He managed the key entry of 50 years of handwritten data and he performed the electronic transfer of an additional 20 years of data from an obsolete database system. Mr. Beckers expanded the capability of the LMS-RMPv2 to incorporate unique features of the Newark watershed. He installed the software and database on Newark computers and provided training for Newark personnel in use of the Newark Water Supply Management Program.

Project Manager of Newark Historical Water Database, and Newark Water and Sewer Budget Ledger DatabaseConversion Project, City of Newark, New Jersey, Department of Water and Sewer Utilities, Division of Water and Sewers. Conversion of existing UNIX water and sewer databases from an obsolescent UNIX computer to a modern Windows-based computer network. He managed the work of a sub-consultant, who provided a new Windows application for the Newark Historical Water Database. He also identified an available conversion program that enables execution of the existing Budget Ledger UNIX software under the Windows operating system. Mr. Beckers performed the installation of the conversion software on the Windows network and the transfer of the Budget Ledger databases for water and sewer. He trained Newark Water and Sewer personnel in the use of the new software systems.

Review of UWNY Ramapo River Flow Augmentation Model, United Water Management Services for United Water New York. Review of the development, use and results of an Excel spreadsheet model evaluating the proposed use of Potake Pond (Rockland County, New York) to augment flows in the Ramapo River to enable continued use of the Ramapo Valley Well Field during drought conditions. He wrote a report on his findings that was part of the permit application package submitted to New York State Department of Environmental Conservation for the diversion permit.

Safe Yield of Letchworth Reservoir System, United Water New York. Due diligence analysis of the safe yield of the Letchworth Reservoir system in Rockland County, New York, in anticipation of purchase of the system by United Water New York.

Project Manager of Lake DeForest Rule Curve Evaluation and Litigation Support, United Water New York, and LeBoeuf, Lamb, Greene and MacRae for United Water New York. Detailed technical review of the model developed by the New York State Department of Environmental Conservation (NYSDEC) to establish rule curves for operation of the Lake DeForest Reservoir, modified the model to aid in evaluation of the effects of additional water sources on those rules, and provided detailed recommendations regarding the interpretation of the existing rule curves. He developed an implementation procedure for management of Lake DeForest to comply with the existing rule curves. When Rockland County, New York initiated regulatory proceedings with NYSDEC regarding operation of the reservoir, Mr. Beckers provided technical support to the outside counsel handling the matter for United Water New York (UWNY). Mr. Beckers made presentations on the interpretation of the rule curves to legal counsel, as well as senior management of both UWNY and United Water New Jersey.

Project Manager of Boonton Reservoir Safe Yield Study, City of Jersey City, New Jersey, Department of Water. He Design and program of Version 2 of the LMS H_2*Online*^{SM} Reservoir Management Program (LMS-RMPv2) and applied it to the Jersey City watershed, creating the Jersey City Water Supply Management Program (JCWSMP). He oversaw the key entry of approximately 50 years of handwritten data for the JCWSMP database. Mr. Beckers used the JCWSMP to evaluate the safe yield of the Boonton and Splitrock reservoir system, and wrote the final report documenting the JCWSMP and the results of the safe yield analysis. He installed the JCWSMP on the Jersey City computer system and trained Water Department personnel in its use. Mr. Beckers presented a paper on the study to an annual meeting of the Water Environment Federation.

Development of the Wanaque South Management Program, North Jersey District Water Supply Commission with United Water New Jersey. Conceptual development of the Wanaque South Management Program, which LMS developed to assist managers in deciding when to initiate and continue pumping operations at the Wanaque South Pumping station, for transfer of water from the Pompton River to Wanaque Reservoir.

Project Manager, Kensico Reservoir Water Pollution Control Project, Roy F. Weston, Inc. for New York City Department of Environmental Protection Agency. Mr. Beckers served as project manager for the tasks LMS performed in this multi-faceted study of water quality in New York City's Kensico Reservoir: Bathymetric and sediment thickness mapping to determine the current size and shape of the reservoir and the distribution of sediments, Sediment sampling and laboratory analyses to evaluate the quality of the sediments and any potential impacts on the overlying water column, Dispersion dye surveys to determine the travel paths and mixing of the influents from the Catskill and Delaware aqueducts within the reservoir, Application of a three-dimensional, dynamic model (RMA-10) to simulate hydrodynamics, thermal stratification and concentrations of fecal coliform bacteria, total coliform bacteria and total suspended solids for a period of 18-months at a 1.5-hour timestep. Mr. Beckers presented papers on the project to meetings of the American Society of Civil Engineers, the Water Environment Federation, and the American Water Resources Association.

WATER QUALITY PROJECTS

Project Manager, Various Projects Related to Permitting of Stormwater Discharges from Airports, Port Authority of New York and New Jersey. Providing guidance to staff developing information to assist the Port Authority in negotiation of permits for various New York City-area airports.

Project Manager of Restoration of Tidal Flows to Manitou Marsh, Museum of the Hudson Highlands. Field survey to determine soil elevations within Manitou Marsh and to estimate the effect of railroad culverts on relative tides in the Hudson and the marsh. Mr. Beckers then developed a Visual BASIC model to evaluate the potential for restoring tidal influence in the region immediately to the south of the road across the marsh, by reconstructing collapsed culverts under the roadbed. Mr. Beckers presented a paper on the project to an annual meeting of the Society of Wetland Scientists.

Project Manager of Nutrient Modeling of Paulinskill River, Montgomery-Watson for Town of Newton, New Jersey. Field survey of the Paulskill River to develop a data set for calibration and verification of the QUAL-2e model. The water quality data included diurnal dissolved oxygen, carbonaceous BOD, nitrogenous BOD, phosphorus, and temperature. A dye study was also done to determine time of travel. The QUAL-2e model was calibrated and verified, and used to evaluate proposed nutrient limits in the NJPDES permit for the Town of Newton wastewater treatment plant. Mr. Beckers also prepared responses to comments from New Jersey Department of Environmental Protection.

Project Manager of Thames River Water Quality Modeling Study, Connecticut Department of Environmental Protection. Application of CE-QUAL-W2 to model the estuarine hydrodynamics and water quality of the Thames River. The purpose of the study was to evaluate alternatives for elimination of eutrophication in the upper reaches of the estuary related to CSO, point, and nonpoint sources. In addition to technical oversight of the project, Mr. Beckers served as interface between the project and a public advisory committee organized by the Southeastern Connecticut Regional Planning Agency.

Project Manager of Modeling of heavy metals and dissolved oxygen in the Rio Cibuco, Puerto Rico, Davis Polk Wardell for Warner Pharmaceuticals. As project manager, Mr. Beckers applied the RMA-2 and RMA-4 models to the Rio Cibuco and tributaries in Puerto Rico to evaluate constraints on discharge of heavy metals and oxygen-demanding substances, in support of a NPDES permit renewal for a pharmaceutical plant.

Project Manager, Study of Cooling Water Discharge – Knolls Atomic Power Laboratory. As project manager, Mr. Beckers conducted a study of chlorine concentrations in the cooling water discharge from the Knolls Atomic Power Laboratory, and the ability to comply with a New York State SPDES permit limit.

Project Manager World Trade Center SPDES Permit Services Project, Port Authority of NY and NJ. Mr. Beckers served as project manager on this multiyear project to study biological, thermal and chlorination impacts in the Hudson River related to withdrawal and discharge of air conditioning cooling water. The project included field data acquisition, entrainment/impingement studies, in-plant monitoring, and discharge plume modeling. (The project was discontinued as a result of the *first* World Trade Center bombing.)

Preliminary Evaluation – Nut Island Emergency Discharge. Mr. Beckers employed CORMIX modeling to evaluate the potential water quality impacts in Boston Harbor resulting from activation of an emergency discharge point for a cross-harbor sewage force main.

Marina Permitting Review, Battery Park City Authority. Mr. Beckers evaluated the permitting requirements for a proposed marina on the Hudson River at the northern end of Battery Park City, Manhattan County, New York.

Impacts of Prison Barge Mooring, NYC Department of Correction. Mr. Beckers evaluated the effects of circulation changes resulting from docking a New York City Department of Correction prison barge on sedimentation patterns in the East River.

Pump Flow Calibration Study, Hartford (CT) Steam Company. Mr. Beckers used fluorescent dye injection techniques to calibrate pump flow in the Hartford Steam Company once-through cooling water system, by measuring time-of-travl through the system.

LMS-DAS Development Project, Lawler, Matusky & Skelly Engineers. In this internally funded hardware development project, Mr. Beckers used early laptop computer technology to implement the automated LMS-Data Acquisition System (LMS-DAS) for acquisition of dye dilution survey data to support application of hydrodynamic water quality and sedimentation models of New York City's 14 Wastewater Pollution Control Plant discharges.

Prior Employment

KVH Industries, Inc. **1987-1990**
Middletown, Rhode Island

Government Programs Manager
Managed government funded programs for development and manufacture of electronic compasses and compass systems totaling over $9 million (with over $13 million follow-on potential) for applications including laser rangefinders, radio direction finders and small vessels, as well as advanced research and development.

East Passage Marine, Inc. **1983-1989**
Newport, Rhode Island

Owner/Operator
Conducted marine salvage business; built, operated and maintained steel-hulled diesel tug. Performed ocean and environmental consulting, including technical writing services for oceanographic instrument manufacturers; reviewed stormwater runoff control plans for Middletown (RI) Planning Board.

Raytheon Service Company **1982-1987**
Middletown, Rhode Island

Senior Engineer
Managed deployment, operations and computerized data analysis for US Antarctic Research Program environmental field study of wastewater discharge at McMurdo Station

Managed development of computerized database for Central California Coastal Circulation Study under U.S. Bureau of Land Management funding.

Performed detailed review and fault analysis on defective electromagnetic ocean current meter design.

Developed test requirements and test procedures for AN/BSY-1 bathymetric subsystem.

Raytheon Ocean Systems Company **1979-1982**
East Providence, Rhode Island

Manager-Systems Engineering 1981-1982
Managed and performed systems engineering study for selection of advanced technology tide gauge for the National Tide and Water Level Measurement System; wrote manual for DSF6000N Fathometer System.

Senior Engineer 1979-1981
Analyzed problems with USEPA's RAMSES computerized estuarine water quality model and identified corrective actions under USEPA funding.

Managed analysis of estuarine water quality effects of submerged discharge from Newport (RI) Wastewater Treatment Plant for the City.

Raytheon Submarine Signal Division **1970-1979**
Portsmouth, Rhode Island

Manager-Applied Modeling 1978-1979
Managed and developed RECEIV-III computerized water quality model in Fortran IV on CDC Cyber 174 for US Environmental Protection Agency.

Managed and applied SWMM and STORM computerized stormwater management models on CDC Cyber 174 in analysis of stormwater pollution for the state of Rhode Island under USEPA funding.

Managed field studies and application of various water quality analysis techniques to problems relating to wastewater discharge from chicken processing plant in Accomac, VA, for Perdue Chickens.

Managed and applied computerized plume and receiving water models to analysis of pollution discharges from various wastewater treatment plants in New England under USEPA funding.

Senior Engineer 1975-1978
Managed stormwater pollution field data acquisition program for Hampton Roads, VA, region under Hampton Roads Sanitation District funding.

Developed full thermal modeling improvements to RECEIV-II under funding from Connecticut Department of Environmental Protection and managed demonstration on Thames River estuary.

Engineer 1970-1975
Applied RECEIV-II and other water quality models to numerous waterways in New England and mid-Atlantic states including the Housatonic River, and installed models on state-owned mainframe computers under USEPA funding.

Developed RECEIV-II computerized water quality model in Fortran IV on CDC Cyber 174 for U.S. Environmental Protection Agency.

Sperry Systems Management Division **1970**
Great Neck, New York

Engineer
Reviewed oceanographic instrument specifications for application to National Data Buoy System.

Nereus Corporation **1968-1970**
Narragansett, Rhode Island

Technical Consultant
Developed real-time data acquisition and analysis program for water quality instrument system using assembler on HP-6000-series minicomputer.

Managed and performed limnological survey of Burlington Bay, Lake Champlain, Vermont, for local sanitation district.

Publications

"The Pequannock River Thermal TMDL and the Newark Water Supply Reservoirs", Proceedings of the Water Environment Federation TMDL 2005 Conference, Philadelphia, PA, 26-29 June 2005 (with Anthony DeBarros).

"Evaluation of Water Reuse to Augment Water Supplies in Rockland County, New York", Proceedings of the American Water Resources Association 2003 International Water Congress on Watershed Management for Water Supply Systems, New York City, 30 June-02 July 2003 (with T. Vanderbeek, M. Skell, D. Distante, R. Delo, M. Tamblin and R. Butterworth).

"Watershed Safe Yield Analysis Using the Jersey City Water Supply Management Program", Proceedings of WEFTEC'98, Orlando, Florida, October 3-7, 1998, Water Environment Federation, Alexandria, Virginia. (with R. Lorfink, J. Lawler, and G. Nissen)

"Modeling of Kensico Reservoir Watershed Management Alternatives", Proceedings of the Water Environment Federation 69th Annual Conference & Exposition, Dallas, Texas, October 5-9, 1996, Vol.4, pp. 129-139. (with B. Klett, J. Lawler, and T. Englert)

"Evaluation of Watershed Management Alternatives Using the Kensico Water Quality Model", Proceedings of the AWRA Session on New York City Water Supply Studies, J.J. McDonnell, D.J. Leopold, J.B. Stribling and L.R. Neville (eds.), 1996, American Water Resources Association, Herndon, VA, pp. 123-132. (with B. Klett)

Global Positioning System - Updating mobile water quality evaluation practices. Water Environment & Technology. August 1996. (with G. Apicella, R. O'Neill, and D. Distante)

"Kensico Reservoir Water Pollution Control Study", Integrated Water Resources Planning for the 21 st Century: Proceedings of the 22nd Annual Conference, Cambridge, MA, May 7-11, 1995, M.F. Domenica (ed.), American Society of Civil Engineers, pp. 297-301. (with A. Sharpe and D. Parkhurst)

"Currents, water quality, bottom sediments, and bathymetry in McMurdo Sound near McMurdo Station", *Antarctic Journal of the United States*, XXI (4): 12-14, December 1986. (with D. 0. Cook, M.J. Falla, G.C. Parker, and M.J. Speranza)

"A Treasure Trove in San Pedro", *Cruising World*, 9(3):17-18, March 1983

"Sailing Under the New Inland Rules (Part I)", *Cruising World*, 8(1):80-86, January 1982.

"Sailing Under the New Inland Rules (Parts II)", *Cruising World*, 8(2):43-48, February 1982.

"Sensor Subsystem for the Next Generation Tide and Water Level Measurement System", OCEANS 81 Conference Record, Boston, September 16-18, 1981, 2:1100-1105, Institute of Electrical and Electronic Engineers. (with R. Franklin and T. Smith)

"Phase I Final Report Evaluating Sensor Systems for the Measurement of Tide and Water Level", Report to National Ocean Survey, Rockville, MD, under contract NA-80-SAC-00619, 4 May 1981. (et al. for Raytheon Ocean Systems Company)

"Interim Technical Working Report Evaluating Recording Technologies and Techniques for the Measurement of Tide and Water Levels", Report to National Ocean Survey, Rockville, MD, under contract NA-80-SAC-00619, 23 December 1980. (et al. for Raytheon Ocean Systems Company)

"Interim Technical Report Evaluating Sensor Technologies and Techniques for the Measurement of Tide and Water Levels", Report to National Ocean Survey, Rockville, MD, under contract NA-80-SAC-00619, 10 November 1980. (et al. for Raytheon Ocean Systems Company)

"Make Your Own Awning in One Day", *Cruising World*, 6(3):108-110, March 1980.

"Requirements on Water Quality Modeling Used to Establish Treatment Facility Discharge Limits", Journal of the New England Water Pollution Control Association, 3(1):4-18, April 1979. (with A. Khayer)

"Minimum Data Requirements for Selection of 'Textbook' Water Quality Model Coefficients", Proceedings, USEPA Symposium on Rate Constants, Coefficients, and Kinetics Formulations in Surface Water Modeling, Concord, California, February 23-25, 1977, U.S. Environmental Protection Agency, Washington, D.C.

"RECEIV-II: A Generalized Dynamic Water Quantity and Quality Model", Proceedings, Twelfth American Water Resources Conference and Symposium, Chicago, September 20-22, 1976, American Water Resources Association. (with R.N. Marshall and S.G. Chamberlain)

"Validation, Calibration and Verification of Generalized Dynamic Water Quality Models", Proceedings, Twelfth American Water Resources Conference and Symposium, Chicago, September 20-22, 1976, American Water Resources Association.

"RECEIV-II: A Generalized Dynamic Planning Model for Water Quality Management", Proceedings of the Conference on Environmental Modeling and Simulation, Cincinnati, Ohio, April 19-22, 1976, U.S. Environmental Protection Agency Report No. EPA 600/9-76-016, p. 344. (with P.E. Parker, R.N. Marshall, and S.C. Chamberlain)

"RIBAM, A Generalized Model for River Basin Water Quality Management Planning", Proceedings of the Conference on Environmental Modeling and Simulation, Cincinnati, Ohio, April 19-22, 1976, U.S. Environmental Protection Agency Report No. EPA 600/9-76-016, p. 45.

"Preliminary Design of Estuarine Water Quality Monitoring Systems", Proceedings of the OCEANS 74 Conference, Halifax, Nova Scotia, August 21-23, 1974, Institute of Electrical and Electronic Engineers. (with S.C. Chamberlain)

"Cost-effective Water Quality Surveillance Systems", Proceedings, 20th Annual Meeting, Institute of Environmental Sciences, Washington, DC, April 28-May 1, 1974, pp. 310-317. (with S.G. Chamberlain and R.D. Shull)

"Quantitative Methods for Preliminary Design of Water Quality Surveillance Systems", *Water Resources Bulletin,* 10(2):199-219, April 1974. (with S. G. Chamberlain, G. P. Crimsrud, and R.D. Shull)

"Design of Cost-effective Water Quality Surveillance Systems ", U.S. Environmental Protection Agency Report No. EPA-600/5-74-004, January 1974. (with S.G. Chamberlain)

"Quantitative Methods for Preliminary Design of Water Quality Surveillance Systems", U.S. Environmental Protection Agency Report No. EPA-R5-72-001, November 1972. (with S.G. Chamberlain and G.P. Grimsrud)

"Evidence of Internal Kelvin Waves in Lake Champlain", Fifteenth Conference on Great Lakes Research, Madison Wisconsin, April 5-7, 1972, International Association for Great Lakes Research.

"A Review of the Buzzard Bay SWORD System", IEEE Second International Geoscience Electronics Symposium Digest of Technical Papers, Washington, D.C., April 14-17, 1970, p 5-2 ff. (with J.E. Spence)

Exhibit 2

14 December 2007

Elise N. Zoli, Esq.
Goodwin Procter LLP
Exchange Place
Boston, MA 02109

re: Draft Environmental Impact Statement for State Pollutant Discharge Elimination System Permits for Bowline Point, Indian Point 2&3, and Roseton Steam Electric Generating Stations, December 1999:

Appendix VI-3-A, Thermal Modeling of Ebb and Flood Tide Thermal Plumes

Appendix VI-3-B, Thermal Modeling of Near Slack-water Tide Thermal Plumes

Dear Ms Zoli:

This letter responds to your inquiry regarding our historic work on the above, confirming the key points of our discussion of 11 December 2007.

The principal in charge of the engineering analyses documented in the subject appendices was John P. Lawler, Ph.D., P.E., a partner in Lawler, Matusky & Skelly Engineers LLP ("LMS", predecessor to HDR|LMS). I served as project manager for the engineering analyses. Dr. Lawler, Mr. Michael Vecchio, and I performed the engineering analyses on the project, with the assistance of other staff engineers as needed. LMS also employed the consulting services of M. Llewellyn Thatcher, Ph.D., P.E., regarding application of the so-called MIT model. While the subject appendices are signed by Dr. Lawler, as partner-in-charge, I am the principal author of those documents. Mr. Vecchio and I are currently employed by HDR Engineering, Inc.; Dr. Lawler and Dr. Thatcher both retired several years ago.

The contents of the subject appendices must be evaluated in the context of the time in which the analyses were conducted; more is known about modeling and the Hudson River today than when the analyses were done. While the date of the Draft Environmental Impact Statement (DEIS) is December 1999 and the date of the Final Environmental Impact Statement (FEIS) is June 2003, the actual analyses described in Appendix VI-3-A and Appendix VI-3-B were performed during the early and mid-1990s. Although not shown in the appendix, the date of the report presented in Appendix VI-3-A is June 1993, and it reports the results of work performed during the preceding several years. The date of the letter presented in Appendix VI-3-B is November 1998 and it reports analyses done during 1996 and 1997.

By direction of New York State Department of Environmental Conservation (NYSDEC), LMS was initially charged with calculating the thermal effects of the three generating stations on the Hudson River ("River") under the worst case ambient River and operational conditions that could occur, regardless of the likelihood of that event happening. Those conditions were taken to include all thermal discharges to the Hudson River discharging at the maximum permitted thermal load simultaneously for a long enough period of time so that the River could reach a state of dynamic equilibrium (sometimes also called "quasi-steady state"). For the case studied, a state of dynamic equilibrium meant that, while the actual conditions in the River would vary in response to such naturally variable processes as tides, currents and weather, the thermal loads were constant for a long enough time so that transient effects due to changes in loads had reached their maximum values. Because those discharges also vary in normal operation, the actual effect on the River would typically be less than the effect calculated under the assumption that they operate continuously, at maximum load, for a long period of time. In other words, LMS was tasked with evaluating a hypothetical worst case condition, not the actual effects of the discharges or the actual resulting conditions in the River. Appendix VI-3-A presents the results of that worst case analysis.

Subsequently, NYSDEC requested the additional analysis presented in Appendix VI-3-B and specified the conditions to be modeled for that analysis. As noted in the Discussion that begins on Page 7 of that appendix, the tidal and current conditions specified by NYSDEC never occur in the River, and the freshwater flows represent a highly atypical condition. Thus, the conditions modeled were wholly unrealistic and the results represent conditions that can never occur in the River, because the tidal and current conditions specified never occur.

LMS employed the most reliable modeling methods then available to perform the analyses reported in the subject appendices. While far-field models with higher spatial dimensionality were available at that time, it was our judgment that the available data would not support the application of those models, because they provided insufficient information on cross-river and vertical variability. LMS elected to use the one-dimensional, cross-sectionally averaged, time-variable MIT

Dynamic Network Model to represent far-field conditions, and the CORMIX model to represent near-field conditions, because the available data were sufficient to support that level of modeling detail. In recent years, far-field models with higher degrees of dimensionality have been successfully applied to the River, based on newer data collected in the intervening period. The CORMIX near-field model remains today the preferred model for analysis of discharge plumes, as recognized by the United States Environmental Protection Agency. CORMIX is unique in that it does not require calibration.

However, modeling is not solely dependent on the models employed; it relies heavily on the knowledge and experience of the modelers both with respect to the water body and conditions being modeled, and with respect to the capabilities of the models being used. In particular, it is important that the modeler have direct experience with the water body under study. The individuals who performed the studies documented in the subject appendices were (and are) both experienced modelers and intimately knowledgeable about the Hudson River. For example, Dr. Lawler had about 30 years experience in modeling the Hudson River at that time. At that time, I had about 20 years experience in the development and application of multi-dimensional, time-variable hydrodynamic and water quality models.

The results presented in the subject appendices tend to overstate the effects of the discharges on the River. It is my understanding that, in specifying the conditions to be modeled, NYSDEC intended the results presented in the subject appendices to overstate the effects of the discharges modeled on the Hudson River, to be protective of the resource. In addition, one of the techniques experienced modelers use when analyzing water bodies with limited data is to make conservative assumptions and use conservative approaches, to assure that the results are protective of the resource. Throughout the modeling effort presented in the subject appendices, the LMS modelers made conservative assumptions whenever assumptions were required. As a consequence, the results presented in the subject appendices tend to overstate the effects of the discharges modeled on the River.

When interpreting the results presented in the subject appendices, it must be kept in mind that those results are representative of both the highly unusual conditions that LMS was directed to model and the conservative modeling assumptions made in the analysis. The conditions modeled in Appendix VI-3-A rarely, if ever, could occur in the real world, and the conditions used in Appendix VI-3-B never occur.

As a result, the information presented in the subject appendices cannot be used as the basis for a judgment regarding the actual, day-to-day performance of any of the generating stations evaluated, including Indian Point,. Specifically, the finding presented in Appendix VI-3-A that Indian Point would have caused exceedances of the New York State thermal criteria under the conditions modeled cannot be construed as meaning that Indian Point actually causes exceedances of those criteria in day-to-day operations.

If you have any further questions on this topic, please do not hesitate to contact me.

Sincerely,
Henningson, Durham & Richardson Architecture and Engineering, P.C.

Charles V. Beckers, Jr., P.E.
Senior Project Manager

Entergy's Objections to Declaration of Peter Henderson in Support of Riverkeeper's Contention EC-1, Attachment 2, *Status of Fish Populations and the Ecology of the Hudson*, Pisces Conservation Ltd. (Nov. 2007) ("Pisces Hudson Report")

Source: Pisces Hudson Report, at 5-6

Statement: Given the considerable efforts that have been taken to reduce organic pollution, and the great improvement in water quality in the vicinity of New York City, these declines in [dissolved oxygen] are disappointing, and potentially important indictors of a decline in water quality for fish.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with particularity that declines in dissolved oxygen content "are disappointing, and potentially important indicators of a decline in water quality for fish." *See In re S. Nuclear Operating Co.* (Vogel ESP Site), 52-011-ESP, 65 N.R.C. 237, 254 (2007) (observing that "neither mere speculation nor bare or conclusory assertions, even by an expert, alleging that a matter should be considered will suffice to allow the admission of a proffered contention"); *In re Duke Cogema Stone & Webster* (Savannah River Mixed Oxide Fuel Fabrication Facility), 070-03098-ML, 61 N.R.C. 71, 80 (2005) (noting that "[w]hile the expert's method for forming his opinion need not be generally recognized in the scientific community, the opinion must be based on the 'methods and procedures of science' rather than on 'subjective belief or unsupported speculation'"); *see also Pelletier v. Main Street Textiles*, 470 F.3d 48, 52 (1st Cir. 2006) (concluding plaintiff's expert's opinion was speculative and was based on insufficient facts and data because he had never visited the site of the accident and apparently based his opinions on deposition testimony and preliminary expert reports about the accident); *Bouchard v. N.Y. Archdiocese*, No. 04 Civ. 9978 (CSH), 2006 WL 3025883, at *7 (S.D.N.Y. Oct. 24, 2006) (concluding expert's opinions were "argumentative and conclusory" because they were speculative and not based on sufficient facts and data); *Colt Defense LLC v. Bushmaster Firearms, Inc.*, No. Civ. 4-240-P-S, 2005 WL 2293909, at *4 (D. Me. Sept. 20, 2005) (concluding plaintiff failed to demonstrate the qualifications of its expert, because the expert, who grounded his opinion in an inadequate review of secondary sources, failed to base his expert opinion on sufficient facts or data); *see also* FED. PROC. § 80:225 (June 2006) ("In keeping with the judicially expressed notion that experts' opinions are worthless without data and reasons, FRE 702, as amended in 2000, requires as one of the conditions of the admissibility of expert testimony that the testimony be based upon sufficient facts or data, as opposed to hypotheses and "guesstimations" which have little grounding in actual physical realities. Thus, evidence is subject to exclusion where it is not founded on objective data, studies, or sampling techniques.") (internal citations omitted); *Clough v. Szymanski*, 809 N.Y.S.2d 707, 709 (N.Y. Supr. Ct. 2006) ("[m]ere speculation, including that set forth in an expert's affidavit, is insufficient to raise an issue of fact").

Source: Pisces Hudson Report, at 28

Statement: Alewife had very low abundance indices in 1998 and 2002, and high indices in 1999 and 2001. This suggests a population that is becoming destabilised and more dependent on

occasionally good recruitment years. **Objection(s):** • Speculation: Drs. Seaby and Henderson set forth insufficient facts and data to support their statement that the Alewife low abundance indices "suggest" that the Alewife population in the Hudson "is becoming destabilised and more dependent on occasionally good recruitment years." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.
Source: Pisces Hudson Report, at 30 **Statement:** Juvenile Rainbow smelt have disappeared from the survey since the mid 1990s (Figure 30). This may to be due to a change in their distribution, possibly due to the invasion of zebra mussels, which occurred from 1992 onward (Strayer 2004). However . . . rainbow smelt has one of the lowest upper temperature tolerances of Hudson fish. It is therefore possible that the species has declined because of rising water temperatures. **Objection(s):** • Speculation: Drs. Seaby and Henderson set forth no facts or data showing with particularity any support for the idea that "[i]t is therefore possible that [juvenile rainbow smelt have] declined because of rising water temperatures." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.
Source: Pisces Hudson Report, at 36 **Statement:** There has been a recent increase in average water temperature and a decrease in dissolved oxygen levels. This may be influencing some of the changes observed and will increase the impact of thermal discharges. **Objection(s):** • Speculation: Drs. Seaby and Henderson set forth no facts or data showing with particularity that increases in water temperature coupled with declines in dissolved oxygen content "may be influencing some of the changes observed and will increase the impact of thermal discharges." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709. • Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See In re Duke Energy Corporation*, (Catawba Nuclear Station), CLI-04-21, 60 N.R.C. 21, 27 (2004) (a "witness may qualify as an expert by 'knowledge, skill, experience, training, or education' to testify

'[i]f scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue'"); *In re Duke Power Co.* (McGuire Nuclear Station), 50-369-OL, 15 N.R.C. 453, 474-75 (1982) (affirming decision finding expert to be unqualified where "his claimed expertise on the subjects at issue rest[ed] mainly on his asserted ability to 'understand and evaluate' matters of a technical nature due to his background of 'academic and practical training' and 'years of reading AEC and NRC documents'").
Source: Pisces Hudson Report, at 36 **Statement:** It is important to factor in potentially increasing water temperatures in any discussion of Hudson River fish. Small rises in the background temperature could have a significant effect on the impacts of thermal discharges into the river. **Objection(s):** • Speculation: Drs. Seaby and Henderson set forth no facts or data showing with particularity that there are "potentially increasing water temperatures" in the Hudson and that "[s]mall rises in the background temperature could have a significant effect on the impacts of thermal discharges into the river." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709. • Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.
Source: Pisces Hudson Report, at 36 **Statement:** Even if the power companies are not the sole cause of degradation of the Hudson River fish community, the loss of such high proportions of the fish populations must be important. **Objection(s):** • Relevance: What Drs. Seaby and Henderson subjectively believe is irrelevant to the question of whether the NRC should approve Entergy's application. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

Entergy's Objections to Declaration of Peter Henderson in Support of Riverkeeper's Contention EC-1, Attachment 3, *Entrainment, Impingement and Thermal Impacts at Indian Point Nuclear Station*, Pisces Conservation Ltd. (Nov. 2007) ("Pisces EI Report")

Source: Pisces EI Report, at 1

Statement: The data used recently by Entergy to assess this impact are old, having been gathered between 1980 and 1990. Since then, the estuary has changed considerably, with several species declining in abundance, and some species, most notably striped bass, increasing. There have been large changes in the river environment and important biological invasions.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth insufficient facts and data to support their statement that the "estuary has changed considerably" or that "[t]here have been large changes in the river environment and important biological invasions," making this statement speculative. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709. Indeed, a director at Riverkeeper stated in 2002 that the Hudson "is the only large river in the North Atlantic that retains strong spawning stocks of its entire collection of historical migratory species." Testimony of Robert F. Kennedy, Jr. Before the U.S. Senate Environment and Public Works Committee In Recognition of the 30th Anniversary of the CWA (October 8, 2002).

Source: Pisces EI Report, at 1

Statement: Modern data suggest that striped bass entrainment is likely to have increased by over 750% from the level at the time when the data was gathered.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity why striped bass entrainment is "likely to have increased by over 750%" from levels at the time the DEIS was filed. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Pisces EI Report, at 2

Statement: The impact of the mortalities caused by impingement and entrainment and thermal discharges on the fish populations of the Hudson is large.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity that Indian Point causes fish mortality or that this fish mortality is "large." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005

WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.
Source: Pisces EI Report, at 4 **Statement:** The impact on other species is un-quantified and may be significant. **Objection(s):** • Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity why the impact of other fish species "may be significant." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.
Source: Pisces EI Report, at 7 **Statement:** Considerable ecological changes have taken place over the last 20 years, so that entrainment numbers derived from the DEIS can no longer give a reliable guide to present entrainment. **Objection(s):** • Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity that "[c]onsiderable ecological changes have taken place over the last 20 years[.]" *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.
Source: Pisces EI Report, at 7 **Statement:** In general, these numbers are notably high, especially when it is remembered that several of the species under consideration are showing long-term declines in abundance in the Hudson. The CMR numbers indicate that Indian Point is killing an appreciable proportion of the Atlantic tomcod, white perch and bay anchovy populations in the estuary. These deaths will be contributing to the decline of these species. **Objection(s):** • Speculation: Drs. Seaby and Henderson set forth insufficient facts and data to support their statements that "Indian Point is killing an appreciable proportion of the Atlantic tomcod, white perch and bay anchovy populations in the estuary." Moreover, Pisces's reliance on CMR data is factually inaccurate because CMR measures the proportion of age 0 fish (i.e., from egg to age 1) lost to entrainment, not "the available population living in the Hudson Estuary." The ER describes a CMR as "the mortality to the fraction of the river population caused by IP2 and IP3 entrainment if there were no other sources of mortality implicated. ER, at 4-12. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Pisces EI Report, at 7

Statement: In this statement, the key populations are presumably common species, and as shown in Pisces (2007), many of these species are showing long term trends. With many species in decline, it is unclear how the observation of a general trend is to be shown to be unrelated to the power plants, if there are direct observational data demonstrating that the power plants are killing the species. For example, it is clear that tomcod are killed by cooling water systems. The Atlantic tomcod population is in decline. It would be almost certain that if these individuals were not killed, the population would be larger."

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity why observation of general trends in fish populations must be attributable to Indian Point. Indeed, this statement is symptomatic of the flaws in the Pisces reports – there is no evidence linking Indian Point to the catastrophic impacts prophesied by Drs. Seaby and Henderson. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Pisces EI Report, at 7

Statement: It is probable that similar levels of impact will be felt by the many rarer species that spawn or spend part of their life stages in the lower Hudson River.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity why "it is probable that" impacts allegedly felt by certain species due to Indian Point "will be felt by the many rarer species that spawn or spend part of their life stages in the lower Hudson River" or that Indian Point impacts such species at all. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Pisces EI Report, at 7

Statement: What is clear, from these data and analyses . . . is that entrainment and impingement . . . are eliminating a significant portion of the most abundant species in their egg and larval stages. It is probable that similar levels of impact will be felt by the many rarer species that spawn or spend part of their life stages in the lower Hudson River.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity that entrainment at impingement due to Indian Point "are eliminating a significant portion of the most abundant species in the egg and larval stages." Similarly, there is no support for the statement that "it is probable" that impacts allegedly felt by certain species due to Indian point "will be felt by the many rarer species that spawn or spend part of their life stages in the lower Hudson River" or that Indian Point impacts such species at all. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Pisces EI Report, at 11

Statement: Entrainment data for Atlantic tomcod are not available, but are likely to be significant, with an estimated conditional mortality rate (CMR) indicating that 12% of the Atlantic tomcod population are being killed by Indian Point each year.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity why entrainment mortality data, *though not even available*, "are likely to be significant." Moreover, Pisces's use of CMR data is factually inaccurate because CMR measures the proportion of age 0 fish (i.e., from egg to age 1) lost to entrainment, not "the available population living in the Hudson Estuary." The ER describes a CMR as "the mortality to the fraction of the river population caused by IP2 and IP3 entrainment if there were no other sources of mortality implicated. ER, 4-12. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Pisces EI Report, at 11

Statement: A rough approximation of the number of striped bass entrained indicates that the number may have increased by 750% over old estimates.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity why a "rough approximation" of entrainment data shows that striped bass entrainment "may have increased by 750% " from previous estimates. Such "rough approximations" are inherently speculative. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Pisces EI Report, at 11

Statement: In a system that is under stress from many sources, the entrainment of 1.2 billion fish attributable to Indian Point is significant. With CMR for Indian Point as high as 12% for Atlantic tomcod, 10% for bay anchovy, 1% for river herring, 8% striped bass and 5% for white perch, the mortalities caused by Indian Point are large."

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth insufficient facts and data to support their

statements that "In a system that is under stress from many sources, the entrainment of 1.2 billion fish attributable to Indian Point is significant" or that Indian Point is the cause of fish mortality. The speculative nature of Drs. Seaby and Henderson's argument is buttressed by the fact that they misconstrue 1.2 billion *fish* with 1.2 billion fish *eggs and larvae*. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.
Source: Pisces EI Report, at 11 **Statement:** Closed-cycle cooling, required under the draft SPDES permit for Indian Point, represents about a 95% reduction in water use relative to the existing once-through system. This alone would also reduce entrainment mortality by 95% and could, if needed, allow other entrainment reducing technologies to be used. **Objection(s):** • Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity why closed cycle cooling "alone would also reduce entrainment mortality by 95% and could, if needed, allow other entrainment reducing technologies to be used." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.
Source: Pisces EI Report, at 13 **Statement:** Experiences in angling and fish farming demonstrate that quite minor damage may lead to bacterial and fungal infections, resulting in eventual death. **Objection(s):** • Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity why "minor damage may lead to bacterial and fungal infections, resulting in eventual death." Furthermore, there is no reason that "[e]xperiences in angling and fish farming" are applicable to the instant case. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.
Source: Pisces EI Report, at 15 **Statement:** Salinity is probably important because damage to the skin results in a loss of osmotic control. **Objection(s):** • Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity whether salinity is "probably important" due to osmotic pressure. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also*

Pelletier, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Relevance: What Drs. Seaby and Henderson believe is "probably important" is irrelevant to whether the NRC should approve Entergy's application. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

Source: Pisces EI Report, at 21

Statement: As noted in the FEIS, it seems clear that Indian Point's thermal discharge does not meet applicable thermal criteria.

Objection(s):

- Entergy operates under a current DEC-issued SPDES permit, which explicitly states that it meets the New York State Criteria Governing Thermal Discharges (1987 SPDES Permit, at 11).
- Compliance with 10 C.F.R. §51.53(c)(3)(ii)(B) renders contentions regarding the results of Entergy's hydrothermal modeling moot and, therefore, immaterial. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").
- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 21

Statement: The term "Near field" is used here to describe the area in the vicinity of the outfall where there is a discrete thermal plume.
Infrared images highlight the surface extent of the thermal plume released from Indian Point (Figure 11). The image below, taken from the FEIS, shows the high proportion of the width of the river that is impacted by the Unit 3 discharge of Indian Point. The following quotation describes the concern:

> "The surface extent of thermal discharges from the HRSA plants is also a concern. Figure 8 is an aerial thermal image of the plume from Indian Point, Unit 3 only, on the east side of the Hudson plus the smaller plume from Lovett on the west bank. In this image, the two plumes came very close to meeting on the surface, even with Indian Point running at less than its full capacity." (FEIS, Chapter 5 p 71)

In summary, the surface extent of the thermal plume produced by Indian Point covers a high proportion of the width of the river.

Objection(s):

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 22-23

Statement: The FEIS also expresses concern about the vertical distribution of the thermal plume. In general, heated effluents are buoyant, and thus the impacts are mostly restricted to the surface waters and any area of bank which the plume contacts. However, if the plume is sufficiently large then heated water will penetrate to the bed of the river and impact bottom living and deep-water species. Such deeper water penetration of the thermal plume is always a matter for concern, as it may lead to damage to the benthic food chain and also not allow migrating fish to pass under the heated water plume. It is clear that almost the entire vertical water column in the vicinity of Indian Point holds water heated above background temperatures (Figure 12). The FEIS states:

> "A study by HydroQual, Inc., examined passive particle movement and also investigated thermal and salinity profiles in several river reaches, including the portion of the Hudson River where the HRSA plants are located. Figures 6 and 7 of this FEIS (following pages), excerpted from that study, show two vertical temperature profiles of the Hudson River from NYC to just above the northernmost of the HRSA plants, one during a spring and the other during a neap tide. Based on these representations, it appears that there may be times and conditions where effluent-warmed waters occupy nearly the entire vertical water column." (FEIS, Chapter 5 p 71)

Objection(s):

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 25

Statement: In any event, the FEIS states on page 71:

> Thermal discharges were inadequately addressed in the DEIS. The DEIS asserts, with no supporting evidence, that "... [t]he surface water orientation of the plume allows a zone of passage in the lower portions of the water column, the preferred habitat of the indigenous species." Other data and analyses cast doubt on this assertion.

The FEIS goes on to say, on page 72:

> Given the extent of warming shown in the HydroQual graphs, combined with the recent dramatic declines in tomcod and rainbow smelt as discussed previously, the Department believes it prudent to seek additional thermal discharge data for each facility, including a mixing zone analysis, and anticipates requiring triaxial thermal studies as conditions to each of the SPDES renewals. Depending on the results of those analyses, additional controls may be required to minimize thermal discharges.

Objection(s):

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 25

Statement: Further, there are occasions when the temperature exceeds 100°F; this is a temperature at which many aquatic organisms living in the estuary will suffer acute harm or death.

Objection(s):

- Entergy operates under a current DEC-issued SPDES permit, which explicitly states that it meets the New York State Criteria Governing Thermal Discharges (1987 SPDES Permit, at 11).

- Compliance with 10 C.F.R. §51.53(c)(3)(ii)(B) renders contentions regarding biological impacts moot and, therefore, immaterial. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 26

Statement: Far field predictions can be made using existing temperature measurements or modelling methods. The Massachusetts Institute of Technology dynamic network model was used in the DEIS for Indian Point, Bowline and Roseton generating stations. In the DEIS this far field model is referred to as the FFTM (Far Field Thermal Model).

There are a variety of natural and anthropogenic heat inputs into the Hudson Estuary, and to assess the far field impact of Indian Point we need to be able to distinguish the impact of Indian Point from these other sources. Fortunately, this is possible and we can give a reasonable estimate of the increase in the far field temperature caused by the Indian Point discharge. The table below is copied from the DEIS, and gives the heat loads from the principal anthropogenic sources. Note that Indian Point at this time injected considerably more heat into the system than the other sources considered at this time.

Objection(s):

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 27

Statement: The Massachusetts Institute of Technology dynamic network model was reported in the DEIS for a range of power plant discharge scenarios. A typical output is presented in Figure 14. A comparison of lines 3 and 5 show the appreciable effect of Indian Point generating station, which was predicted to increase river temperature by > 1°F for more than 10 miles of estuary.

Objection(s):

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 27-28

Statement: Water temperatures in the Hudson are increasing. This is clearly demonstrated by the statistically significant increase in mean average annual water temperature measured at Poughkeepsie Water Treatment Facility (Figure 15). The mean annual temperature in recent years is about 2°C (3.6°F) above that recorded in the 1960s. Examination of the daily temperatures for 2005 plotted against the mean, minimum and maximum temperatures from 1951 to 2004, show that the temperature for several summer months in 2005 was close to the maximum ever recorded. However, in the winter, it also reached some of the lowest temperatures recorded over a 53 year period. In summary, the temperature regime is becoming more extreme.

Objection(s):

- Relevance: Whether the water temperature in the Hudson River is increasing is irrelevant to the question of whether the NRC should approve Entergy's application. Moreover, there is no evidence supporting the implication that Entergy is responsible for the increase in the water temperature in the Hudson. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

Source: Pisces EI Report, at 29-30

Statement: Figure 17 from Langford (1990) shows the rapid decline for phytoplankton in lakes. It is likely that a similar response would occur with Hudson River phytoplankton.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity why data from Langford, who published on phytoplankton in *lakes*, is applicable to the Hudson *River*. This application is speculative. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 31-32

Statement: It is quite likely that larger fish will simply avoid entering the warm water plume, and thus will not suffer direct harm. However, these animals will be denied access to warmed areas. The thermal impacts will likely be felt most severely by the eggs and weakly swimming early life stages. Maximum temperatures in the discharge may exceed 35°C. It therefore seems inevitable that the heated discharge will result in the death of, or harm to, any American shad, Atlantic tomcod and river herring early life stages in the region of the discharge.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity why "animals will be denied access to warmed areas" or why "thermal impacts will likely be felt most severely by the eggs and weakly swimming early life stages." Similarly, there are no facts to support the contention that "[i]t therefore seems inevitable that the heated discharge will result in the death of, or harm to, any American shad, Atlantic tomcod and river herring early life stages in the region of the discharge." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 33

Statement: Moreover the ability of individuals to survive is not the same as the ability of the species to continue; increased temperatures may advance or delay breeding seasons, encourage breeding in the wrong place, or inhibit fish migration.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of particularity that Indian Point causes "increased temperatures [that] may advance or delay breeding seasons, encourage breeding in the wrong place, or inhibit fish migration." Without such a link, this contention is speculative. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 36

Statement: Thermal issues are likely to become ever more important over the coming years as we are clearly following a warming trend in river temperature.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of certainty that "we are clearly following a warming trend in river temperature." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 36

Statement: It is appropriate for Entergy, when considering the future, to model scenarios with higher river temperatures than those observed in the recent past or even the present.

Objection(s):

- Misleading and mischaracterizes the significance of the results of Entergy's existing hydrothermal modeling efforts. Entergy has already modeled an extreme thermal scenario for the 1999 DEIS, which was undertaken at the direction of DEC. DEC set the extreme case conditions to be modeled. Declaration of Charles V. Beckers, Ph.D. in Opposition to Riverkeeper Proposed Contention EC-1 and New York Attorney General Contention 30, Ex. 2 at 1-2 (hereinafter "Beckers Declaration"). The conditions modeled were wholly unrealistic and the results represent conditions that can never occur in the River, because the tidal and current conditions specified never occur. *Id.* at 2. NYSDEC intended the hydrothermal modeling results presented in the 1999 DEIS to overstate the effects of the discharges modeled on the Hudson River, to be protective of the resource. *Id.* at 3. To require Entergy to "model scenarios with higher river temperatures than those observed in the recent past or even the present," if these temperatures are higher than those mandated by the DEC, would setup an even more unrealistic set of River conditions that are highly unlikely to occur. The results of such modeling, therefore, would be suspect.

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 36

Statement: Absolute temperatures of riverine heated effluents of 26°C (78°F) or more are potentially lethal to smelt and tomcod. The spatial and vertical extent of the Indian Point plume is sufficient to raise concerns about the passage of fish and impacts on the benthic life of the river.

Objection(s):

- Misleading and mischaracterizes the significance of the results of the Entergy's hydrothermal modeling: the Pisces experts neglect to mention that the hydrothermal modeling performed for the 1999 DEIS was undertaken at the direction of DEC, which set the extreme case conditions to be modeled. Beckers Declaration, Ex. 2 at 1-2. The conditions modeled were wholly unrealistic and the results represent conditions that can never occur in the River, because the tidal and current conditions specified never occur. *Id.* at 2. NYSDEC intended the hydrothermal modeling results presented in the 1999 DEIS to overstate the effects of the discharges modeled on the Hudson River, to be protective of the resource. *Id.* at 3. Thus, conclusions should not be drawn from the "spatial and vertical extent of the Indian Point plume."

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Pisces EI Report, at 36

Statement: The changes in the flora and fauna of the Estuary indicate that it would be unwise to allow the statutory temperature limits to be exceeded.

Objection(s):

- Speculation: Drs. Seaby and Henderson set forth no facts or data showing with any degree of certainty that there are "changes in the flora and fauna of the Estuary [that] indicate that it would be unwise to allow the statutory temperature limits to be exceeded." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Drs. Henderson and Seaby are not qualified in the design and selection of models assessing the effect of hydrothermal conditions on fish and plant behavior. As such, they are not competent to opine on matters related to the hydrothermal models used by Entergy to conclude that the hydrothermal effects of Indian Point are small. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

GZA
GeoEnvironmental, Inc.

Engineers and Scientists

January 7, 2008
File No. 41.0017869.10

Mr. Robert Evers
Enercon Services, Inc.
Indian Point Energy Center
450 Broadway
Buchanan, NY 10511-0308

Subject: Hydrogeologic Site Investigation Report
Indian Point Energy Center
Buchanan, New York

One Edgewater Drive
Norwood
Massachusetts
02062
781-278-3700
FAX 781-278-5701
www.gza.com

Dear Mr. Evers:

GZA GeoEnvironmental, Inc. (GZA) is pleased to provide the attached Hydrogeologic Site Investigation Report for the Indian Point Energy Center. The report provides a summary of the investigative methods, findings/conclusions and recommendations for work conducted from September 2005 through the end of September 2007.

If you have any questions, please contact either David or Matt.

GZA appreciates the opportunity to provide continued support to Enercon Services and Entergy.

Sincerely,

GZA GEOENVIRONMENTAL, INC.

David M. Winslow, Ph.D., P.G.
Associate Principal

Matthew J. Barvenik, LSP
Senior Principal

Michael Powers, P.E.
Senior Principal

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

ACRONYMS

ADT	Aquifer Drilling and Testing
AGS	Advanced Geological Services
ALARA	As Low As Reasonably Achievable
AREOR	Annual Radiological Environmental Operating Report
ATV	Acoustical Televiewer
CSS	Containment Spray Sump
CSB	Chemical Systems Building
CSM	Conceptual Site Model
EPA	Environmental Protection Agency
EVS	Environmental Visualization Software
GA	Geophysical Applications, Inc.
GPR	Ground Penetrating Radar
GZA	GZA GeoEnvironmental, Inc.
IP	Indian Point
IP1-CSB	Indian Point Unit 1 Chemical Systems Building
IP1-FHB	Indian Point Unit 1 Fuel Handling Building
IP1-SFDS	Indian Point Unit 1 Sphere Foundation Drain Sump
IP1-SFPS	Indian Point Unit 1 Spent Fuel Pool
IP1-CB	Indian Point Unit 1 Containment Building
IP2-FSB	Indian Point Unit 2 Fuel Storage Building
IP2-PAB	Indian Point Unit 2 Primary Auxiliary Building
IP2-SFP	Indian Point Unit 2 Spent Fuel PoolS
IP2-TB	Indian Point Unit 2 Turbine Generator Building
IP2-TY	Indian Point Unit 2 Transformer Yard
IP2-VC	Indian Point Unit 2 Vapor Containment
K	Hydraulic Conductivity
NGVD 29	National Geodetic Vertical Datum of 1929
NYSDEC	New York State Department of Environmental Conservation
MGM	Million Gallons per Minute
MNA	Monitored Natural Attenuation
MW	Monitoring Well
NEI	Nuclear Energy Institute
NCD	North Curtain Drain
NRC	Nuclear Regulatory Commission
OCA	Owner Controlled Area
OTV	Optical Televiewer
RWST	Reactor Water Storage Tank
RQD	Rock Quality Designation
SFDS	Sphere Foundation Drain Sump
SFP	Spent Fuel Pool
SOP	Standard Operating Procedure
SSC	Structures, Systems and Components
TGB	Turbine Generator Building
TY	Transformer Yard
USGS	United States Geological Survey
VC	Vapor Containment

EXECUTIVE SUMMARY

This report presents the results of a two-year comprehensive hydrogeologic site investigation of the Indian Point Energy Center (Site) conducted by GZA GeoEnvironmental, Inc. (GZA). The study was initiated in response to an apparent release of Tritium to the subsurface, initially discovered in August of 2005 during Unit 2 construction activities associated with the Independent Spent Fuel Storage Installation Project. These investigations were subsequently expanded to include areas of the Site where credible potential sources of leakage might exist, and encompassed all three reactor units. Ultimately, these investigations traced the contamination back to two separate structures, the Unit 2 and Unit 1 Spent Fuel Pools (SFPs). The two commingled plumes, resulting from these SFPs releases, have been fully characterized and their extent, activity and impact determined. The two primary radionuclide contaminants of interest were found to be Tritium and Strontium. Other contaminants, Cesium, Cobalt, and Nickel, have been found in a subset of the groundwater samples, but always in conjunction with Tritium or Strontium. Therefore, while the focus of the investigation was on Tritium and Strontium, it inherently addresses the full extent of groundwater radionuclide contamination. The investigations have further shown that the contaminated groundwater can not migrate off-property to the North, East or South. The plumes ultimately discharge to the Hudson River to the West.

Throughout the two years of the investigation, the groundwater mass flux and radiological release to the Hudson River have been assessed. These assessments, along with the resulting Conceptual Site Model, have been used by Entergy to assess dose impact. At no time have analyses of existing Site conditions yielded any indication of potential adverse environmental or health risk. In fact, radiological assessments have consistently shown that the releases to the environment are a small percentage of regulatory limits.

SOURCES OF CONTAMINATION

As stated above, the investigations found that the groundwater contamination is the result of releases from the Unit 2 and the Unit 1 SFPs. Our studies found no evidence of any release from Unit 3.

The predominant radionuclide found in the plume from the Unit 2 SFP pool is Tritium. The releases were due to: 1) historic damage in 1990 to the SFP liner, with subsequent discovery and repair in 1992; and 2) a weld imperfection in the stainless steel Transfer Canal liner identified by Entergy in September 2007, and repaired in December 2007. To the extent possible, the Unit 2 pool liner has been fully tested and repairs have been completed. The identified leakage has therefore been eliminated and/or controlled by Entergy. Specifically, Entergy has: 1) confirmed that the damage to the liner associated with the 1992 release was repaired by the prior owner and is no longer leaking; 2) installed a containment system (collection box) at the site of the leakage discovered in 2005, which precludes further release to the groundwater; and 3) after an exhaustive liner inspection, identified a weld imperfection in the Transfer Canal liner that was then prevented from leaking by draining the canal. The weld was then subsequently repaired by Entergy in mid-December 2007. Therefore, all identified Unit 2 SFP leaks have been addressed. Water likely remains between the Unit 2 SFP stainless steel liner and the concrete walls, and thus additional active leaks can not be completely ruled out. However, if they exist at all, the data indicate they must be small and of little impact to the groundwater.

The Unit 1 plume is characterized by Strontium from legacy leakage of the Unit 1 fuel pools. At present, the Unit 1 pools have been drained with the exception of the Unit 1 West Fuel Pool which still contains spent fuel. This West Pool leaks water under the fuel building and is responsible for the Unit 1 Strontium groundwater plume discovered in 2006. Prior to that time, the previous owner had identified leakage from the West Fuel Pool in the 1990's and was managing the leakage by collecting it from a re-configured footing drain that surrounded the fuel building. However, based on the groundwater investigation, it has been determined that the pool leakage management program was not successful in collecting all of the leakage. As a result, uncollected contaminants released from the Unit 1 Spent Fuel Pools, past and present, have been observed during the groundwater investigation effort at various locations near the site of Unit 1. In response to the finding that the leak collection system was not functioning as believed, Entergy promptly initiated a program to reduce the concentration of radionuclides in the Unit 1 West Pool's water, beginning in April 2006, via enhanced demineralization water treatment. The planned fuel removal and pool draining will completely eliminate this release source by year end 2008.

EXTENT OF CONTAMINATION

The groundwater contamination is, and will remain, limited to the Indian Point Energy Center property, because the migration of Site contaminants is controlled by groundwater flow, which, in turn, is governed by the post-construction hydrogeologic setting. Plant construction required reduction in bedrock surface elevations and installation of foundation drains. These man-made features have lowered the groundwater elevations beneath the facility, redirecting groundwater to flow to the West towards the Hudson River; and not to the North, East or South. Because of the nature and age of the releases, groundwater contaminant migration rates, and interdictions by Entergy to eliminate/control releases, the groundwater contaminant plumes have reached their maximum spatial extent and should now decrease over time.

LONG TERM MONITORING

Long term groundwater monitoring is ongoing; a network of multi-level groundwater monitoring installations has been established at the facility. These "wells" are located downgradient of, and in close proximity to, both existing and potential release locations. Groundwater testing is performed quarterly on the majority of these wells, with the rest remaining on standby to provide added detail, if required. The resulting information is provided on a yearly basis to the Nuclear Regulatory Commission

(NRC). The information is used to assess changes in groundwater relative to dose impact assessment and to detect future releases, should they occur.

In addition to the groundwater samples from the network of monitoring wells, Entergy obtained various off-Site samples of environmental media including off-Site wells, reservoirs and the Hudson River. In addition, Entergy participated in a fish sampling program with the NRC and New York State Department of Environmental Conservation (NYSDEC). None of the samples analyzed, including the samples split with regulatory agencies, detected any radioactivity in excess of environmental background levels.

GZA believes that the recommended remediation technology discussed below will cause the concentrations of radionuclides in the groundwater plumes to decrease over time. The continued monitoring of groundwater is expected to demonstrate that trend and support the conclusion that the identified leaks have been terminated. However, GZA expects that contaminant concentrations will fluctuate over time due to natural variations in groundwater recharge and that a potential future short term increase in concentrations does not, in and of itself, indicate a new leak. It is further emphasized that the groundwater releases to the river are only a small percentage of the regulatory limits, which are of no threat to public health.

PROPOSED REMEDIATION

GZA has recommended the following corrective measures to Entergy, which they are implementing:

1. Repair the identified Unit 2 Transfer Canal liner weld imperfection (completed December 2007).
2. Continue source term reduction in the Unit 1 West Pool via the installed demineralization system (ongoing until completion of No. 3 below).
3. Remove the remaining Unit 1 fuel and drain the West Pool (in-process).
4. Implement long term groundwater monitoring (in-process).

The proposed remediation technology is source elimination/control (Nos. 1 and 3 above) with subsequent Monitored Natural Attenuation, or MNA. MNA is a recognized and proven remedial approach that allows natural processes to reduce contaminant concentrations. The associated monitoring is intended to verify that reductions are occurring in an anticipated manner. The Indian Point Energy Center Site is well suited for this approach because: 1) interdictions to eliminate or reduce releases have been made; 2) the nature and extent of contamination is known; 3) the contaminant plumes have reached their maximum extent; and 4) the single receptor of the contamination, the Hudson River, is monitored, with radiological assessments consistently demonstrating that the releases to the environment are a small percentage of regulatory limits, and no threat to public health or safety.

1.0 INTRODUCTION

This report presents the results of hydrogeological studies performed by GZA GeoEnvironmental, Inc. (GZA) at the Indian Point Energy Center (IPEC) in Buchanan, New York (Site). See **Figure 1.1**[1] for a Locus Plan. The report was prepared by GZA under the terms of an agreement with Enercon Services, Inc. for Entergy Nuclear Northeast, and describes services completed between September 2005 (the beginning of our services) and September 2007.

Our investigations were conducted in a cooperative and open manner. Entergy provided full and open access and there were regular and frequent meetings with representatives of the United States Nuclear Regulatory Commission (NRC), the United States Geological Survey (USGS), and the New York State Department of Environmental Conservation (NYSDEC). Further, we presented our preliminary findings at a number of external stakeholder and public meetings.

From the onset of the investigations, GZA routinely computed the groundwater mass flux[2] and associated radiological release to the Hudson River. Using these data, the potential impacts of releases to the river were assessed by Entergy and compared to existing regulatory thresholds. At no time did these analyses yield any indication of potential adverse environmental or health risk as assessed by Entergy as well as the principal regulatory authorities. In fact, radiological assessments have consistently shown that the releases to the environment are a small percentage of regulatory limits, and no threat to public health or safety. In this regard, it is also important to note that the groundwater is not used as a source of drinking water on or near the Site.

This report documents two years of comprehensive hydrogeological investigations. The text of the report describes Site conditions, GZA's investigations, and findings, and presents conclusions and recommendations. Supporting information is provided in tables, on figures and in appendices. To understand how we formed our opinions, it is important to review the report in its entirety, including **Appendix A** Limitations.

1.1 PURPOSE

The overall purpose of our services was to identify the nature and extent of radiological groundwater contamination that originates at IPEC, and assess the hydrogeological implications of that contamination. More specifically, our objectives were to:

- Identify the nature and extent of radiological groundwater contamination;
- Establish the sources of the radiological groundwater contamination;

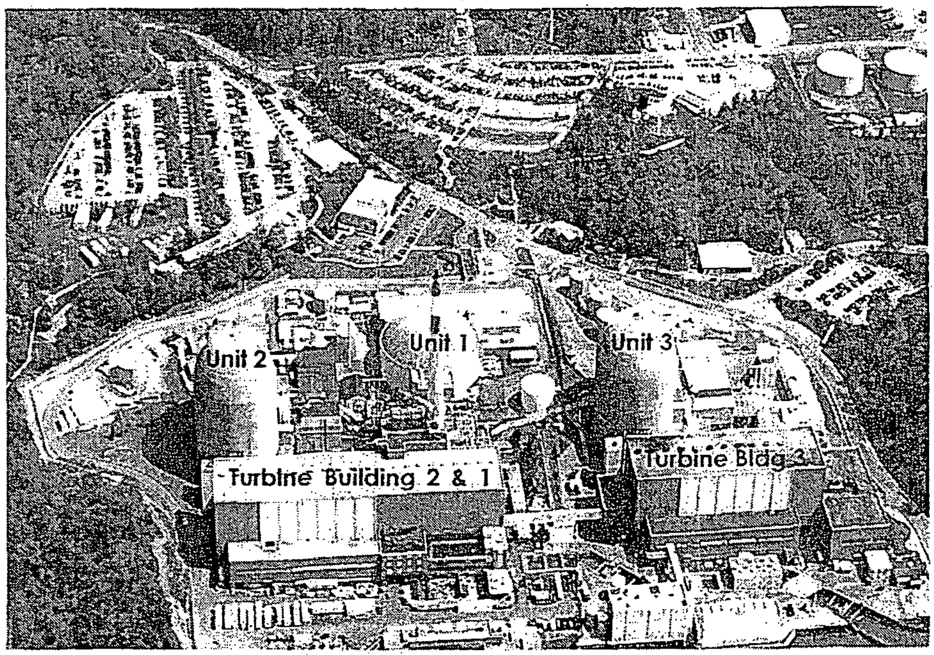
---

[1] Figures referenced by specific number are contained as full size drawings in Volume 3 of this report. Additional smaller scale figures, photographs, etc. are embedded within the text for immediate reference.
[2] Flux (or mass flux) is defined as the amount of groundwater that flows through a unit subsurface area per unit time.

- Evaluate the mechanisms controlling the groundwater transport of radiological contamination;
- Estimate both the mass of groundwater transporting contaminants, and the radiological activity associated with these contaminant pathways;
- Develop a groundwater monitoring network that addresses IPEC's short term and long term needs, and is consistent with the Nuclear Energy Institute's (NEI's) Groundwater Protection Initiative; and
- Recommend, as required, appropriate remedial measures.

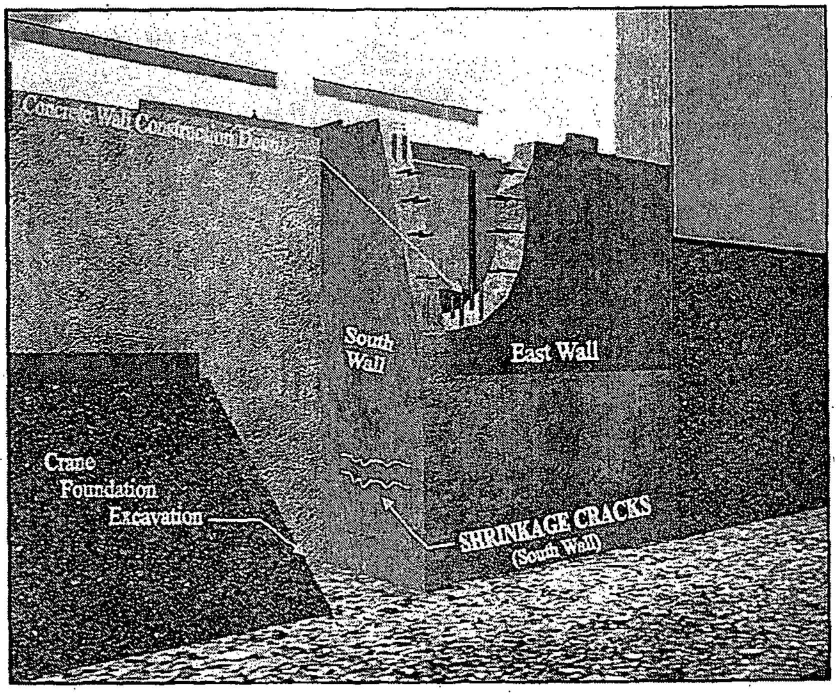
1.2 BACKGROUND

In August 2005, Entergy was excavating in the Unit 2 Fuel Storage Building (IP2-FSB) Loading Bay, adjacent to the South wall of the Spent Fuel Pool (IP2-SFP), in preparation for installation of gantry crane foundations required for the Independent Spent Fuel Storage Installation Project (see **Figure 1.2** and the following illustration).



IPEC LOOKING EAST FROM ABOVE THE HUDSON RIVER

While removing existing backfill material from along the South wall of the SFP, two shrinkage cracks in the concrete pool wall (about 1/64" wide) were observed (refer to **Section 8.1** for additional information). The concrete wall in the area of these cracks appeared damp.



UNIT 2 SFP SHRINKAGE CRACKS IDENTIFIED IN SEPTEMBER 2005

Initially, a temporary, plastic membrane collection device was installed to facilitate water retention and sampling as there was no visibly free-flowing liquid. Analyses of the collected moisture indicated that it had the radiological and chemical characteristics of IP2-SFP water. The primary radioactive constituent was Tritium. This finding initiated work to terminate the known release from these shrinkage cracks. Permanent containment of the release, and prevention of any further migration into the subsurface, was accomplished by installing a waterproof physical containment ("collection box") over the two shrinkage cracks prior to backfilling the gantry crane foundations and SFP wall. This containment was then piped to a permanent collection point such that any future leakage from the crack could be monitored[3]. In addition, Entergy also began extensive investigations of the stainless steel liner in the Unit 2 Fuel Pool itself, as well as the integral Transfer Canal. Subsurface investigations were also started to evaluate if the groundwater had become contaminated from the release.

---

[3] Subsequent monitoring has indicated that the leakage from the crack, which had only been typically as high as 1.5 L/day (peak of about 2 L/day) from its discovery through the fall of 2005, has since fallen off dramatically. (L=liters).

As part of these early investigations, Entergy sampled groundwater on September 29, 2005 from a nearby existing downgradient monitoring well, MW-111. This monitoring well is located between the IP2-SFP and the downgradient Hudson River to the West (see **Figure 1.3** for well location). The analysis results, reported on October 5, 2005, indicated an elevated Tritium concentration. The elevated Tritium in MW-111 was consistent with a release from the shrinkage cracks that had migrated into the on-Site groundwater. Entergy therefore began an extensive investigation to understand the extent of the Unit 2 groundwater contamination and potential impacts to the environment.

Although the early subsurface investigations were focused primarily on potential sources of contamination, the project team also reviewed: regional hydrogeological information, plant design/construction details, and available Site-specific groundwater monitoring results. This early work led to three conclusions:

- The recently identified shrinkage cracks had resulted in releases of Tritium to the groundwater;
- It was unlikely that contaminated groundwater was migrating off-property to the North, East or South; and
- Tritium-contaminated groundwater likely had, and would continue to, migrate to the Hudson River to the West.

In response to these three early conclusions, Entergy tasked GZA with developing a network of groundwater monitoring wells. The primary objectives for this network were to facilitate comprehensive investigation of the IP2-SFP Tritium release location, as well as evaluate the potential for releases at other locations across the Site. Additional objectives included:

- Monitoring of the southern boundary of the Site (previously identified by others as downgradient);
- Monitoring attenuation of the contaminant plume(s) identified on-Site;
- Early detection of leaks in areas of ongoing active operations, should they occur in the future; and
- Monitoring of the groundwater adjacent to the Hudson River to provide the required groundwater data for Entergy's radiological impact evaluations.

The groundwater monitoring network ultimately developed by GZA, and supported by Entergy, was comprised of shallow and deep installations at 59 monitoring locations. These installations were completed in both soil overburden and bedrock. The installations generally include multi-level instrumentation which allows acquisition of depth-discrete groundwater samples and automatic recording of depth-specific groundwater elevations via electronic pressure transducers. The wells were drilled in a phased manner, with resulting data being used to modify and guide the work of subsequent investigations. This iterative progression is in accordance with the Observational Method[4] approach (see **Section 2.0**).

During the course of the expanded investigations in 2006, Strontium-90 was detected in, and downgradient of, the western portion of the Unit 2 Transformer Yard (IP2-TY). While the transformer yard is located immediately downgradient of the Unit 2 Spent Fuel Pool (IP2-SFP), the source of this Strontium in the groundwater could not reasonably be associated with a release from the IP2-SFP. This conclusion was particularly appropriate when evaluated in light of the sampling data from the upgradient transformer yard wells and ultimately from wells directly adjacent to the SFP itself. The ongoing subsurface investigation program was therefore further expanded to encompass not only the IP2-SFP source area, but also other potential sources across the entire Site, including Units 1 and 3. These subsequent phases of investigation ultimately established the retired Unit 1 plant as the source of the Strontium contamination identified[5] in the groundwater. More specifically, the Unit 1 fuel storage pool complex, where historic legacy pool leakage was known to exist, was confirmed as the Strontium source. This fuel pool complex is collectively termed the Unit 1 Spent Fuel Pools (IP1-SFPs). Following detection of radionuclides in the groundwater associated with IP1-SFPs, Entergy accelerated efforts to reduce activity in the IP1-SFPs, along with acceleration of the already ongoing planning for the subsequent fuel rod removal and complete pool drainage.

As indicated above, later phases of the investigations encompassed the entire Site, including all three Units (IP1, IP2 and IP3). These investigations found no evidence of releases to the groundwater from the IPEC Unit 3 plant complex. In this regard, it is important to note that the design and construction of the IP3-SFP incorporates a secondary leak detection telltale drain system, in addition to the primary stainless steel liner. The earlier Unit 1 and Unit 2 SFPs were not designed with this feature.

---

[4] a. *Use of the Observational Method in the Investigation and Monitoring of a Spent Fuel Pool Release*, Barvenik, et. al., NEI Groundwater Workshop, Oct. 2007.

b. *Use of the Observational Method in the Remedial Investigation and Cleanup of Contaminated Land*, Dean, A.R. and M.J. Barvenik, The Seventh Geotechnique Symposium - Geotechnical Aspects of Contaminated Land, sponsored by the Institution of Civil Engineers, London, Volume XLII, Number 1, March 1992.

c. Advantages and Limitations of the Observational Method in Applied Soil Mechanics, Peck, R.B., Geotechnique 1969, No. 2, 171-187.

[5] In addition to Strontium, other radionuclides (Nickel, Cobalt and Cesium) were also sporadically detected in groundwater. These other radionuclides were continuously assessed within the context of the overall hydrologic model. Based upon their occurrence, Strontium, in combination with Tritium, provides full delineation of radiological groundwater plumes at the IPEC Site.

2.0 SCOPE OF SERVICES

This section outlines the scope of our two-plus year-long investigation. Consistent with well established hydrogeologic practices, GZA followed the Observational Method. That is, GZA developed a Conceptual Site Model (see **Section 3.0**) that described our understanding of groundwater flow and contaminant transport at IPEC, and performed investigations to test the validity of our model. In response to test data, we revised the model and/or performed additional testing to clarify findings. This iterative, step-wise phased approach allows for better focused testing, and a more comprehensive review of data. It also reduces the chances of missing critical information, and generally completes studies in less time. GZA executed the scope in three phases.

2.1 PHASE I

Phase I investigations commenced in September 2005. Consistent with the concerns raised by the observed IP2-SFP crack leakage, the Phase I investigation program focused on: 1) Identifying the groundwater flow paths which would intercept potential releases from IP2-SFP; and 2) Evaluating groundwater contaminant fate and transport mechanisms in this area of the facility. This work included:

- Identification, retrieval and evaluation of historic geologic, hydrogeologic and geotechnical reports to form the basis of our initial Conceptual Site Model (CSM);
- Development of an initial CSM;
- Identification, retrieval and evaluation of historic facility Site plans and construction details pursuant to the impact of man-made features on groundwater flow directions and Tritium migration, with subsequent refinement of the CSM;
- Installation of nine groundwater monitoring wells, a number of which contained multiple sampling levels, in the area of the Tritium release;
- Installation of four stilling wells[6], three within the Discharge Canal and one in the Hudson River, to allow groundwater elevations to be compared to these surface water elevations (to evaluate if the Hudson River is the ultimate discharge point for any potential IP2-SFP release);
- Performance of elevation and location surveys to establish reference points for groundwater elevation measurement;
- Installation of electronic pressure transducers in newly drilled boreholes and previously existing wells to continuously monitor groundwater elevation fluctuations, as influenced by climatic/seasonal variability, tidal influences and the drilling of nearby boreholes (to assess interconnections between boreholes at different locations);
- Geophysical borehole testing to provide further bedrock fracture identification, location and groundwater flow information;

---

[6] Stilling wells are typically constructed of slotted pipe or well screen. They are placed in surface water bodies to house pressure transducers for water level measurement. Their purpose is to dampen-out high frequency pressure fluctuations in the water body, typically due to flow-induced turbulence, such that more representative readings can be obtained. Stilling wells are not included as monitoring wells with reference to numbers of monitoring wells installed.

- Packer testing of specific bedrock boreholes to provide initial depth-specific groundwater samples, measurement of depth-specific groundwater elevations and flow capacity of the fracture zones;
- Completion of the boreholes as screened overburden wells, open bedrock wells, or multi-level monitoring wells as appropriate for the subsurface conditions encountered;
- Testing of open bedrock and screened boreholes to measure formation groundwater flow capacity;
- Ground Penetrating Radar (GPR) analysis of the key locations to evaluate top of bedrock elevations relative to preferential groundwater flow through soil backfill;
- Sampling of groundwater from the monitoring wells and analyzing the samples for Tritium and gamma emitters; and
- Computation of the groundwater flux and radiological activity to the Hudson River for use by Entergy in their dose computations.

2.2 PHASE II

Phase II investigations commenced in January 2006. The focus of this work was to: 1) Confirm initial findings; 2) Better estimate the quantity of contaminated groundwater at the facility that discharges to the Hudson River; and 3) Establish a network of wells suitable for identifying potential leaks at all three units across the Site and for long term monitoring of groundwater. This phase of work included:

- Re-evaluation of our CSM to guide the selection of borehole locations and establish testing requirements;
- Identification of accessible areas from which to drill boreholes to measure groundwater elevations and the contaminant concentrations;
- Drilling of 23 additional boreholes through soil and bedrock to depths of up to 200 feet, including coring to provide bedrock core samples for inspection (to locate fractures in the bedrock which likely conduct groundwater flow);
- Performance of elevation and location surveys to establish reference points for groundwater elevation measurement;
- Installation of electronic pressure transducers in newly drilled boreholes to continuously monitor groundwater elevation fluctuations, as influenced by climatic/seasonal variability, tidal influences and the drilling of nearby boreholes (to assess interconnections between boreholes at different locations);
- Geophysical borehole testing to provide further bedrock fracture identification, location and groundwater flow information;
- Packer testing of specific bedrock boreholes to provide depth-specific groundwater samples, measurement of depth-specific groundwater elevations and flow capacity of the fracture zones;
- Completion of the boreholes as screened overburden wells, open bedrock wells, or multi-level monitoring wells as appropriate for the subsurface conditions encountered;
- Conducting tests on open bedrock and screened boreholes to measure formation groundwater flow capacity;
- Ground Penetrating Radar (GPR) analysis of the key locations to evaluate top of bedrock elevations relative to preferential groundwater flow through soil backfill;

- Sampling of groundwater from the monitoring wells and analyzing the samples for Tritium and additional radionuclides of interest (including Strontium, gamma emitters, Nickel-63 and transuranics); and
- Re-computing the groundwater flux and radiological activity to the Hudson River (based on the more current data and refined CSM) for use by Entergy in their dose computations.

2.3 PHASE III

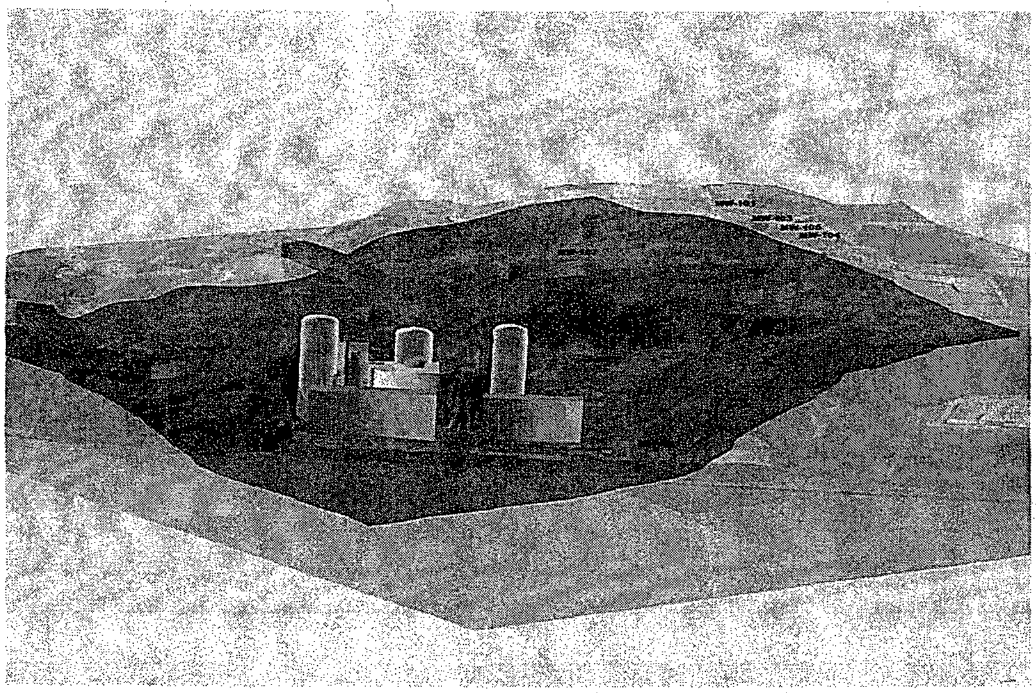
Phase III investigations commenced in June 2006. The focus of the Phase III work was to: 1) Better delineate the extent of Strontium detected during Phase II investigations; and 2) Improve characterization of bedrock aquifer properties to allow evaluation of remedial alternatives. This phase of work included:

- Re-evaluation of our CSM to guide the selection of borehole locations and establish testing requirements;
- Installation of additional wells (MW-53 through MW-67 and U1-CSS) to further delineate the horizontal extent of groundwater contamination (this work was begun in Phase II);
- Installation of deep wells (MW-54, -60, -61, -62, -63, -66, and -67) to establish the vertical extent of contamination;
- Conducting hydraulic tests on boreholes and completed wells to assess the transmissivity of bedrock fracture zones and overburden;
- Installation of electronic pressure transducers in newly drilled boreholes and existing wells to continuously monitor groundwater elevation fluctuations due to climatic/seasonal variability, tidal influences and the drilling of nearby boreholes (to assess interconnections between boreholes at different locations);
- Geophysical borehole testing to provide further bedrock fracture identification, location and groundwater flow information;
- Packer testing of specific bedrock boreholes to provide depth-specific groundwater samples, measurement of depth-specific groundwater elevations and flow capacity of the fracture zones;
- Completion of the boreholes as screened overburden wells, open bedrock wells, or multi-level monitoring wells as appropriate for the subsurface conditions encountered;
- Conducting a 72-hour Pumping Test to assess hydraulic properties of the bedrock as well as to assess the feasibility of managing Tritium-contaminated groundwater through hydraulic containment;
- Performance of a tracer test to better assess contaminant migration and transport mechanisms, particularly in the unsaturated zone;
- Sampling of groundwater from the monitoring wells and analyzing the samples for radionuclides; and
- Re-computing the groundwater flux and radiological activity to the Hudson River (based on the more current data and refined CSM) for use by Entergy in their dose computations.

3.0 CONCEPTUAL HYDROGEOLOGIC MODEL

This section, together with associated figures, constitutes our Conceptual Site Model (CSM). The key components of the model consisted of: the hydrogeologic setting; general groundwater flow patterns; identified contaminant sources; contaminants of potential concern; and identified receptors. GZA used the CSM to guide our investigations, identify and fill data gaps, assess the reasonableness of findings, and develop parameters controlling contaminant transport. It was an iterative process and, as studies progressed, we modified the CSM to better fit observed conditions. With completion of the investigations and further refinement of the CSM, our CSM was consistent with both the Site-specific project data and published data for the area.

The CSM incorporates our understanding of Site construction practices as they influence contaminant migration. Critical in this regard is that, according to construction plans, lean concrete was used as backfill material for foundation walls in a number of locations, primarily associated with Unit 1 structures. We also note that in some areas where construction plans show soil backfill, we found that lean concrete was actually used. This is likely due to the relatively low cost of concrete during the 1950's and the uniqueness of the construction for these first nuclear power plants. At the subsequently constructed Units 2 and 3, it appears soil or blast rock was the material most commonly used as backfill against foundation walls.



SCHEMATIC REPRESENTATION OF GROUNDWATER FLOW INTO THE SITE FROM THE NORTH, SOUTH, AND EAST

3.1 HYDROGEOLOGIC SETTING

The Site watershed is limited in areal extent. GZA assumed that the top of the watershed defines a no-flow boundary in the aquifer. The distance from the upgradient no-flow boundary located at the top of the watershed, to the river, is on the order of 2,200 feet (see **Figure 3.1**). This length limits the volume of precipitation available for aquifer recharge. Recharge is further limited by the density of structures and areal extent of paving, which induces direct run-off. An average annual recharge rate of 5.5 inches per year was initially selected[7] as representative for the Site area, which is the USGS estimated average in Westchester County where IPEC is located.

3.2 GENERAL GROUNDWATER FLOW PATTERNS

Groundwater flow takes place in three dimensions. In general, flow at the top of the watershed is largely downward and flow near the river's edge is largely upward. In the mid-section of the watershed, flows are predominantly horizontal. Based on the location of the Site in the watershed and information indicating that the top of the bedrock is more fractured, GZA initially estimated, and later confirmed that the bottom of the local groundwater flow to be at or above elevation -200 feet (National Geodetic Vertical Datum of 1929[8], NGVD 29)[9]. Note that temporal and spatial variations in areal recharge rates, rock heterogeneities, and tidal influences cause local variations from these general flow patterns. In fact, Site groundwater flow patterns in some areas are dominated by shallow anthropogenic Site features. These features include pumping from building foundation drains, foundation walls, subsurface utilities, and flows in the intake structures and Discharge Canal.

Based upon the regional topography, Site topography (see **Figure 3.2**), anthropogenic influences, and the geostructural setting, even at the initial stages of the investigations GZA expected that groundwater would flow into IPEC from the North, East and South, and then discharge to the Hudson River, with portions of the flow being intercepted by the cooling water intake and Discharge Canal (see **Figure 3.3**). However, based on our review of reports available at the start of the investigations, it was unclear what the role that anisotropic bedrock structure played in groundwater migration. That is, there was information suggesting groundwater flows would have a primarily southern component (see **Section 6.4** for a description of the regional area and Site-specific geologic setting).

---

[7] As discussed in **Section 6.0**, the initial average areal recharge rate of 5.5 inches/year was subsequently increased somewhat as we refined our CSM.

[8] The National Geodetic Vertical Datum of 1929 (NGVD 29) is the renamed Sea Level Datum of 1929. The datum was renamed because it is a hybrid model, and *not a pure model of mean sea level*, the geoid, or any other equipotential surface. NGVD 29, which is based on "an averaging" of multiple points in the US and Canada, is the vertical "sea level" control datum established for vertical control surveying in the United States of America by the General Adjustment of 1929. The datum is used to measure elevation or altitude above, and depression or depth below, "mean sea level" (MSL). It is noted that there is no single MSL, because it varies from place to place and over time.

[9] During a mid-phase of the work, we concluded that the bottom of the local groundwater flow may be deeper, more likely between elevations -200 to -350 feet NGVD 29. This conjecture was based on the observed vertical distribution of heads, bedrock fracture patterns, and the observed contaminant concentrations at the time. We therefore increased our drilling depth to 350 feet (multi-level monitoring well installation MW-67) to investigate this issue. Subsequently, the most recent data better fit with a 200-foot-deep flow model.

Based on our studies, including a full-scale Pumping Test and tidal response testing, we have shown that in the area of groundwater contamination, and on the scale of the contaminant plumes, the direction and quantity of groundwater flow can be estimated using an equivalent porous media model. We state this recognizing that an individual bedrock zone may represent flow in a single or limited number of fractures which over a relatively short distance is not representative of average conditions. In terms of our equivalent porous media model, this condition represents an aquifer heterogeneity. However, over sufficient volumes of bedrock (which is the case for the work at IPEC), the bedrock groundwater flux can be estimated based on an equivalent porous media model using Darcy's Law[10].

3.3 IDENTIFIED CONTAMINANT SOURCES

GZA, in conjunction with facility personnel, conducted a review of available construction drawings, aerial photographs, prior reports, and documented releases, and interviewed Entergy personnel to identify potential groundwater contaminant sources.

That review, in conjunction with the observed distribution of contaminants, identified IP2-SFP and IP1-SFPs, along with legacy piping associated with Unit 1, as sources of the radiological groundwater contamination. The locations of these structures are shown on **Figure 3.4.** No release was identified in the Unit 3 area. This finding is consistent with, and reflects, changes in construction practices over time[11]. Refer to **Section 8.0** for additional information pursuant to source area description.

3.4 CONTAMINANTS OF INTEREST

Throughout this report, Tritium and Strontium are discussed as the principal radiological constituents associated with the groundwater contamination investigation performed at IPEC. Both radionuclides served as the most representative contaminant tracer tools from the perspective of frequency of observed occurrence, as well as contaminant transport[12] across the Site. Other radionuclides (primarily Cs-137, Ni-63, Co-60) were more sporadically identified and isolated to specific locations within the Site. These radionuclides are encompassed by the Unit 2 (Tritium) and Unit 1 (Strontium) plumes. We also note these other radionuclides carry a smaller potential radiological impact as compared to Strontium. These contaminants were also continuously assessed within the context of the overall site hydrological model as well as the plume information gleaned from the Unit 1 and Unit 2 plume data. All detected radionuclides have been

---

[10] *Interpretation of Hydraulic Tests and Implications Towards Representative Elementary Volume for Bedrock Systems,* Thomas Ballerstero, October 2003, AGU San Francisco.

[11] The absence of Unit 3 sources is attributed to the design upgrades incorporated in the more recently constructed IP3-SFP.

[12] A combination of Tritium and Strontium allow full characterization of radiological groundwater plume nature and extent at the IPEC Site given their divergent behavior in the subsurface. Tritium is completely conserved in the groundwater with no partitioning to natural or anthropogenic subsurface materials. It, therefore, moves with and as fast as the groundwater, and thus serves as an indicator of the leading edge of a recent release. Strontium provides strong partitioning characteristics and long half-life. It is, therefore, an indicator of older, historic releases.

accounted for by Entergy in their dose assessment analyses (radiological impact evaluations). Accounting for these data was performed via USNRC Annual Reporting documents that have been made public (year-end 2005 and 2006) and will continue to be reported on (Refer to RG1.21 report). Additional discussion of the identified sources of contaminants and the properties affecting contaminant migration are provided in **Sections 8.0** and **9.0.**

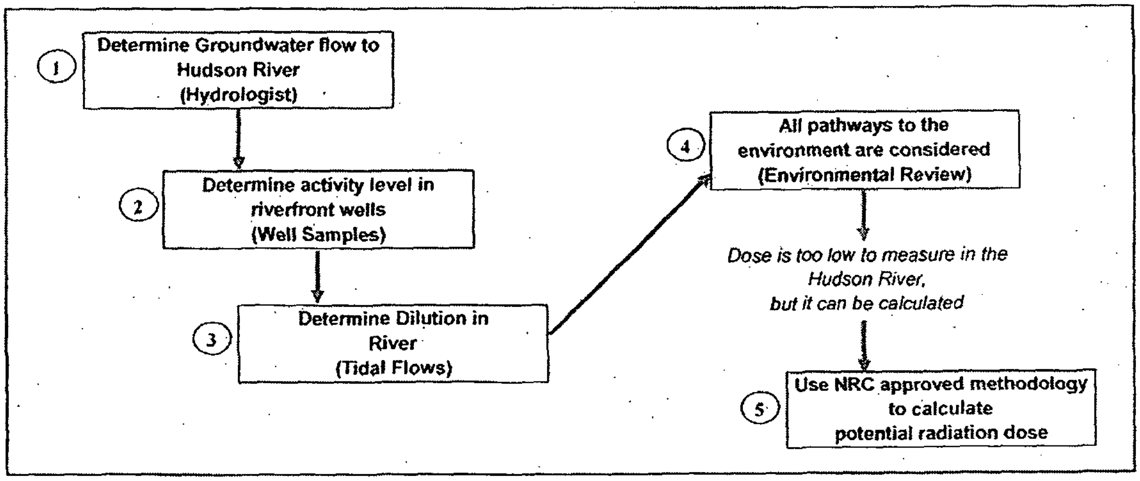
3.5 IDENTIFIED RECEPTORS

The NRC has set forth guidance for calculations of radiation dose to the public, and IPEC follows this guidance for radioactive effluents, including those from groundwater. IPEC is required to perform an environmental pathway analysis to determine the possible ways in which radioactivity released to the Hudson River can cause radiation dose. Receptors for radioactive releases to the environment are considered to be actual or hypothetical individuals exposed to radioactive materials either directly or indirectly.

Title 10 of the Code of Federal Regulations, Part 50 (10CFR50) Appendix I states: "*Account shall be taken of the cumulative effect of all sources and pathways within the plant contributing to the particular type of effluent being considered.*" 10CFR50 Appendix I provides numerical guidelines on liquid releases of radioactivity, such that releases "*will not result in an estimated annual dose or dose commitment from liquid effluents for any individual in an unrestricted area from all pathways of exposure in excess of 3 millirems to the total body or 10 millirems to any organ.*"

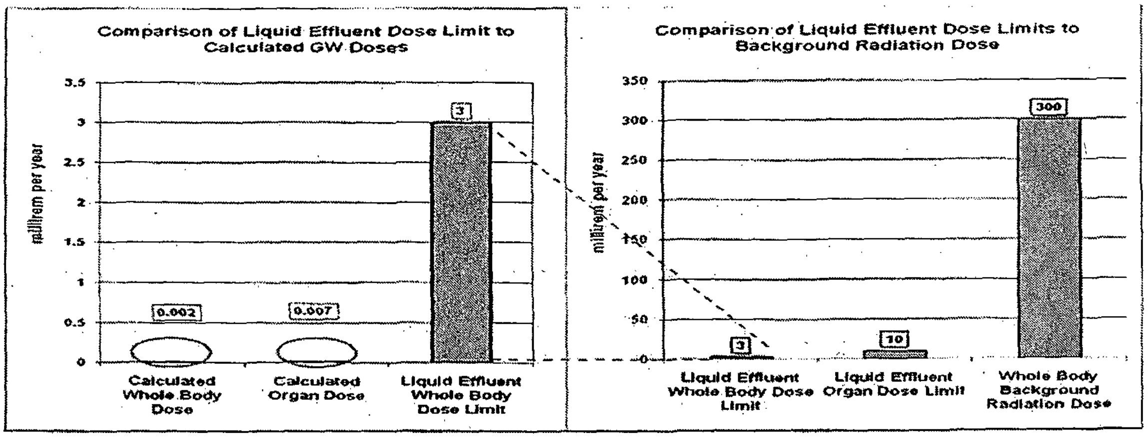
IPEC has reviewed the potential pathways that result in dose to the public and are viable for the Site. Potential pathways considered included drinking water consumption, aquatic foods, exposure to shoreline sediments, swimming, boating, and irrigation. As discussed below, drinking water is not a viable pathway for releases to the Hudson River. Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50, Appendix I" provides guidance and acceptable methodologies for calculating radiation dose from environmental releases. The NRC guidance uses the maximum exposed individual approach, where doses are calculated to hypothetical individuals in each of four age groups (infant, child, teen, and adult). Maximum individuals are characterized as "maximum" with regard to food consumption and occupancy. Regulatory Guide 1.109 describes a pathway as "significant" if a conservative evaluation yields an additional dose increment of at least 10 percent of the total from all pathways. Based on the above description, the only significant pathway for liquid releases is for consumption of aquatic foods; i.e., Hudson River fish and invertebrates.

The specific methodology used to calculate doses from liquid radioactive effluents is based on NRC guidance and is contained in the Indian Point Offsite Dose Calculation Manual (ODCM). The volume of groundwater traversing the site and discharging into the Hudson River, as estimated by GZA using the data as presented in this groundwater report, is used in conjunction with measured concentrations of radionuclides in groundwater to estimate the total amount of radionuclides to the Hudson River, and their potential dose impact. In 2005 and 2006, groundwater releases resulted in a small fraction of the offsite dose limits established by the NRC for each site. This dose is calculated from measured radionuclides in groundwater, using the methodology in the ODCM. A simplified description of the methodology is shown in the figure below.



SIMPLIFIED GROUNDWATER DOSE CALCULATION METHODOLOGY

Radiation doses are reported annually by IPEC in an NRC-required Annual Radioactive Effluent Report. An overview of the results is shown in the figure below.



COMPARISON OF BACKGROUND, DOSE LIMITS, AND CALCULATED GROUNDWATER DOSE – 2006

For the purposes of this study, the migration of contaminated groundwater is the pathway of interest. The contaminants of interest are not volatile; therefore, they remain in the subsurface bedrock, soil and groundwater until discharge to the river.

There is no current or reasonable anticipated use of groundwater at the IPEC. According to the NYSDEC[13], there are no active potable water wells or other production wells on the

---

[13] Early in the investigative process, the NYSDEC requested that the New York State Department of Health assess the presence of drinking water supply wells in the vicinity of the Site. The NYSDEC informed Entergy and GZA that no drinking water supply wells were located on the East side of the Hudson River in the vicinity of the Site in June 2006.

East side (Plant side) of the Hudson River in proximity to the IPEC[14]. Drinking water in the area (Town of Buchanan and City of Peekskill) is supplied by the communities and is sourced from surface water reservoirs located in Westchester County and the Catskills region of New York. The nearest of these reservoirs (Camp Field Reservoir) is located 3.3 miles North-Northeast of the Site and its surface water elevation is hundreds of feet above the IPEC, in a cross-gradient direction and several watersheds away. In addition, groundwater flow directions on the Site are to the West towards the Hudson River. Therefore, it is not possible for the contaminated groundwater at IPEC to ever impact these drinking water sources.

Groundwater beneath the IPEC flows to the Hudson River and therefore flows through portions of the river bank and river bottom. The river bank at the Site consists of sections of vertical bulkheads and some rip-rap outside of the contaminated flow zone. The size of the Hudson River and the hydraulic properties of the underlying bedrock preclude natural or pumping-induced migration of contaminated groundwater to the West side of the river. Therefore, conditions at the IPEC pose no threat to potable water supplies.

In summary, the only pathway of significance for groundwater is through consumption of fish and invertebrates in the Hudson River, and the calculated doses are less than 1/100 of the federal limits. As described above, potable water is not a viable pathway and no dose calculations are necessary in that regard.

GZA utilized Environmental Data Resources, Inc. to conduct a search for public water supply wells within 1 mile of the Site. According to records maintained by the USEPA, there were no water supply wells located within the search radii.

[14] According to the Rockland County Department of Health, there are municipal drinking water supply wells operated in Rockland County. GZA formally requested, through a Freedom of Information Law Application (F01-07-004), information regarding the elevation of groundwater in these wells to assess if there was any potential for IPEC to impact these wells. The information was not made available to GZA for security reasons. The closest active drinking water well in Rockland County is over 4.5 miles Southwest of the Site on the West side of the Hudson River.

4.0 FIELD INVESTIGATIONS

This section provides a description of our field activities. The studies were conducted in three phases between October 2005 and September 2007. Field activities were performed, in accordance with general industry practice and regulatory guidelines, to develop and validate our CSM (see **Section 3.0**).

The field exploration program was developed by GZA in cooperation with Enercon and Entergy. A team of GZA engineers, geologists and scientists was present to observe and document drilling efforts, classify soil and rock samples, direct field testing (packer tests, etc.) and collect other hydrogeologic data. Borehole development, well installation and packer testing were performed by GZA and the drilling contractor, Aquifer Drilling and Testing (ADT), New Hyde Park, New York. The exploration program also included the use of geophysical exploration techniques to help identify underground utilities, evaluate the location of the bedrock surface, and evaluate the nature of bedrock fractures in select boreholes. Advanced Geological Services (AGS) and Geophysical Applications, Inc. (GA), both under GZA's oversight, conducted this work.

The following provides a broad overview of our investigations. Refer to subsequent subsections for more information.

Geological Reconnaissance

- Review of Relevant Geological Literature and Previous Reports
- Site Reconnaissance to Observe Outcrops of Bedrock
- Geostructural Logging of the Rock Wall within the IP2-FSB Crane Foundation Excavation

Test Drilling - Planning, Execution, Post-Drill Activity

- Review of Existing Utility Plans
- Surface Geophysical Utility Surveys (to further locate utilities)
- Vacuum Excavation of 39 boreholes (for safety; to reduce risk of encountering underground utilities or structures)
- Test Boring Advancement (bedrock borings, overburden borings)
- Borehole Development (to remove rock cuttings and drill water; preparation for hydraulic testing in boreholes)
- Borehole Geophysical Surveys (to evaluate fractures along the borehole wall)

Monitoring Well Installations

- Bedrock Wells
- Open Rock Wells
- Waterloo Systems
- Nested Wells
- Overburden Wells
- Wellhead Completion

- Wellhead Elevation Surveying

Hydraulic Testing to Evaluate Hydraulic Conductivity of Bedrock

- Specific Capacity Testing
- Rising Head Hydraulic Conductivity Testing (pneumatic and hydraulic slug tests)
- Bedrock Packer Hydraulic Conductivity Testing
- A Pumping Test (a 72 hour Pump Test to evaluate the hydraulic properties of the bedrock)

Water Sampling

- On-Site Sampling of Groundwater, Surface Water and Facility Water
- Off-Site Sampling of Groundwater and Surface Water

Groundwater Elevation Monitoring and Pressure Transducer Data

- Installation of In-Situ and Geokon Transducers
- Data Retrieval

Organic Dye Tracer Testing

- Injection Well Construction
- Tracer Introduction
- Sampling Methods

Geophysical Testing – Identification of Preferential Groundwater Flow Paths

- Ground Penetrating Radar Surveys at Unit 2, Unit 3 and the Owner Controlled Area (OCA) Access Road
- Seismic Refraction, GPR and Electromagnetic Surveys between the Protected Area and southern Warehouse

As-built locations of the explorations are shown on **Figure 1.3**. **Table 4.1** provides a summary of well locations and installation details. The following sections describe the key aspects of the completed work. Explorations logs, test records and additional information are presented in the Appendices.

4.1 GEOLOGIC RECONNAISSANCE

To develop a preliminary understanding of the subsurface conditions expected to occur beneath the Site, GZA reviewed USGS publications relating to the local and regional geology as well as available Site-specific geologic reports. GZA further conducted a reconnaissance of the Site to identify the type of bedrock exposed, relative fracture density and locations of expected overburden. Specifically included was the logging of the rock wall in the construction excavation at Unit 2 (refer to **Section 6.0** for additional detail on Site Geology). This information was used to help design the subsurface investigation methods.

4.2 TEST DRILLING

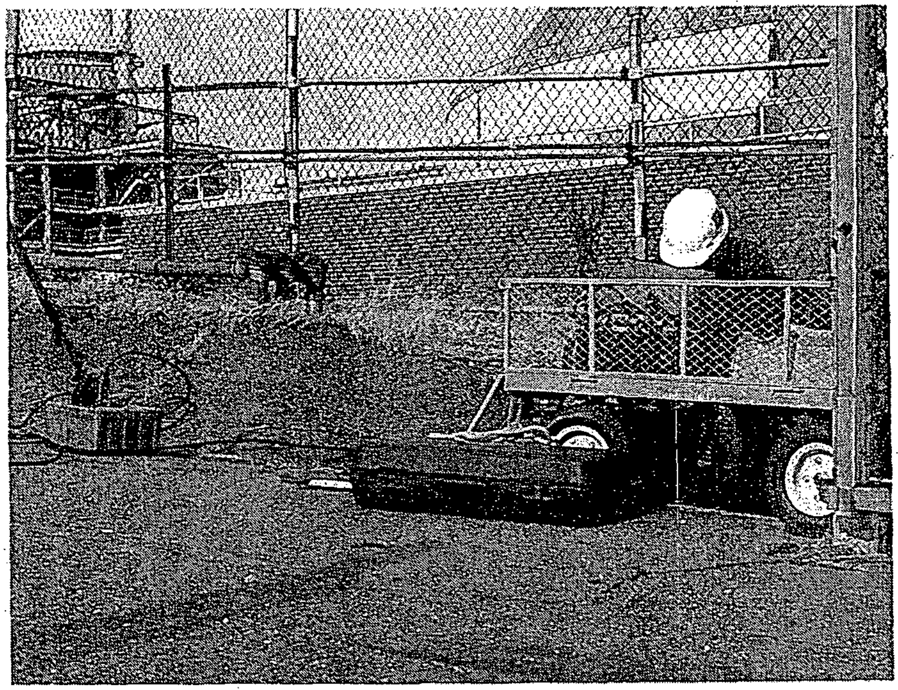
Forty-seven borings were completed by GZA as part of this program, forty-two of these borings were converted to monitoring installations, one was converted to a recovery well and one was converted to a tracer injection point[15]. Boring logs for the bedrock borings and the additional overburden borings are provided in **Appendix B**. Boring locations and elevations are provided in **Table 4.1**. Final sampling elevations are also provided in **Table 4.1**. Test Boring/Monitoring Installation locations are shown on **Figure 1.3**. In viewing the figure, note that test boring designations are the same as the monitoring installation[16] designations (see **Section 4.3.4**). In addition, a tracer injection point was installed along the side of the casing of MW-30 (see **Section 7.0** for details).

Prior to advancement of the borings, a utility identification and clearance program was implemented to reduce the risk of encountering underground utilities, and to maintain the safety of on-Site personnel during drilling activities. GZA personnel, AGS personnel and Site personnel first performed a reconnaissance of the proposed boring locations. Site personnel then utilized Site plans to assess the potential presence of subsurface utilities in the area of the proposed boring locations. Following this initial screening, AGS personnel performed a surface geophysical survey of the area around the proposed boring locations using GPR and radiofrequency utility locating equipment. The results of the survey were marked on the ground surface using spray paint. Entergy personnel performed a final reconnaissance prior to approving the locations.

---

[15] Borings are defined as test sites that were excavated with hand held or mechanical drilling devices. Monitoring installations are defined as boreholes (or wellbores) that were completed to allow groundwater monitoring and generally include multiple monitoring levels over the depth of the boring (either "nested well" casings within one borehole or Waterloo multi-level completions). In several instances, a monitoring installation location designation, such as MW-49, may have two discrete borings, in which case it is counted as two installations, but represented on the figures as a single location for clarity. Attempted borings which met refusal and had to be re-drilled are not included in the boring count.

[16] *Monitoring installations* are commonly referred to as *Monitoring wells*, which in this usage, may include multiple, individual well casings. This generic usage is also used herein.

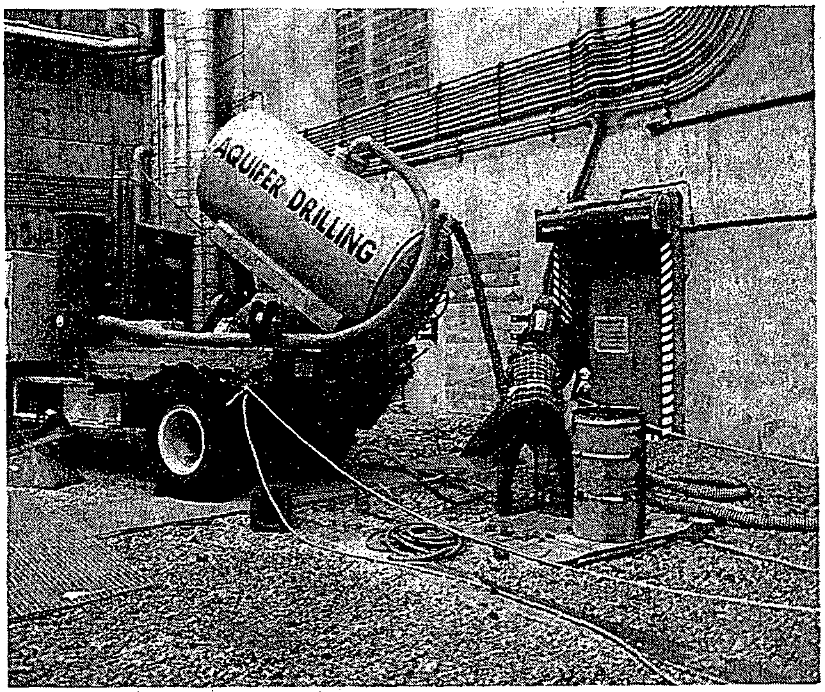


SURFACE GEOPHYSICAL SURVEY

At thirty nine of the boring locations, overburden was vacuum-excavated until bedrock was encountered, or to the practical limits of the vacuum excavation technique. To further reduce the risk associated with the drilling program, during advancement of the borings to bedrock, a downhole magnetometer was utilized every two feet to assess the presence of metallic objects potentially related to subsurface utilities.

The test borings were performed by ADT with a combination of three drill rigs: a track-mounted CME LC55 rotary drill rig, a truck-mounted CME 75 rotary drill rig, and an electric track-mounted Davie DK 515 rotary drill rig. The original program consisted of advancing borings into bedrock to desired terminal depths using wire line HQ direct rotary coring techniques. This resulted in a nominal 3.85-inch diameter borehole. Where overburden was present, either a four-inch or six-inch casing was installed into the rock and grouted in place.

At certain locations where overburden occurred beyond the bottom of the vacuum-excavated test pits, soil samples were collected at 5-foot intervals, from the bottom of the vacuum-excavated test pit, using a 2-inch outside diameter (OD) split-spoon sampler driven by a 140-pound hammer falling 30 inches, to characterize soils. These samples were visually classified using the Burmister Classification System. At all locations, either vacuum-excavated test pits or hand-excavated test pits were performed to clear utilities prior to advancing boreholes. Grab samples were collected during the advancement of the test pits to visually characterize the overburden soils.



VACUUM EXCAVATION

During the drilling program, rigorous field protocols were implemented to limit the risk of cross-contamination. All down-hole drilling tools, testing equipment, and well materials were steam cleaned or pressure washed prior to use on the Site, subsequent to the completion of a boring, and prior to leaving the Site. Water used during drilling, testing and well installations was drawn from the Buchanan, New York public water supply from on-Site connections. Waste water, waste soil, and decontamination wash water were placed in 55-gallon drums and transferred to Site personnel for proper disposal.

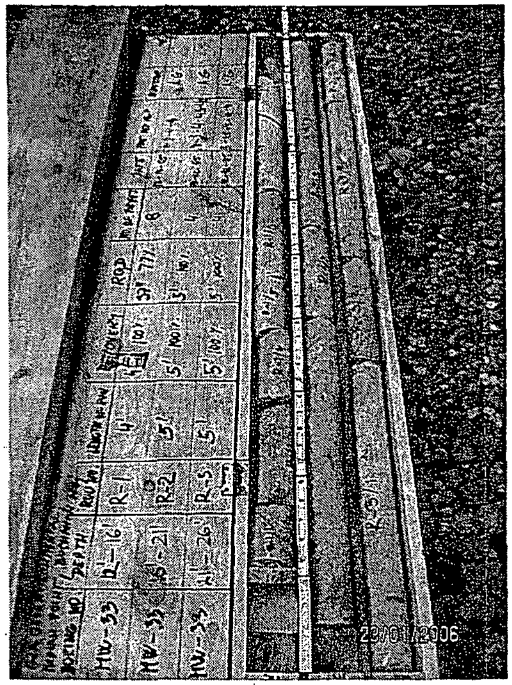
4.2.1 Bedrock Borings

Thirty-eight of the borings were drilled in bedrock, including U1-CSS which was installed horizontally through the East wall of the Unit 1 Containment Spray Sump using hand coring techniques. The borings were completed using rotary techniques with water as the drilling fluid and either permanent 4-inch or temporary 6-inch casing to keep the borehole open through overburden soils. Once rock was encountered, it was cored using HQ-size double-tube core barrels with diamond studded bits in general accordance with ASTM D2113 [6]. Core runs were generally 5 feet in length, with a nominal 3 inch diameter. Shorter or incomplete runs were made when the drilling team believed the core barrel to be blocked.

The rock samples were classified and logged by GZA field personnel, and the descriptions and rock quality designations were reviewed and checked by a Senior GZA Geologist. Rock classification was based on the International Society of Rock Mechanics (ISRM) System with adaptation to suit the identified rock and structure.

The rock core was logged as soon as practical after it was extracted from the core barrel. The following information was generally noted for each core run:

- Depth of core run
- Percent core recovery
- Rock Quality Designation (RQD)
- Rock type, including color, texture, degree of weathering and hardness
- Character of discontinuities, joint spacing, orientation, roughness and alteration
- Nature of joint infilling materials, where encountered
- Presence of apparently water-filled fractures



BEDROCK CORE OBTAINED FROM DRILLING USED FOR EVALUATION OF FRACTURES

During rock coring activities, potable water was used as a drilling fluid to cool and lubricate the core barrel and remove cuttings from the borehole. The drilling fluid was circulated down the borehole around the core that had been cut, flowed between the core and core barrel, and exited through the bit. The drilling fluid then circulated up the annular space and was discharged at the land surface to a mud tub. The volume of water lost during drilling was recorded and later, during development, an attempt was made to remove the amount lost to the formation.

In addition, drilling parameters, such as the type of drilling equipment, core barrel and casing size, drilling rate, and groundwater condition were recorded. Cumulatively, this information provided insights relative to rock conditions, and the potential for the transport of groundwater migration in bedrock fractures.

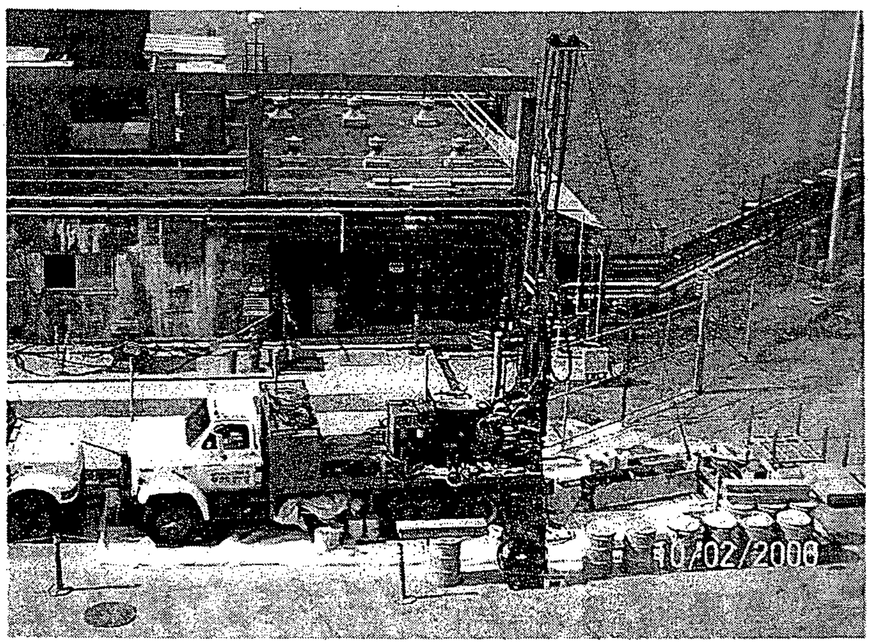
Bedrock borings ranged in depth from 30 feet below ground surface at MW-33, -34 and -35 to 350 feet below ground surface at MW-67. As described below in **Section 4.4,** the majority of the rock borings were completed as monitoring well locations. One exception was MW-61, which was abandoned when a length of HQ casing separated in the borehole due to drilling difficulties related to a 70-foot length of clay-filled fault gouge, and could not be retrieved. The boring was subsequently grouted and a second boring, designated MW-66, was advanced approximately 10 feet East of the MW-61 location.

As discussed earlier, one boring, U1-CSS, was installed using a hand-held coring machine through the East wall of the IP1-CSS. This borehole was advanced horizontally approximately 70 inches into the bedrock to the East of the Superheater Building.

4.2.2 Overburden Borings

In areas where groundwater was encountered in the overburden deposits, overburden (soil) borings were drilled to further evaluate water quality in the shallow aquifer. Five borings, designated MW-49, -52, -62, -63, and -66 were advanced immediately adjacent to the bedrock boring of the same name. In addition, three overburden borings, designated MW-38 and MW-64, were advanced at stand alone locations. MW-38 was advanced to assess groundwater quality and migration pathways along the Discharge Canal. MW-64 was advanced to determine the backfill material and construction properties of the Discharge Canal as it runs beneath the Superheater Building, and was terminated at a depth of 3 feet when concrete was encountered beneath the slab of the building. Additionally, a tracer injection well (T1-U1-1) was installed within overburden above the North Curtain Drain (NCD) along the North wall of the IP1-FHB.

Seven of the borings were advanced using water rotary techniques and temporary six-inch casing. MW-64 was advanced using a concrete core until lean concrete was encountered under the building slab. Seven of the borings were completed as single monitoring wells.



ADVANCEMENT OF BORINGS ALONG RIVERFRONT

4.2.3 Borehole Development

After drilling was completed and prior to conducting hydraulic tests within a borehole, borehole development was conducted to remove rock cuttings from the borings, which could otherwise restrict water flow into the fractures and alter packer testing results, as well as to remove drilling water lost to the formation during drilling. The boreholes were developed either by pumping and surging with a 3.7-inch surge block and a Grundfos Redi-Flo 2 submersible pump, or by pumping with a submersible pump along the length of the borehole. Sufficient water was pumped out of the borehole to account for water lost during drilling and until well water was visually free of turbidity.

4.2.4 Borehole Geophysical Analysis

Upon completion of borehole development, a suite of geophysical surveys was conducted in select boreholes (borehole geophysics was biased towards the deeper boreholes) by GA of Holliston, Massachusetts to obtain information on the presence of water bearing fractures in the rock. This work took place between November 2005 and July 2007, and involved twenty-three borings MW-30, -31, -32, -33, -34, -39, -40, -51, -52, -53, -54, -55, -56, -57, -58, -59, -60, -62, -63, -65, -66, -67 and RW-1.

GA performed fluid resistivity, temperature and conductivity logging; heat pulse flow meter logging; and optical and acoustical televiewer logging (OTV/ATV). A Mount Sopris model 4MXA or 4MXB logging winch equipped with a Mount Sopris model MGX-11 electronics console recorded conventional logs at each well. All conventional log data was recorded at 0.1-foot depth increments.

Fluid temperature and fluid resistivity logs were recorded during the first downward logging run at each borehole using a Mount Sopris caliper probe with a fluid temperature/fluid resistivity subassembly. These fluid logs were obtained using a downward logging speed of approximately 4 to 5 feet per minute. Caliper data were subsequently recorded while pulling the same probe upward at approximately 10 feet per minute.

ATV data were obtained using an Advanced Logic Technologies (ALT) model AB140 acoustical televiewer probe with a Mount Sopris winch and an ALT model Abox electronics console. ATV data were recorded at 0.01-foot depth intervals with 288 pixels for a 360-degree scan around the borehole wall. Logging speeds were approximately 4 feet per minute with this probe.

OTV data were recorded using an ALT model OB140 probe, also with a Mount Sopris winch and the ALT electronics console. OTV data were stored at depth increments of 0.007 feet, with 288 pixels for each 360-degree scan around the borehole wall. OTV logging speeds were also approximately 4 feet per minute.

A pair of centralizer assemblies positioned the ATV and OTV probes near the middle of each borehole. Each centralizer included four stainless steel bow springs, clamped to the probe housings with brass compression fittings, at positions recommended by the probe manufacturer to minimize the risk of interference with the probes' three internal component magnetometers.

Flowmeter data were recorded with a Mount Sopris model HPF-2293 heat-pulse flowmeter probe at specific depths selected from field graphs of the caliper, fluid temperature and fluid resistivity logs. Flowmeter data were initially recorded under ambient conditions. The same test depths were subsequently repeated while pumping at 0.4 to 0.75 gallons per minute (gpm) with a Grundfos, Fultz or Whale pump. The pump was positioned a few feet below the observed static water level in each well. In some cases, the pump was operated so as to maintain the water level some number of feet below the static level (if the well produced little water and the water level was constantly dropping while pumping).

A detailed description of the geophysical logging results for each borehole is included in **Appendix C.**

4.3 WELL INSTALLATIONS

Bedrock and overburden monitoring installations were constructed in boreholes to allow for future recording of groundwater levels and the collection of groundwater quality samples. Further, we installed nested piezometers in single boreholes to screen multiple levels of bedrock and overburden within a single borehole and alleviate the need for multiple borings in areas not easily accessed. For specific well installation details, refer to the well construction logs provided in **Appendix D**. In addition, eighteen monitoring wells were previously installed at the Site prior to this investigation and included: MW-101, MW-103, MW-104, MW-105, MW-107, MW-108, MW-109, MW-110, MW-111, MW-112, U3-1, U3-2, U3-3, U3-4S, U3-4D, U3-T1, U3-T2 and I-2.

4.3.1 Bedrock Wells

Following borehole advancement and testing, GZA evaluated the rock cores, geophysical logs, and other hydrologic and radionuclide test data to assess fracture spacing and potential yield. Using these data, GZA selected intervals within the boreholes to be completed as permanently screened monitoring wells. The selected well screen intervals were intended to span hydraulically active zones within the bedrock.

4.3.1.1 Open Rock Wells

Four bedrock borings, designated MW-33, -34, -35 and -46, were left as open borehole monitoring points. MW-46 is located in the Unit 3 Transformer Yard (IP3-TY), and MW-33, -34 and -35 are located in the Unit 2 Transformer Yard (IP2-TY) where the water table spans the hydraulically active shallow bedrock. The wetted lengths of the borehole were appropriate for one sampling zone at these locations.

Recovery well RW-1, located in the IP2-FSB truck bay, is also an open borehole. The borehole was installed and a Pumping Test conducted (described in **Section 4.4.4**) to test the feasibility of using hydraulic containment in the vicinity of Unit 2, should it be found appropriate. This location was used as the pumping well during the Pumping

Test. During the interim between completion of the Pumping Test and completion of a hydraulic containment system, a series of temporary packers were installed in the borehole to prevent or limit non-ambient, downward migration of radionuclides through the borehole. RW-1 was also used as a monitoring point during the tracer test.

MW-66 is an open borehole to 200 feet below grade. A Flute liner system was installed in the borehole in September 2007 to limit the vertical migration of contaminants until such time as either a multi-level monitoring well is completed or the boring is abandoned.

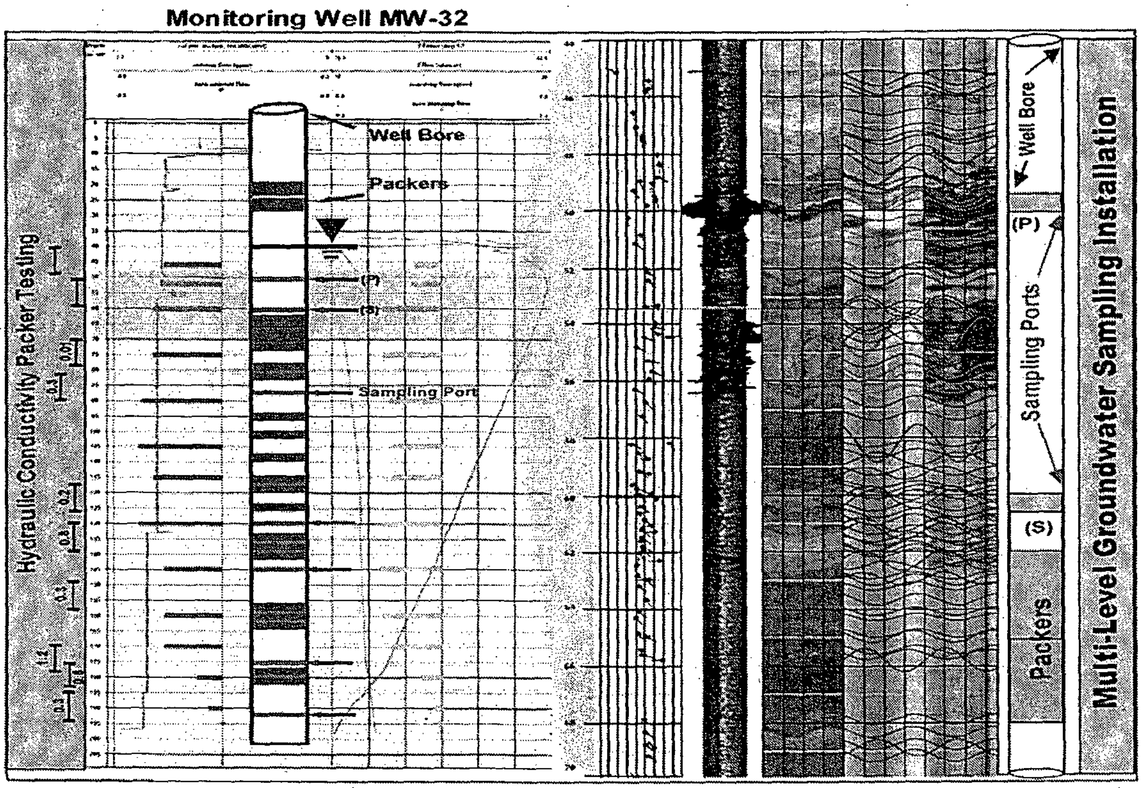
U1-CSS is an open borehole advanced horizontally into the bedrock behind the East wall of the Superheater Building. A watertight flange was mounted to the concrete wall of the IP1-CSS and steel piping was extended vertically upward through the floor of the Superheater Building. The well was completed as a standpipe with shut-off valves and overflow bypass in case of any artesian effect.

4.3.1.2 Waterloo Multi-Level Completion Wells

Twelve borehole locations, designated MW-30, -31, -32, -39, -40, -51, -52, -54, -60, -62, -63, and -67, were completed with Waterloo multi-level sampling systems. The Waterloo system uses modular components which form a sealed casing string of various casing lengths, packers, ports, a base plug and a surface manifold. This configuration allows accurate placement of ports at precise monitoring zones. Stainless steel sampling pumps are connected to the stem of each port and individually connect that monitoring zone to the surface. The Waterloo systems are constructed of 2-inch-diameter Schedule 80 PVC risers with 3-foot-long packers that inflate to fill a 4-inch borehole.

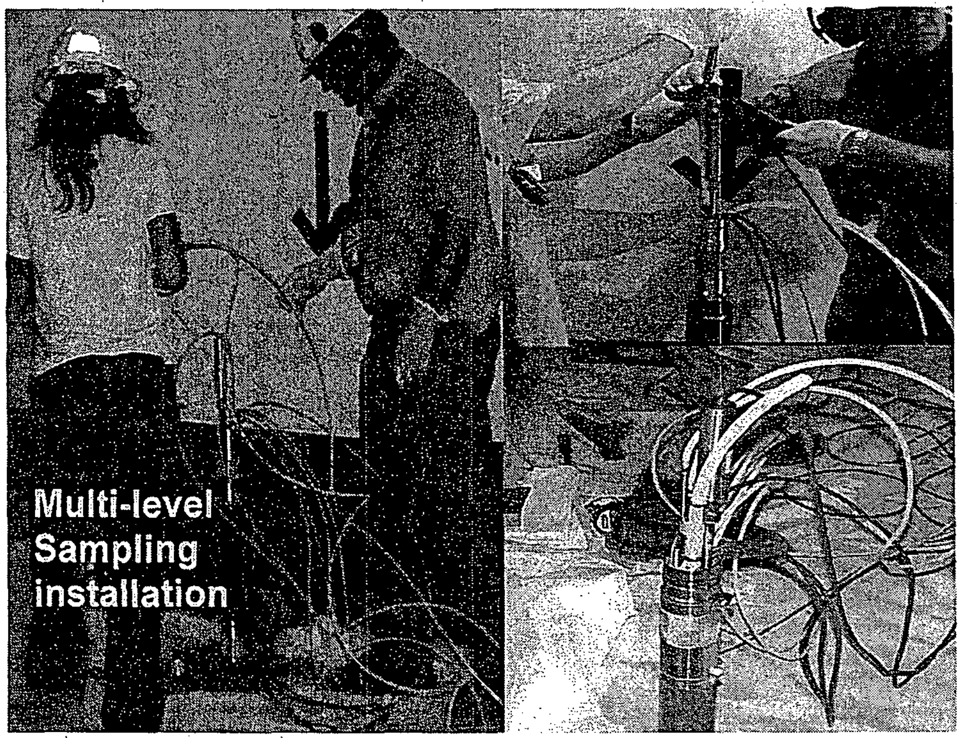
Multiple levels of monitoring ports were installed in each borehole. In several cases, redundant ports were also installed (typically, within approximately two feet of each other). In the borehole, the associated sampling zones are isolated from each other by a series of packers. The monitoring ports are constructed from stainless steel. Each monitoring port has two openings: one for sampling and one for monitoring piezometric pressures. A sampling pump and pressure transducer are dedicated to each monitoring port. Each sampling pump is individually connected to the surface manifold by 0.25-inch nylon tubing. In general, monitoring ports were placed within sampling zones adjacent to the fractures that were observed to be the most hydraulically active. Sampling zone lengths were varied with the objective of making them less than ten feet in length, but longer where either: 1) more low transmissivity fractures were required to allow enough flow for reasonable sampling times, and/or 2) two conductive fractures needed to be captured within a single sampling zone given that the total number of monitoring ports was limited to seven per borehole. Packers were placed at locations where the data (geophysical logging, packer testing, rock core photographs, etc.) indicated that the bedrock was the least fractured. In areas where packer placement could not avoid all fractures, zones with nearly horizontal fractures were favored. The overall objective of packer placement was to achieve a vertical borehole conductivity equal to or less than that of the original bedrock removed from the borehole.

A schematic of the data and analysis process used to design the multi-level installations is included below.



EXAMPLE OF DATA AND ANALYSES USED TO DESIGN MULTILEVEL INSTALLATION

The manifold completes the system at the surface. It organizes, identifies, and coordinates the sample tubing, air drive line tubing, and/or transducer cables from each monitoring zone (see photo below of tubing and cabling during system assembly and installation). The manifold allows connection to each transducer in turn, and a simple, one-step connection for operation of pumps. Dedicated pumps allow individual zones to be purged separately; the manifold also allows for the purging of many zones simultaneously from one borehole to reduce sampling times.



SAMPLING PORTS, TUBING AND CABLING FOR MULTI- LEVEL SYSTEM ASSEMBLY AND INSTALLATION

4.3.1.3 Nested Wells

Nested monitoring wells were installed in 18 locations, designated MW-36, -37, -41, -42, -43, -44, -45, -47, -48, -49, -50, -53, -55, -56, -57, -58, -59, and -65. In general, the nested wells consisted of the installation of one or more one-inch diameter Schedule 80 PVC wells screened at varying intervals in bedrock and a two-inch Schedule 80 PVC well in the shallow West sampling zone of the boring, either in the bedrock or overburden.

In general, well screens consisting of 0.02-inch slotted PVC pipe were installed at lengths between 2 and 10 feet. Once the screened intervals were selected, the PVC well point was lowered into the boring to the desired depth. Appropriately sized filter pack material was placed from one foot below the screened interval to a minimum of one foot above the screened interval. The depth of the filter pack was measured on several occasions during installation to assess the affects of bridging and verify that the filter pack material was placed at the required depths. The intervals between well screens were sealed using bentonite pellets.

4.3.2 Overburden Wells

Three wells, MW-38, -49-26, -52-12 were completed as either two-inch diameter or four-inch diameter groundwater monitoring wells. The wells were constructed of Schedule 40 PVC screen and solid riser to ground surface. A 0.02-inch slot size was selected for the well screens based on existing knowledge of the Site soil conditions. From field observations, the shallow groundwater table was expected to be influenced by daily tidal fluctuations of approximately 2.7 feet. Consequently, well screens were installed such that the top of the screens were above mean high-tide water levels and of sufficient length to accommodate groundwater sampling needs. The annular space around the screen and riser was backfilled with #2 filter sand to approximately 2 feet above the top of the screen. The remaining annular space was backfilled with bentonite and grout.

In order to sample two intervals in deep fill and overburden deposits observed near the Hudson River (in borings at MW-62, -63, and -66), GZA installed two one-inch Schedule 40 PVC wells, or one one-inch and one two-inch well, at these three locations. One of the well screens spanned the tidally influenced shallow water table, and one at the top of rock in a more gravel-rich layer beneath silty, historic, river bottom sediments.

In addition, GZA installed one tracer injection well situated in the overburden above the Unit 1 North Curtain Drain. This well is constructed of two-inch Schedule 40 PVC. The screened interval was backfilled with #2 filter sand to approximately 2 feet above the screen. The remaining annular space was backfilled with bentonite grout. A second tracer injection point was completed adjacent to MW-30's casing.

4.3.3 Wellhead Completion

To protect the monitoring installations against damage and the elements, most installations were finished at the ground surface with an 8-inch or 12-inch flush mount protective casing with a concrete pad. To accommodate the multi-purge, sampling manifold of the Waterloo Systems well installations, the wellheads were completed with a 2 foot by 2 foot by 2 foot well vault. The well vaults were concreted in-place by Entergy subcontractors after the completion of the rock borings. The well vaults are equipped with hinged diamond plate steel lids that are rated for truck wheel loads.

4.3.4 Well Nomenclature

GZA designated names to newly installed monitoring installations[17], typically with the prefix "MW-". Nomenclature of single-interval installations, such as MW-33, were designated a number typically indicative of the order in which locations were selected prior to drilling. Nomenclature of installations containing Waterloo systems or nested piezometers, such as MW-30-69, were designated a number followed by a monitoring depth interval. In Waterloo installations, the depth interval suffix is indicative of the depth to the sampling port from the top of the well casing. In nested piezometers, the monitoring depth interval suffix is indicative of the depth to the bottom of the piezometer from the top of the well riser. These depths are rounded to the nearest foot.

Throughout the course of the investigation, alterations were made to well casings and adjacent ground surfaces due to equipment installation, hydraulic conductivity testing,

---

[17] *Monitoring installations* are commonly referred to as *Monitoring wells*, which in this usage, may include multiple, individual well casings. This generic usage is also used herein.

well vault installation, and Site construction activities. In May 2007, GZA reassigned the names of multilevel installations to maintain the above described nomenclature basis as an easily verifiable tool in the field. Changes in installation nomenclature are provided in **Table 4.2**. It should be noted that the provided groundwater and tracer test analytical data, piezometric data, well construction and development logs, transducer installation logs, sampling logs, hydraulic conductivity testing logs, and survey reports dated prior to May 2007 reference the original designated installation nomenclature.

4.3.5 Wellhead Elevation Surveying

As-built surveys of the newly installed monitoring installations were performed in December 2005, March 2006, April 2006, November 2006, January 2007, and May 2007 by Badey and Watson, Inc. **Figure 1.3** reflects the surveyed locations. The survey results are summarized in **Appendix E** and in **Table 4.1**. Note that **Appendix E** survey reports dated prior to May 2007 reference original installation nomenclature. **Table 4.3** includes changes in casing and ground surface elevations and dates of alterations and resurveys throughout the course of the investigation. Elevations are reported with respect to the National Geodetic Vertical Datum of 1929 (NGVD 29)[18], which is also the datum used by the plant.

4.4 HYDRAULIC TESTING

Four types of in situ tests were performed on existing and newly installed monitoring wells to characterize hydrogeologic properties of the bedrock and overburden, and facilitate the selection of well screen and piezometric sampling intervals. These included short duration specific capacity tests, rising head hydraulic conductivity tests, bedrock packer hydraulic conductivity tests, and the Pumping Test. The following sections describe the equipment and procedures used during this testing program.

4.4.1 Short Duration Specific Capacity Tests

A total of eight specific capacity tests and eight extraction tests were performed to assess hydraulic conductivity (K). See **Table 4.4** for a summary of hydraulic conductivity data.

The testing was conducted by pumping water from the well at a constant rate in order to achieve "measurable drawdown" within the well that would stabilize after a relatively short period of time. "Measurable drawdown" was considered between 1.5 and 10 feet for the purposes of this study. Once drawdown apparently stabilized, pumping was allowed to continue at a constant rate for at least thirty additional minutes before pumping ceased.

---

[18] The National Geodetic Vertical Datum of 1929 (NGVD 29) is the renamed Sea Level Datum of 1929. The datum was renamed because it is a hybrid model, and *not a pure model of mean sea level*, the geoid, or any other equipotential surface. NGVD29, which is based on "an averaging" of multiple points in the US and Canada, is the vertical "sea level" control datum established for vertical control surveying in the United States of America by the General Adjustment of 1929. The datum is used to measure elevation or altitude above, and depression or depth below, "mean sea level" (MSL). It is noted that there is no single MSL, because it varies from place to place and over time.

If measurable drawdown within the well could not be achieved, and the maximum capacity of the pump was reached, pumping was allowed to continue at a constant rate for approximately thirty minutes, and the pump was turned off. If the characteristics of the monitoring well and immediately surrounding hydrogeology did not allow for a more suitable method of hydraulic testing, the well was characterized as having a K value "greater than" the value estimated at the maximum pumping rate.

If stabilized drawdown within the well could not be achieved, and the water level in the well continued to decline after attempts to minimize pumping rate to the minimum pumping capability of the pump, the pump was turned off. If alternative methods of testing could not be appropriately implemented due to well characteristics, water levels during the recovery period of this test were analyzed and interpreted for K values.

A Grundfos II Readi-Flo submersible pump or peristaltic pump was used for specific capacity testing, and drawdown was measured using an electronic water level meter and/or pressure transducers. Flow rates were either measured using an in-line flow meter, or estimated by measuring the time required to fill a calibrated container. Transducer-logged water level measurements were typically recorded at thirty second or one minute intervals, while manual water level measurements were typically logged every one to five minutes. The entire pumping duration for each test was typically between thirty and ninety minutes.

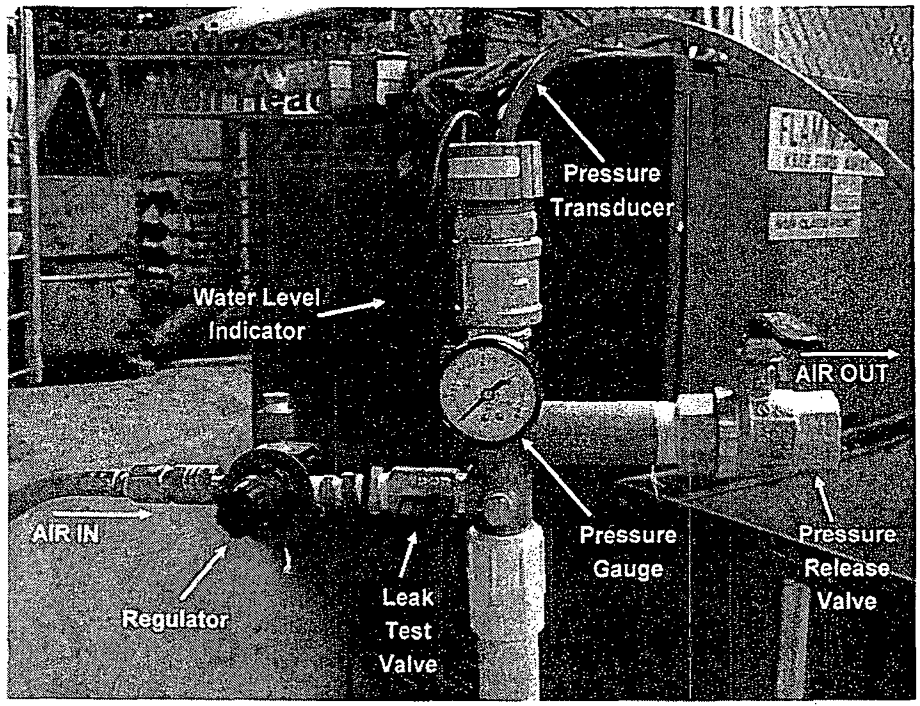
GZA performed specific capacity tests between January 2006 and April 2007. Measurements were also recorded during borehole development. The logs are included in **Appendix F**.

4.4.2 Rising Head Hydraulic Conductivity Tests

A total of forty-three rising head hydraulic conductivity tests were performed at eighteen monitoring wells at the Site. Rising head K tests (slug tests) were performed in MW-36-41, -36-53, -37-57, -41-64, and -42-51 via traditional slug testing. Pneumatic slug tests were performed in monitoring wells MW-53-120, -55-24, -55-24, -55-35, -55-54, -56-85, -57-20, -57-45, -58-65, -59-31, -59-45, -59-68, and -65-80. Hydraulic conductivity (and transmissivity) estimates were then calculated from those results. The calculations for the hydraulic conductivity estimates are provided in **Appendix G**.

At each of the traditional slug tested monitoring wells, the resting (static) water level was measured along with the depth and diameter of the well. A pressure transducer was installed within the screened portion of the tested well to record water level measurements at 10 second intervals. Pressure transducers in immediately adjacent wells also recorded water level measurements at 10 second to one minute intervals. During the first part of the slug test a rod (slug) of approximately 7 feet long was quickly inserted into the tested well below the water table in order to nearly instantaneously displace a volume of water equivalent to the volume of the slug. The raised head of the water column was then dissipated back down to its initial static level. When equilibration at static water level was reached a rising head test was conducted. The slug was quickly withdrawn from the monitoring well, resulting in a nearly instantaneous decline in the water level within the tested well. The lowered head of the water column recovered to its initial static water level.

At each of the pneumatic slug tested wells, static water level was recorded, as well as the depth and diameter of the well. Pressure transducers were installed within the screened portion of the tested well and in adjacent wells to record water level measurements at 1 to 3 second intervals. A pneumatic slug test well head was attached and sealed to the top of the tested well (see enclosed photo below). The well head was then pressurized using compressed air in order to lower the water column to a predetermined depth that was measured using pressure transducers. The water column was not permitted to decline below the top of the well screen. When pressure transducer readings stabilized and the water level in the well was below the water level indicated, the air pressure was instantaneously released through a valve on the pneumatic slug test well head, and the water column was allowed to recover to its initial static water level.

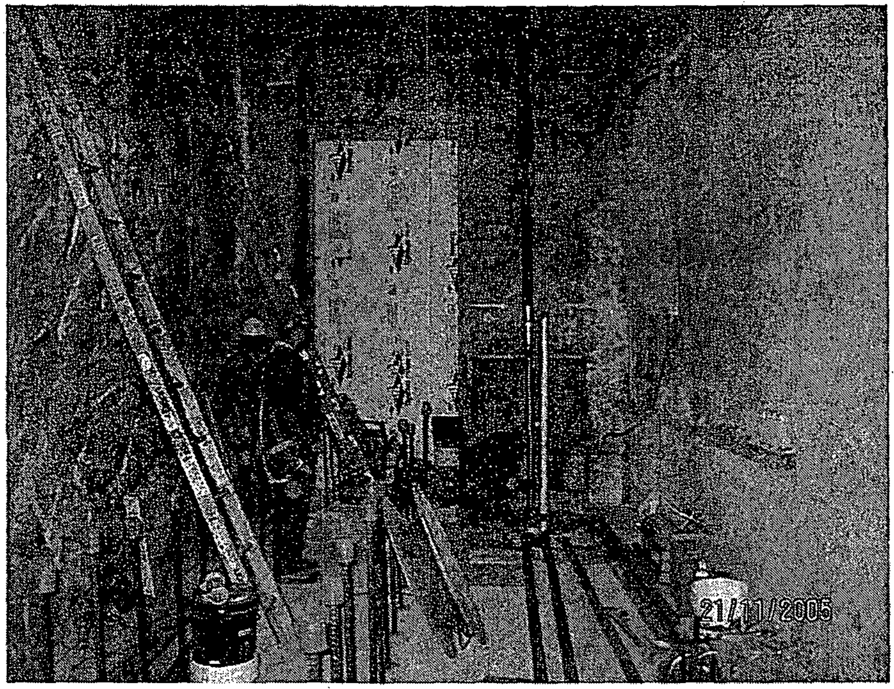


PNUEMATIC SLUG TEST WELL HEAD INSTRUMENTATION

Slug test logs are provided in **Appendix H**. Estimated K values are provided in **Table 4.4. Figure 4.1** represents a diagram of the pneumatic slug test well head.

4.4.3 Bedrock Packer Extraction Hydraulic Conductivity Testing

Under the direction of GZA personnel, ADT conducted 186 packer hydraulic conductivity tests between November 2005 and August 2007 in boreholes MW-30, -31, -32, -39, -40, -51, -52, -54, -60, -62, -63, -66 and -67.



PACKER TESTING OF MW-30 WITHIN IP2-SFP EXCAVATION

Bedrock packer hydraulic conductivity testing (packer testing) was performed to estimate the equivalent hydraulic conductivity of the bedrock in the vicinity of the borehole locations. The use of packers permitted the localization of a specific depth interval within a bedrock borehole for sampling and hydraulic conductivity testing. The primary hydraulic conductivity of unfractured marble is insignificant. Bedrock groundwater flow, therefore, is controlled by fractures in the rock formation. However, not all rock fractures are hydraulically active. Accordingly, packer tests were used to assess which rock zones have the ability to transmit measurable quantities of groundwater, and to estimate the equivalent hydraulic conductivities of those fractures.

During packer testing, water samples were collected for Tritium analysis for each tested interval in all boreholes except MW-40. Water samples were also collected for Strontium analysis for every other tested interval in boreholes MW-54, -60, -62, -63, -66, and -67.

Prior to the initiation of packer testing at the Site, the packer assembly was pressure tested. Also, prior to the start of packer testing at each borehole, all downhole equipment was disassembled and steam cleaned. The submersible pump was removed from the packer assembly and decontaminated using a fresh water and Alconox solution. A quality assurance/quality control (QA/QC) sample was collected from this pump after the decontamination process was completed. After reassembly of the packer equipment, packers and air lines were tested for leaks.

Packer tests were performed using an assembly composed of two inflatable bladders, or "packers", with a length of perforated pipe making up the 10-foot test zone between the two packers. A Grundfos Rediflo II submersible pump was placed within this 10-foot-long test zone. Pressure transducers were positioned above, within and below the test zone.

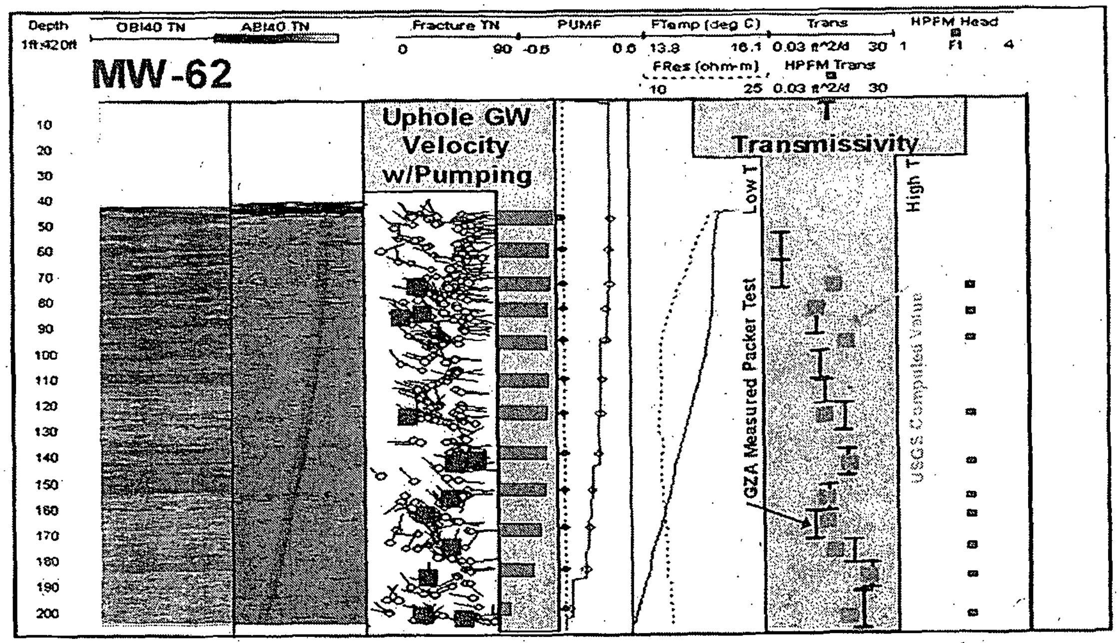
Using a drill rig hoist, the packer assembly was lowered on two-inch-diameter Schedule 80 pipe to the appropriate test depths within each tested borehole. See **Figure 4.2** for a schematic of the packer test assemblage.

Water levels above, within, and below the tested zone were recorded at ten second intervals using pressure transducers. Packers were inflated with 160-195 psi of nitrogen, and water levels were allowed to equilibrate. Once pressures had equilibrated, the pump was turned on and the tested zone was slow purged for at least ten minutes at a rate of 2 to 10 gallons per hour (gph). During this initial purge, a sample was collected for Tritium analysis in boreholes MW-30, MW-31, MW-32, MW-39, MW-51 and MW-52. Immediately following this initial purging period, the pumping rate was increased to a rate of 0.5 to 4 gallons per minute (gpm) in order to achieve drawdown of approximately 10 to 30 feet within the tested zone.

During drawdown, pressure transducer data was observed and compared to assess the potential for cross-zone communication, either through fractures interconnecting around the packer or incomplete seals by the packers. If significant drawdown could not be achieved, a short term sustained yield test was conducted. Once significant drawdown was achieved, or sustained yield was maintained for at least 30 minutes, a sample was collected for Tritium analysis. The pump was turned off, and the water level within the test zone was allowed to recover for either 30 minutes or until 80 percent recovery was achieved. For test zones in which sufficient recovery had been achieved, a final sample was collected for Tritium analysis. This sample was collected from all packer test zones except in borehole MW-40. In some test zones, as noted above, an additional sample was collected for Strontium analysis. After samples were retrieved, the packers were deflated and pressure transducer data was collected.

Packer test intervals and test pressures were measured in the field and recorded by GZA personnel along with all pertinent testing data. Hydraulic conductivity calculations and methodologies are presented in **Appendix G**. Packer test result summary sheets are presented in **Appendix I**. **Table 4.4** summarizes hydraulic conductivity data collected during packer testing.

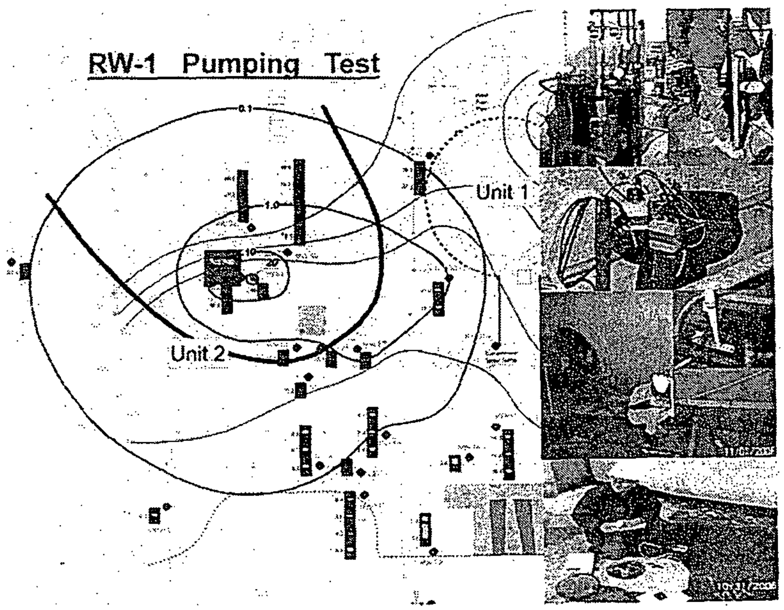
In addition to the analyses referenced above, depth-specific borehole transmissivity values were also computed by the USGS using the heat pulse flow meter data collected during the geophysical logging. These data generally confirmed the packer testing values computed as discussed above (see figure below for an example comparison). In some cases however, these two methods did not correlate well, as reflective of the limitations inherent with each method. For example, the heat pulse flow meter analyses yielded lower transmissivity values where the packer testing transducer data indicated leakage around the packers. In other cases, the heat pulse flow meter analyses proved to be too insensitive to measure lower transmissivity values.



COMPARISON OF PACKER TESTING TO HEAT PULSE FLOW METER ANALYSIS OF TRANSMISSIVITY

4.4.4 Pumping Test

GZA conducted a step drawdown, constant rate drawdown, and aquifer recovery test in recovery well RW-1 near the IP2-SFP as shown on **Figure 1.3**. Collectively, these tests are referred to as the "Pumping Test." The Pumping Test was performed in general accordance with our Standard Operating Procedure (SOP) dated October 11, 2006 and submitted as part of the "Pumping Test Report" dated and submitted to Entergy on December 8, 2006. A schematic of the Pumping Test data, testing and pumping equipment, and data monitoring is provided below.



EQUIPMENT, MONITORING AND DATA FROM PUMPING TEST OF RW-1

Prior to the Pumping Test, GZA installed select instrumentation including flow meters, precision gauges, and valving at the well head to control flow and to collect samples, and transducers in wells and drains to measure water level response to pumping.

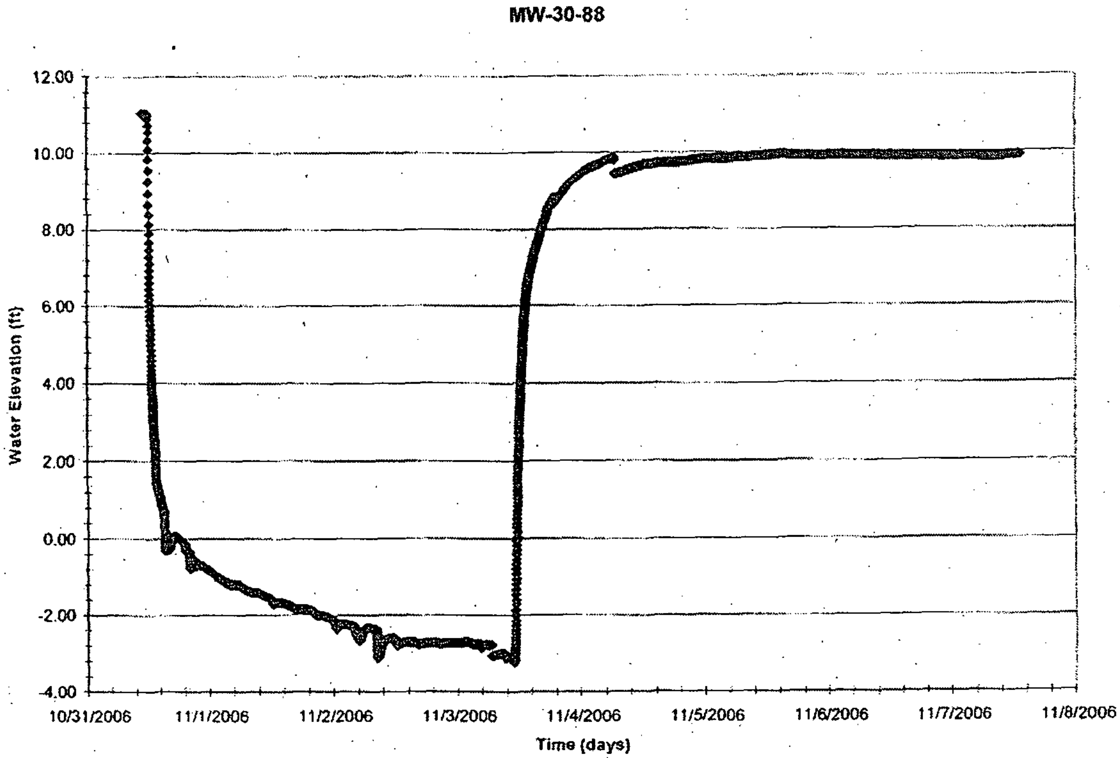
GZA conducted the Pumping Test by extracting groundwater from RW-1 at the following average flow rates:

Test Name	Begin Date	End Date	Pumping Rate at RW-1
Step Drawdown	10/25/2006	10/25/2006	2 gpm for 88 minutes 4 gpm for 77 minutes 5 gpm for 63 minutes 7 gpm for 28 minutes
Constant Rate Drawdown	10/31/2006	11/3/2006	4 gpm for 71 hours
Recovery	11/3/2006	11/6/2006	No pumping

PUMPING TEST SUMMARY TABLE

During the Pumping Test, we monitored and recorded the following:

- Water level elevations with 75 pressure transducers at 44 groundwater monitoring wells at the Site. Water levels in the 15 primary monitoring wells (i.e., I-2, MW-30, -31, -32, -33, -34, -35, -36, -37, -42, -47, -51, -52, -53, and -111) were monitored once per minute. The remaining 29 wells (MW-38, -39, -41, -43, -44, -45, -46, -48, -49, -50, -54, -55, -56, -57, -58, -59, -60, -62, -63, -65, -108, -109, U3-2, U3-3, U3-C1, U3-T1, U3-T2, U3-4D, and U3-4S) were monitored hourly.
- Water quality parameters; we also collected groundwater samples for Tritium and Strontium analysis during the step drawdown and constant rate drawdown test at RW-1.
- Flow rates at the IP1-NCD and IP1-SFDS, and the IP2-Curtain Drain; generally at the frequency and using the methods stated in the SOP.
- Precipitation via data available from the on-Site meteorological tower or via information available at www.wunderground.com for the surrounding area.



EXAMPLE OF TIME VS DRAWDOWN CURVE FOR MW-30

The Pumping Test activities are further detailed in our December 8, 2006 report. The results of the Pumping Test are described in **Section 6.0**.

4.5 WATER SAMPLING

Sampling of on-Site groundwater and surface water sources and off-Site groundwater and surface water sources was conducted during the period of this study. The locations and methods of sampling are described in the following sections. The results of the sampling are discussed in **Section 10.0**.

4.5.1 On-Site Groundwater Sampling

On-Site groundwater sampling commenced in August 2005, upon observation of the moist shrinkage cracks in the IP2-SFP wall. Through May 2007, sampling was conducted primarily by Entergy personnel. During this period, GZA personnel collected groundwater samples only during packer testing and when conducting low flow groundwater sampling at monitoring wells MW-30 and MW-42. After May 2007, GZA personnel conducted all groundwater sampling. Over 700 groundwater samples were collected during the study.

GZA and Entergy personnel collected groundwater samples using traditional purge techniques, modified purge techniques, or low flow sampling techniques. Groundwater samples were collected from specific intervals in monitoring wells MW-30 and the 2-inch diameter well-screened interval of MW-42 using low flow purging and sampling methods described in the USEPA's Low Flow Purging and Sampling Guidance document. These sampling techniques are described in the following sections.

4.5.1.1 Purging

At the early stages of the project, Entergy personnel sampled open borehole wells and nested piezometers by purging the traditional 3 to 5 times the volume of water standing in the well casing[19]. This was accomplished with either a dedicated submersible pump, a peristaltic pump with dedicated tubing, or a Waterra foot-valve pump with dedicated tubing. As the investigation proceeded, GZA became concerned that the standardly-required purge volume could force unrepresentative displacement of contaminants in the low conductivity bedrock through sampling-induced drawdown in the wells. We therefore reduced the purge volume, for wells not low flow-sampled, to 1.5 well volumes for the remainder of the investigation. This modification to the sampling procedures was discussed with the regulators. By May 2007, low flow sampling procedures had been adopted and implemented for all wells.

4.5.1.2 Low Flow Sampling

The low flow sampling method allows collection of groundwater samples representative of ambient flow conditions at discrete sampling zones, while limiting the accumulation of wastewater, mobilization of contaminants, and turbidity of samples by reducing pumping rate and drawdown. GZA collected low flow groundwater samples using peristaltic pumps, Grundfos Readiflo II submersible pumps, and several models of submersible pumps manufactured by Proactiv. Low flow samples were also collected at discrete sampling intervals of deeper boreholes using Solinst Multilevel Waterloo sampling systems. The use of Waterloo systems for low flow sample collection is summarized in the following section. With the exception of wells MW-30 and MW-42, GZA began low flow sampling in May 2007. GZA collected samples from MW-30 and MW-42 using low flow techniques starting in January 2006.

GZA collected low flow samples by slowly pumping from a predetermined well depth while monitoring water quality parameters, including pH, specific conductance, temperature, turbidity, dissolved oxygen, and oxygen reduction potential (ORP). Water quality parameters were monitored using a Horiba U22 water quality meter with an in-line flow-through cell. Pumping rates were typically between 100 and 400 ml per minute, and drawdown within the well was typically limited to between 0.1 and 1.0 foot.

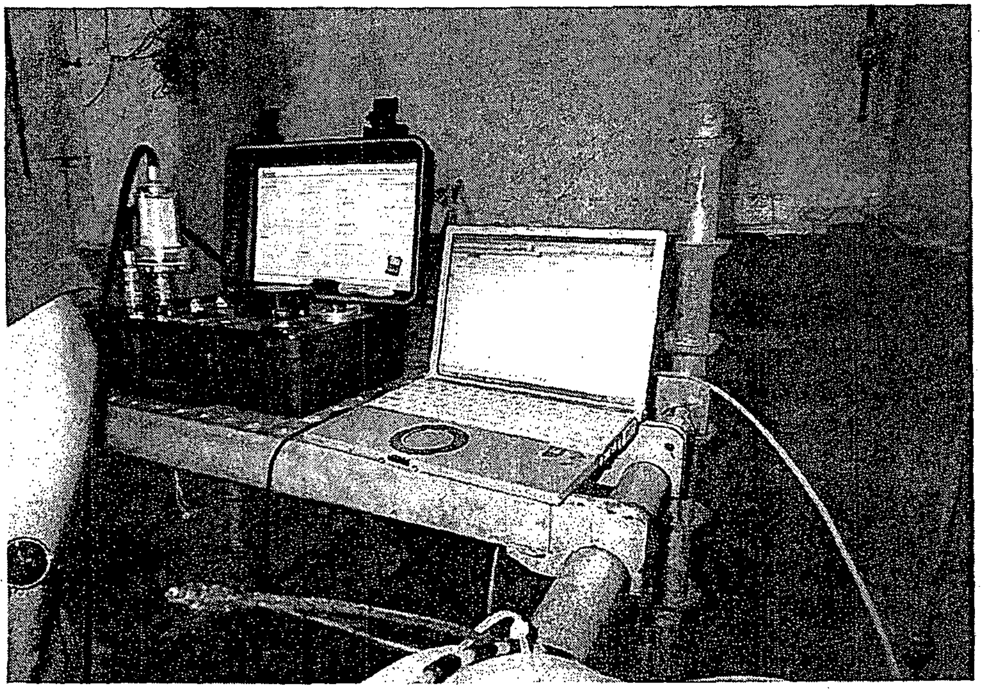
GZA recorded water quality parameters, water level, and flow rate every five to ten minutes during a pre-sampling purge which lasted generally between one half hour and three hours. Samples were collected upon stabilization of water quality parameters listed above. Low flow sampling logs are provided in **Appendix J**. Note that sampling logs dated prior to May 2007 reference original well nomenclature.

---

[19] Water quality parameters during well purging were not measured by Entergy personnel as part of their groundwater sampling rounds.

4.5.1.3 Waterloo Low Flow Sampling

Low flow sampling was also conducted in Waterloo installations at MW-30, -31, -32, -39, -40, -51, -52, -54, -60, -62, -63, and -67. Samples were taken from discrete intervals unless the interval was depressurized, in which case 1.5 well volumes were purged prior to sampling.



LOW FLOW SAMPLING OF MW-30

4.5.1.4 Discrete Interval Packer Sampling

During packer testing prior to installation of Waterloo systems, GZA collected groundwater samples representative of several distinct elevations within each borehole. GZA collected water samples for Tritium analysis for each tested interval in all boreholes except MW-40. Water samples were also collected for Strontium analysis in boreholes MW-54, -60, -62, -63, and -66. Sampling procedures were described in **Section 4.4.3.**

4.5.2 On-Site Surface Water Sampling

On January 19, 2007, GZA collected samples from the Discharge Canal and Hudson River to evaluate major cation geochemistry. This sampling was designed to help us assess potential sources of water found within monitoring wells MW-38 and -48. Samples were collected with dedicated high density polyethylene bailers. In addition, Entergy routinely collects composite water samples from the Discharge Canal to evaluate the discharge of radionuclides to the Hudson River. These samples are collected using peristaltic pumps at locations indicated in the Annual Radiological Environmental Operating Report (AREOR).

4.5.3 Off-Site Groundwater Sampling

At the beginning stages of the investigation, prior to a thorough understanding of the hydrogeology of the Site, several off-Site groundwater wells were sampled by Entergy personnel to assess the potential for off-Site contamination. These data are presented in the AREOR and the sampling is conducted under the Radiological Environmental Monitoring Program (REMP). During the course of this study, the normal sampling frequencies were increased to either monthly or quarterly to assess regional background concentrations of contaminants of interest. These sampling points included: four USGS monitoring wells, three LaFarge property wells, and the Fifth Street well in Buchanan. **Figure 4.3** shows the locations of the USGS Wells. **Figure 1.3** portrays the location of the LaFarge wells. Please refer to the AREOR for the location of the Fifth Street well.

USGS Wells - On December 5 and 6, 2006, GZA personnel, accompanied by a New York State Department of Environmental Conservation (NYSDEC) representative, collected groundwater samples from four USGS groundwater monitoring wells to assess background concentrations for Tritium, Strontium and Cesium in the region. The wells were located in Harriman State Park, Rockland County, (RO543); Carmel, New York, Putnam County (P1217); Fort Montgomery, New York, Orange County (local municipal water monitoring well); and Doodletown, New York, Rockland County (RO18). All four monitoring wells were completed in bedrock. The NYSDEC provided GZA with borehole geophysical data. All four wells exhibited upward vertical gradients. GZA selected sample locations based upon the flowmeter data so as to sample the groundwater at a depth just below where it was presumed to be exiting the borehole. The groundwater samples were transported to Entergy under chain of custody procedures. Entergy personnel then shipped the samples to Areva Laboratories in Westboro, Massachusetts for analysis of Tritium, Strontium and Cesium.

LaFarge Wells - GZA personnel supervised the collection of groundwater samples from the Lafarge property immediately South of the Site from groundwater monitoring wells MW-1 through MW-3. Samples were collected by LaFarge's environmental consultant, Groundwater and Environmental Services, Inc., under the oversight of Entergy personnel, GZA and NYSDEC representatives on September 19, 2006. Groundwater samples were collected using a bladder pump following low flow procedures described below. The depths of the wells are shown on **Table 4.1**.

Fifth Street Well - Entergy personnel, accompanied by NRC and NYSDEC personnel, collected samples from the Fifth Street well in Buchanan, New York on November 30, 2005. This well is a former private drinking water well no longer in use.

4.5.4 Off-Site Surface Water Sampling

During the course of this study, off-Site surface water was sampled at the following locations: the Camp Field Reservoir and the New Croton Reservoir, Algonquin Creek, Trap Rock Quarry, the LaFarge property (Gypsum Plant) outfall, and the Hudson River (see **Figure 4.4** for the locations of the Reservoirs). The sampling frequency discussed in the AREOR was increased during the investigation. Detailed sample locations are discussed in the AREOR.

4.6 PIEZOMETRIC LEVELS AND PRESSURE TRANSDUCER DATA

GZA measured piezometric levels at 67 locations at the Site over time (between October 2005 and September 2007) using a system of electronic pressure transducers. These measurements were converted to groundwater elevations (NGVD 29) by referencing the depth of the transducer below the water table at a given time to the elevation of the top of the monitoring well riser. GZA used the resulting data to estimate hydraulic properties of the soil and bedrock, and assess the effects of precipitation, tidal influences, seasonality, and pumping on groundwater flow patterns.

This section describes the methods we used to collect and manage this data. Discussions on the use of the data are presented in **Sections 6.0** and **10.0**.

4.6.1 Transducer Types and Data Retrieval

GZA used two types of transducers, depending on the well type and application. In open wells, GZA installed MiniTroll and LevelTroll transducers, which are vented pneumatic transducers with internal dataloggers. These transducers are manufactured by In-Situ® Inc. In wells equipped with Waterloo systems, GZA installed non-vented vibrating wire transducers manufactured by Geokon® Inc. Each of these transducers was connected to a Geokon datalogger box located within the well vault.

GZA selected and installed pressure transducers within the appropriate operating pressure range required for each well or well interval. **Table 4.5** provides the accuracy of the transducers as reported by In-Situ and Geokon. This table also provides the type of transducer used in each well or well interval.

GZA collected data from In-Situ transducers typically every one to three months, or as needed. We exported data collected from each transducer from data files recognizable only by Win-Situ software into Microsoft® Excel® spreadsheets. Generally, no external data manipulation was required for these data reports. On occasion, adjustments to data were required to correct for daylight savings time, or to correct for measured disturbance of the transducer position within the well.

GZA collected water level data from each Geokon datalogger typically every two weeks to two months, or as needed. After collection, we exported the raw data into Excel spreadsheets and converted reported water levels to water elevations. Because the Geokon transducers are not vented, we adjusted total pressures to account for barometric pressure changes. Into each data report, GZA incorporated: 1) the barometer reading recorded during wellhead zeroing of the respective transducer; and 2) the barometric pressures recorded at or near the Site at the time the total pressures were recorded. Barometric pressures for this project were recorded on an on-going basis on Site using a Geokon transducer exposed to atmosphere. At different times, the barometric pressure transducer was installed several feet above the maximum water table in MW-31, MW-65, and MW-56. For verification, GZA also used barometric pressure data collected by West Point Military Academy, less than ten miles from the Site.

4.6.2 Data Availability and Preservation

A compact disk containing piezometric data collected between October 2005 and September 2007 is provided in **Appendix K**. The data is organized by well number in Excel spreadsheets. Note that piezometric data dated prior to May 2007 reference original well nomenclature.

Graphs of water levels between October 2005 and February 2007 are presented in **Appendix L**. Transducer installation logs are provided in **Appendix M**. As indicated by the legend on the first sheet of this Appendix, colors on these graphs illustrate changes in groundwater temperature. Each graph presents water levels from wells that are grouped together based on proximity to each other and association with selected Site features. Well locations are shown in **Figure 1.3**.

4.7 TRACER TESTING

To further test the Conceptual Site Model and assess groundwater flow paths from the source areas, GZA conducted an organic tracer test consisting of the injection of Fluorescein (a common dye used in anti-freeze) at a tracer introduction point located close to a potential source of Tritium at IP2-FSB. The injection well was installed approximately four feet South of the expansion crack observed in the South wall of the IP2-SFP, adjacent to monitoring well MW-30. The injection well was designed to allow the injection of tracer onto the top of bedrock located at elevation 52 feet. This elevation corresponds to the bottom of the IP2-SFP. Tracer was then gravity fed into the injection well and flushed with water. After injection, routine sampling and monitoring for the presence of tracer in Site wells commenced and continued for 27 weeks[20].

The tracer introduction was made on February 8, 2007. Tap water was introduced into the injection well adjacent to MW-30 beginning at 10:30 hours. By 10:41 hours, 30 gallons of water had been introduced into the injection well to wet the surfaces of the material down gradient from the injection well. The water introduction was then suspended while ten pounds of Fluorescein dye mixture containing approximately 75% dye and 25% diluent, all of which had previously been dissolved in ten gallons of water, was introduced into the injection well. The dye mixture was introduced between 10:42 and 10:50 hours. Tap water introduction was resumed at 10:51 hours and continued until 11:40 hours. A total of 210 gallons of water was used: 30 gallons to wet the surfaces, 10 gallons to dissolve the tracer, and 170 gallons to flush the tracer out of the dry well into the surrounding bedrock fracture system. Water introduction was made at a mean rate of three gallons per minute.

Sampling and monitoring continued through mid-August 2007, which constituted the completion of the test. The well locations monitored during the organic tracer test and the sampling results are presented in **Appendix N**.

---

[20] In addition to the routine sampling, specific wells were sampled for a longer period of time as part of short term variability testing (see **Section 9.0**).

The following sections describe the key elements of the test. The results of the tracer test are discussed in **Section 7.0.**

4.7.1 Injection Well Construction

Following excavation of soil and rock along the southern wall of the IP2-SFP for the construction of a new foundation for a heavier crane, the top of rock was exposed along the South wall of the IP2-SFP at elevation 52 feet. Prior to pouring a mud-mat, construction of the crane foundation and backfilling of the excavation, GZA installed one groundwater monitoring well (MW-30) and one dye injection well. The dye injection well was constructed of one-inch Schedule 40 PVC pipe which terminated at elevation 52 feet. In order to provide a reservoir for the dye to accumulate in prior to seeping into bedrock fractures, a one-foot-thick layer of ¾-inch crushed stone was placed on the top of rock over an area approximately 6 feet by 6 feet square. A mud-mat was poured over the crushed stone layer and across the entire floor of the excavation. The excavation was then backfilled. This injection well design allowed for the dye to be injected on the top of rock and infiltrate into the bedrock in a similar manner as water leaking from the South wall of the IP2-SFP.

4.7.2 Background Sampling

Prior to injection of dye, GZA collected background samples to assess the potential of Fluorescein to be present in the subsurface. Almost all sample locations (which included manholes, surface water bodies, nested wells, Waterloo wells) were sampled for approximately one week periods two to five times prior to dye introduction. This set of data helped in the selection of dye type and quantity, and assured that background levels of Fluorescein were not an obstacle to conducting the groundwater tracing investigation.

4.7.3 Sampling Stations

Sampling stations were selected by GZA for their relevance to the project. Some stations were established as control stations. Control stations were established to detect any fluorescent compounds not introduced as part of this investigation which might enter the study area. Most sampling stations were established to detect dyes introduced during this investigation.

Sampling stations included manholes into the Site drainage system, open waters such as the Discharge Canal and the Hudson River, clusters of nested wells, open borehole wells, and wells with Waterloo packer systems installed. Primary reliance for the detection of dye was placed on activated carbon samplers except at Waterloo locations. One carbon sampler was placed in each well and two were placed in open water locations and in manholes. Open water locations may have strong currents that could damage or wash away a sampler. Placing two samplers at these locations helped ensure that data would be collected for any given time interval and provided duplicate samples for quality assurance. At Waterloo wells, water was the only sampling medium.

Carbon samplers are continuous, accumulative samplers that virtually assure that dye migrating with groundwater is not missed at sampling locations. These samplers, however, provide information on the concentration of dye at a specific time. Because water is an instantaneous sample instead of a continuous sample the Waterloo wells were sampled more frequently.

The sampling schedule was designed to help ensure that the time the tracer arrived was recorded, and that it would be unlikely that a transient event would fail to be detected at any sampling location. The latter point only applies to the Waterloo sampling locations, since carbon packets collect samples continuously. Grab samples of water only represent the conditions at the instant the water is collected.

High frequency (or high intensity) sampling stations were selected based primarily on three criteria:

- The boundaries of the Unit 1 plume. Most wells that are located within the plume were sampled frequently.
- The premise that non-detections of dye could be as important as detections. Therefore, a "halo" of wells expected to have no detectable dye were sampled surrounding the Unit 1 plume so that the boundaries of the tracer plume would be well defined.
- That there was the possibility of poor correspondence between the tracer plume and the Unit 1 plume at some locations, and that the network might have to be adjusted to maintain the halo of non-detection sampling locations. This resulted in frequent review of the sampling network, and sampling stations were moved from the low intensity to high intensity sampling schedule as tracer was detected near the margins of the high intensity sampling network.

4.7.4 Analysis Schedule

Samples were typically shipped from the Site on the sample collection day or the next day to accommodate next day delivery. Primary samples (both carbon and water) were analyzed within five working days after receipt. Water samples analyzed because of tracer detections in the associated carbon samplers were analyzed within five working days following the carbon analyses. Results were communicated to both Ozark Underground Laboratory (OUL) and GZA project management for review of the detections and consideration of whether or not the sampling network should be modified.

4.8 ADDITIONAL GEOPHYSICAL TESTING TO EVALUATE FLOW PATHS

In addition to the downhole geophysical testing described in **Section 4.2.4**, a series of geophysical surveys was conducted to assess the depth to bedrock in certain areas of the Site and to identify the potential presence of preferential groundwater flow paths along utility trenches cut into bedrock. The major findings of the surveys are graphically shown on **Figure 1.3.**

Under the oversight of GZA, AGS conducted surface geophysical surveys to assess depth to bedrock within the IP2-TY, along the North side of IP2-Turbine Generator Building (TB), within the IP3-TY and along the OCA access road on the southern side of the Protected Area. AGS used ground penetrating radar (GPR) and electromagnetic (EM) survey equipment to complete the surveys. The survey reports are attached in **Appendix O.** The results of the surveys indicate that bedrock is fairly shallow beneath the areas investigated, except for the areas along the Hudson River where the depth to bedrock increases.

Specifically, the following work was completed:

- A GPR survey was conducted to assess depth to bedrock and potential utility trenches cut into bedrock in the IP3-TY.
- A GPR survey was conducted to assess the potential for contaminants to enter groundwater through leaking stormwater pipes (E-Series) and flow with groundwater towards the Hudson River within utility trenches cut into rock along the OCA access road on the South side of the Protected Area, and to identify depth to bedrock and any utility trenches cut into rock along this roadway.
- In order to assess the presence of subsurface utility trenches to provide preferential pathways for contaminated groundwater to flow to the North, thus accounting for the impacts to groundwater observed in monitoring well MW-48 and MW-38, AGS performed a geophysical survey consisting of a seismic refraction survey, GPR survey, and an EM survey to provide information on bedrock topography on the southern side of the Site between the Protected Area and the southern warehouse.
- In addition, several utilities were identified using EM survey techniques. However, no information regarding the nature of the backfill along the utilities could be discerned from the geophysical information.

The findings of the geophysical survey work are discussed in **Section 6.0.**

5.0 LABORATORY TESTING

Entergy and GZA arranged for, and managed, the analyses of groundwater samples. Between October 2005 and the end of September 2007, over 700 samples were analyzed for radiological contaminants, and, as part of the tracer test, nearly 4,400 samples were analyzed for Fluorescein. In addition, a limited number of samples were analyzed for selected water quality parameters. This section describes the respective testing programs as well as some of the Quality Assurance/Quality Control (QA/QC) procedures used to assess the validity of the data.

5.1 RADIOLOGICAL

Entergy and GZA personnel both collected groundwater samples for radiological analysis from existing and newly installed wells between October 2005 and September 2007. Groundwater samples were sent by Entergy personnel via chain of custody to outside laboratories for analysis of select parameters including Tritium, Strontium, gamma emitters (including Cesium, and Cobalt), and Nickel[21]. Samples were analyzed at the following laboratories: IPEC, Teledyne Brown Engineering, Inc., located at 2508 Quality Lane, Knoxville, Tennessee; Areva NP, Inc. located at 29 Research Drive, Westboro, Massachusetts; James A Fitzpatrick, NPP Environmental Laboratory, located at 268 Lake Road, Lycoming, New York; and General Engineering Laboratories located at 2040 Savage Road, Charleston, South Carolina. The results of the groundwater analyses are summarized in **Table 5.1**. Note that the sample nomenclature for groundwater analytical data collected after May 2007 are provided in the figures, however, location nomenclature prior to May 2007 may differ[22] due to subsequent casing reference point upgrades.

5.1.1 Hydrogeologic Site Investigation Analytical Data

Groundwater samples were typically analyzed for the following: Tritium by EPA Method 906; Strontium by EPA Method 905; and gamma emitters (including Cesium and Cobalt). In addition, transuranics and Nickel (as well as other "hard to detect" radionuclides) were also analyzed in specific instances, as appropriate.

Quality control criteria utilized during this investigation included the following as appropriate: laboratory blanks; field duplicates; laboratory duplicates; laboratory control samples; matrix spikes and matrix spike duplicates; initial and continuing calibrations; instrument tuning; internal standards; and regulatory split samples.

---

[21] Tritium and Strontium were the primary radionuclides focused on during the current work pursuant to source identification, groundwater flow analysis and contaminant plume delineation. Radionuclides other than Tritium and Strontium also exist to a limited extent and are fully addressed within the context of the Unit 2 Tritium and Unit 1 Strontium discussions.

[22] See **Section 4.3.4.** Note, however: 1) High priority and fast track sampling preceded casing elevation surveys and vault installation in several cases, 2) low flow sampling within a well screen resulted in collection of samples at depths differing from the well nomenclature, and 3) reinstallation of Waterloo multilevel wells to upgrade packer assemblies. In addition, sample intervals are designated by depth from top of casing.

An overall evaluation of the data indicates that the sample handling, shipment and analytical procedures have been complied with, and the analytical results should be useable. However, during one time period (August and September 2006), Strontium analytical results from Teledyne Brown Engineering, Inc. were as much as an order of magnitude different than split samples analyzed by the NRC and the NYSDOH. (Following verification of this information, the laboratory was dropped from the investigation program.) Therefore, that sample set was not utilized as part of the investigation.

Data Collection and Tracking

The data collection and data tracking phase included the following:

- Preparing all sample bottle labels and chain-of-custody forms;
- Documenting all required data in field log books and field logs;
- Performing data entry of the sampling information into Entergy's database system; and
- Quality assurance/quality control reviews of all data entry.

Laboratory Analysis

The laboratory analysis phase included the following:

- Regular communication between the laboratory and the project laboratory data manager;
- Reviewing the laboratory's sample receipt acknowledgement form;
- Documenting the project's progress in Entergy's database system; and
- Laboratory preparation of the Electronic Data Deliverable (EDD).

Data Loading

The data loading phase included the following:

- Loading all EDDs into the database;
- Resolving any data loading issues;
- Creating a post-load report for content review; and
- Notifying the project team when EDDs were available.

Data Visualization and Analysis

The data visualization and analysis phase included the initial data review by the project team and the production of data queries and draft reports to interpret the data. This phase was accomplished through the use of query tools and preformatted reports in the database.

5.2 ORGANIC TRACER

Sampling for the tracer was based on both activated carbon samplers and on grab water samples. All analyses were conducted using a Shimadzu RF5301 fluorescence spectrophotometer operated under a synchronous scan protocol. Details of the analytical approach are presented in the Ozark Underground Laboratory (OUL) procedures and criteria document **(Appendix P)**.

5.3 WATER QUALITY PARAMETERS

Groundwater samples were collected from monitoring wells MW-38, MW-48-23, and MW-48-38 and also from the Discharge Canal and Hudson River. The groundwater was collected as a grab sample using low flow sampling techniques. The surface water samples from the top of the water column were collected using bailers. The samples were collected at high and low tides. Groundwater samples were also collected at mid tide[23]. The samples were sent under chain-of-custody procedures to Life Science Laboratories, Inc., Brittonfield Parkway, Suite 200, East Syracuse, NY 13057. The samples were analyzed for Bicarbonate Alkalinity (as $CaCO_3$) under EPA Method M2320; Iron, Magnesium, Sodium, and Calcium under EPA Method 6010; and Sulfate and Chloride under EPA Method E300.

---

[23] Sample nomenclature was as follows: Monitoring Location Name-Depth Interval (if applicable), Tide Interval (H=High, M=Mid, L=Low) and replicate number (if applicable).

6.0 HYDROGEOLOGIC SETTING

This section describes the hydrogeologic setting at IPEC. Our description is based on a literature search and the findings of our field investigation program. The hydrogeology is described in reference to the two components of an unconfined aquifer found at IPEC; overburden and bedrock. Both the overburden (in select areas) and bedrock are groundwater-bearing zones which are monitored at the Site. Refer to **Section 4.0** for a summary of the groundwater monitoring system.

6.1 REGIONAL SETTING

The surface topography in the region of the Site slopes downward relatively steeply towards the Hudson River and is characterized by ground surface elevations ranging between approximately 10 and approximately 140 feet above the National Geodetic Vertical Datum of 1929 (NGVD 29). Refer to **Figures 1.3** and **3.2** for Site and regional topographical maps.

The Hudson River is a tidally influenced estuary in the vicinity of the Site, generally experiencing two high tides and two low tides daily. Near high tide, the river experiences a flood current running North. Near low tide, the river experiences an ebb current flowing South. Surface water elevations of the Hudson River as measured at Peekskill, NY, approximately two miles North of the Site, from October 20, 2005 through May 8, 2006 have ranged from -1.31 feet to 3.26 feet NGVD 29. On-Site measurements indicate that the Hudson River elevations vary between -1.1 feet to 3.8 feet NGVD 29.

Other surface water features include the cooling water Discharge Canal with a mean surface water elevation of approximately 1.7 feet above the Hudson River. The Discharge Canal is shown on **Figure 1.3**. The Discharge Canal conveys up to 1.76 million gallons per minute (MGM) from Units 2 and 3, discharging to the Hudson River. As shown on cross-sections A-A' and B-B' on **Figure 1.3**, the walls of the canal are constructed of low structural concrete. However, the current condition and thickness of the canal bottom is variable and appears to range from a 0.5-foot-thick mud slab in the IP2 area (based on construction drawings) to a bedrock bottom in the IP1 area.

Stormwater at developed portions of the region and Site is directed towards and collected in catch basins and discharged to surface water bodies. Stormwater discharges from the Site are routed to the cooling water Discharge Canal[24], the Hudson River, or the groundwater regime through leaks from the storm system.

6.2 GROUNDWATER RECHARGE

Groundwater recharge at and near the Site is limited to precipitation. That is, there is no significant artificial recharge or irrigation in the area. Precipitation in the vicinity of the

---

[24] There are stormwater outfalls that discharge directly to the Hudson River.

Site is approximately 36 inches per year[25]. Recognizing that a portion of precipitation is lost to evaporation, transpiration, and run-off, direct recharge to an aquifer was estimated. Large scale modeling performed by the USGS for Westchester County, NY[26], suggests that groundwater recharge to glacial till-covered bedrock hills, typical of the conditions near Indian Point, ranges from 3.6 to 7.5 inches per year with an average of 5.5 inches per year. Our experience in a similar hydrogeologic setting[27] found higher natural recharge rates, averaging approximately 10 inches per year. Considering all available information, we believe recharge at the Site is between 1/10 and 1/3 of precipitation. Based on our evaluation, we estimate recharge on and up-gradient of the Site is approximately 10 inches/year[28]. Note that for the purposes of this study (as opposed to water supply evaluations), it is conservative to use high estimates for recharge.

6.3 GROUNDWATER DISCHARGE

Groundwater flows from areas of higher heads to areas of lower heads along the path of least resistance. At the Site, discharge from the groundwater occurs into the Discharge Canal, the Hudson River, and to system underdrains. As evidenced by Site groundwater contours, groundwater discharge is not uniform along the river or to the Discharge Canal. That is, the aquifer in areas of the Site with higher transmissivities (lower resistance to flow) will discharge more water than other areas. Similarly, the water table fluctuates seasonally (due to long term changes in average recharge rates) and locally during rainfall events and periods of snow melt. Consequently, groundwater discharge is not constant in time. Additionally, changes in the river elevation cause additional short term variations in discharge rates.

The Hudson River is the regional sink in the area. As such, groundwater from the upland areas to either side of the river valley flow towards and discharge to the river under ambient conditions, see **Figure 6.10**. Groundwater from IPEC does not flow under the river to the other side (e.g., to Rockland County) under ambient conditions. Further, because of the hydraulic properties of the bedrock, as well as the size of the Hudson River in this area, there is no reason to believe that pumping or injection (non-ambient conditions) could induce such flows.

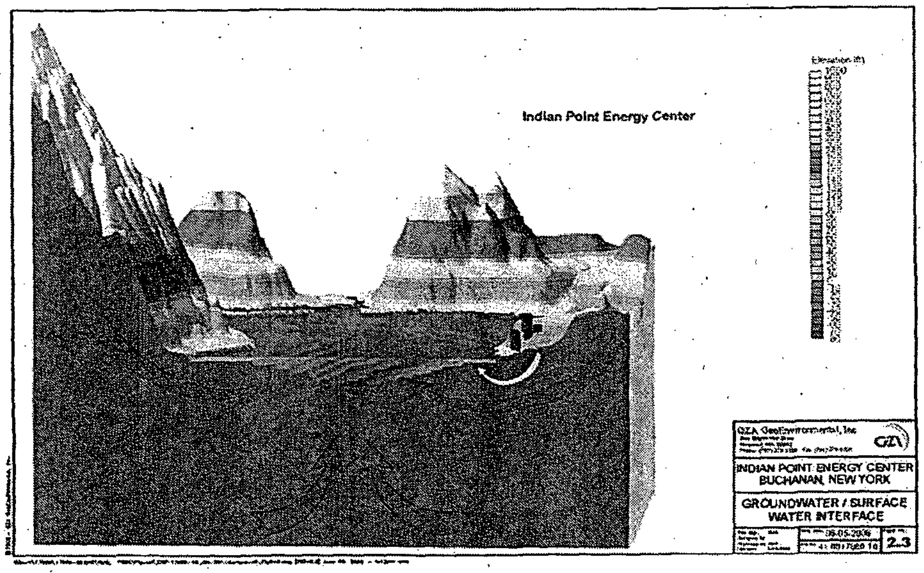
---

[25] This precipitation value is a 10 year average of data available from the on-Site meteorological station.

[26] USGS. Water Use, Ground-Water Recharge and Availability, and Quality of Water in the Greenwich Area, Fairfield County, Connecticut and Westchester County, New York, 2000-2002.

[27] Calibrated Groundwater Model, Central Landfill Super Fund Site, Johnston Rhode Island, June 2006

[28] Areal Recharge varies temporarily and spatially. The average of 10 inches per year is an estimated watershed-wide, long term average. The development at the Site induces additional runoff. We believe that this potential decrease in areal recharge is offset by recharge from exfiltration of leaky stormwater systems. As discussed in **Section 6.7**, this appears to be the case.



GROUNDWATER FLOW BELOW AND INTO HUDSON RIVER

Foundation drains at three structures (see **Section 6.7**) intercept groundwater (see **Figure 1.3**). This water is conveyed, via gravity flow and/or pumping, to the Discharge Canal, creating local depression in the water table and a flattening of hydraulic gradients downgradient of the structure. With these conditions noted, over a period of months the rate of groundwater discharge to the river at IPEC is continuous and fairly constant. Discussions on the rate of discharge are provided in **Section 6.7.**

6.4 GEOLOGY

This section describes the geology of the Site and region. It is based upon a literature search and the results of our investigations. **Figure 6.2** portrays the regional bedrock geology. The narrative is organized to convey the role of geologic and tectonic processes in creating the mechanisms by which groundwater flows through the Site[29]. Findings support our Conceptual Site Model (CSM) and indicate that the bedrock at the Site is characterized by sufficiently interconnected small bedrock fractures to allow the hydrogeologic system to function and be modeled as a non-homogeneous, anisotropic, porous media.

6.4.1 Overburden Geology

The Lower Hudson Valley has been subjected to repeated glacial advance and retreat, creating a typical glacial morphology of main and tributary valleys and bedrock ledges. The glaciers have controlled the deposition of unconsolidated deposits in the region, although these are absent locally due to erosion and excavation. Glacial till lies directly on the bedrock surface and is generally less than 10 feet thick, although it is locally thicker against steep North-facing bedrock slopes. The till is typically unstratified and

---

[29] The Inwood Marble, which predominates at the Site, is a crystalline metamorphic rock type. As such, it has a very low primary porosity (i.e., water does not flow through the intact rock itself, but is confined to the fractures in the rock.

poorly sorted. Locally, it consists of a silty, fine- to medium-grained, brown, sandy matrix containing fine gravel to boulder-size bedrock fragments. Fluvial and lacustrine glacial deposits occur in valley bottoms and valley walls. The glacio-fluvial deposits are typically medium to coarse sand and gravel with minor silt. The lacustrine deposits are finely laminated and varved clays fining upwards to fine- to medium-grained sand, and the fluvial/deltaic sediments are mixtures of coarser sands and gravels and finer sands to clays. Recent deposits are essentially flood plain and marsh deposits along the Hudson River, its tributaries, and small enclosed drainage basins.

Overburden geology at the Site is limited to a layer ranging from ground surface to between 3.5 and 59 feet below ground surface (bgs), with thicknesses generally increasing towards the Hudson River. Overburden materials are dominated by anthropogenic fill (borings MW-41, -49, -52, as well as the upper 20 feet of -39, -48, -61, -62, -63, -66 and 67). Soil-based fill materials at the Site consist primarily of silty clay, sand and gravel mixtures (i.e., regraded/transported on-site glacial till) or gravel/cobble/boulder-size blast rock. In areas adjacent to structures excavated into bedrock, the fill occurs as concrete, compacted granular soils, and blast rock fill. Native materials occur as open areas of glacial till overlying bedrock, or silty clays, organic silt and clay, and sandy material overlain by granular fill. A 20- to 50-foot-thick sequence of river sediments (organic silts) is found along the Hudson River above bedrock in borings MW-38, -48, -61, -62, -63, -66 and 67 The approximate location of natural materials is shown on **Figure 6.3**.

6.4.2 Bedrock Geology

The geology of the Site has been investigated and reported by Dames & Moore (1975) prior to this program. **Figures 6.2** and **6.4** show the bedrock geology of the region and the Site, respectively. The current investigations have added substantial detail to this assessment which shows that the bedrock beneath the Site is considerably fractured and contains sufficient interconnectivity to support groundwater flow, at the scale of the Site, as flow through a non-homogeneous, anisotropic, porous media.

The Site is located in a complex of Cambro-Ordovician rocks represented by the Manhattan Formation and Inwood Marble Formation in angular unconformity. The Site lies predominantly upon the Inwood Marble Formation as an angular unconformity with the Manhattan Formation. The oldest rock is the Inwood Formation, which was derived from deposition of carbonate materials in a shallow inland sea during the Cambrian through the early Ordovician period. The Manhattan Formation is interpreted to post-date the Middle Ordovician regional unconformity with the Inwood Marble and represents sediments derived from continental or volcanic island materials in deeper waters.

During the Ordovician period, an island arc system consisting of a series of volcanic islands appeared off the coast of what is currently North America as a subduction zone developed in response to oceanic crust colliding with continental crust. The presence of the volcanic island arc system resulted in interlayering of volcanic material with the sedimentary rocks of the Inwood Marble and Manhattan Formations. As continued subduction occurred and continental land mass began to collide with continental North America during the Taconic and Acadian Orogenies, the rocks of the Inwood Marble

Formation and the Manhattan Formation underwent substantial metamorphism and deformation.

The Inwood Marble is a relatively pure carbonate rock of dolomitic and/or calcic mineralogy with silica rich zones. The rock tends to be coarsely sacherroidal with remnant foliation and intercalated mica schist. The color and crystalline texture vary from place to place due to the various levels of metamorphism; the color is typically white to blue grey. The metamorphic grade is locally elevated due to minor intrusions. The common minerals are calcite, dolomite, muscovite, quartz, pyrite and microcline. The Manhattan Formation is represented on the Site by two distinct members. The lower member is an assemblage of schist, schistose gneiss and amphibolites intercalated with marble, white quartzite and fine-grained metapelite. The marble bearing lower member of the Manhattan Formation likely represents transition from a shallow carbonate sea to deeper water sedimentation and maybe the equivalent to the Balmville Limestone which occurs in Dutchess County[30]. The middle member is garnet rich mica schist. The upper member consists of biotite-muscovite mica schist with quartz-feldspar laminae.

The original sediments have undergone repeated intense phases of burial, metamorphism, uplift, folding and faulting due to: three phases of continental collision (the Taconic, Acadian, and Alleghanian); continental rifting as the present Atlantic Ocean began to form in the Mesozoic; erosion/uplift; and recent glacial rebound. All of these processes have resulted in the presence of fractures that affect the hydraulic properties of the material. The main deformational events are represented by multiple superimposed textures and structures including faults, healed breccias, crenulations, foliation slips, micro-faults, and continuous/truncated joints/fractures. The first phase of fold deformation (F_1) was essentially ductile and produced isoclinal folds contemporaneous with the most intense metamorphism. It was at this time that the dominant foliation likely developed along original bedding planes. The cooling period following this phase marks the onset of regional brittle faulting and development of fractures along the bedding planes. The second phase of folding (F_2) is characterized by flexural slip, indicative of brittle conditions, producing distinct fault and fracture orientations: a conjugate system normal to the foliation; West-Northwest and North-South conjugate strike-slip faults; Northwest faults and fractures parallel to the direction of extension; and thrust and extension fractures parallel to the foliation.

The Cortlandt Complex (a large igneous intrusion located East of the Site) was intruded during the F_2 phase. The post-Cortlandt dislocations were associated with a third phase of folding (F_3) causing a mutual rotation of the structural elements producing a complex of conjugate features with a wide range of orientations as described by Dames & Moore and found during our study. On the Site, the regional features are represented by North-Northeast and North-Northwest trending faults in cross-cutting relationships, representing a conjugate system with a North-South regional compression direction. The final tectonic event was associated with a shear system oriented North-East, reactivating movement along Northeast-trending faults and minor North-Northeast to North-Northwest-trending faults. In addition to these major events, there has been minor

---

[30] In Vermont, this unit is equivalent to the Whipple Marble.

normal movement on North-South and Northwest-trending faults associated with continental rifting during the Mesozoic Era.

Finally, post-deformational uplift and glacial rebound have resulted in a series of fractures related to expansion, after the rock mass/ice load was removed during erosion and glacial retreat. These manifest themselves as semi-sinuous or undulating horizontal relief fractures.

6.4.3 Groundwater in Bedrock

In metamorphic bedrock such as the marble present at the Site, groundwater occurs and migrates in open spaces such as fractures. These void spaces are termed secondary porosity. The primary porosity consists of void spaces within the rock matrix itself. The Inwood Marble has a very low primary porosity which does not contribute to the flow or storage of significant volumes of water. Therefore, the presence of fractures and faults ultimately determines the hydraulic conductivity of the bedrock mass. The fracture aperture spacing and the degree of fracture interconnectivity are dominant variables in how groundwater flows through the fractured bedrock environment. Groundwater flows from areas of higher hydraulic head to areas of lower hydraulic head along fractures providing the least resistance. If the structure of the rock is dominated by fractures and foliations of a single orientation, then groundwater flow will be along this orientation towards areas of lower hydraulic head. Also, if fractures are separated by large distances and not interconnected, groundwater will flow in a relatively limited number of fractures and flow will be governed by the orientation of local structures within the rock. This may result in groundwater flow occurring along paths that may not be reflected in topography. However, if there are abundant sets of fractures of differing orientations relatively close together and interconnected, groundwater flow will typically mimic topography.

GZA found no evidences of solution features (i.e., cavities, voids). Such features (if present) can control the direction of groundwater flow. Carbonate rocks have relatively high solubility under certain ambient surface conditions. This can result in solution cavities and caves known as karst systems. In these situations, groundwater can flow predominantly along open cavities and result in preferential pathways. Our assessment of over 3,200 linear feet of rock core and 2,950 linear feet of borehole geophysical logs found no evidence of any large scale solution features. Minor, discontinuous vugs (small unfilled cavities) and voids were observed primarily along partially healed fractures with euhedral calcite crystals growing into fractures. This evidence suggests that prior to denudation, resulting in exposure of the rocks to the current elevations; hydrothermal fluids were percolating through open fractures. Mineralization occurred along the fracture planes resulting in a significant number of healed fractures observed in the rock. In some cases, the fractures were partially healed, resulting in the occurrence of vugs in some of the more brecciated zones. The presence of calcite deposition in fractures supports our observations that solution features are not prevalent at the Site. That is, open fractures are due to tectonic forces, that carbonate is precipitating within the fractures, and no large solution cavity process is occurring.

Since earlier conceptual models for the Site hypothesized that groundwater flow would be to the South-Southeast along the original F1 foliation and fracture sets, we performed a detailed structural analysis of the bedrock to assess whether groundwater flow would be dominated by discrete fracture flow or would behave more in accordance with flow through porous media. This analysis had implications relative to on-Site contaminant migration and the potential for off-Site migration via dominant fracture sets.

6.4.4 Regional Scale Geostructure

GZA assessed regional fracture patterns presented in the Dames & Moore (1975) report as a photo lineament analysis (**Figure 6.5**). On the regional scale of the lineament analysis, there are three sets of intersecting fracture orientations. The major strike orientations within a 15 mile radius of the Site indicated a Northeast, North, and East-West trend. A review of the major tributaries to the Hudson River indicates the drainage pattern is predominantly aligned with similar orientations and generally structurally controlled.

6.4.5 Site Scale Geostructure

On a Site scale, GZA projected the fracture plane orientations calculated from the borehole geophysical data onto one elevation (elevation 10 feet) to create a Site lineament analysis (**Figure 6.6**). Assessment of the more permeable fractures on this projection showed that fractures were oriented consistent with the regional assessment (Northeast, North and East-West), and that fracture orientations intersect one another. In addition, our Site scale lineament analysis showed a number of Northwest orientated fractures located between Unit 1 and Unit 2 in the area where the Unit 1 and Unit 2 plumes commingle. Evaluation of the preconstruction bedrock topography also indicated that this was a low point in the bedrock surface. Low points in marble bedrock surfaces are usually associated with areas of higher fracture density or faulting as these would be areas more prone to weathering, erosion and glacial gouging. This presents further evidence for a zone of higher transmissivity.

Based upon the regional and Site scale lineament analyses, it was apparent that the multiple fracture orientations result in intersections of fracture planes. However, more detailed analysis was required. Therefore, GZA assessed the individual rock cores and fracture orientations calculated from the borehole geophysical analysis.

6.4.6 Borehole Scale Geostructure

Twenty-three of the forty-seven boreholes were evaluated using acoustical televiewer (ATV) and optical televiewer (OTV) borehole logging techniques by Geophysical Applications, Inc. The ATV data establishes naturally occurring joint/fracture dip angles and planer dip directions for planer features intersecting a borehole.

The apparent joint/fracture orientations and depths were input into a stereographic framework using DIPS software developed by RocScience, Inc. of Toronto, Canada, after correction from magnetic North to true North. The stereographic projections are a southern hemispheric view and are equal-angle based. The program presents the joint/fracture dip and dip direction in a tabular format with customizing options, and allows joint/fracture set selection to establish groups of domains and families of geostructural data.

The 4,623 data points from the 23 boreholes were input into the DIPS program. The polar projections for all the boreholes are presented as **Figure 6.7**. In our opinion, these data show three dominant, apparent, conjugate sets of fractures striking to the Northeast-Southwest, East-West, and North-South. The majority of the dip angles range consistently between 30 and 70 degrees for each major orientation. In addition, there are many horizontal and vertical fractures. The orientations of the fractures, the conjugate sets of fractures, and the presence of vertical and horizontal fractures all support a high degree of interconnectivity.

The database also contains columns showing the depth of the individual joint/fractures and apparent vertical continuous spacing[31]. In each borehole, three average values of apparent vertical joint set spacing for depths between 0-30 feet, 30-100 feet, and depths greater than 100 feet were calculated and summarized in the following table. No significant differences in joint spacing with depth were found.

AVERAGE APPARENT JOINT SPACING, FT							
	Depth Below top of the rock				**Depth Below top of the rock**		
Borehole	**0~30ft**	**30ft~100ft**	**>100ft**	**Borehole**	**0~30ft**	**30ft~100ft**	**>100ft**
MW-30	0.53	0.64	--	MW-55	0.48	0.47	--
MW-31	1.46	0.63	--	MW-56	--	0.32	--
MW-32	--	0.36	0.39	MW-57	0.55	0.30	--
MW-34	0.72	--	--	MW-58	0.32	0.66	--
MW-35	0.80	--	--	MW-59	0.35	0.41	--
MW-39	--	0.66	0.67	MW-60	1.38	0.83	0.59
MW-40	0.37	1.11	1.69	MW-62	--	0.49	0.64
MW-51	0.37	0.88	0.84	MW-63	--	0.35	0.44
MW-52	0.45	0.58	0.89	MW-65	--	1.26	--
MW-53	--	0.71	--	MW-66	--	0.75	0.59
MW-54	0.47	0.58	0.39	MW-67	0.47	0.59	0.54
				RW-1	--	2.22	1.71

AVERAGE APPARENT JOINT SPACING

Joint spacing is a significant parameter in assessing flow in a fractured rock and assessing the validity of using an equivalent porous media flow model. The spacing of joints was determined by direct measurement from rock core samples or from ATV data in 22 boreholes, and is presented in a database (**Appendix Q**). These data indicate an apparent joint/fracture spacing between 0.3 and 2.2 feet, with an average of 0.7 feet.

Based upon the assessment described above, the data suggest that the bedrock aquifer can be visualized as a series of polygonal blocks separated by interconnected fractures. This geometry is graphically portrayed by a series of seven apparent fracture

[31]Apparent vertical spacing is the distance between joint/fractures along the vertical line of the borehole.

profiles designated A-A' through G-G' presented on **Figure 6.9**; profile locations are presented in **Figure 6.8**. The profiles show the orientation and potential connectivity of the geostructure if the ATV borehole measured planes extended for 1,000 feet (500 feet on either side of the borehole). The joint/fracture lines represent the trace of the plane projected onto a vertical profile. Additional illustrations of the fracture orientations in three dimensions are presented in **Section 6.4.8**.

6.4.7 Geologic Faults

The groundwater flow pattern and thus contaminant transport can be further influenced by the presence of faults. These faults can either act as barriers or conduits to flow depending on the presence of clay-rich fault gouge. Rock core samples revealed significant clay fault gouge zones that generally ranged between 0.2 and 0.7 vertical feet thick at borehole locations MW-31, -50, -54, -60, and -61. These zones were encountered at depths ranging between 39 and 200 feet below existing grades. The dip angles were measured by the ATV methods and ranged between 49 and 82 degrees at locations MW-31, MW-54, and MW-60, with dip directions toward the East (MW-54) and the Southeast (MW-31 and MW-60). No ATV measurements were conducted at MW-50 or MW-61. At MW-61, no core was recovered between 156 feet bgs and 221 feet bgs. Collection of split spoon samples in this interval verified the presence of a clay-filled fault gouge. This boring likely intersected a steeply dipping North-South trending fault. The presence of this fault is consistent with faults previously mapped by Dames & Moore (1975). The near vertical orientation of the fault is further supported by observations of bedrock core from locations MW-66, advanced within 8 feet of MW-61. No fault gouge was observed in this boring. A fracture zone was noted between 136 and 145 feet bgs and is characterized by low RQDs, however, this fracture zone did not exhibit clay filled fault gouge and was more consistent with tightly spaced fractures.

Because the fault extends to the top of the bedrock, the question arises as to why we did not observe the fault zone above 156 feet bgs at MW-61. This is due to the geometry of the fault. The fault zone is sub-vertical, i.e. less than 90 degrees, but also may vary in orientation with depth. As the boring was advanced deeper into the bedrock, it intersected the fault zone at 156 feet bgs. The boring continued within the fault, in a near vertical portion of the fault, to the termination of the boring.

Furthermore, the rock core samples revealed several fracture zones ranging between approximately 0.5 feet and 110 feet thick. Significant zones of poor to no recovery are evident at MW-50, MW-61 and MW-66: boring MW-50 and MW-54 were aligned along or near the trace of historic faults mapped by Dames & Moore (1975). MW-49 and MW-61, may be aligned along the extension of a historic fault mapped by Dames & Moore (1975). The poor recovery observed at MW-50 and MW-61 is indicative of clay gouge that was washed out during the drilling process (which is consistent with, but not fully verified by, the split spoon samples containing clay, recovered in these borings). We further note the presence of this fault zone does not appear to materially alter groundwater flow directions or contaminant migration towards the Hudson River.

Figure 6.4 portrays faults mapped on the Site by Dames & Moore (1975). There are three major groups of faults with associated fractures identified at and in the vicinity of the Site. These groups have azimuths of approximately 45, 75, and 290 degrees. The East to N75E faults consist of conjugate faults where the sinistral set strikes West to N70W dipping southward, and the dextral set strikes East to N75E dipping southward. These faults are most often offset or truncated by younger faults. West striking faults in the Inwood Formation are typically characterized by breccias which have been healed by a re-crystallized calcite cement.

An additional fault or fracture zone appears (not shown on **Figure 6.4**) to extend from the Hudson River Southwest between Units 1 and 2, as expressed by fracture orientations and a low in the preconstruction bedrock contours. This appears be a zone of higher transmissivity as indicated by inflections in groundwater contours, tidal response measurements, and the shape of the contaminant plume.

6.4.8 Bedrock Structure Visualization

In order to aid in the visualization of the role bedrock structure plays on groundwater flow as well as show the apparent interconnectivity at the Site, GZA imported data collected throughout the various phases of investigation into a 3-dimensional visualization model. The Environmental Visualization Software (EVS) software suite, created by CTech Development Corporation, was the primary software application used for the development of this model. This software package provides real-time model rendering, animation/flyover capabilities, database and GIS interface utilities, and numerous image output options. EVS also provides the ability to interpolate variably spaced datasets via kriging, an established geostatistical technique. The EVS kriging process selects an optimal semi-variogram model for each kriged dataset in order to estimate unknown values, and provides statistical confidence for estimated values. The results of these analyses can then be rendered across three dimensions (x, y and z) to provide a spatially referenced visualization model.

GZA incorporated the borehole geophysical data provided by GA, the packer testing results, and the USGS evaluation of the HPFM data into the 3-dimensional visualization model. Our goal was to illustrate transmissive fracture locations. For many of the zones identified as transmissive, several fractures likely contribute to the estimated transmissivity. In these cases, a percentage of the estimated zone transmissivity was allocated to each contributing fracture based on the HPFM results and ATV/OTV logs. In addition, multiple fractures in close proximity and exhibiting similar planar characteristics were combined to present a single planar feature to avoid redundancy in the model. The fracture data set was imported into the 3-dimensional visualization model intact.

Figures 6.10 through **6.14** present the locations of transmissive fractures within each boring. Fractures are represented as disks with 50 foot radii. A single disk represents the strike direction and dip angle of a transmissive fracture feature. Fracture disks are also color coded to reflect the assigned transmissivity value. Boring designations and locations highlighted in yellow indicate the borings for which geophysical and transmissivity information was available. Boring designations and locations highlighted in white are lacking geophysical data; therefore, fractures are not presented. The transmissive fracture data set was divided into low transmissive (0.02 - 10 ft^2/day, **Figure 6.10**), moderate transmissive (10 – 50 ft^2/day, **Figure 6.11**) and high transmissive (50 – 250 ft^2/day, **Figure 6.12**) subsets. While there are limited geophysical data for borings located to the South and East of the Site, the available data do indicate that there appears to be a zone composed of more transmissive fractures within the center of the Site. This observation coincides with a low in the bedrock as elucidated by preconstruction bedrock contours (**Figure 6.4**). This historic depression may be the result of weathered or fractured bedrock being susceptible to glacial advance and retreat, indicating the potential for a fault to be present in this area. This is consistent with the observation of a lineament West of Unit 2 toward the Hudson River discussed above.

Figure 6.13 represents the same fracture data set, but with the fracture disk radius extended to 250 feet. A horizontal cutting plane has been extended across the Site at elevation 10 feet, identifying the strike direction of each fracture as it intersects the plane. For a selected diameter of disk, the width of the strike line has significance. A shallow dipping disk would have more contact with the horizontal cutting plane than a steeply dipping disk. Accordingly, a wider strike line indicates a fracture strike direction with a shallower dip angle. The East-West lineament is clearly visible in this figure, aligned approximately from Unit 2 toward the Hudson River, and comprised of moderate and high transmissive fractures. **Figure 6.14** represents the same horizontal slice concept; however, the slice plane is now placed at elevation -100 feet. There are no high transmissive fractures intersected at this elevation, indicating high transmissive fractures are more predominant at shallow depths. This is consistent with **Figure 6.13**, the Conceptual Site Model, hydraulic conductivity tests and previous reports (Tectonics, 2004). Because we observed no decrease in fracture spacing with depth (see **Section 6.4.6**), this suggests the hydraulic aperture of fractures decreases with depth.

While there are some localized trends in fracture strike direction, there is an abundance of intersecting fractures on a Site-wide scale occurring at all elevations. In addition, the fracture disk component of the 3-dimensional visualization model has been reviewed to identify potential fracture connections on a borehole-to-borehole scale. No significant interconnections were identified. These observations suggest that bedrock is highly fragmented on a Site-wide scale, high transmissive fractures are not continuous across IPEC, and groundwater flow through the Site may be modeled as flow through a non-homogeneous, anisotropic, porous media.

6.4.9 Bedrock Surface Elevations and Preferential Groundwater Flow Pathways

The results of the surface geophysical surveys are portrayed on **Figure 1.3**. The geophysical survey identified apparent bedrock at depths of between 2 and 18 feet below ground surface (bgs) within the IP2-TY. A depression in the bedrock surface exists in the vicinity of monitoring well MW-111. Bedrock in the depression was found at a depth of 16 to 18 feet bgs. Along the North side of the IP2-TB, apparent depth to bedrock was approximately 8 to 12 feet bgs and only intermittent groundwater associated with rainfall events has been encountered. This is likely the depth bedrock was cut in order to accommodate the service water lines. No discrete utility trenches were observed in the bedrock. Based upon the results of the geophysical survey it is more likely that bedrock was cut to a depth to accommodate deep subsurface utilities and potentially dewatering, rather than install utilities in individual trenches. On the eastern, western and southern sides of the Transformer yard, rock was encountered between 2 feet and 7 feet bgs. No groundwater was encountered in the overburden in these areas. However, groundwater was encountered in the backfill found along the western wall of the Discharge Canal, which forms the eastern boundary of the IP2-TY.

Within the IP3-TY, the approximate depth to bedrock ranged between 7.5 and 10.5 feet bgs. Generally the northern and southern ends of the survey area had the deepest and shallowest depths to bedrock, respectively. Again, the surveys did not exhibit evidence of individual utility trenches cut into bedrock. No groundwater was observed in overburden within borings advanced within the IP3-TY.

To assess the potential for contaminants to enter groundwater through leaking stormwater pipes (E-Series) and flow with groundwater towards the Hudson River within utility trenches cut into rock along the OCA access road on the South side of the Protected Area, the depth to bedrock and utility trenches cut into rock along this roadway was evaluated. The approximate depth to bedrock ranged between 8 and 16 feet bgs. Bedrock reflectors appeared to be less defined in this survey area compared to other areas at the Site. Many potential utilities were observed in the survey area, however it appears that one large bedrock trench was excavated to accommodate the utilities as well as the roadway. The bedrock appeared to be deeper near the "delta gate" along the East side of the survey area, reaching an apparent depth of 16 feet bgs. Further to the West the apparent bedrock surface was observed at a depth of approximately 8 feet bgs.

Seismic data collected around the warehouse on the South side of the Protected Area provided good subsurface information to a depth of approximately 50 feet bgs. In general, the apparent bedrock surface was found at depths of approximately ground surface on the East side of the survey area and sloped down to depths greater than 45 feet to the West. Near MW-48, the bedrock was located at 25 feet bgs. Topography of the bedrock interface ranged from flat to highly variable over relatively short distances and there were a few locations where the bedrock interface "disappeared" or was located greater than 40 to 45 feet bgs. Over most of the area, the bedrock interface was more gradual and slightly undulating along the profile lines. In general, the depth to bedrock was greater then 20 feet across most of the survey area, indicating that subsurface utilities would not be cut into bedrock trenches.

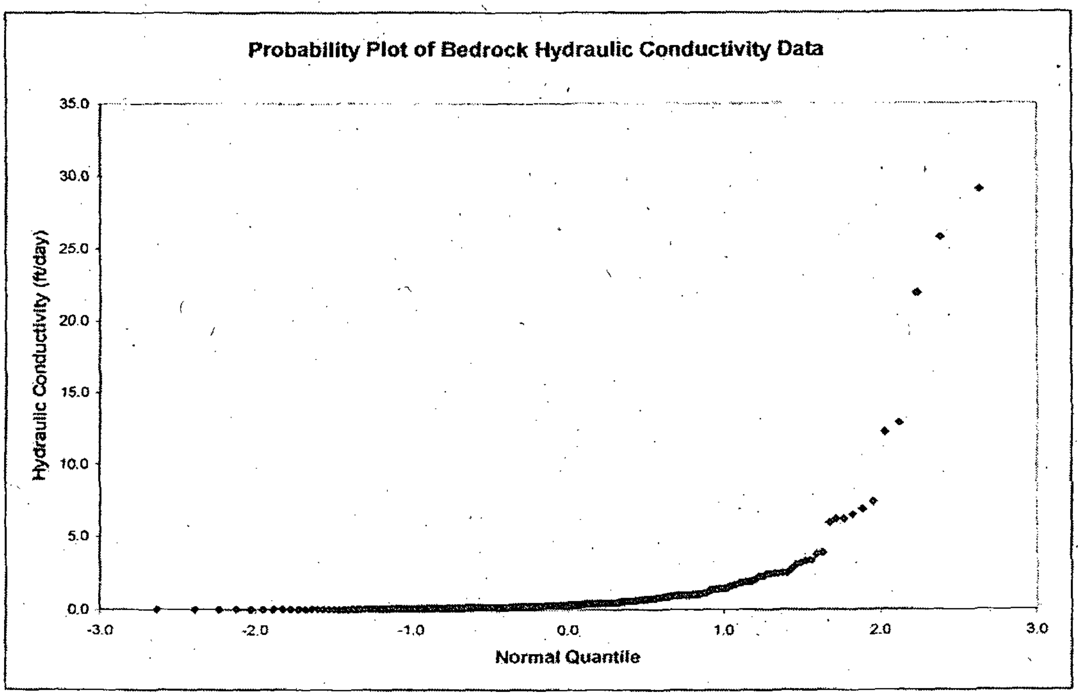
6.5 AQUIFER PROPERTIES

Our investigations demonstrate that, for the purposes of evaluating groundwater flux, bedrock beneath the Site can be modeled as flow in porous media. Following are the hydraulic properties we assigned to our equivalent conceptual porous media model.

6.5.1 Hydraulic Conductivity

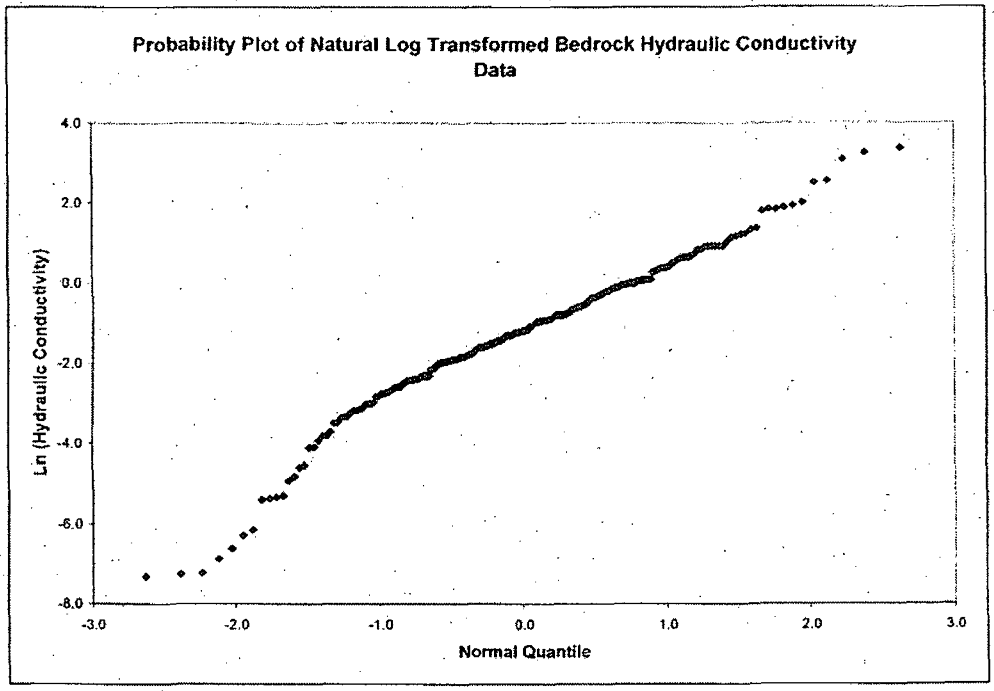
Transmissivity and hydraulic conductivity[32] data were collected as part of the hydrogeologic investigation in both the overburden and bedrock. The geometric mean of hydraulic conductivity in the overburden zone is 12.6 ft/day and the geometric mean in the bedrock is 0.27 ft/day. As indicated below, calculated hydraulic conductivities within the bedrock were found to be log-normally distributed.

GZA used probability graphs to evaluate the statistical distribution of the bedrock hydraulic conductivity data. As shown on the following two graphs, the log-transformed data better approximates a straight line. This indicates the log-transformed hydraulic conductivities are approximately normal and the hydraulic conductivity values are log-normal. This indicates that the geometric mean is a good approximation.



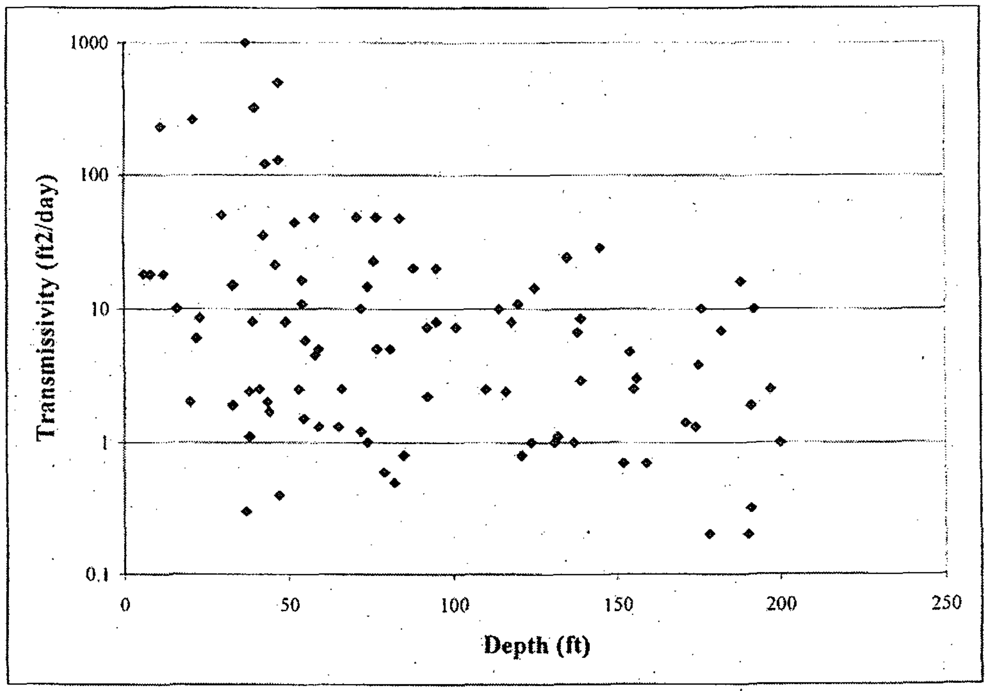
STATISTICAL ANALYSIS OF HYDRAULIC CONDUCTIVITY MAGNITUDE

[32] Transmissivity, as used here, is the property measured in the field and is the product of an equivalent hydraulic conductivity (K) and the test interval.



STATISTICAL ANALYSIS OF HYDRAULIC CONDUCTIVITY MAGNITUDE (NATURAL LOG TRANSFORMED)

As shown below, GZA also developed a graph of depth versus transmissivity of bedrock. In viewing that graph, note that all USGS[33] measured transmissivities of greater than 100 ft^2/day were found at depths of less than approximately 50 feet bgs.



TRANSMISSIVITY VS DEPTH

---

[33] Transmissivities shown were computed by the USGS from their heat pulse flow meter data which were in agreement with our packer test data.

It should be noted that the hydraulic conductivity values are based on aquifer tests conducted at specific locations and limited hydraulic loading, and are therefore only representative of the aquifer immediately adjacent to the subject borehole.

GZA also conducted a Pumping Test which imposed a larger hydraulic stress over a larger portion of the aquifer. We believe this test provides us with the most reliable estimate of transmissivity of the bedrock in the area of the Pump Test. However, the area of influence of the Pump Test did not encompass the zone of higher hydraulic conductivity within the fracture zone between Units 1 and 2. Depending on the methods used to evaluate the Pumping Test data, we estimate bedrock transmissivity values generally in the range of 30 ft^2/day to 50 ft^2/day[34]. This suggests an average hydraulic conductivity of between 0.2 and 0.4 feet/day.

To further evaluate the vertical distribution of the hydraulic conductivity, we computed the geometric mean of measured values in the upper 40 feet of the aquifer and the geometric mean of all values measured below that depth. This calculation resulted in values of 0.4 feet per day for the upper forty feet and 0.2 feet per day for the deeper aquifer.

6.5.2 Effective Porosity

Evaluation of Pumping Test data also allows calculation of storativity. Our Pumping Test results show the storativity of the bedrock aquifer is 0.0003. (Note: overburden wells were not present within the cone of depression and, therefore, storativity for the overburden could not be evaluated.) Because the bedrock aquifer is unconfined and the primary porosity of the marble is, essentially, zero, the effective porosity of the bedrock can be as small as the storativity. However, due to dead-end fractures, the effective porosity is likely to be higher.

To evaluate the reasonableness of estimated properties, we used the cubic equation, as shown below, to estimate the hydraulic aperture and storativity of the fracture system:

$$Q = \frac{\rho_w g b^2}{12\mu}(bw)\frac{\partial h}{\partial l}$$

Where:

Q = volumetric flow (ft^3)
ρ_w = density of water (62.4 lb/ft^3)
g = gravitational constant (32.2 ft/s^2)
b = aperture opening (ft)

[34] The Pumping Test indicated the transmissivity of the rock was fairly isotropic, and only limited horizontal anisotropy was observed during the Pump Tests (e.g., in the drawdown observations at monitoring well MW 53-120). At the scale of the, Pumping Test we believe there are sufficient heterogeneities that the aquifer can be considered to be a non-homogeneous isotropic porous media.

$\mu =$ dynamic viscosity of water (0.0006733 lb/ft*s)

$w =$ fracture width perpendicular to the flow direction (ft)

$\frac{\partial h}{\partial l} =$ groundwater gradient

From this, the concept of an equivalent hydraulic conductivity has been developed[35]:

$$K = \frac{\rho_w g n b^3}{12\mu}$$

Where:

Variables are as previously defined, and;

$n =$ number of open features per unit distance across the rock face

Using a fracture spacing of one foot and an equivalent bulk hydraulic conductivity of 0.27 feet per day (9 x 10^{-5} cm/sec), this calculation indicates a hydraulic aperture of approximately 75 microns, and a theoretical minimum porosity of 2.4 x 10^{-4}. The calculated porosity is in good agreement with estimates of storativity developed from Pumping Test data (**Section 4.4.4**) and tidal responses (**Section 6.6**).

In summary, the measured effective porosity of the bedrock aquifer is approximately 0.0003.

6.6 TIDAL INFLUENCES

As discussed previously, the Hudson River, adjacent to the Site, rises and falls in response to ocean tides. Based on our measurements, this tidal variation (the numerical difference between low water and subsequent high water elevations) in 2006 ranged from approximately 1.4 feet to 4.3 feet, and averaged approximately 2.7 feet. This variation occurred between approximately elevation -1.5 feet to 3.7 feet NGVD 29 (i.e., the low tide elevations were typically above elevation -1.5 feet and the high tide elevations were typically below elevation 3.7 feet). These data are in good agreement with published information (see **Section 6.1**).

This natural variation produced measured effects that helped us better understand hydrogeologic information obtained at the Site. One such effect is water level changes in monitoring wells at the Site. The observed changes demonstrate that the bedrock aquifer is significantly fractured, and provided additional insight into aquifer properties.

Discharge of heated cooling water, in conjunction with tidal influences, produced a second effect; temporal temperature changes in groundwater in wells located near the Discharge

---

[35] Snow, D.T. 1968. Rock Fracture Spacings, Openings, and Porosities. Journal of Soil Mechanics., Found. Div. Proc. Am. Soc. Civil Engrs., v. 94, p. 73-91.

Canal. We used that information to help explain water quality data collected from two specific wells (MW-38 and MW-48, originally proposed as southern boundary monitoring wells), which did not initially conform with our Conceptual Site Model (see **Section 6.6.2** below). These two effects are described in the following sections.

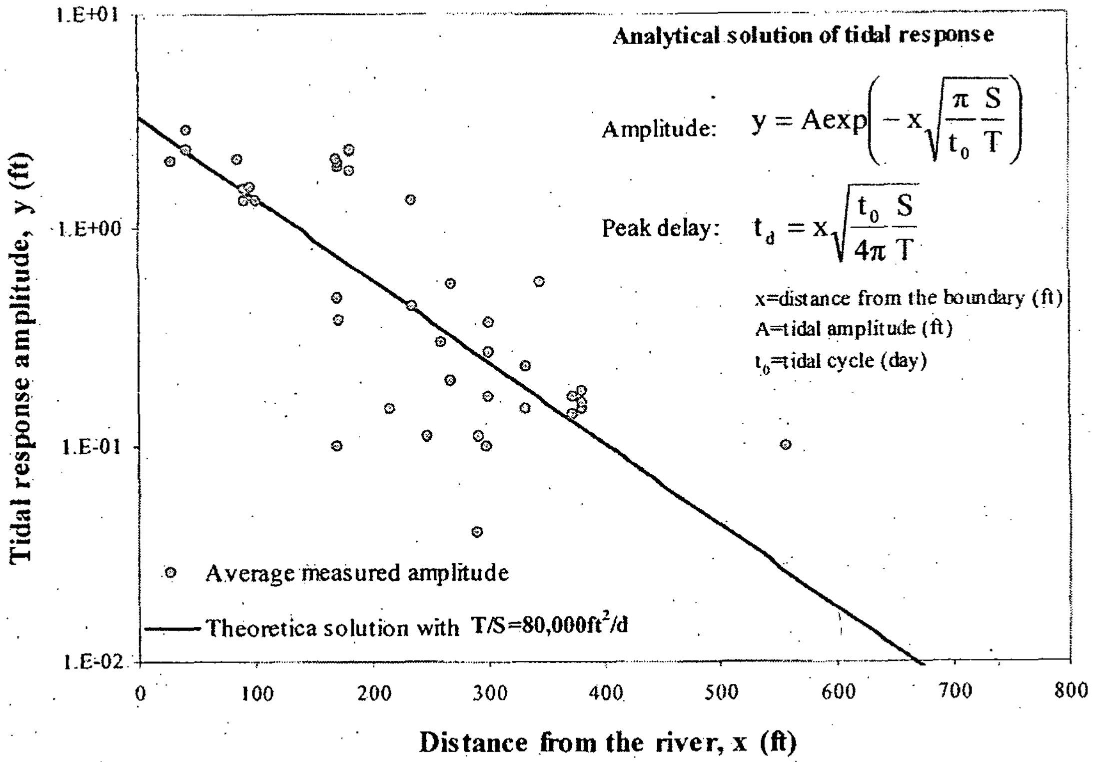
6.6.1 Groundwater Levels

The tidal-induced variations in surface water levels near the edge of the Site's aquifer (in the river and intake structures and Discharge Canal[36]) induced pressure changes in groundwater that were observed in monitoring wells at the IPEC. As a general statement, these responses (as anticipated) varied over time as sinusoidal-like curves that decreased in amplitude and exhibited greater lag time with increased distances from the river/Discharge Canal[37].

At the time of our tidal response study, there were 87 transducers installed in 49 monitoring wells. As shown on the following graph, we observed measurable hydraulic responses to tidal variations at 43 of these transducer locations. In viewing that graph, note distances are measured from the edge of the Hudson River. We chose this as the boundary because data suggests the river has more influence on piezometric levels in the bedrock aquifer than do the intake structures and Discharge Canal. We further note that: 1) 41 of the 44 pressure transducers within 400 feet of the Hudson responded to tidal variations; 2) at greater distances, tidal responses may have occurred but were too small to be recorded because of the accuracy of the transducers; and 3) the tidal response in wells located in the higher hydraulic conductivity area between Units 1 and 2 was more pronounced than in other areas. Cumulatively, these data demonstrate:

- The aquifer is in strong hydraulic communication with the Hudson River; and
- The bedrock aquifer is well-fractured.

[36] The elevation of the water in the Discharge Canal rises and falls with the river elevation, but is maintained approximately 20 inches above the river level.
[37] Observed variations from this trend, in our opinion, are consistent with anticipated heterogeneities in an equivalent porous media model.



TIDAL RESPONSE VS DISTANCE FROM THE HUDSON RIVER

Fetter[38] provides an analytical solution for the theoretical piezometric response of an aquifer adjacent to a tidal boundary (see above graph). The assumptions upon which this solution is based are quite restrictive. In addition to the normal difficulties (aquifer heterogeneities, anisotropic properties, etc.) which limit the practical use of the solution in estimating aquifer properties, [39] it is not clear if water levels at the Site are responding to changes in the river level, changes in the Discharge Canal levels, or perhaps, a combination of both. Further complicating this issue, the concrete canal walls, and at some locations (not all) the concrete canal bottom, should clearly affect propagation of tidal fluctuations in the canal.

With these limitations noted, our review of data indicates that the hydraulic diffusivity[40] (transmissivity, T, divided by storativity, S) of the rock, as estimated by the tidal responses, is on the order of 80,000 ft^2/day. See the above graph and information in **Appendix K**.

As presented in **Section 6.5,** we believe the average transmissivity of the bedrock aquifer is typically in the range of 30 to 50 ft^2/day. Using a transmissivity of 40 ft^2/day and a diffusivity of 80,000 ft^2/day, it follows the storativity of the bedrock aquifer is on the order of 5×10^{-4}. This value is in good agreement with the values we computed from an evaluation of the Pumping Test data and from the cubic equation (see **Section 6.5.1**).

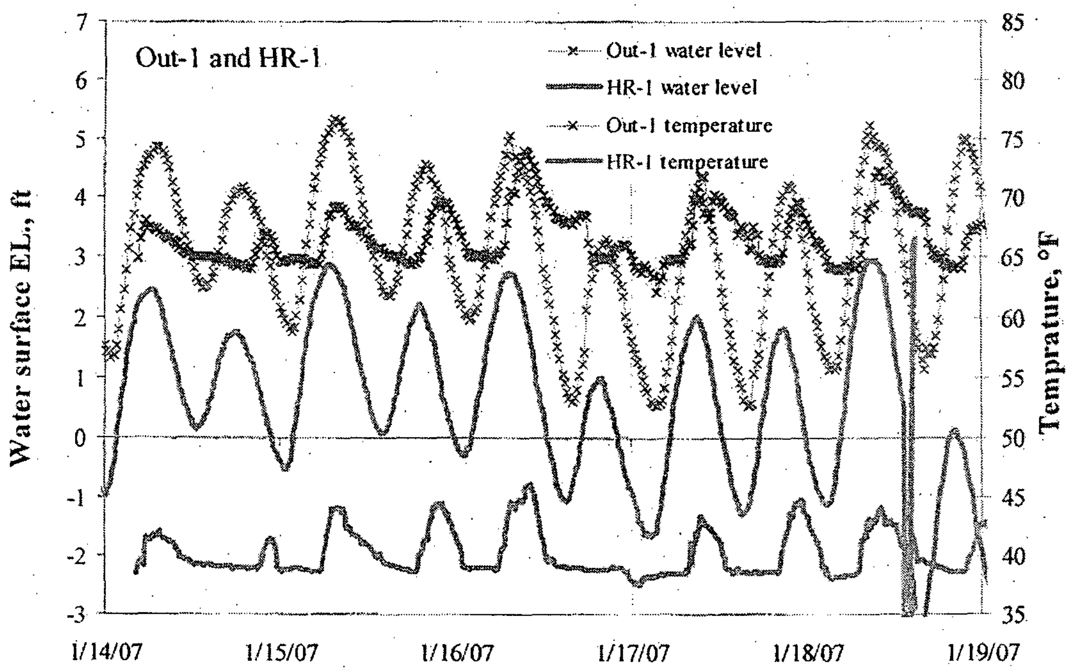
---

[38] C.W. Fetter, *Applied Hydrology*, Second Edition, Merrill 1988.
[39] Patrick Powers, *Construction Dewatering*, Second Edition.
[40] Freeze & Cherry, *Groundwater* Prentice-Hall 1979.

Another effect of river tidal changes is manifested in monitoring wells in close proximity to the river or Discharge Canal as follows. As the river approaches high tide, the groundwater gradients in proximity to the river become flatter, and at certain locations and tides, are reversed; that is, on a temporary basis, groundwater discharge to the river is generally slowed, and in at least some locations, groundwater flow normally to the river is reversed to then be from the river into the aquifer.

6.6.2 Groundwater Temperature

The cooling water intake structure is located North (upstream) of the cooling water discharge structure (see **Figure 1.3**). When the river is near high tide, the cooling water intake draws river water that contains discharge water[41] (i.e., river flow reverses and water begins to flow away from the ocean). At periods near low tide, the current in the river reduces or eliminates this circulation (within the river) of cooling water. A consequence of this tidal influence is that the temperature of water in the Discharge Canal, in addition to always being warmer than the river water, varies with tidal cycles. This is illustrated on **Figure 6.15** as well as the graph below, a double-axis graph to show the water level and temperature data collected in January 2007 from two stilling wells: Out-1, located at the southern end of the Discharge Canal, and HR-1, located in the cooling water intake structure of Unit 1[42].



WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR DISCHARGE CANAL AND HUDSON RIVER (JAN. 07)

---

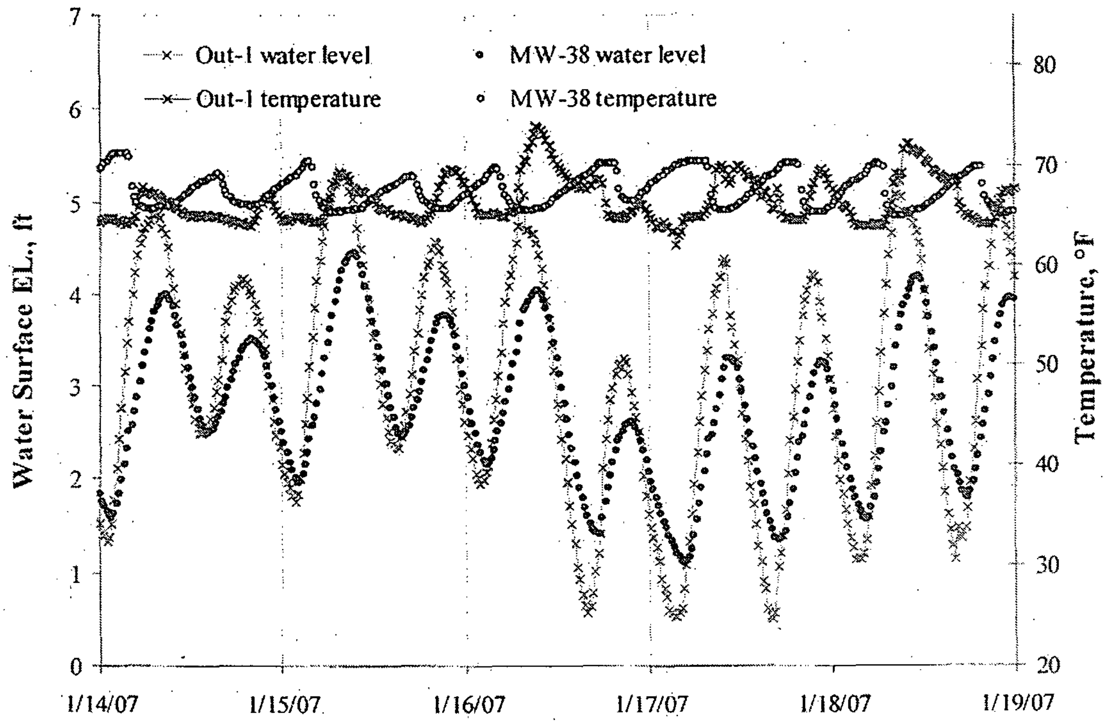
[41] The direction of the flow in the river is tidally influenced, which at periods near high tide, is to the North, away from the ocean.

[42] Unit 1 is inactive and this stilling well should provide a good measure of the river elevations with time.

Based on this information and water quality variations (see **Section 6.6.3**), we evaluated the potential for the Discharge Canal water to influence water quality at two locations originally proposed for southern property boundary monitoring[43], MW-38 and MW-48 (located adjacent to the canal and river respectively; see **Figure 1.3**).

6.6.2.1 Monitoring Well MW-38

Groundwater response to tidal influence of the cooling water Discharge Canal (at this location) is strong and appears to vary between tidal cycles. We note, however, that we observed responses from approximately 60% to at least 86% with an average of approximately 70%.



WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR DISCHARGE CANAL AND MW-38 (JAN. 07)

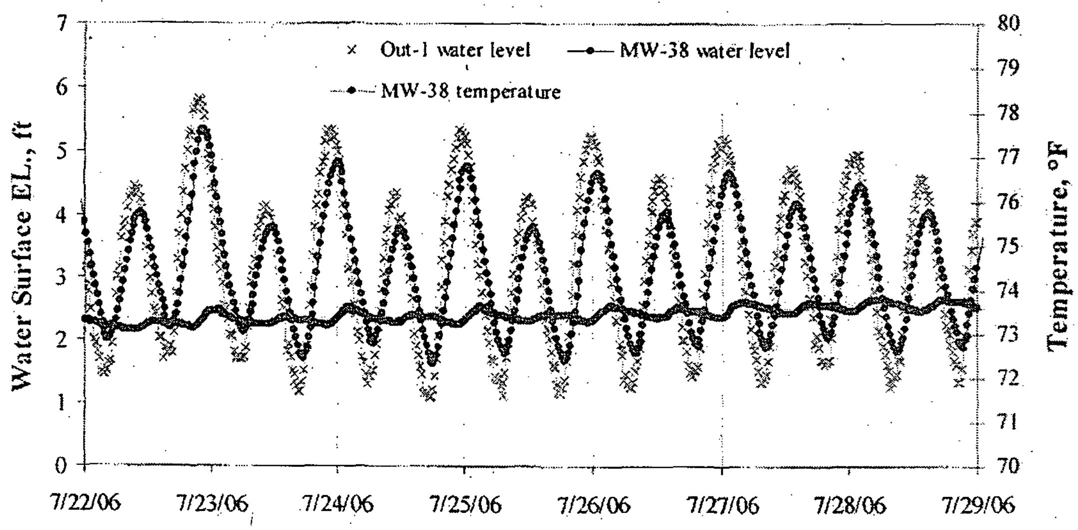
Additionally, at high tide the canal level is above the water level in MW-38 and at low tide the water level in MW-38 is above the level of the canal (see above graph). These data demonstrate the potential for water in the canal to migrate to the proximity of MW-38 during periods of high tide.

Groundwater temperature data collected from MW-38 indicate that canal water does in fact, at times, migrate to well MW-38. This is shown on the above graph

---

[43] The results of our analyses demonstrate that monitoring wells MW-38 and MW-48 are impacted by Discharge Canal water at various times. Therefore, these wells are not suitable for measuring southern boundary groundwater radiological conditions.

which shows water levels and temperatures collected in January 2007. In reviewing this graph, note that the temperature of groundwater in MW-38 is: 1) warmed significantly above ambient ground water temperatures (averaging approximately 70° F as compared to an ambient temperature of approximately 55° F); 2) on average, during this period, warmer than the canal water; 3) at its lowest temperature near high tide; and 4) increases in temperature while water levels in the well decline. These observations are consistent with groundwater discharge to the canal at low tide and canal water flow to the vicinity of well MW-38 during high tide.

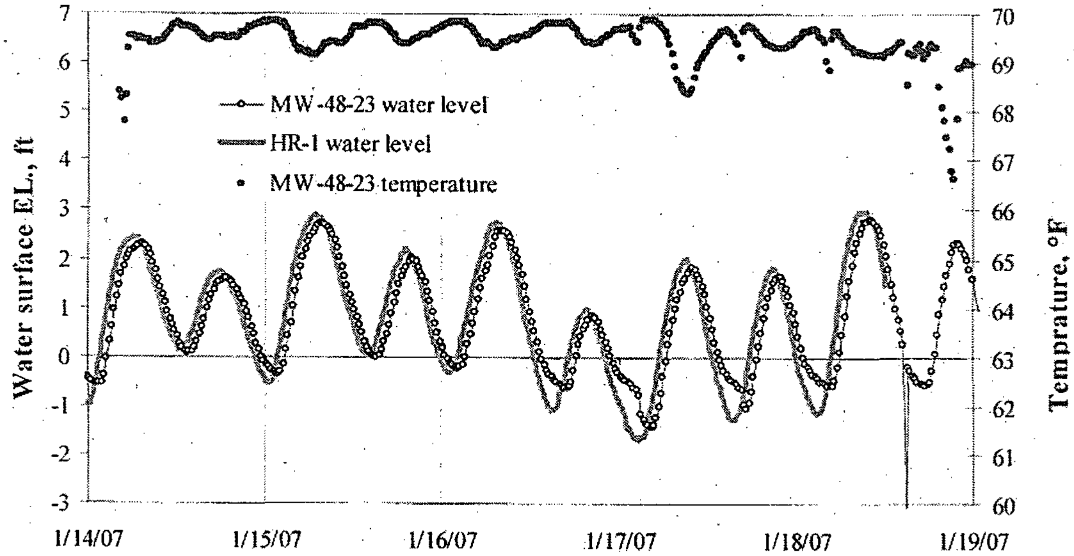


WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR DISCHARGE CANAL AND MW-38 (JULY 06)

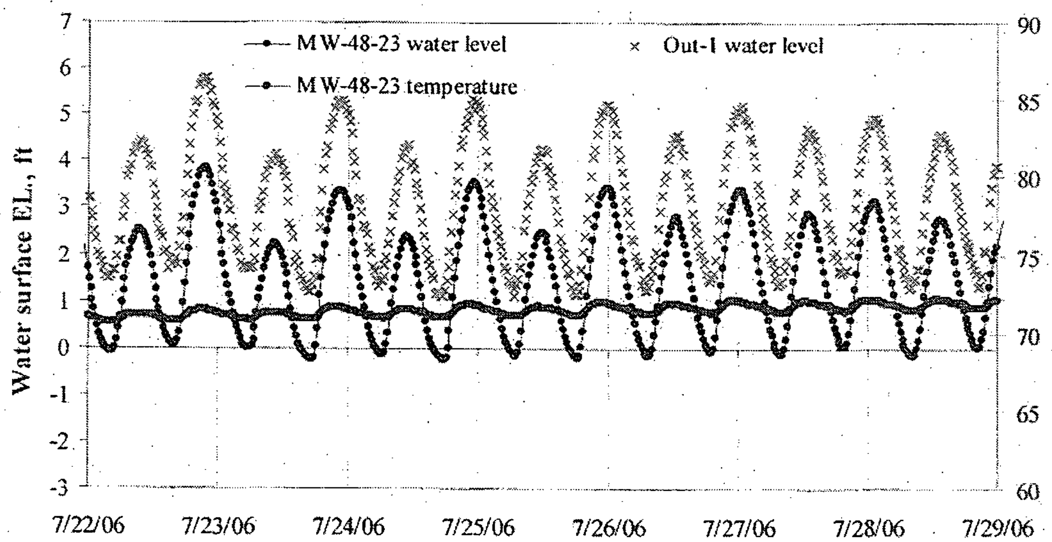
Data presented above, which is for MW-38 in the summer of 2006, while not as dramatic, supports our conclusion that groundwater in MW-38 is mixed, at times, with canal water. In reviewing this graph, note the canal water is significantly warmer than the groundwater, and that water temperature in the well water increases while the canal water level is above the level of water in the well.

6.6.2.2 Monitoring Well MW-48

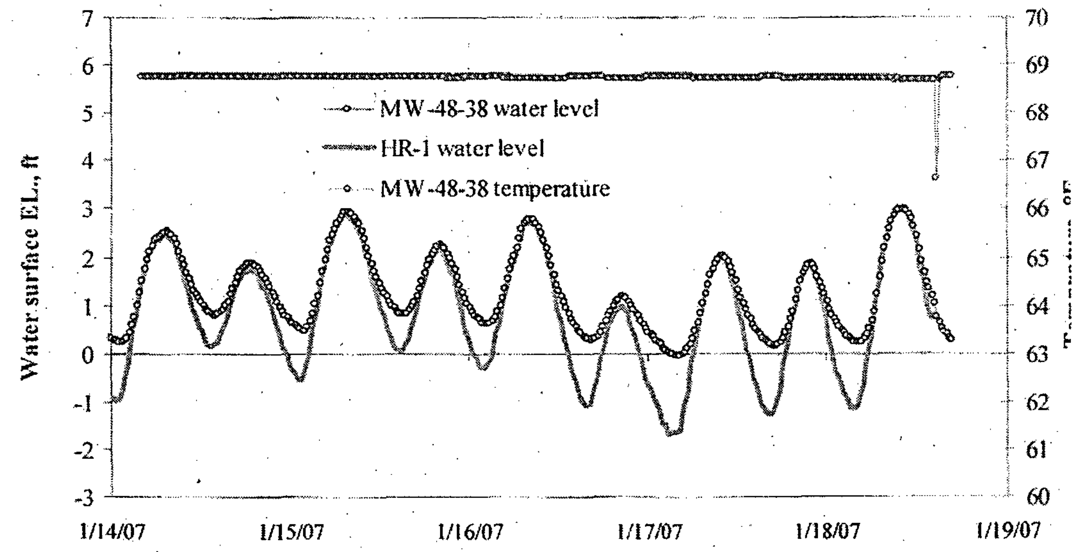
Water levels respond to tidal changes in both wells (MW-48-23 and MW-48-38) at the MW-48 location. The water levels and temperature variations in these two wells are presented and described below.



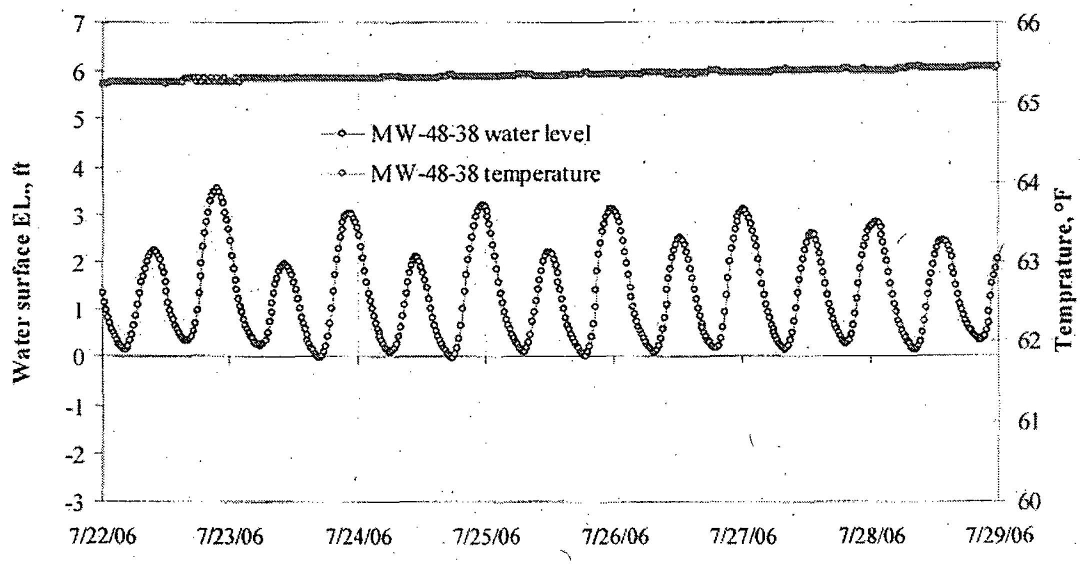
WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR HUDSON RIVER AND MW-48-23 (JAN. 07)



WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR DISCHARGE CANAL AND MW-48-23 (JULY 06)



WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR HUDSON RIVER AND MW-48-38 (JAN. 07)



WATER LEVEL AND TEMPERATURE RELATIONSHIPS FOR MW-48-38 (JULY 06)

At high tide, the level of water in both of these wells is very close to the river level, while at low tide, it is slightly above the river level and approximately 2 feet below the level of the Discharge Canal. The vertical gradient at this location is upward, with a stronger gradient at low tide. These data are consistent with anticipated trends, indicating groundwater discharge to the river occurs predominantly at low tide.

Note that the river water temperatures shown on graphs in this report are not representative of the temperature of the water in the river adjacent to monitoring wells MW-48. This is due to the location of river transducer HR-1, and tidal induced flows in the river. However, the elevated (above ambient) temperature of the groundwater at these locations (65 to 69° F) indicates it has been warmed by the Site's cooling water discharge.

The temperature of water in monitoring well MW-48-23 varies with some tide cycles, with the coolest temperature being near high tide in the winter, and the warmest temperature being near high tide in the summer. This pattern of temperature change is consistent with this monitoring well receiving river water at times of high tide.

The temperature of water in monitoring well MW-48-38 does not appear to vary with tidal cycles. We interpret these data to mean that physical water quality in monitoring well MW-48-38 is not typically influenced by large exchanges of river water[44]. The elevated groundwater temperature at this location, and the piezometric data, suggest, however, that flows created by purging of the well prior to sampling, at times of high tide, could induce river water flow to this location.

6.6.3 Aqueous Geochemistry

Routine groundwater monitoring indicated the presence of Tritium in a limited number of samples collected from monitoring wells MW-38 and MW-48. MW-38 was originally installed under the first phase of investigation to bound the southern extent of Tritium contamination at the Site along the cooling water Discharge Canal. However, subsequent sampling events indicated the presence of Tritium in groundwater at this location. The presence of Tritium in this well did not fit our CSM or what we knew of groundwater flow at the Site. A second well, MW-48, was installed at the southern Site boundary along the Hudson River to establish if any Tritium would potentially migrate off-Site. Tritium was detected intermittently in groundwater samples collected at this location as well. As neither of these locations was hydraulically downgradient of identified release areas, another mechanism other than groundwater migration from the release area was postulated. This mechanism involved releases from the legacy piping that conveyed contaminated water from the IP1-SFDS to the "E"-series stormwater piping that runs beneath the access road on the South side of the Protected Area and discharges stormwater to the cooling water Discharge Canal. While evaluating this hypothesis, we found evidence, as discussed in **Section 6.62**, that at certain tidal cycles, water from the Discharge Canal and the Hudson River may back flow into these groundwater monitoring wells. To help identify the source of Tritium in these two wells, we developed a focused water quality program specific to these wells. Generally, the water quality program involved analyzing select aqueous geochemical parameters in groundwater and surface water samples. Evaluation of these data can allow conclusions to be drawn regarding the source of the sampled water.

Both data sets (elevation and water chemistry) indicate that water collected from these wells may contain river or cooling water from the Discharge Canal. Based on these findings, we recommend that groundwater sample laboratory results from these well locations not be used to evaluate the extent of groundwater contamination or contaminant

---

[44] Relatively large exchanges of water are required to overcome the thermal mass of the subsurface deposits surrounding the well bore. Therefore, while smaller exchanges of groundwater/river water may go undetected via temperature change, they may still be large enough to adversely impact radiological water quality, particularly in consideration of the data from the proximate well screens. Also see discussion in **Section 6.6.3**.

flux to the Hudson River and that these wells not be incorporated into the Long Term Monitoring Plan as Boundary Wells.

6.6.3.1 Sampling

Groundwater samples were collected from monitoring wells MW-38, MW-48-23, and MW-48-38 and from the Discharge Canal and Hudson River on January 19, 2007. These samples were analyzed for bicarbonate alkalinity (as $CaCO_3$), magnesium, sodium, calcium, sulfate, and chloride. The data was graphed on Stiff diagrams and is shown on **Figure 6.16**.

6.6.3.2 Water Quality Evaluation

GZA used the six water quality indicators (bicarbonate alkalinity [as $CaCO_3$], magnesium, sodium, calcium, sulfate, and chloride) to assess whether or not Discharge Canal and/or river water was present or mixed with groundwater at the two locations of interest (note that the MW-48 monitoring well location contains a shallow and a deep well). A summary of our findings follows.

- The river and canal samples are chemically similar and are dominated by sodium and chloride. The sodium and chloride contents are highest at the mid tide sampling event. These data indicate that at mid tide there was a greater vertical mixing of river water which caused the water to contain more sodium and chloride[45].
- The MW-48-23 samples collected at low, mid and high tide are all geochemically similar and are dominated by the sodium and chloride ions. However, the electrolyte concentration of these two ions is approximately half of that measured in the river or canal samples. Additionally, at low tide, there is slightly less sodium chloride and slightly more bicarbonate anion than at mid or high tide. We believe this indicates that at low tide, this location receives relatively more groundwater.
- Samples collected from MW-48-38 at low, mid, and high tide were generally all dominated by calcium and magnesium cations and chloride and bicarbonate anions. These samples also contained similar sodium, chloride, calcium, bicarbonate, magnesium, and sulfate electrolyte concentrations. However, at mid and high tide, there was somewhat more calcium, magnesium, and bicarbonate measured in these samples. It is further noted that the cation/anion imbalance for the MW-48-38 samples (except MW-48-38-L1) was greater than 5%. This indicates a lack of accuracy or the presence of unanalyzed ions in the groundwater samples. While samples from MW-48-38 currently appear more representative of groundwater than those from wells MW-38 and MW-48-23, it is not certain that they are always fully representative of groundwater only[46].

---

[45] We believe the river and canal samples are similar (in part) because the river sample location was situated immediately down-river of the Discharge Canal outfall. In addition, the river sampling location visibly appears to remain within the discharge water heat plume. Therefore, the river samples are likely Discharge Canal water or at least mixed with what is being discharged from the canal.

[46] For example, 573 pCi/L of Tritium was detected in this interval on September 5, 2006. Tritium had never previously been detected and has since not been detected in this interval. It may be that this sample was misidentified in the field and the sample was actually obtained from the upper interval of this well where Tritium is routinely detected. However,

- The samples collected from MW-38 at low, mid and high tide are all geochemically similar and are dominated by the sodium and chloride ions. However, the electrolyte concentration of these two ions is less than half of that measured in the river or canal samples. Additionally, at low tide, there is slightly less sodium and chloride than at mid or high tide. We believe this likely indicates that at low tide, this location sees relatively more groundwater.

These data indicate that water samples collected from MW-38 and MW-48-23 are largely representative of the proximate surface water bodies at the Site. Recognizing the source of water in these wells, the other *chemistry data* (e.g., Tritium and Strontium) are suspect and should not be used for evaluation of groundwater contaminant migration or flux. Based on the available data, MW-48-38 may provide samples *more* representative of Site groundwater than MW-38 and MW-48-23. However, further analysis would be necessary to allow this well to be recommended as a southern boundary monitoring location, particularly in light of the above analysis pursuant to the proximate well screens and the potential for false positives. Given the demonstrated groundwater flow directions in this area[47], it is GZA's opinion that an additional southern boundary monitoring location (in addition to MW-51 and MW-40) is not required proximate to MW-48-38.

6.7 GROUNDWATER FLOW PATTERNS

A major purpose of this groundwater investigation was to identify the fate and level of groundwater contaminant migration. The contaminants of potential concern are soluble in groundwater, and at somewhat varying rates, move with it. This section provides a description of identified groundwater flow patterns in and downgradient of identified contaminant release areas. The piezometric data, shown in **Table 6.1**, which form the basis of this evaluation are independent of chemical data collected at the same monitoring locations. Consequently, our evaluation of piezometric data provides an assessment of where contaminants are expected to migrate in various time frames. Refer to **Section 9.0** for information on the observed distribution of contaminants and a discussion on discrepancies between anticipated and observed conditions.

Testing has indicated that the bedrock is sufficiently fractured to, on the scale of the Site, behave as a non-homogeneous, anisotropic, vertically porous media. This finding indicates that groundwater flow is perpendicular to lines of equal heads. This assessment appears particularly valid in horizontal (East-West & North-South) directions.

The nature of bedrock fracturing suggests the hydraulic conductivity is higher in the horizontal than in the vertical direction. Furthermore it appears the upper portions of the rock are more conductive than the deep rock except within the zone of higher hydraulic conductivity between Units 1 and 2. These findings suggest that the bulk of the

---

it also is possible that this sample is reflective of river water induced into the well through sampling and/or the specific conditions existing at the time the sample was taken.

[47] While the representativeness of the chemistry data in these wells (MW-38, MW-48-23 and MW-48-38) is not certain, the groundwater elevation data is reliable for establishing flow direction.

groundwater moves at shallower depth, with small masses being reflected deeper into the rock mass than would be seen in anisotropic aquifer.

6.7.1 Groundwater Flow Direction

Groundwater elevations from pressure transducers at a representative low tide have been used to construct a potentiometric surface map of the aquifer beneath the Site (see **Figure 6.17**). We chose this data set after evaluating a number of piezometric data sets. More specifically we have mapped six groundwater conditions:

- Low tide during the drier portion of the year (2/12/07)
- High tide during the wetter portion of the year (3/28/07)
- Low tide during the wetter portion of the year (3/28/07)
- High tide during the drier portion of the year (2/12/07)
- Groundwater elevations at sample locations with the greatest Tritium impact during wet season
- Groundwater elevations at sample locations with the greatest Tritium impact during the dry season

Based on this evaluation, it appears that there is not a great deal of change in groundwater flow patterns over time (see **Appendix S**). However, as groundwater elevations have a smaller tidal response (amplitude) than the fluctuations of the river, low tide is a time with a relatively high degree of groundwater flux from the Site. Furthermore, low tide during the drier portion of the year likely represents a period of highest groundwater flux.

Groundwater flow is in three dimensions. A representative set of groundwater elevations was used to construct a cross-sectional groundwater contour map as shown on **Figure 6.18**. This figure is based on a 1:1 horizontal to vertical hydraulic conductivity. Because horizontal fractures transmit flow in only a horizontal direction, and vertical fractures transmit flow in both a horizontal and vertical direction, the aquifer is vertically anisotropic with a preference for horizontal flow. Conversely, if the vertical hydraulic conductivity decreases with depth, the groundwater flow should be driven deeper than shown on the figure, but would still ultimately discharge to the Hudson River. Based on the observed vertical distribution of piezometric heads, the deepest flow paths of potential interest for this investigation originate near Unit 2. Based on the observed vertical distribution of contaminants (see **Section 9.2**), these flow paths are limited to depths of between 200 and 300 feet below ground surface.

As discussed previously, groundwater flow patterns are also influenced by anthropogenic sources and sinks. The groundwater sources/sinks are shown on **Figure 1.3** and are summarized below:

- Unit 1 Chemical Systems Building (IP1-CSB) Foundation Drain: This drain discharges into the Sphere Foundation Drain Sump (SFDS) and is designed to maintain groundwater elevations beneath IP-1-CSB subbasement to an elevation of approximately 12 feet NGVD 29. The reported groundwater extraction rate from this drain is approximately 10 gallons per minute (gpm).

- IP1-NCD: This drain is designed to maintain groundwater elevations beneath the Unit 1 containment building (IP1-CB) and the Unit 1 Fuel Handling Building (IP1-FHB) at an elevation ranging from 33 to 42 feet NGVD 29. The reported groundwater extraction rate from this drain is approximately 5 gpm.
- Unit 2 Footing Drain: This drain is designed to maintain groundwater elevations beneath the Unit 2 Vapor Containment (IP2-VC) at an elevation ranging from approximately 13 to 42 feet NGVD 29. The long term flow rate from this drain is not known, but short term measurements made prior to and during the Pumping Test indicate it is likely on the order of 5 gpm.
- Unit 3 Footing Drain: IP3-VC is known to have a Curtain Drain. However, specifics of its construction were not available. It is known that a pipe that connects to the Unit 3 Curtain Drain is currently under water in a manhole Northeast of Unit 3. Due to this condition, it is unknown how much or whether or not this drain is removing groundwater.
- Unit 1, 2, and 3 storm drains: The storm drains surrounding Units 1, 2, and 3 were constructed of corrugated metal piping. These pipes and associated utility trenches have been shown to allow at least some infiltration/exfiltration. That is, depending on rainfall and location, these structures may either receive groundwater or recharge the aquifer.

6.7.2 Groundwater Flow Rates

In the interest of evaluating conditions when a relatively large amount of groundwater (and associated constituents) flux to the Hudson River occurs, our discussion of lateral groundwater flow direction focuses on the low tide potentiometric surface contours as shown on **Figures 6.19** and **6.20**. These groundwater contours show that groundwater generally flows toward the Site from the North, East and South, with a generally westerly flow direction across the Site with a gradient averaging about 0.06 feet per feet.

6.7.2.1 Seepage Velocities

We used Darcy's Law to estimate the average groundwater seepage velocity across the Site:

$$V = K * \frac{dh}{dl} * \frac{1}{n_e}$$

Where:

V = average linear groundwater velocity

K = hydraulic conductivity (0.27 feet/day [see **Section 6.50**])

$\frac{dh}{dl}$ = groundwater gradient (0.06)

n_e = effective porosity (assumed to be 0.0003 based on specific yield measured during Pumping Test)

Based on this equation and Site data, we computed the average groundwater seepage velocity to be on the order of 55 ft/day. This is an upper end estimate in that it does not account for the effect of dead-end fractures and irregularities in fracture apertures. That is, we believe the effective porosity is larger than that indicated by hydraulic testing. Also note that this is an average velocity with flow rate in individual fractures being controlled by the local gradient and hydraulic aperture of the fracture. Based on the tracer test (see **Section 7.3.2**), actual measured average seepage rates were substantially less than 55 ft/day.

6.7.2.2 Groundwater Flux

To estimate groundwater flows (i.e., groundwater mass flux) beneath the IPEC, a calibrated analytical groundwater flow model was constructed. This model was based on two independent equations, both of which provide groundwater flow estimates. The first of these equations is based on a mass balance. That is, on a long term average, the groundwater discharging from the aquifer is equal to the aquifer recharge. The second equation is "Darcy's Law", which states the flow per unit width of aquifer is equal to the transmissivity of the aquifer multiplied by the hydraulic gradient.

As discussed in the following subsections using Site-specific data for the governing parameters, both of these independent methods provided similar results. Because we were conservative (that is, we chose values for both equations that we believe may somewhat overestimate flows), we believe the model is appropriate for its intended use for estimating the mass of groundwater discharging to the Hudson River as part of dose impact computations[48]. Please note, this model is not, therefore, conservative for all purposes. For example, we believe it would likely overestimate the yield of extraction wells should they be developed at the facility.

While the calculated groundwater flux from the Site directly to the river (approximately 13 gpm) may intuitively seem small, it is consistent with our Conceptual Site Model and the identified hydrogeological setting.

<u>Mass Balance</u>

The mass balance approach recognizes that the only substantial source of recharge to aquifer is areal recharge derived from precipitation. Precipitation in the area reportedly varies from 49 inches per year (30-year average) to 36 inches per year (10-year average) at the IPEC Meteorological Station. Areal recharge is that portion of precipitation that reaches the water table (total precipitation minus run-off, evaporation and transpiration). The average areal recharge is dependent on total precipitation, the nature and timing of individual storm events, soil types, topography, plant cover, the percentage of impervious cover (roads, buildings, etc.) and precipitation recharge through exfiltrating

---

[48] It is noted that the dose impact computations reported for 2006 were based on the mass balance model only. These analyses were completed prior to obtaining sufficient data to implement the Darcy's Law model. It is recommended that future dose impact computations also be based on the mass balance model, but with upgrades based on Darcy's Law analyses.

stormwater management systems. Based on our review of available information, we believe that the areal recharge at the IPEC is greater than 6 inches per year and less than 12 inches per year. For the purposes of this study, an average of 10 inches per year was used (see **Appendix S** for information on how we arrived at this average).

Topographic divides were used to defined the recharge area (see **Figure 3.1**). This provides a recharge area of approximately 4,000,000 square feet (92 acres) and a calculated recharge rate of 38 gpm. From this value, the 20 gpm extracted by pumping from foundation drains was subtracted (see **Section 8.0**). This approach, therefore, indicates that the groundwater discharge to the cooling water Discharge Canal and the Hudson River is approximately 18 gpm.

__Darcy's Law__

Darcy's Law is presented below:

$$Q = K * A * \frac{dh}{dl} = T * W * \frac{dh}{dl}$$

Where:

Q = volumetric flow (ft^3)
T = transmissivity (ft^2/day)
W = width of the streamtube

To estimate transmissivities, the aquifer was divided into two layers or zones: the upper forty feet; and between depths of 40 feet and 185 feet, the identified bottom of the significant groundwater flow field. In each of the zones, transmissivities were calculated using the geometric mean of hydraulic conductivity testing. The facility was further divided into 6 flow zones representing areas beneath pertinent Site features; and data East (upgradient) of the Discharge Canal was reviewed independently of that West (downgradient) of the Discharge Canal. This process, shown on the following four tables, provides an estimate of the groundwater flux passing beneath structures of interest that discharge to the cooling water Discharge Canal and the Hudson River. In reviewing these calculations, note the resulting total groundwater flow East of the canal is approximately 18 gpm, which indicates that the long term areal recharge to the aquifer is 10 inches per year, or 28% of the 10-year average precipitation recorded at the IPEC.

Unit	Transmissivity (ft^2/day)	Width (ft)	Hydraulic Gradient (ft/ft)	Volumetric Flow Rate (gpm)
Northern Clean Area	0.36	209	0.600	0.23
Unit 2 North	1.59	294	0.014	0.03
Unit 1/2	31.97	215	0.007	0.26
Unit 3 North	29.87	324	0.054	2.74
Unit 3 South	16.02	338	0.038	1.07
Southern Clean Zone	24.34	879	0.037	4.12
			Total→	8.45

SHALLOW ZONE <u>BEFORE</u> CANAL (OVERBURDEN AND TOP 40 FEET OF BEDROCK)

Unit	Transmissivity (ft^2/day)	Width (ft)	Hydraulic Gradient (ft/ft)	Volumetric Flow Rate (gpm)
Northern Clean Area	0.36	209	0.600	0.23
Unit 2 North	1.59	221	0.038	0.07
Unit 1/2	31.97	146	0.022	0.52
Unit 3 North	29.87	316	0.013	0.61
Unit 3 South	16.02	248	0.011	0.24
Southern Clean Zone	24.34	879	0.037	4.12
			Total→	5.79

SHALLOW ZONE <u>AFTER</u> CANAL (OVERBURDEN AND TOP 40 FEET OF BEDROCK)

Unit	Transmissivity (ft^2/day)	Width (ft)	Hydraulic Gradient (ft/ft)	Volumetric Flow Rate (gpm)
Northern Clean Area	10.77	209	0.068	0.80
Unit 2 North	10.77	294	0.030	0.49
Unit 1/2	62.15	215	0.023	1.61
Unit 3 North	37.65	324	0.022	1.41
Unit 3 South	22.02	338	0.040	1.55
Southern Clean Zone	19.66	879	0.043	3.83
			Total→	9.69

DEEP ZONE <u>BEFORE</u> CANAL (FROM 40 TO 185 FEET BELOW TOP OF BEDROCK)

Unit	Transmissivity (ft^2/day)	Width (ft)	Hydraulic Gradient (ft/ft)	Volumetric Flow Rate (gpm)
Northern Clean Area	10.77	209	0.068	0.80
Unit 2 North	10.77	294	0.023	0.29
Unit 1/2	62.15	215	0.018	0.83
Unit 3 North	37.65	324	0.018	1.09
Unit 3 South	22.02	338	0.016	0.45
Southern Clean Zone	19.66	879	0.043	3.83
			Total→	7.25

DEEP ZONE <u>AFTER</u> CANAL (FROM 40 TO 185 FEET BELOW TOP OF BEDROCK)

GZA's groundwater flux calculations are used by Entergy to calculate radiological dose impact. Entergy currently estimates this dose based upon the precipitation mass balance approach alone. Refinements to this dose model are feasible utilizing the hydrogeologic data presented above. These refinements will improve the overall data fit of the flow model in concert with the long term monitoring program being implemented by Entergy.

The resultant dose assessments are expected to remain close to, or be somewhat lower than, what has already been estimated. It is recommended that Entergy evaluate the refinements to the existing model for inclusion in the next annual effluent assessment report.

7.0 GROUNDWATER TRACER TEST RESULTS

A tracer test was conducted to help assess groundwater migration pathways from IP2-SFP. As discussed in the following sections, the test also helped to confirm migration pathways from Unit 1. The test was designed to simulate a leak from IP2-SFP, in that the tracer (Fluorescein) was released directly to the bedrock at the base of the structure, immediately below the shrinkage cracks associated with the 2005 release. The bedrock surface at this location is approximately elevation 51 feet, and thus approximately 40 feet above the water table (as measured in the immediately adjacent MW-30 - see **Figure 7.1**). This approach was taken (recognizing it would complicate tracer flow paths relative to injection directly into the groundwater) to provide better understanding of the role of unsaturated bedrock in storing and transporting Tritium.

A major difference in the test, as compared to possible releases at IP2-SFP, is the rate of the injection. The 2005 Tritium release was measured at a peak rate of approximately 2 liters per day (0.005 gpm), as opposed to the tracer injection that occurred relatively instantaneously (as compared to the Tritium release) at a rate of approximately 3.5 gpm over approximately an hour. This higher injection rate was used to insure that a sufficient mass of Fluorescein was released at a known time. As anticipated, and discussed in subsequent sections, this practice appears to have enhanced the lateral spreading of the tracer in the unsaturated zone.

7.1 TRACER INJECTION

Preparation for the injection began on January 29, 2007 with the injection of potable water to test the ability of the injection point[49], T1-U2-1, to accept water and to pre-wet fractures. The first potable water injection was conducted on January 29, 2007. Five hundred gallons of water (measured using an inline totaling water meter) was introduced as fast as the water source would permit (approximately 8.5 gpm). The water level in the well did not rise significantly. The second potable water injection was conducted on January 30, 2007. A total of 1,012 gallons of tap water was introduced at a mean rate of approximately 8.3 gpm.

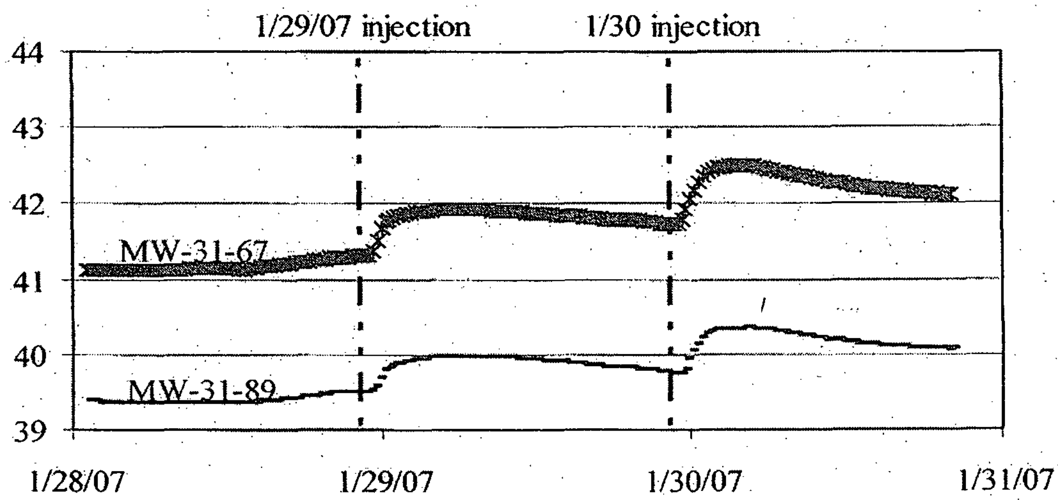
The piezometric data collected during that period from wells MW-30, MW-31, MW-33, MW-34 and MW-35 were reviewed for evidence of groundwater mounding. (Note: transducers were not installed in RW-1 and MW-32 on that date.) Mounding, on the order of 0.5 to 1 foot, was recorded at MW-31. No response was noted at the other four nearby monitored locations. Note that MW-31 is located upgradient of the injection point from a *saturated* zone groundwater flow perspective, and unsaturated zone flow in this direction is

---

[49] The injection point as shown on **Figure 7.2** is constructed from two-inch steel pipe that ends in a tee and perforated piping running directly on the bedrock surface, well above the water table. This perforated piping was covered with approximately 0.5 feet of crushed stone extending from the bedrock excavation face to the South face of the SFP, over a length of approximately 8 feet. The crushed stone was covered with filter fabric prior to placing the concrete mud-mat for gantry crane foundation construction; the mud-mat covers the entire bedrock excavation "floor" adjacent to the South side of the SFP.

consistent with the bedrock strike/dip directions. Based on the shape of the time response curve at MW-31, GZA believes that:

1. The center of the release to the water table was at some distance from MW-31 (see time lag), and;
2. Injected water was released to the water table over a longer duration than the two hour injection test. This opinion is based on the relatively slow decay of the mound at MW-31. This response is shown on the figure below:



PIEZOMETRIC GROUNDWATER RESPONSE TO WATER INJECTION

We have insufficient information to render an opinion on the shape or height of the tracer injection-induced groundwater mound. We note, however, because of the lower rate of the tracer injection, the short duration of the injection (see below), and the groundwater flow velocities, as derived from the tracer test, GZA believes mounding had relatively little effect (compared to unsaturated flow) on the lateral spreading of the tracer. That is, the life of the mound was not of sufficient duration to cause long term, widespread lateral migration in the groundwater.

The tracer injection was performed on February 8, 2007. It consisted of the release of 7.5 pounds of Fluorescein with 210 gallons of water. More specifically, prior to Fluorescein injection, 30 gallons of potable water was released to the well, this was followed by 10 gallons of a Fluorescein-water mixture, followed by 170 gallons of potable water (to flush the Fluorescein out of the well). This procedure resulted in a minimum initial average tracer concentration of 4,300,000 ppb.

7.2 TRACER CONCENTRATION MEASUREMENTS

The concentrations of Fluorescein in groundwater were routinely measured between February 8, 2007 and August 21, 2007[50] at 63 locations. This resulted in the collection analysis of 4,488 samples, including background samples, charcoal samplers and water samples. These data are tabulated and presented on time-concentration graphs in **Appendix N**.

Measurements of Fluorescein concentrations were made by two methods. The first is through aqueous sample analysis (1,969 individual samples). These water sample analyses provide direct concentration measurements, at the time of sampling, with a detection limit of less than 1 ppb.

A second method entailed desorbtion of Fluorescein from packets of activated carbon (carbon samplers) suspended in the groundwater flow path at multi-level sampling locations. This method provides a measure of the mass of Fluorescein moving through a monitoring well screen over the period the activated carbon is in the well. However, the actual concentration of Fluorescein in the groundwater is not determinable from this test. Among other things, carbon sample analyses are useful in establishing that the Fluorescein mass being transported by groundwater did not pass sampling locations between discrete sampling events. This was important for this study because of the potential for high transport rates (see **Section 6.0**).

7.3 SPATIAL DISTRIBUTION AND EXTENT OF FLUORESCEIN IN GROUNDWATER

The groundwater tracer test was developed primarily to identify groundwater migration pathways. We have divided our discussion on observed pathways into three subsections: unsaturated zone migration, the lateral distribution of Fluorescein, and the vertical distribution of Fluorescein.

Unsaturated Zone Transport

By design, Fluorescein was released atop the bedrock, in the unsaturated zone. The bedrock structure (strike and dip direction of bedrock fractures) therefore played a dominant role in controlling tracer migration to the water table. This is witnessed by the significant Fluorescein concentrations observed in the upgradient monitoring well MW-31 and MW-32 (see below) and at lower concentrations in the more distant and upgradient Unit 1 monitoring well MW-42.

The observed unsaturated zone migration to the South and East is consistent with the observed bedrock fracturing (see **Section 6.0**). This mechanism is also evidenced by data showing the highest Fluorescein concentration (49,000 pico-curies per liter - pCi/L)[51]

---

[50] In addition to the routine sampling, specific wells were sampled for a longer period of time as part of short term variability testing (see **Section 9.0**).

[51] pCi/L is a standard unit of radiation measurement.

being found in well MW-32, located 60 feet to the South of the injection location, and not in MW-30, located immediately below the injection location.

In reviewing tracer test results, it should be recognized that the Fluorescein released at a single location on the bedrock was not released to the water table at a single location, rather, it reached the water table over an undefined area that likely extends to the East of MW-31, to the South to MW-42, and likely not far to the North of the injection well. As discussed in **Section 7.5**, this limits our ability to evaluate migration rates, but increases our ability to understand likely Tritium migration pathways from IP2-SFP.

The spreading of Fluorescein in the unsaturated zone was likely more pronounced than the spreading of Tritium because of the higher release rate. The tracer test, however, supports data that shows the Unit 2 plume to extend upgradient of the source area and laterally to Unit 1 to the South of IP2-SFB.

Lateral Distribution

Two conditions were selected to show the lateral distribution of Fluorescein in a manner illustrating conditions influencing the migration of groundwater in the vicinity of IP2-SFB. These are:

1. The maximum observed concentrations; and,
2. Conditions just prior to, and including, June 14, 2007.

While the maximum observed concentrations do not illustrate an actual condition, the resulting figure is useful in highlighting migration pathways. We chose June 14th because it represents conditions approximately 4 months after the injection. With estimated Fluorescein transport rates on the order of 4 to 9 feet per day (see **Section 7.4**), conditions proximate to that date clearly illustrate the effects of subsurface storage on both Fluorescein and Tritium[52].

Lateral Distribution – Maximum Observed Concentrations

The distribution of the observed maximum concentrations of Florescein, at any depth, in groundwater is shown on **Figure 7.2**. This figure was developed based on both the observed concentrations and our understanding of groundwater flow directions (inferred from groundwater contours). This figure does not show conditions at any single time; rather it represents our interpretation of the highest tracer concentration, at any time during the test, at a location. In reviewing that figure please note:

- The maximum observed tracer concentration was 49,000 ppb; approximately 1% of the calculated average injection concentration. We interpret these data to mean that there is considerable spreading and mixing of the tracer in the unsaturated and shallow saturated zones.

[52] Later dates were not selected because of the associated reduction in the sampling frequency and/or number of sampling locations.

- The 50 ppb contour represents approximately 1/100,000 the concentration of the injected tracer. Because Tritium concentrations in IP2-SFP are approximately 20,000,000 pCi/L this contour (50 ppb Fluorescein) represents the detection limit of a release of Tritium from IP2-SFP (at the injection well)..
- The general shape of the resulting plume is strikingly similar to the observed Unit 2 plume, see **Figure 8.1**. This supports our interpretation of contaminant migration from IP2-SFP.
- Because tracer was detected in MW-42 and MW-53, the test can be used to help assess migration pathways from Unit 1. The observed distribution of Fluorescein in the vicinity of Unit 1 supports our interpretation of the migration of Strontium, with a westward migration towards the Hudson River in a fairly narrow zone (see **Figure 7.2**).
- The low concentrations to the West (downgradient) of the cooling water Discharge Canal (as compared to East of the canal) indicate the canal received a significant mass of the tracer, as opposed to direct discharge to the river.
- Concentrations found in Manhole Five (MH-5) indicate the IP-2 Curtain Drain received tracer (see **Section 7.5**).

Lateral Distribution – June 14, 2007

GZA's interpretation of the distribution of Fluorescein in groundwater proximate to June 14, 2007 is shown on **Figure 7.3**. Again, concentrations are the highest measured at any depth. While not ideal for the observed concentrations, the contour interval was selected to match the contour intervals shown on **Figure 7.2**. In reviewing that figure, please note:

- The shape of the plume is more representative of an ongoing release than of a four-month-old instantaneous release in a strong groundwater flow field. This supports other data which indicate water is stored in the unsaturated bedrock (and potentially within the upper water bearing zone) and is released to the groundwater flow field over time.
- The center of the Fluorescien mass in groundwater, in the release area, shifted to the North. (See data for wells MW-30 and MW-32 on **Figures 7.2** and **7.3**). GZA interprets these data to mean:
  - There is more storage in the unsaturated zone in proximity to IP2-FSB, than to the South or West; and
  - The relatively high injection rate resulted in more lateral spreading of the tracer than would have resulted from a slow, long duration release.

Vertical Distribution

The table provided below presents data on the vertical distribution of Fluorescein along the center line of the tracer plume (see **Figure 7.2** for well locations). It presents the maximum observed concentration at each depth and the approximate concentration[53] proximate to June 14, 2007.

---

[53] Data estimated for the June 14th date are based on time concentration graphs (see **Appendix N**).

FLUORESCEIN CONCENTRATIONS

MW-31		MW-32		MW-30		MW-33		MW-111		MW-37	
Depth	Conc.	Depth	Conc.	Depth	Conc.	Depth	Conc.	Depth	Conc.	Depth	Conc.
53	1600 / 0.5	62	49,000 / 2	74	5690 / 2600	18	6.6 / 1	16	2.9 / 2.9	22	47 / 10
67	12,700 / 200	92	24,300 / 500	88	167 / 110					32	1.3 / ND
89	1810 / 3	140	15,300 / 6								
		165	4160 / 16								
		197	621 / 56								

1600 / 0.5 = Max. conc. / conc. proximate to 6/14/07 in µg/L
Depth = Below Ground Surface (Feet)
ND = Not Detected

The available data indicate the bulk of the Fluorescein was migrating at fairly shallow depths, although not always at the water table. As anticipated (consistent with the Conceptual Site Model), it also suggests the pathway becomes somewhat deeper downgradient of the injection point, likely being below the well screens at MW-33 and MW-111. The comparatively low concentrations at MW-111, as compared to Tritium concentrations, likely highlights the importance of unsaturated zone migration in groundwater contaminant distributions.

7.4 TEMPORAL DISTRIBUTION OF FLUORESCEIN IN GROUNDWATER

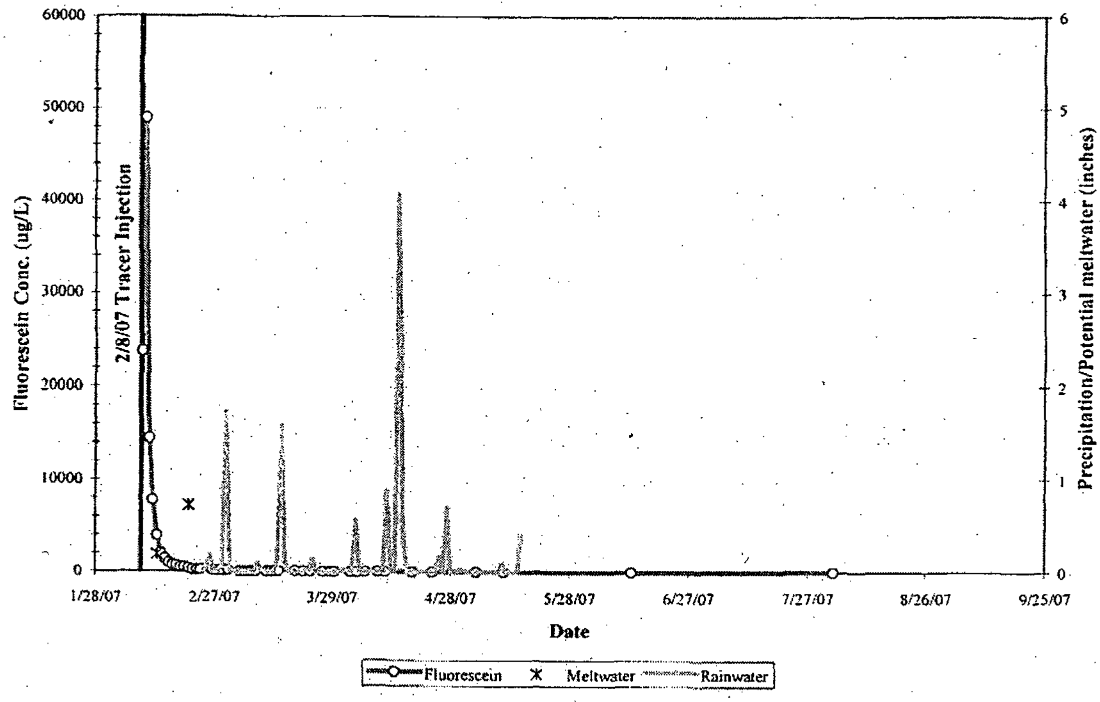
Groundwater samples were collected at regular intervals between February 8 and August 21, 2007[54]. These data are shown on graphs provided in **Appendix N** with selected information shown below. Interpretation of these graphs is complicated, beyond the normal difficulties associated with interpreting tracer test data in fractured rock. This is because the tracer was *not* injected directly to the water table, as would be more typical. Rather, the tracer was released at the top of the bedrock, in the unsaturated zone, so as to better mimic the behavior of the Tritium release from the cracks in the fuel pool wall; as was the primary objective of the tracer test. Therefore, the tracer then entered the groundwater regime at numerous locations due to unsaturated zone spreading from the release point. In addition, these numerous release points remained active over an extended period of time (months) due to storage in the unsaturated zone; see the previous subsection and **Section 8.1.2** for further discussion.

With these limitations noted, the following observations/interpretations are provided:

- At some locations, the release to the water table was rapid. For example, at monitoring well MW-32-62, located approximately 60 feet to the South of the injection point, the tracer arrival time[55] was approximately one day. Conversely, at MW-30-74, located adjacent to the injection well, the arrival time was approximately 25 days. See the following figures.

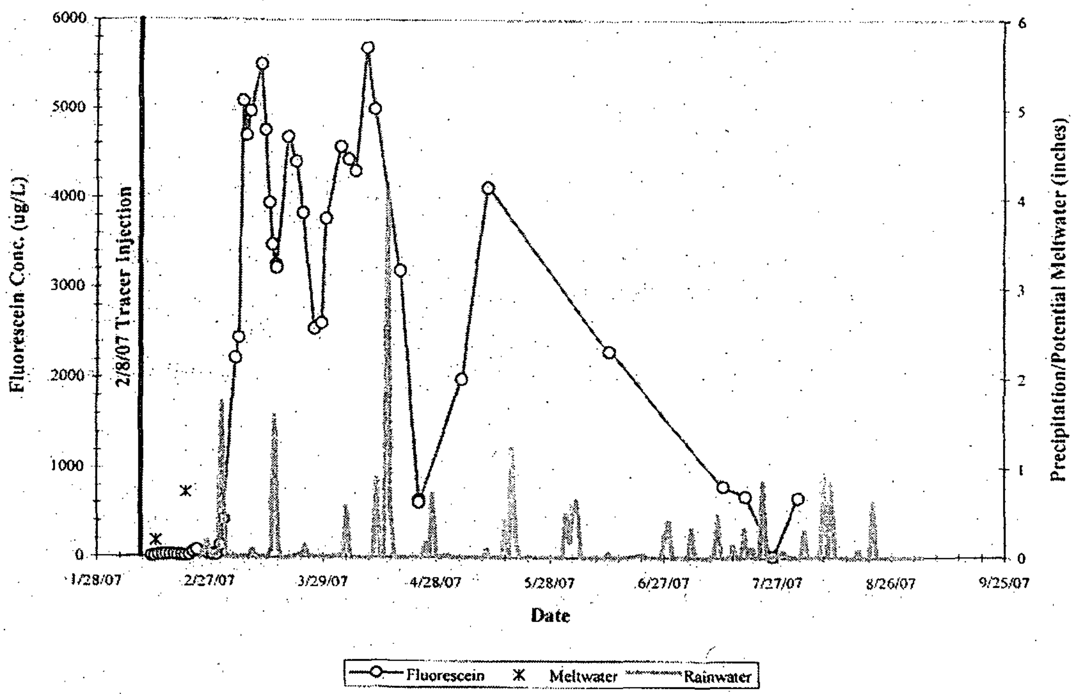
[54] In addition to the routine sampling, specific wells were sampled for a longer period of time as part of short term variability testing (see **Section 9.0**).
[55] Arrival times are generally established as the center of mass (often the peak) of the concentration vs. time graph.

MW-32-62



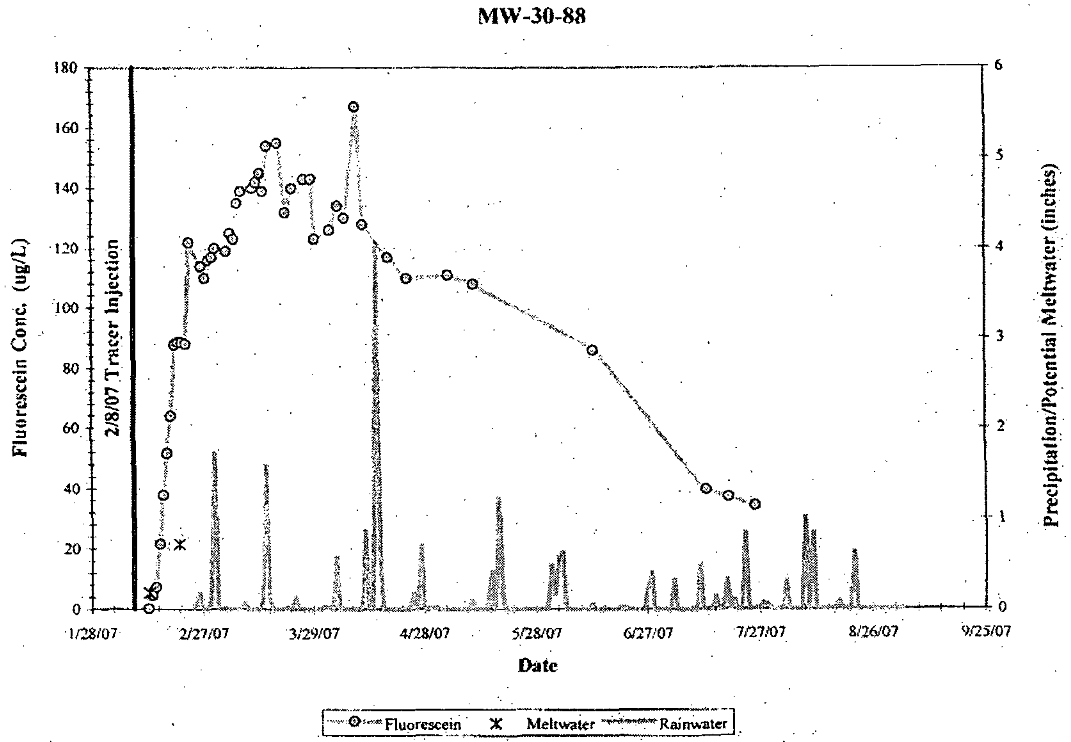
MW-32-62 FLOURESCEIN AND PRECIPITATION VS TIME

MW-30-69



MW-30-69 FLOURESCEIN AND PRECIPITATION VS TIME

- In mid-June 2007, there was still an ongoing source of Fluorescein to the water table in the vicinity of IP2-FSP. This is evidenced by the time-concentration graphs for MW-30 -74 (see previous figure) and MW-30 -88, presented below:



MW-30-88 FLOURESCEIN AND PRECIPITATION VS TIME

- Because the locations and times of releases from the unsaturated zone to the water table are not known, it is difficult, at best, to estimate tracer transport velocities. However, as shown below, the average value appears to be on the order of 4 to 9 feet/day.

Well Location	Time of Arrival Date	Time (Days)	Distance (Feet)	Velocity (Ft/Day)
MW-33	3-5-07	25	110	4.4
MW-111	3-14-07	34	145	4.3
MW-37-22[56]	4-10-07	61	300	4.9
MW-55[57]	3-28-07	48	240	5 to 9

FLOURESCEIN ARRIVAL TIMES AND TRANSPORT VELOCITIES

[56] The source of the Fluorescein observed in MW 37-22 is uncertain. It may be entirely from migration in the bedrock slightly to the North of that location, or may be due, in part or in whole, to transport via storm drains and in the backfill around the Discharge Canal walls. See **Section 4.5**.

[57] The calculated velocity depends on which flow path is selected. Using a flow path from MW-32 (day of release) to MW-55, the calculated velocity is approximately 5 feet/day. Using a flow path between MW-53 and MW-55 (the Strontium flow path) the calculated velocity is 9 feet/day.

Also note, the carbon sampler data supports these estimates to the extent that no evidence of significant Fluorescein migration between aqueous sampling events was found.

The observed tracer migration rates are approximately 1/5 to 1/10 the calculated groundwater velocity of 55 ft/day, see **Section 6.7.2**. GZA attributes the difference between the "observed" and the "computed" transport velocities primarily to the effective porosity of the bedrock. That is, we believe the actual effective porosity is considerably larger (more on the order of 0.003) than that computed from our analyses of the Pumping Test (see **Section 6.5.1**); the aquifer response testing (see **Section 6.6.1**); or the hydraulic aperture of the bedrock (see **Section 6.5.2**). This slower transport velocity helps to explain the observed long term temporal variations in both tracer and Tritium groundwater concentrations, and supports the use of a porous media flow model. As a practical matter, this slower transport velocity encourages the use of conventional groundwater monitoring frequencies (quarterly or longer); and reduces concerns over the possibility of high concentrations of contaminants migrating by a monitoring location between sampling events.

7.5 FLUORESCEIN IN DRAINS, SUMPS AND THE DISCHARGE CANAL

Fluorescein was also detected within storm drain catch basins, foundation drain sumps, and the Discharge Canal. Fluorescein was detected in manholes MH-4, MH-5 and MH-6. In reviewing these data, note:

- MH-5 receives discharge from the IP2-VC Curtain Drain system. The presence of tracer in this manhole indicates that tracer entered the Curtain Drain system due to lateral spreading at the release point during injection. Once in the Curtain Drain system, the tracer migrated to MH-5.
- Water in MH-5 flows towards the cooling water Discharge Canal passing through MH-4, discharging at MH-4A.
- The concentrations detected in MH-4 are very similar to the Fluorescein concentrations detected in samples collected from MH-5, while Fluorescein was not detected in samples collected from the downstream manhole MH-4A. This suggests that either dilution in MH-4A reduced Fluorescein to below method detection limits, and/or the tracer is lost via exfiltration from piping between MH-4 and MH-4A. This loss (if it occurs) in conjunction with flow in the canal backfill, could explain the Fluorescein observed in MW-37. Available data are not adequate to fully address this issue. In any event, the test further demonstrates the need to account for the Tritium being transported in the IP2-VC Curtain Drain (see **Section 7.6**).
- In reviewing data, note that the tracer concentrations in MH-6 are lower than the concentrations observed in MH-5 (peak in MH-6 of 14.4 ppb as opposed to a peak in MH-5 of 43.1 ppb). We attribute the concentrations in MH-6 to groundwater infiltration in the area of the identified tracer plume. Also note the flow from MH-6 is to MH-5.

Fluorescein was also detected in the IP1-NCD, the IP1-SFDS, and the Containment Spray Sump (CSS). We have attributed the presence of tracer at these locations to unsaturated zone migration to the vicinity and West of MW-42. The concentration and arrival times at these three locations are not easily explained but, taken as a whole, are consistent with the observed migration of Tritium.

Fluorescein was detected at low concentrations, at various times, in carbon samples collected from the cooling water Discharge Canal. Because of the substantial dilution in the canal, the extended release of tracer to the canal and the low concentrations of tracer found in the samples, we believe these data represent background conditions[58], and cannot be used to evaluate the tracer test.

7.6 MAJOR FINDINGS

As an overview, the tracer test, supports our CSM and the observed distribution of contaminated groundwater. GZA also concludes that:

- Unsaturated zone flow is important to the migration of contaminants released above the water table in the vicinity of Unit 2. Bedrock fractures induce this flow to the South and East of the release.
- There is significant storage of contaminated groundwater above the water table or in zones of low hydraulic conductivity (homogeneities) in the saturated zone. These features allow a long-lived release of contaminants to the Site groundwater flow field.
- Observed tracer migration rates are lower than calculated theoretical migration rates. As a practical matter, this "migration" indicates that the use of the estimated average hydraulic conductivity (0.27 ft/day or 1×10^{-4} cm/sec) will overestimate the volume of groundwater migrating through a given area. That is, we attribute the lower transport velocity to be due, in part, to a lower average hydraulic conductivity.
- In our opinion, the tracer test, in conjunction with the Tritium release, indicates that the existing network of monitoring wells can be used to monitor groundwater at IPEC.

[58] It is noted that Fluorescein is the primary colorant in automobile coolant anti-freeze. Therefore, leaks from cars to parking lot/road surfaces can impact surface water bodies via storm drain systems and/or direct runoff. Fluorescein was detected in the Discharge Canal prior to initiation of the tracer injection, further indicating its presence as background.

8.0 CONTAMINANT SOURCES AND RELEASE MECHANISMS

GZA conducted a review of available construction drawings, aerial photographs, prior reports, and documented releases, and interviewed Entergy personnel to assess potential contaminant sources. The primary[59] radiological sources identified were the Unit 2 Spent Fuel Pool (IP2-SFP) located in the Unit 2 Fuel Storage Building (IP2-FSB) and the Unit 1 Fuel Pool Complex (IP1-SFPs)[60] in the Unit 1 Fuel Handling Building (IP1-FHB. These two distinct sources are responsible for the Unit 2 plume and the Unit 1 plume, respectively.

No release was identified in the Unit 3 area. The absence of Unit 3 sources is attributed to the design upgrades incorporated in the more recently constructed IP3-SFP. These upgrades include a stainless steel liner (consistent with Unit 2 but not included in the Unit 1 design) and an additional, secondary leak detection drain system not included in the Unit 2 design.

The identified specific source mechanisms associated with the IP2-SFP and the IP1-SFPs are discussed in the following sections. We have segregated this source discussion based on primary contaminant type; those classified as primarily Tritium sources, as associated with the Unit 2 plume, and those classified as primarily Strontium sources, as associated with the Unit 1 plume. While the groundwater plumes emanating from their respective source areas can clearly be characterized using each plume's primary constituent, radionuclides other than Tritium and Strontium also exist to a limited extent and are fully addressed within the context of the Unit 2 and Unit 1 plume discussions[61].

Discussion of the two primary source types will be parsed further as follows:

- The Unit 2 (Tritium) plume source analyses will be split into: 1) "direct sources" defined as releases to the exterior of Systems Structures and Components (SSCs); and 2) "indirect storage sources" related to natural hydrogeologic mechanisms in the unsaturated zone (such as adsorption and dead-end fractures) and potential anthropogenic contaminant retention mechanisms (such as certain subsurface foundation construction details);
- The Unit 1 (Strontium) plume source analyses will be split into the mechanisms specific to the individual plume flow paths identified.

---

[59] In addition to sources that directly impact groundwater, atmospheric deposition from permitted air discharges was also identified as a potential source of diffuse, low level Tritium impact to the groundwater.

[60] All of the pools in the IP1-SFPs contained radionuclides in the past. However, only the West pool currently contains any remaining fuel rods and all of the other IP1 pools have been drained of water. It is also noted that the Unit 1 West pool has been undergoing increased processing to significantly reduce the amount of radioactive material in the pools. Once fuel is removed, the IP1-SFPs will no longer constitute an active source of groundwater contamination.

[61] Contaminants associated with the Unit 2 leak were found to be essentially comprised of Tritium. The Unit 1 plume is comprised primarily of Strontium, but also includes Tritium and sporadic observation of Cesium-137, Nickel-63 and Cobalt-60 at low levels in some wells downgradient of the IP1-SFP (see **Figure 8.3**). Entergy accounts for all radionuclides that can be expected to reach the river in their required regulatory reporting of estimated dose impact.

8.1 UNIT 2 SOURCE AREA

The majority of the Tritium detected in the groundwater at the Site was traced to IP2-SFP. This pool contains water with maximum Tritium concentrations of up to 40,000,000 pCi/L[62].

The highest Tritium levels measured in groundwater (up to 601,000 pCi/L[63]) were detected early in the investigation at MW-30. This location is immediately adjacent to IP2-SFP and directly below the 2005 shrinkage cracks. As shown on **Figure 8.1**, the Tritium contamination ("the plume[64]") then tracks with downgradient groundwater flow[65] through the Unit 2 Transformer Yard, under the Discharge Canal and discharges to the river[66] between the Unit 2 and Unit 1 intake structures. During review of the following sections, it is important to recognize that only small quantities of pool leakage (on the order of liters/day) will result in the Tritium groundwater plume observed on the Site.

---

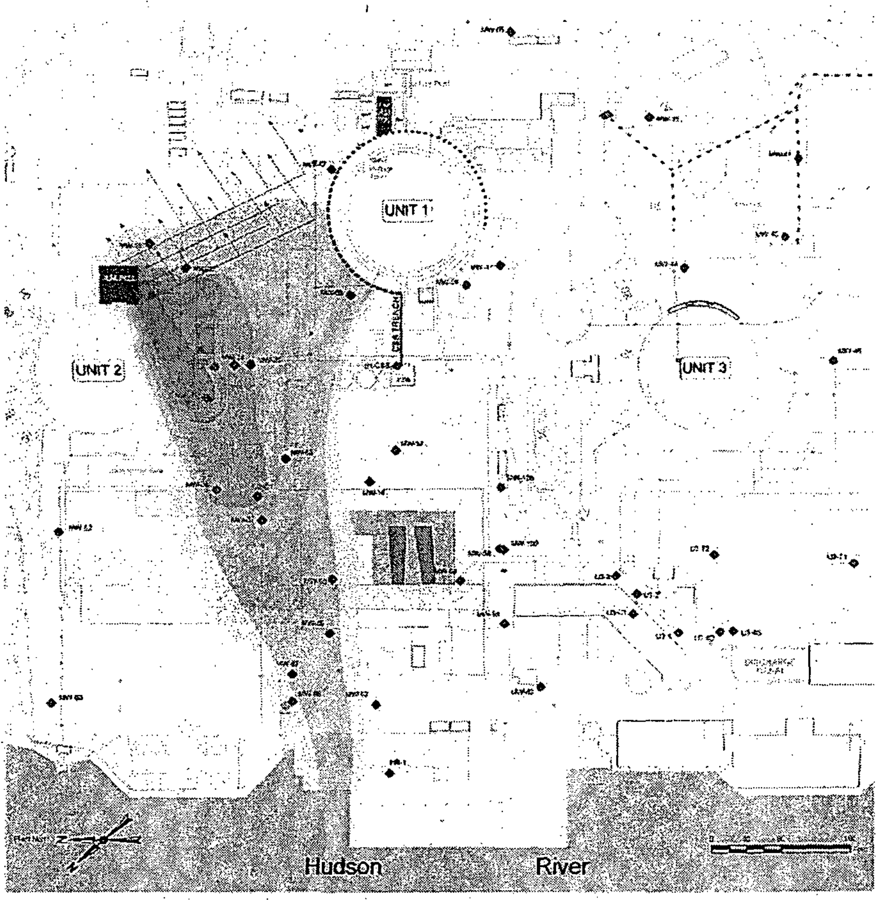
62 In contrast, the levels of Tritium in the Unit 1 West pool are only on the order of 250,000 pCi/L. Strontium concentrations in IP2-SFP are on the order of 500 pCi/L.

63 The 601,000 pCi/L Tritium concentration was measured during packer testing of the open borehole prior to multi-level completion. This value is therefore actually a *lower bound* estimate for depth-specific Tritium concentrations at that time. If the multi-level sampling instrumentation could have been completed prior to obtaining these data (not possible because the packer testing was required to design the multi-level installation), samples would have yielded *equal or higher concentrations*. This conclusion reflects the limited standard length and temporary emplacement of the packers used during the packer testing, and thus the greater potential for mixing and dilution between zones, as compared to the numerous packers permanently installed in the multi-level completions.

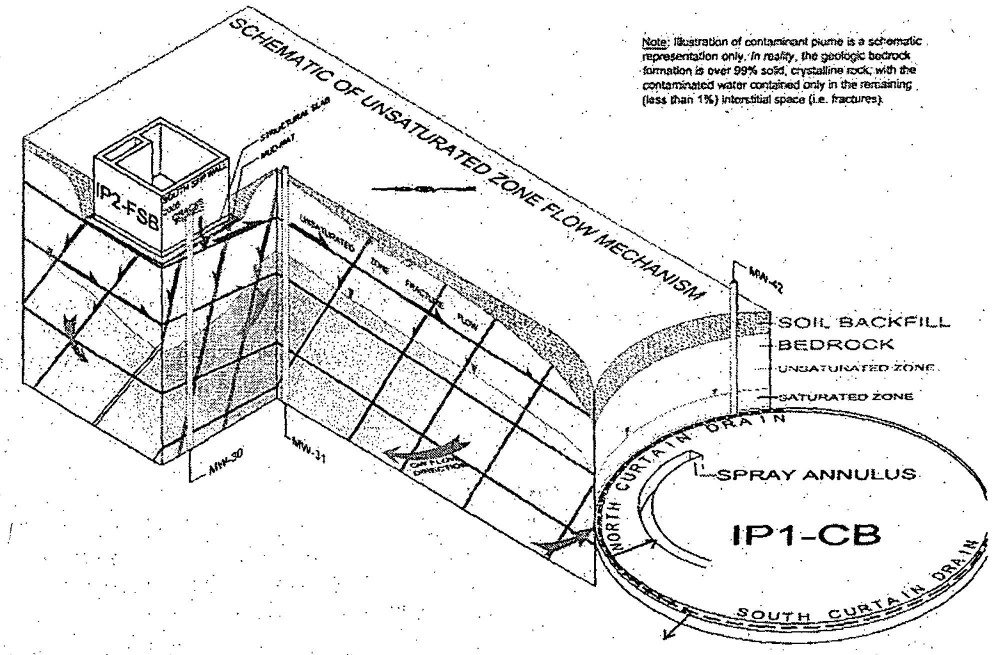
64 It is noted that **Figure 8.1** does *not* show an actual Tritium plume; the isopleths presented contour upper bound concentrations for samples taken at *any time* and *any depth* at a particular location, rather than a 3-dimensional snapshot of concentrations at a single time. As such, this "plume" is an overstatement of the contaminant levels existing at any time. It should also be noted that the lightest colored contour interval begins at one-quarter the USEPA drinking water standard. While drinking water standards do not apply to the Site (there are no drinking water wells on or proximate to the Site), they do provide a recognized, and highly conservative, benchmark for comparison purposes). Lower, but positive detections outside the colored contours are shown as colored data blocks. See figure for additional notes.

65 It is recognized that low concentrations of Tritium likely extend to the South, all the way to Unit 1. This conclusion is supported by: 1) the low Tritium concentrations remaining in IP1-SFPs (250,000pCi/L); 2) the data from MW-42 and MW-53; and 3) the Tritium balance between that released by the IP1-SFPs leak and that collected by the NCD. The transport mechanism is through *unsaturated* zone flow which follows bedrock fracture strike/dip directions rather than groundwater flow direction (see schematic of unsaturated zone flow mechanism included below). The levels of Tritium detected *upgradient* of IP2-SFP in monitoring wells MW-31 and MW-32 are also due to unsaturated zone transport from IP2-SFP along the generally southerly striking and easterly dipping bedrock fractures (see structural geology analysis in **Section 6.0** and tracer test discussions in **Section 7.0**).

66 As the Tritium moves under the Discharge Canal, a significant amount discharges directly to the canal before the plume reaches the Hudson River.



UNIT 2 BOUNDING ACTIVITY ISOPLETHS



IP2-SFP UNSATURATED ZONE FLOW MECHANISM

The IP2-SFP contains both the fuel pool itself as well as its integral Transfer Canal. IP2-SFP is founded directly on bedrock which was excavated to elevation 51.6 feet for construction of this structure. As such, this pool's concrete bottom slab is located approximately 40 feet above the groundwater (as measured directly below the pool in MW-30[67]). During construction, a grid of steel "T-beams" was embedded in the interior surface of the 4-to 6-foot-thick concrete pool walls. These T-beams provided linear weld points for the 6 by 20 foot stainless steel liner plates. Given this construction method, an interstitial space exists between the back of the ¼-inch-thick stainless steel pool liner and the concrete walls. The space is expected to be irregular[68] and its exact width is unknown, but nominal estimates of a $^1/_8$ to ¼ inch are not unreasonable for assessing potential interstitial volume. Using these estimates, the volume of the space behind the liner could be on the order of 1500 gallons. In addition, the degree of interconnection between the spaces behind the individual liner plates is also expected to be highly variable given the likely variability of weld penetration into the "T beams." Therefore, the travel path for pool water that may penetrate through a leak in the liner is likely to be highly circuitous.

8.1.1 Direct Tritium Sources

Two confirmed leaks in the IP2-SFP *liner* have been documented, as well as the 2005 shrinkage crack leak through the IP2-SFP concrete wall[69]. The first liner leak dates back to the 1990 time frame, under prior ownership. This legacy leak was discovered and repaired in 1992. With the more recent discovery of the concrete shrinkage cracks in September 2005, Entergy undertook an extensive investigation of the IP2-SFP liner integrity. Within areas accessible to investigation, no additional leaks were found in the liner of the pool itself. However, after draining of the IP2-SFP Transfer Canal in 2007 for further liner investigations specific to the Transfer Canal, a single small weld imperfection was detected in one of these liner plate welds. This was the only leak identified in the Transfer Canal where the entire surface and all the welds could be and were inspected. This second liner leak is expected to have released tritiated pool water into the interstitial space behind this area of the liner plates whenever the Transfer Canal was filled above the depth of the imperfection (the Transfer Canal is currently drained and this imperfection will be welded leak-tight prior to refilling the Transfer Canal). All identified leaks have therefore been terminated. While additional active leaks can not be completely ruled out, if they exist, the data[70] indicate they must be very small and of little impact to the groundwater[71].

---

[67] While similar and lower groundwater elevations persist downgradient to the West, the shallow groundwater elevations are much higher (up to approximately elev. 45 feet) within only 50 feet to the East (MW-31) and Southeast (MW-32) of the pool.

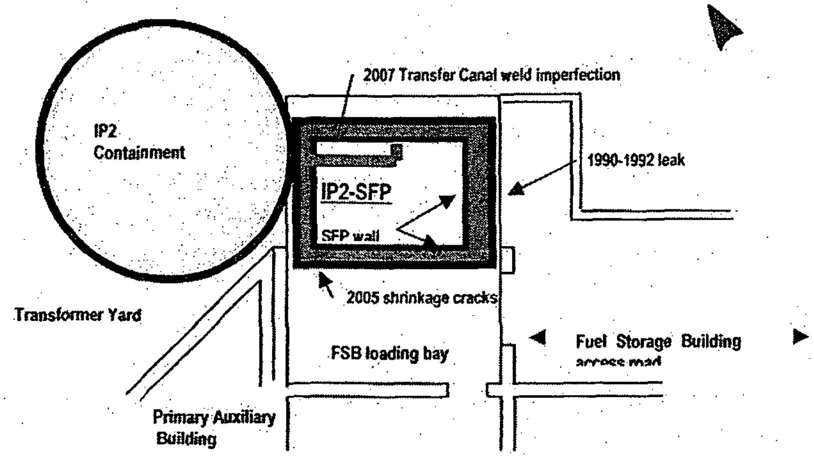
[68] The interstitial space width and uniformity will be related to the degree to which the concrete wall surface falls within a single plane. Because of the practicalities of forming and pouring concrete walls, we believe the surface is unlikely to be planer.

[69] While the 2005 leak from the shrinkage cracks does not appear to be related to a specific leak in the pool liner, it is considered a "direct source" because it still resulted in a release to the exterior of one of the plant's SSCs.

[70] These data include: monitored water levels in the SFP, with variations accounted for based on refilling and evaporation volumes; the mass of Tritium migrating with groundwater is small; and the age of the water in the interstitial space.

[71] For example, the 2005 shrinkage cracks still intermittently release small amounts of water, on the order of 10 to 20 ml/day. This water could represent a transient active leak, or it may just be due to residual water trapped behind the liner plates above the 2005 crack elevation still working its way slowly to the cracks. While this water is contained and prevented from reaching the groundwater, other such small leaks may exist which do reach the groundwater.

The three identified direct sources are discussed individually in the following paragraphs and shown on the figure below.



UNIT 2 FUEL POOL DIRECT SOURCE LOCATIONS

<u>IP2-SFP 1990-1992 Legacy Liner Leak</u> – This leak was first documented on May 7, 1992 when a small area of white radioactive precipitate was discovered above the ground surface on the outside of the IP2-SFP East concrete wall. This boron deposit exhibited radiological characteristics consistent with a potential leak from the pool. A camera survey was then conducted within the IP2-SFP to identify the location of the associated leak(s) in the liner. The survey initially revealed no damage to the liner. However, to further investigatory efforts, divers were utilized to visually inspect accessible portions of the liner. The divers found indications that the liner had been gouged when an internal rack had been removed on October 1, 1990. Two hundred and forty linear feet of the North and West IP2-SFP wall welds were then inspected and vacuum-tested to verify that the identified damage was isolated to this one case. No other leaks were identified, and on June 9, 1992, the leak was repaired.

Subsequent analyses conducted by the previous plant owner indicate that approximately 50 gallons per day could have leaked through the liner. This leak rate and the time scale of the release event would be expected to fill all the accessible interstitial space behind the liner[72]. Once the space behind the liner was filled to elevation 85 feet (the elevation of the 1990 cracks), water then began to leak out of the cracks in the concrete wall, with a maximum total release volume of up to 50,000 gallons. Given the very slow release rate (0.035 gal/min), the porous, hydrophilic nature of concrete, and the location of the leak at approximately five feet above the ground surface, a significant portion of the released water likely evaporated prior to entering the soils. However, given that the soils

[72] While the interstitial space was filling up to elevation 85 feet, any other cracks or joints in the concrete wall below this elevation, such as those identified in 2005, likely released contaminated water to the environment. As discussed below, it is hypothesized that with time, these subsurface cracks/joints may have become sealed due to precipitation of dissolved compounds, either carried with the pool water or derived from the concrete pool wall. This would have been required to allow retention of pool water in the interstitial space below elevation 85 feet after the liner leak was repaired in 1992, and thus subsequent leakage of the 2005 shrinkage cracks.

below the leak were found to be contaminated[73], it is clear that some portion of this release entered the subsurface. While Strontium and Cesium could have largely partitioned out of the pool water to the shallow soils, tritiated water would be expected to have continued to migrate downward to the groundwater.

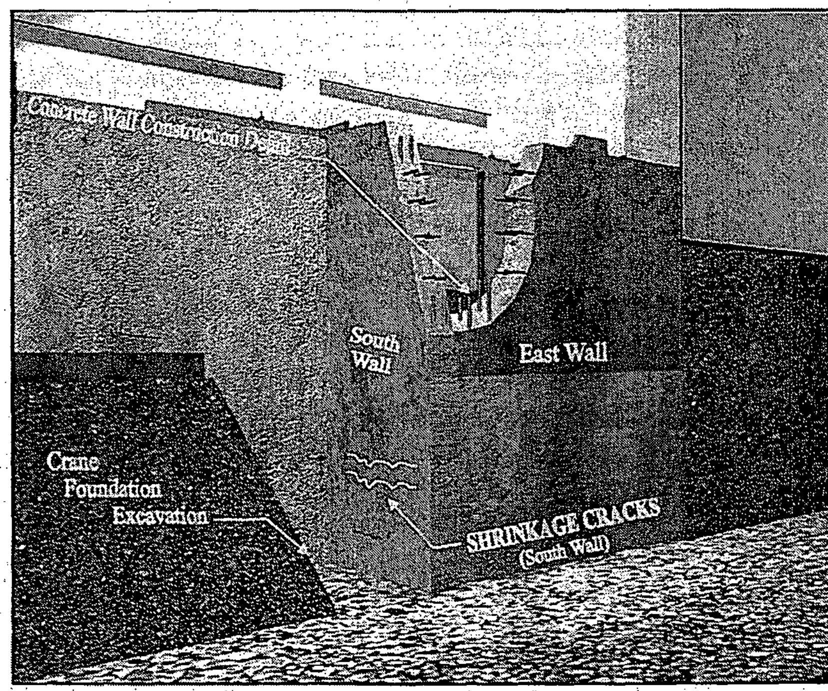
IP2-SFP 2007 Transfer Canal Liner Weld Imperfection – As part of the recently completed liner inspections initiated by Entergy in 2005, the IP2-SFP Transfer Canal was drained in 2007 to facilitate further leak-detection efforts including vacuum box testing of the welds. These inspections discovered a single small imperfection in one of the liner plate welds on the North wall of the Transfer Canal at a depth of about 25 feet, which is approximately 15 feet above the bottom of the pool. All of the welds and the entire liner surface area of the Transfer Canal have been inspected by one or more techniques and no other leaks were found. Engineering assessments indicate this wall imperfection is likely from the original construction activity since there is no evidence of an ongoing degradation mechanism.

Given that the Transfer Canal is now drained, this weld imperfection is no longer an active leak site. However, the historic practice of maintaining water in the Transfer Canal likely resulted in a generally continuous release of pool water into the interstitial space behind the liner over time, and then potentially through the concrete pool walls and into the groundwater.

IP2-SFP 2005 Concrete Shrinkage Crack Leak - During construction excavation in September 2005 for the dry cask storage project, the South wall of the IP2-SFP was exposed and two horizontal "hairline" shrinkage cracks were discovered (see schematic below). These cracks exhibited signs of moisture, though fluid flow was not observed emanating from the cracks. To promote collection of adequate liquid volumes for sampling and analysis, the cracks were subsequently covered with a plastic membrane to retard moisture evaporation and enhance water vapor condensation. The trapped fluid was drained to a sample collection container. This temporary collection effort not only provided leak rate measurement capability and sufficient water for analysis, it also prevented further release to the groundwater.

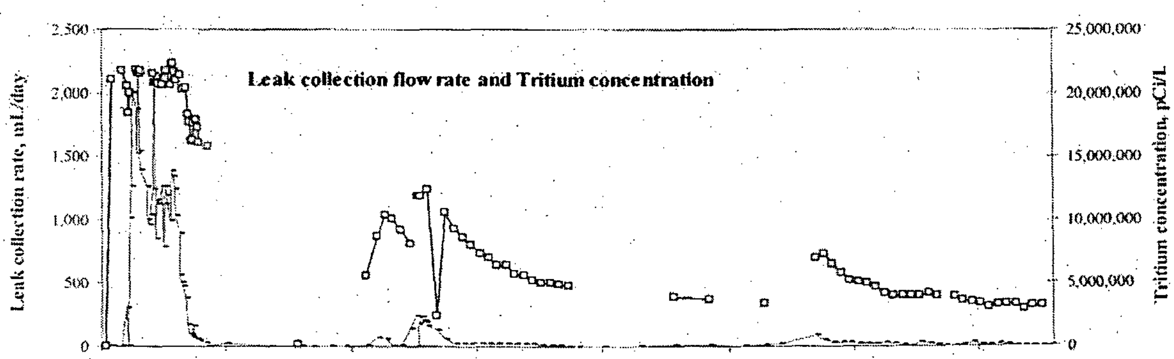
---

[73] Approximately 30 cubic yards of radionuclide contaminated soils were excavated from the area in 1992.



UNIT 2 SFP 2005 SHRINKAGE CRACKS IDENTIFIED IN SEPTEMBER 2005

Initially, the two cracks were found to be leaking at a combined average rate typically as high as 1.5 l/day (peak of about 2 l/day) from the time of crack discovery/initial containment through the fall of 2005. In early 2006, a permanent stainless steel leak containment and collection device was installed. This containment was also piped to a permanent collection point such that any future leakage from the crack could be monitored and prevented from reaching the groundwater. Subsequent monitoring through 2006 and into 2007 has indicated that the leakage rate had fallen off rapidly and become intermittent with an average flow rate of approximately 0.02 l/day, when flowing (see figure below presenting shrinkage crack flow rate and Tritium concentration over time). This small amount of leakage is permanently being contained and it therefore is not impacting the groundwater.



UNIT 2 2005 SHRINKAGE CRACK LEAK RATE AND TRITIUM LEVELS

Based upon two years of flow and radiological and chemical sample data, it appears that excavation of the backfill from behind the pool wall caused the shrinkage cracks to begin releasing water trapped in the interstitial space dating back to 1992. This release mechanism is hypothesized to have developed as follows:

- During the original construction, the fuel pool walls developed shrinkage cracks in the concrete upon curing, as is not atypical for concrete.
- When the pool walls were backfilled with soil, they flexed inward slightly in response to the soil pressures developed during backfill placement and compaction[74].
- The pool was then filled with water which exerts an outward pressure against the walls. However, little outward flexure would be expected given the stiffness of the compacted soil backfill, which assists the concrete walls in resisting outward bending motion due to the water pressure.
- The stainless steel pool liner was punctured in 1990 and began leaking. Over time, this leak filled the interstitial space between the liner and the concrete walls. tritiated pool water then likely first leaked out of the lower-most cracks/joints, such as those responsible for the 2005 leak (elevation 62 to 64 feet), and successively leaked out of higher imperfections until it reached the cracks at elevation 85 feet. At this point, leakage was detected and the leak was fixed in 1992.
- At some point during the leakage, the subsurface cracks apparently became plugged with precipitate which stopped the leakage. This allowed pool water to remain trapped behind the liner at an elevation above the 2005 shrinkage cracks, potentially as high as elevation 85 feet. To the extent that the subsurface cracks/joints in the concrete did not all become completely leak-tight, the interstitial space behind the liner was likely recharged by leakage from the Transfer Canal weld imperfection (up until Transfer Canal drainage in July 2007) and/or other small leak sites in the liner.
- With excavation of the soil backfill from behind the southern pool wall, the pressure exerted by the backfill material was sequentially removed from the top to the base of the concrete wall. The elimination of this inwardly focused backfill pressure allowed the outwardly directed water pressure in the pool to flex the wall outward. It is hypothesized that this motion, while limited, was sufficient to initiate leakage from the 2005 shrinkage cracks at a rate of approximately 1.5 l/day during the fall/winter of 2005.
- The released water is believed to be primarily residual water derived from the 1990-1992 liner leak. However, laboratory results for water samples initially collected from the crack in the September 2005 time frame yielded Cesium-137 to Cesium-134 ratios indicating that the age of the water was approximately 4 to 9 years old. This age does not directly correlate with the 1990-1992 release timeframe. Conversely, the water clearly had exited the pool many years ago. A potential explanation for this intermediate age water is the mixing of water from a then-current small leak in the liner with 1992 age water.
- Over time, the shrinkage crack leak reduced the elevation of the residual water trapped behind the liner to the elevation of the cracks. Beginning in 2006 and through 2007, the leak rate was observed to have quickly become intermittent with typical leak rates, when leaking, of only approximately 0.02 l/day. These

[74] While the 4-to 6-foot-thick concrete walls are stiff, some flexure is required for the walls to develop bending stresses.

subsequent water samples did not contain Cesium-134, indicating that this more recent crack water could, in fact, be old enough to be from the 1990-1992 leak[75].

- As a corollary to the above conceptual model, the intermediate-aged crack water may be partially comprised of leakage from the Transfer Canal weld imperfection. This release pathway could potentially explain the measured intermittent and variable leakage collected in the permanent containment system after 2005. The variations in water elevation and temperature in the Transfer Canal are consistent with this hypothesis. While the Transfer Canal leak water would be recent, it is likely that it would take a substantial amount of time to flow from the North wall of the Transfer Canal to the South wall of the IP2-SFP[76]. This hypothesis is therefore consistent with the lack of short-lived isotopes (as associated with SFP water) currently being found in the water from the shrinkage crack. A more significant leak rate with shorter transit times (e.g., the magnitude of the 1990-92 leak) would be expected to, and did previously show, short-lived radionuclide signatures.
- Although several additional theories have also been postulated and investigated, a definitive explanation of the apparent discrepancy in Cesium age ratios could not be definitively determined. This discrepancy from the early sample data when the crack location was first investigated was an important factor in Entergy's decision to perform intensive pool and ongoing Transfer Canal liner inspections.
- It can also be concluded from the above data and analysis that any ongoing active leak in the pool liner, if one exists, must be quite small. Otherwise, the limited volume of the interstitial space between the liner and the concrete wall would transport a more substantial leak to the shrinkage cracks in a short time and the water would thus show a young age[77].

8.1.2 Indirect Storage Sources of Tritium

The extensive testing of the IP2-SFP liners to date by Entergy provides evidence that all <u>direct sources</u> (i.e., releases from SSCs) of Tritium have been identified and are currently no longer contributing radionuclides to the groundwater[78]. However, the Unit 2 plume, while decreased in concentration relative to the samples taken just after

---

[75] Cesium-137 was present at sufficient concentrations that if the water was "young", Cesium-134 would have also been present at concentrations above method detection limits. It is further noted that the two isotopes of Cesium should partition to solids at the same ratios. Therefore, preferential removal of the Cesium-134 due to partitioning to the concrete is not an explanation for the lack of this isotope in the more recent crack water samples.

[76] It is noted that the seepage path(s) from the liner leak on the North wall of the Transfer Canal to the shrinkage cracks on the southern pool wall is likely to be particularly circuitous. The interstitial space between these two liners can only be connected (if they are connected at all) at the gate from the Transfer Canal to the fuel pool and/or through imperfections in the concrete wall/floor waterstops or in the concrete itself (given the five-foot-thick concrete wall separating the Transfer Canal from the SFP itself).

[77] As a benchmark, pool water from a one-tenth of a gallon per minute leak would be expected to reach the shrinkage crack in less than two weeks given the estimated volume of the interstitial space.

[78] However, some <u>small</u> amount of leakage could still be ongoing from other potential imperfections in the liner and/or concrete pool wall; large ongoing leaks would result in conditions inconsistent with the measurements of both leak rate and water age collected from the 2005 shrinkage crack. A large leak would also be inconsistent with the reductions observed in the Tritium concentrations in the groundwater.

identification of the 2005 shrinkage crack leak[79], still exhibits elevated concentrations. If all of the releases to the groundwater were terminated, it would be expected that the Unit 2 plume would attenuate more quickly than observed[80]. As such, a subsurface mechanism appears to exist in the unsaturated zone under the IP2-FSP that can retain substantial volumes of pool water for substantial amounts of time. The existence of such a "retention mechanism" is also supported by both the results of the tracer test and the recent evaluation of contaminant concentration variability trends over short timeframes and precipitation events.

The tracer test results, discussed more fully in **Section 7.0**, indicate that:

- Tracer injection directly to the top of bedrock below the IP2-SFP above MW-30 did not result in arrivals at MW-30 in time frames expected for vertical transport through the fractured bedrock vadose (i.e., unsaturated) zone. In fact, the earliest arrivals and maximum tracer concentrations were detected in MW-31 and MW-32 at distances of greater than 50 feet from the injection location;
- Tracer concentrations in MW-30 took longer than expected to reach peak concentrations from the time of first arrival;
- The tracer concentration vs. time curves exhibit a "long tail;" and
- The tracer concentrations exhibit significant variation over short periods of time, which may be related to precipitation events moving tracer out of storage.

It is, therefore, apparent that once tracer, and thus tritiated water, is released from directly below the IP2-SFP, it does not flow directly down to the groundwater but can be "trapped" (held in storage) for substantial periods of time.

The Tritium concentrations in MW-30 were measured on a weekly basis between August 8 and August 30, 2007 (see **Section 9.3.1**). These data show significant variability in concentrations over these short timeframes. This variability appears to far exceed that which can be attributed to variation inherent in groundwater sampling or radionuclide analyses. Aliquots submitted for tracer concentration testing also showed similar trends. It appears that these variations may be the result of the displacement of water, as evidenced by both tracer and Tritium, from this storage mechanism by infiltration such as associated with precipitation events.

Based on the above summarized information, two indirect storage mechanisms are postulated to explain the persistence of the Unit 2 plume. The first is the storage of tritiated water in dead-end fractures in the unsaturated zone. The second is the potential for tritiated water from the SFP to be trapped in the blast-rock backfill above the "mud-mat[81]"

---

[79] The earliest samples taken from directly below the SFP in MW-30 (open borehole and packer testing samples) yielded Tritium concentrations over 600,000 pCi/L. More currently, maximum concentrations detected have been below one-half of those initial concentrations.

[80] Rapid attenuation of the Tritium plume would be expected based on 1) Tritium's lack of partitioning to solid materials in the subsurface; and 2) the crystalline nature, low storativity and high groundwater gradients associated with the bedrock on the Site.

[81] Prior to constructing a structural base slab (typically 2 to 5 feet thick) for the fuel pool, a 6-to 8-inch-thick, lean concrete "mud-mat" is typically constructed over blasted bedrock to even out the irregular rock surface and provide a

which was placed prior to construction of the SFP structural base slab. A combination of these two indirect storage mechanisms, as discussed separately below, is a conceptual model that explains the observed Unit 2 plume behavior in the context of the termination of the identified direct release mechanisms[82].

Dead-Ended Bedrock Fracture Storage - Naturally occurring bedrock fractures, as discussed in **Section 6.0,** are seldom long, continuous linear features. Rather, they are more typically networks of interconnected, discontinuous fractures. These networks often contain many dead-ended fractures. While dead-ended fractures are not subject to advective groundwater flow, they still can contain high contaminant concentrations. Contaminants enter these fractures through osmotic pressures set up in the subsurface by concentration gradients (initially high concentrations at the fracture "mouth" and low concentrations within the fracture). Over time, these concentrations equilibrate through liquid-phase diffusion. Therefore, under conditions of high Tritium groundwater concentrations, such as likely occurred during the two year timeframe of the 1990-1992 liner leak, the dead-ended fractures would be expected to end up containing high Tritium concentrations. Once the liner leak was repaired, the input of Tritium to the groundwater would subside and the concentrations in the advective fractures would start to decrease. However, the high Tritium concentrations within the dead-ended fractures would then start to diffuse back out of the dead-ended fractures into the groundwater flowing past them, thus maintaining higher than otherwise expected Tritium concentrations in the groundwater.

Our computation of the volume of the naturally occurring dead-ended fractures in the unsaturated zone below the IP2-SFP yields fracture volumes which are unlikely to support the observed Unit 2 plume for the required time frames (years). However, two additional considerations substantially increase the dead-ended fracture volume: 1) the observed unsaturated flow to the East and Southeast (this migration pathway exposes many more fractures to the Tritium due to the bigger area involved); and 2) construction blasting (which creates more fractures in the bedrock remaining below the structure).

As demonstrated vividly during the tracer test, contaminants released to the bedrock at the bottom of the SFP travel at least 50 to 75 feet to the East and Southeast as evidenced by the high tracer concentrations quickly detected in the upgradient monitoring wells

---

hard, flat surface upon which to set the reinforcing rod "chairs" (these chairs elevate the lowest layer of rods to provide sufficient concrete corrosion prevention cover).

[82] It is noted that we originally believed that the groundwater in the Unit 2 Transformer Yard was uncontaminated with Tritium prior to February of 2000. If true, this finding would be inconsistent with the storage mechanisms proposed. Our original conclusion was based on the sampling results at that time from MW-111; this well was sampled as part of the due diligence for property transfer to Entergy and was found not to contain Tritium above detection limits (900 pCi/L). However, interviews with facility personnel revealed that the sample was collected from the upper surface of the water table with a bailer. There was no attempt to purge the well to obtain samples representative of deeper aquifer water because the samples were taken primarily to look for floating oil in the well. Because this sample was collected from the upper groundwater surface (which will be most subject to infiltration by rain water) without adequate well purging, it is likely that this sample result was biased low. As discussed in **Section 9.0**, this well is subject to wide variations in Tritium concentrations due to rainfall events. Therefore, it is entirely plausible that no Tritium was detected above laboratory method detection limits even if Tritium were present at much higher concentrations deeper in the aquifer. As such, this February 2000 groundwater sample result should not be used to assess Tritium groundwater conditions at that time. See supporting data in **Section 9.3.1**.

MW-31 and MW-32[83]; the same behavior would be expected for Tritium. This wide areal distribution would substantially increase the volume of dead-ended fractures available for storage of contaminants.

In addition to naturally occurring fractures, the founding elevation of the SFP was achieved through construction blasting of the bedrock. While the bulk of the blasted rock was removed to allow construction, a zone of much more highly fractured bedrock typically remains after the founding elevation is reached. While these blast-induced fractures may be interconnected, they may not be fully connected to tectonic fractures that intersect the groundwater, and thus would be dead-ended. Therefore, contaminated water may be stored in these fractures and periodically escape in response to precipitation events.

Blast-Rock Backfill Storage - Following blasting of the bedrock to accommodate the IP2-SFP foundation, standard construction practice would have been to pour a mud-mat[84]. Based on construction photographs, it appears that the areal extent of the blasting was not much bigger than the dimensions of the structural slab for the SFP; this would be typical given standard contracting specifications and the cost of blasting. Therefore, it would be expected that the mud-mat was poured directly against the face of the bedrock excavation, without the use of forms. This hypothesis was confirmed visually during the 2005 excavation alongside the IP2-SFP for dry cask gantry crane foundation construction.

The concrete for a mud-mat is typically placed in a relatively fluid state to enhance self-leveling properties. As this fluid concrete is placed, it is typically pushed up against the perimeter forms, or in this case the bedrock face. This placement procedure would be expected to coat and seal off the fractures in the lower portion of the bedrock sidewalls. While the height above the surface of the mud-mat to which this seal would be formed is highly variable and occurrence-specific, it would not be unreasonable to find a 2-to 6-inch high "lip" of concrete against the bedrock. The net effect would have been to create storage volume above the mud-mat, between the sides of the subsequently constructed structural floor slab and the bedrock sidewalls directly at the base of the SFP. While this space was likely filled with blast-rock fill, the pore volume of this material available for pool water storage could easily be over 30 percent of the total volume. This results in a substantial storage volume when compared to that required to "feed" and maintain the Unit 2 plume over time.

During the 1990-1992 liner leak, a large volume of highly tritiated water appears to have been released from the pool, thereafter traveling down the exterior of the SFP concrete wall. This travel path would place the pool water directly into the hypothesized storage containment. Once full, additional pool water would overtop the containment, migrate into fractures that were not sealed off by concrete, and then travel through the unsaturated zone. Once in the unsaturated bedrock, some tritiated water would quickly

---

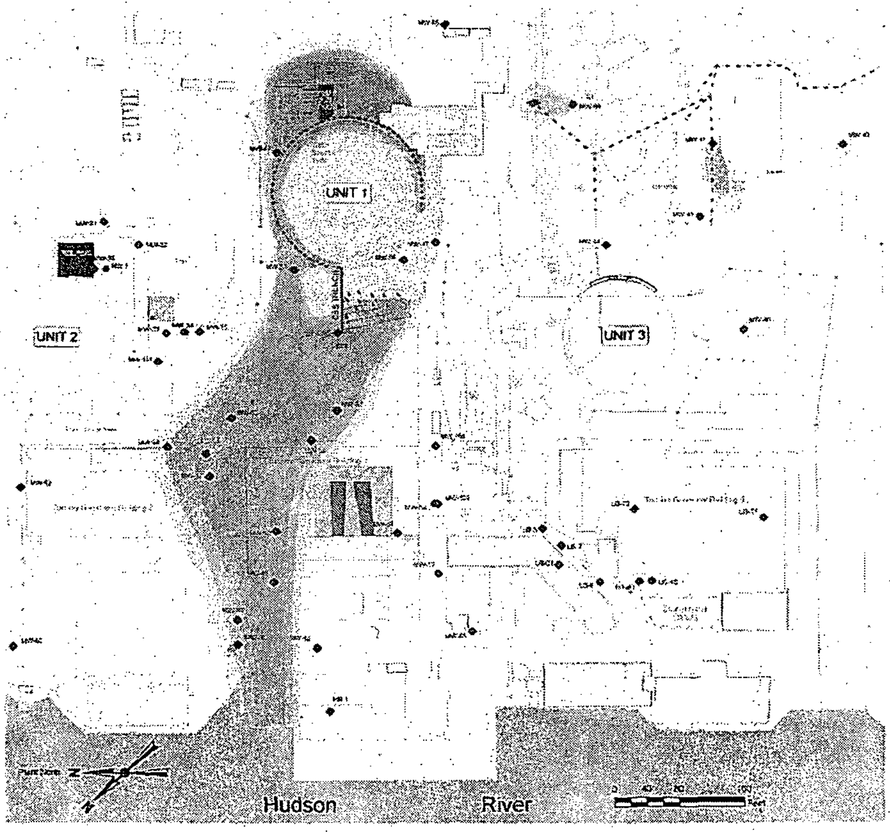
[83] Tracer reached MW-31 and MW-32 in less than four hours (time of first sample), thus supporting the conclusion of unsaturated zone transport to these locations.

[84] A 6-to 8-inch, lean concrete "mud-mat" is typically constructed over blasted bedrock to even out the irregular surface and provide a hard flat surface upon which to set the reinforcing rod "chairs" (these chairs elevate the lowest layer of rods to provide sufficient concrete cover for corrosion prevention).

reach the groundwater and some would be retained in dead-ended fractures, as discussed above. Over time, rainfall events would be expected to repeatedly displace pool water out of the containment and into the bedrock fractures. Contaminated water would therefore continue to impact the groundwater even if all active leaks from the pool were terminated. We believe this process could continue over substantial periods of time[85].

8.2 UNIT 1 SOURCE AREA

The Unit 1 contamination, as shown on **Figure 8.2** and the figure included below, is often referred to as the Strontium "plume"[86]. This is because the other radionuclides detected, including Tritium, Cesium-137, Nickel-63 and Cobalt-60, have a smaller radiological impact when compared to Strontium-90 and the Strontium is found in the entirety of the plume's areal extent, while the other contaminants are found only sporadically and in smaller subsets of the plume's area. The Tritium data for the Unit 1 plume is included on **Figure 8.1** and the Cesium-137, Nickel-63 and Cobalt-60 data are presented on **Figure 8.3**.



UNIT 1 BOUNDING ACTIVITY ISOPLETHS

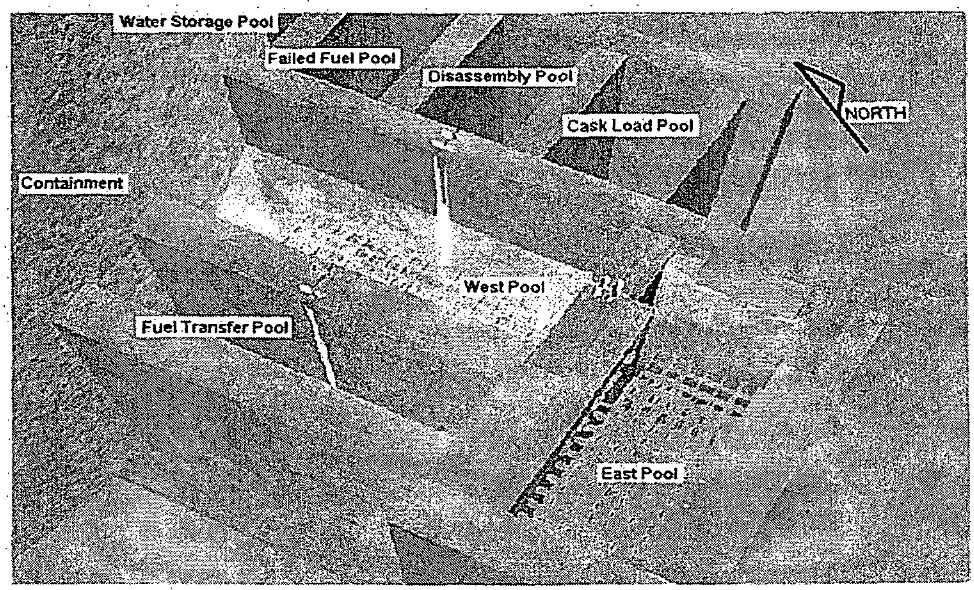
---

[85] See footnote No. 58 above relative to the reported Tritium results for MW-111 as sampled in May of 2000.

[86] It is noted that **Figure 8.2** does <u>not</u> show an actual Strontium plume; the isopleths presented contour upper bound concentrations for samples taken at *any time* and *any depth* at a particular location, rather than a 3-dimensional snapshot of concentrations at a single time. As such, this "plume" is an overstatement of the contaminant levels existing at any time. It should also be noted that the lightest colored contour interval begins at one-quarter the USEPA drinking water standard. While drinking water standards do not apply to the Site (there are no drinking water wells on or proximate to the Site), they do provide a recognized, and highly conservative benchmark for comparison purposes). Lower, but positive detections outside the colored contours are shown as colored data blocks. See figure for additional notes.

The highest levels of Strontium (up to 110 pCi/L) were originally found adjacent to the North side of IP1-SFPs in MW-42[87]. However, since Entergy began processing the pool water to remove the Strontium, the levels of Strontium (and other radionuclides) in this well have decreased. From MW-42, the Unit 1 "plume" tracks downgradient with the groundwater along the North side of the Unit 1 Superheater and Turbine Buildings[88]. As this plume approaches and moves under the Discharge Canal, it commingles with the Unit 2 plume, and discharges to the river[89] between the Units 1 and 2 intake structures, as does the Unit 2 plume. As discussed in **Section 6.0**, the plume track appears to follow a more fractured, higher conductivity preferential flow path in this area.

The source of all the Strontium contamination detected in groundwater beneath the Site has been established as the IP1-SFPs. The IP1-SFPs were identified by the prior owner as leaking in the mid-1990's, and are estimated to currently be leaking at a rate of up to 70 gallons/day. A schematic of this pool complex is included below.



UNIT 1 FUEL POOL COMPLEX

The IP1-SFPs were constructed of reinforced concrete with an internal low permeability coating[90]; stainless steel liners were not included in the design of these early fuel pools. The pool wall thickness ranges from 3 to 5.5 feet thick. The bottom of the IP1-SFPs is

[87] The highest concentrations of the other contaminants associated with the Unit 1 plume, including Cesium-137, Nickel-63 and Cobalt-60 were also found in well MW-42. This location is very close to the IP1-SFPs and it is therefore not unexpected to find these higher concentrations of less mobile radionuclides near the source.
[88] This general introductory discussion of the Unit 1 plume is focused specifically on the "primary Unit 1 plume." Further more detailed discussion of the other "secondary Unit 1 plumes," which all originate from the IP1-SFPs, is provided in subsequent subsections.
[89] As is the case with the Tritium from the Unit 2 plume, some Strontium discharges directly to the Discharge Canal before the plume reaches the Hudson River.
[90] The original coating failed and was subsequently removed.

founded directly on bedrock, generally at elevation 30 feet[91]. As such, there is no significant unsaturated zone below the IP1-SFPs. While all of the pools have been drained except the West Pool, the other pools have all contained radionuclide at various times in the past. The West pool, which is approximately 15 feet by 40 feet in area, currently contains the last 160 Unit 1 fuel assemblies remaining from prior plant operations. This plant was retired from service in 1974.

The IP1-SFPs are contained within the IP1-FHB. The foundation system of the FHB and IP1-CB complex contains three levels of subsurface footing drains (see figure included below). The design objective of these drains, with the potential exception of the Sphere Foundation Drain (SFD)[92], appears to be permanent depression of groundwater elevations to below the bottom of the structures[93].

North and South Curtain Drains - The uppermost IP1-FHB drain encircles the Unit 1 FHB and IP1-CB. This footing drain, typically referred to as the Curtain Drain, is divided into two sections, the North Curtain Drain (NCD) and the South Curtain Drain (SCD). Each of these drains starts at a common high point (elevation of 44 feet) located along the center of the eastern wall of the FHB. These drains then run to the North and South, respectively, and wrap around the Unit 1 FHB and CB. The NCD then discharges to the spray annulus in the IP1-CB[94] at an elevation of 33 feet. From the annulus, the water is pumped for treatment and then discharged. The NCD flows at a yearly average of about 5 gpm carrying a Strontium concentration of 50 to 200 pCi/L (concentrations measured prior to reductions in Unit 1 pool water radionuclides via accelerated demineralization). The SCD pipe remains as originally designed with discharge to the Discharge Canal; however, the SCD is typically dry[95].

Chemical Systems Building Drain - The lowest level of the IP1-CSB (contained within the FHB) is also encompassed by a footing drain. The eastern portion of this drain begins at a high point elevation of 22 feet at its northernmost extent, located proximate to the IP1-CB, and then slopes to elevation 11.5 feet at its low point on the southern side of the IP1-CSB. The western portion of this drain begins at a high point elevation of 12.5 feet at its northernmost extent, again located proximate to the IP1-CB, and then slopes to elevation 11.5 feet at its low point on the southern side of the IP1-CSB. Both portions of the drain join at the southern side of the IP1-CSB where the common drain line runs below the floor slab and drains into the IP1-SFDS (bottom elevation of 6.5 feet). This drain typically flows

---

[91] The bottom elevation of the individual pools range from a high elevation of 36 feet for the Water Storage Pool to a low of 22 feet for the Transfer Pool.

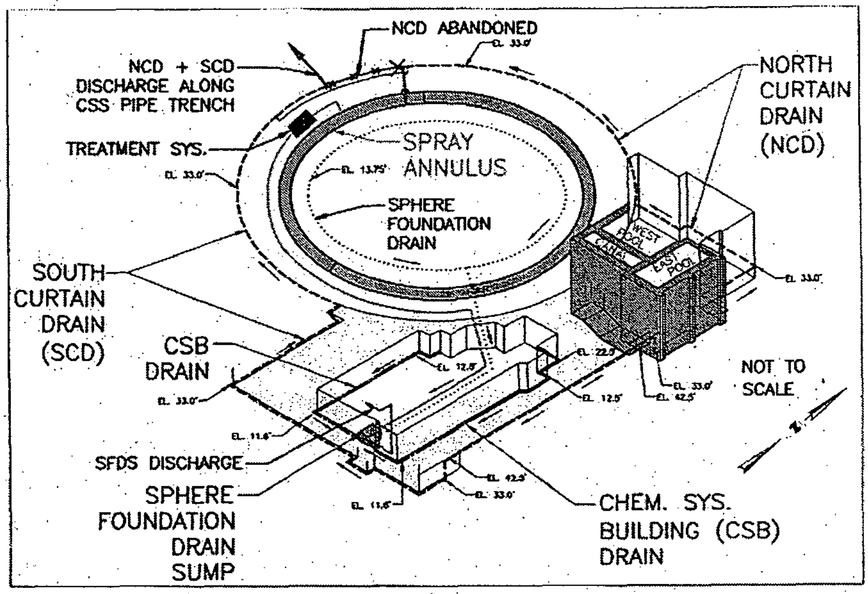
[92] The SFD is constructed at an elevation of 16.5 feet. It is above the bottom of the Sphere (elevation -11 feet) and completely encapsulated in either concrete or grout.

[93] The elimination of hydrostatic uplift pressures allows a "relieved design" to be used for the bottom concrete slabs of the structures. The alternative to a relieved slab design is a "boat slab design." In this case, the slab is heavily reinforced to resist hydrostatic uplift pressures. Boat slabs are more expensive to construct than relieved slabs, and thus are typically only used when it is not feasible to relieve the hydrostatic uplift pressures.

[94] This design modification within the IP1-CB, to allow storage of the footing drain water prior to treatment, was implemented by the former owner once the water was found to contain radionuclides. The initial Unit 1 design connected the two 12-foot perforated footing drain lines into a common 15-inch tee and drain pipe at the entrance to the Nuclear Service Building. This 15-inch footing drain pipe was collocated in the bedrock trench containing the spray annulus to CSS drain line.

[95] The lack of water in the SCD is consistent with the expected impact of the CSB drain given its proximity and lower elevation.

at a yearly average of 10 gpm carrying a Strontium concentration of not detected (ND) to 30 pCi/L.



UNIT 1 FOOTING DRAINS AND DISCHARGE SUMP

Sphere Foundation Drain - The third foundation drain below the IP1-FHB and IP1-CB complex is the SFD. This drain is located directly around the bottom portion of the Sphere and consists of: 1) nine perforated pipe risers spaced around the sphere and tied into a circumferential drain line at elevation 13.75 feet; 2) each vertical riser is surrounded by a graded crushed stone filter; and 3) all of which are within a clean washed sand which encompasses the Sphere from elevation 25 to 16.5 feet (the "sand cushion"). The sand cushion is "sandwiched" between the concrete foundation wall, the Sphere and the grout below the Sphere; it is open at the top, proximate to the annulus. As such, it appears that this drain does not interface with the groundwater, except to the extent that some leakage may occur through imperfections in joint seals. This drain is also connected to the SFDS through a valve.

During the development of the initial Conceptual Site Model, it was understood that the IP1-SFPs were currently leaking, but it was concluded that the footing drainage systems would contain any releases from the IP1-SFPs. This was also the conclusion of a previous analysis performed for the prior owner in 1994[96]. This conclusion was based on:

- The proximity of the drains to IP1-SFPs; in fact, the NCD runs along the North and East walls, and in conjunction with the SCD, completely encompasses the IP1-SFPs;
- The generally downgradient location of the drains relative to the IP1-SFPs;
- The elevation of the drains relative to the bottom of the IP1-SFPs;

---

[96] *Assessment of Groundwater Migration Pathways from Unit 1 Spent Fuel Pools at Indian Point Power Plant, Buchanan, NY*; The Whitman Companies, July 1994

- The elevation of the drains relative to the surrounding groundwater elevations[97];
- The continuous flow of the drains, even during dry periods; therefore, the groundwater surface does not drop below, and thus bypass, the drains;
- The reported predominant southerly strike and easterly dip of the bedrock fractures relative to the southerly location of the CSB footing drain; this expected anisotropy should extend the capture zone of this drain preferentially to the North towards the IP1-SFPs; and
- The existence of IP1-SFPs pool water constituents in the drain discharge[98].

In February 2006, Strontium was detected in the downgradient, westerly portion of the IP2-TY (downgradient of IP2-SFP). Given that Strontium could not reasonably be associated with a release from the Unit 2 SFP, the most plausible source remaining was the retired Unit 1 plant where: 1) the SFPs historically contained Strontium at approximately 200,000 pCi/L (prior to enhanced demineralization[99]); and 2) legacy leakage was known to be occurring. Based on this finding, we concluded that either: 1) an unidentified mechanism(s) must be transporting IP1-SFPs leakage beyond the capture zone of the footing drains[100]; or 2) other sources of Strontium existed on the Site. A number of plausible hypotheses potentially explaining each of these two scenarios were therefore developed, and then each was investigated further. During these investigations, additional detections of Strontium were also identified, including some relatively low concentrations in the area of Unit 3. However, with completion of the investigations and associated data analyses, it was concluded that *all of the Strontium detections could be traced back to leakage from the IP1-SFPs*. These Strontium detections can be grouped into five localized flow paths, each associated with a different IP1-SFPs release area. Collectively, these flow paths define the overall Unit 1 "plume[101]" as listed below:

- The primary IP1 flow path;
- The eastern IP1-CB flow path;
- The southwestern IP1-CB flow path;
- The IP1-CSS trench flow path; and
- The legacy IP1 storm drain flow path.

---

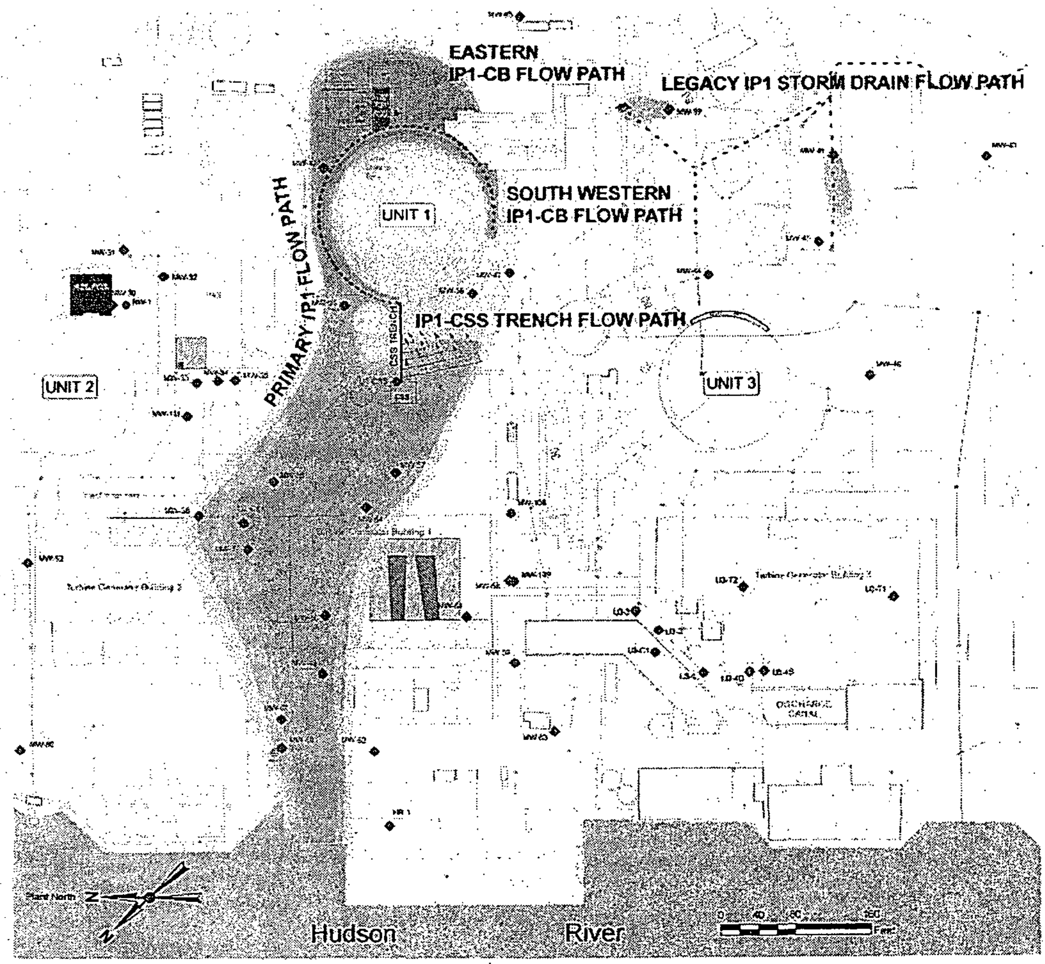
[97] This line of evidence remained supportive of the initial conclusion until the installation of MW-53, which occurred during the third phase of borings (after the discovery of Strontium in the groundwater).

[98] Drain water is treated prior to discharge as permitted monitored effluent.

[99] Strontium levels in IP1-SFPs have been more recently reduced to approximately 3,000 pCi/L under accelerated filtering through demineralization beds. Tritium concentrations in IP1-SFPs are on the order of 250,000 pCi/L.

[100] Once Strontium-contaminated pool leakage enters the groundwater, it is transported in the direction of groundwater flow; Strontium, as well as the other potential radionuclides, do not migrate in directions opposing groundwater flow (with the exception of diffusive flow which is insignificant as compared to advective flow under these hydrological conditions). Therefore leakage entering the groundwater within the capture zone of the footing drains is captured by those drains.

[101] The grouping of Strontium detections into contiguous "plumes" may be an over-simplification, and the detections may, in reality be due to small, isolated individual groundwater entry points and flow paths from the IP1-SFPs. This is likely to be particularly true pursuant to the IP1 Legacy Piping "flow path."



INDIVIDUAL UNIT 1 STRONTIUM FLOW PATH LOCATIONS

The discussions below are focused on the discovery and characterization of these individual flow paths, and the final mechanisms that best explain their existence. Other initially plausible mechanisms were also investigated as part of the Observational Method approach employed[102], but they did not remain plausible in light of the subsequently developed data and analyses, and are therefore not discussed herein. In addition, portions of the discussions below also relate to the concurrent investigation of other potential source areas across the Site. During review of the following sections, it is important to recognize that only small quantities of leakage are required to result in the groundwater plumes observed on the Site.

Primary IP1 Flow Path – Monitoring well MW-42 was initially installed to investigate the premise that contaminants may be leaking into the subsurface from the IP2-Reactor Water Storage Tank (RWST). However, the sample analysis made it clear that IP1-SFPs water was present in the groundwater at MW-42; the radiological profile was consistent with

---

[102] As indicated above, multiple initially plausible hypotheses potentially explaining the genesis of these flow paths were developed and investigated. These investigations proceeded in a step-wise, iterative manner consistent with the Observational Method, whereby various aspects of the Conceptual Site Model (CSM) were modified to develop an overall CSM that better fit all of the data. Not all mechanisms investigated remained plausible in light of all the data and analyses developed as part of this hypothesis-testing.

Unit 1 fuel pool water (low Tritium, high Strontium and Cesium). While IP1-SFPs leakage was known to be ongoing, this conclusion was *not* consistent with the CSM at the time which was predicated, in part, on containment of IP1-SFPs leakage by the footing drains (North and South curtain Drains, and the Chem. Sys. Building Drain).

An additional monitoring well, MW-53, was subsequently installed downgradient of MW-42 (on the Northwest side of the IP1-CB). Groundwater in this well was also apparently impacted by IP1-SFP water, thus resulting in the initial steps in the identification of the Unit 1 primary Strontium flow path. The groundwater elevations measured in MW-53 proved even more enlightening than the radiological profile. In the case of a *continuously flowing* footing drain such as the NCD, groundwater would generally be expected to be flowing into the drain over the entire length of the drain; the corollary to this conclusion is that the groundwater elevation would be above the drain invert along its entire extent. Otherwise, water flowing into the drain along its eastern, upgradient extent would exfiltrate the drain along its western, downgradient extent and thus, water would no longer discharge out of the end of the drain into the IP1-CB Spray Annulus; it would therefore *not* typically be *continuously flowing*. However, the groundwater elevation in MW-53 was measured at approximately elevation 9 to 10 feet, substantially lower than the water table elevation in MW-42 (35 feet) and the elevation of the NCD invert (33 feet). Therefore, it was found that only a portion of the groundwater which infiltrated the drain to the East was observed as continuous flow at the Spray Annulus collection point. The remainder of the water was exfiltrating along the drain further to the West[103], where groundwater elevations were below the drain invert and thus outside the capture zone of the drain.

Therefore, leakage from the IP1-SFPs was initially being captured by the NCD, but then during transport to the Annulus for collection and treatment, a portion of this leakage was discharging to the groundwater outside the capture zone of the drain. This leakage then migrates downgradient to the West with the groundwater and establishes the Unit 1 primary Strontium flow path.

Eastern IP1-CB Flow Path - A Strontium plume is shown on **Figure 8.2** as existing below the entire IP1-SFPs. With the exception of MW-42, there are no monitoring wells in this area to verify that this plume actually exists. However, it is known that the IP1-SFPs have and continue to leak, and the NCD and CSB footing drains have been shown to contain radionuclides consistent with that expected from IP1-SFPs' leakage. The locations of the specific release points are not known, but could be anywhere along the walls and bottom of the IP1-SFPs.

Once leakage from any of the above postulated points enters the groundwater, it will migrate either to the NCD or the CSB drain, depending on where the specific release point is located relative to these drains. Leakage located along the northeastern portions of the IP1-SFPs is likely to migrate to the NCD (elevation 33 feet), whereas leakage located more to the South and West is more likely to migrate to the lower CSB drain (elevation 22 to

[103] It is hypothesized that, in the past, the drain likely did not flow continuously. However, over time, the exfiltration rate has been reduced through siltation such that the drain can no longer release water over its western extent as fast as it infiltrates into the drain further to the East.

11.5 feet). These scenarios, when considered for multiple potential release points, should result in Strontium flow paths that are all contained within the plume boundaries shown on the figure.

Southwestern IP1-CB Flow Path - As part of the investigations to identify other potential releases to the groundwater across the Site, low levels of Strontium (less than 3 pCi/L) were detected in monitoring wells MW-47 and MW-56. Groundwater contamination in this area was inconsistent with the known sources and the groundwater flow paths induced by the IP1-CSB footing drains. A summary of the investigations and analyses undertaken to identify the release mechanism responsible for this Strontium flow path follows.

Construction drawings indicate that the IP1-CB and the IP1-FHB were constructed with an inter-building seismic gap and stainless steel plate between the two structures. This construction detail creates a preferential flow path for any pool leakage through the western walls of the IP1-SFPs, as well as leakage from other locations which migrates to the western side of the IP1-SFPs[104]. While this "plate/gap" separates the structures all the way down through the structural foundation slabs, it likely would not have penetrated the mud-mat[105]. In addition, it would not be uncommon for the surface of the mud-mat to *not* be completely cleaned prior to pouring of the structural slab. Even small amounts of soil, mud, dust, etc. between the mud-mat and the structural slab above would result in a preferential flow path along the top of the mud-mat. Therefore, it is expected that pool leakage in this zone (between the structural slab and the mud-mat) could flow laterally and would still be isolated from the fractured bedrock below. It would then, in turn, also be isolated from the influence of the footing drains (both the NCD and the IP1-CSB drain). To the extent that the above hypotheses are correct, this leakage could then build up and flow along the plate and above the top of the mud-mat. With sufficient input of leakage from the pool, the elevation of this flowing water could also rise above the top of the IP1-CB footing[106].

With the above hypothesized conditions, pool leakage may migrate along the plate all the way around the IP1-CB to the South and West until it reaches the end of the plate (at the intersection of the perimeter of the IP1-CB with the IP1-FHB). At that location, the water would follow the top of the mud-mat (and/or top of footing) along the IP1-CB bottom slab further to the West[107]. This leakage flow path is highlighted on **Figure 8.2**. The leakage water would not be constrained to flow into the SCD given that this footing drain is dry. Once past the end of the plate, the pool leakage could enter the bedrock at multiple points, wherever it encounters bedrock fractures. Thereafter, the leakage would enter the groundwater and thus be constrained to migrate in the direction of groundwater flow.

---

[104] This hypothesis is further supported by the presence of weeps of contaminated water (SFP leakage) in the eastern wall of the IP1-CB at the footing wall joint.

[105] While not shown on the constructions drawings reviewed "as required", construction photos show that a mud-mat was placed prior to rebar cage construction (also see discussion of rationale under Tritium source areas above). Given the consistent bottom elevations of both the VC and the SFPs structural concrete slabs, a single mud-mat was likely constructed.

[106] Leakage flow above the top of the footing (elevation 33 feet) to the East and Southeast of the VC would not be captured by the SCD given that this drain is dry.

[107] See discussion of likely mud-mat/bedrock excavation wall configuration and the impact of precipitation events in the section above under Tritium source areas.

As shown on the figure, pool leakage entering the groundwater along the South side of the IP1-CB would be expected to mound the groundwater somewhat. This is particularly true in this case given the leakage entry point within the "flat zone" encompassing the groundwater divide between flow to the river to the West and flow to the East to the CSB footing drain[108]. The portion of the pool leakage which flows West would form the southwestern IP1-CB Strontium flow path and thus explain the low levels of Strontium found in MW-47 and MW-56. From this point, the "plume" continues to flow West and joins the primary Strontium flow path.

IP1-CSS Trench Flow Path - During the course of the investigation for potential sources, MW-57 exhibited significant Strontium concentrations. Strontium was also detected in the upgradient IP1-CSS, located in the Unit 1 Superheater Building. This sump was investigated to evaluate the extent to which it may be associated with the contamination identified to the West, near the Discharge Canal. A retired subsurface pipe, designed to drain water from the Unit 1 Spray Annulus to the CSS, was determined to be the input source path for water observed within the sump. During Unit 1 construction, this pipe was installed within a 3-foot-wide trench cut up to 20 feet into bedrock, which slopes downward from the Spray Annulus to the CSS[109]. Construction drawings further indicate that this trench was backfilled with soil. This pipe had been temporarily plugged in the mid-1990's when contaminated water from the NCD was routed to the Spray Annulus. However, the temporary inflatable plug was later found to be leaking and the pipe was then permanently sealed with grout.

As part of our investigations, a monitoring well (U1-CSS) was installed horizontally through the East wall of the CSS at an approximated elevation of 4 feet. This horizontal well is connected to a vertical riser which extends to above the top of the CSS. Water levels in this well typically range from elevation 12 to 18 feet and respond rapidly to precipitation events.

Based upon available data, we believe the IP1-CSS is not a source of contamination to the groundwater. Inspections of the sump indicate the likely entry point for water periodically found in the sump is the pipe from the IP1 Spray Annulus, the joint between the concrete sump wall and the sump ceiling (the floor of the Superheater Building), and/or the joint in the sump wall where the pipe penetrates from the rock trench into the sump. These conclusions are based on:

- The groundwater elevations measured in U1-CSS are above the bottom of the CSS which is generally nearly empty (bottom elevation of 1.0 feet);
- The results of the tracer test confirmed that contaminated groundwater can enter the CSS when it is empty; and
- Visual inspections of the interior of the sump and associated piping.

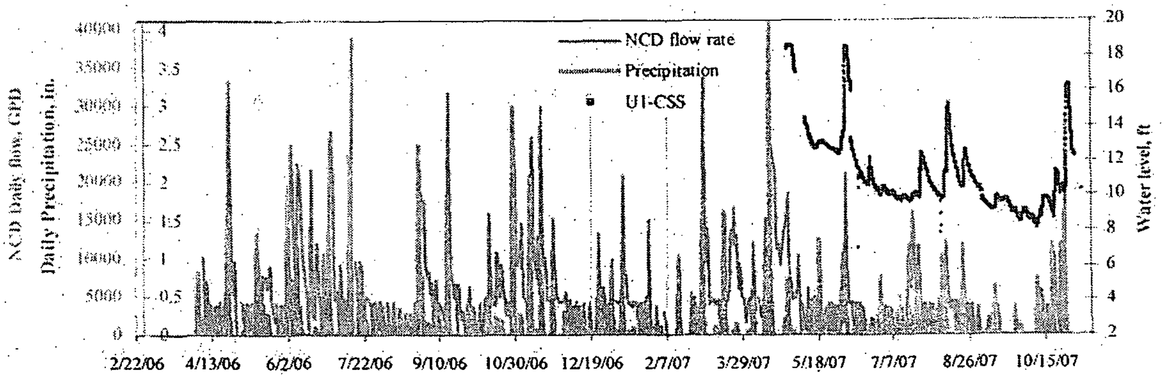
---

[108] While a groundwater divide must exist between the CSB footing drain and river to the West, the exact location of the divide is unknown.

[109] The trench bottom starts at elevation 22.75 feet at the Spray Annulus and slopes gradually to elevation 21.75 feet at a point 9 feet from the CSS. From this point, the trench slopes steeply to elevation 13 feeet at the CSS.

This sump is no longer in service as the system it supported is retired.

While the CSS itself does not appear to be a release point, we believe the associated bedrock trench between the Spray Annulus and the CSS is a source of contamination to the groundwater. As indicated above, the Spray Annulus is used to store releases collected from the IP1-SFPs by the NCD, which contains contaminants. The Annulus water has been historically documented as leaking into the pipe and surveys indicate that the pipe itself likely leaks into the trench. While the leak into the pipe from the Spray Annulus was sealed, other leakage inputs to the trench also likely exist. One such likely leakage path is for water to flow directly from the NCD through the drain backfill and abandoned piping[110] to the pipe trench. This flow path is supported by the trends in U1-CSS water elevation variation as compared to the NCD discharge rate (see figure included below).



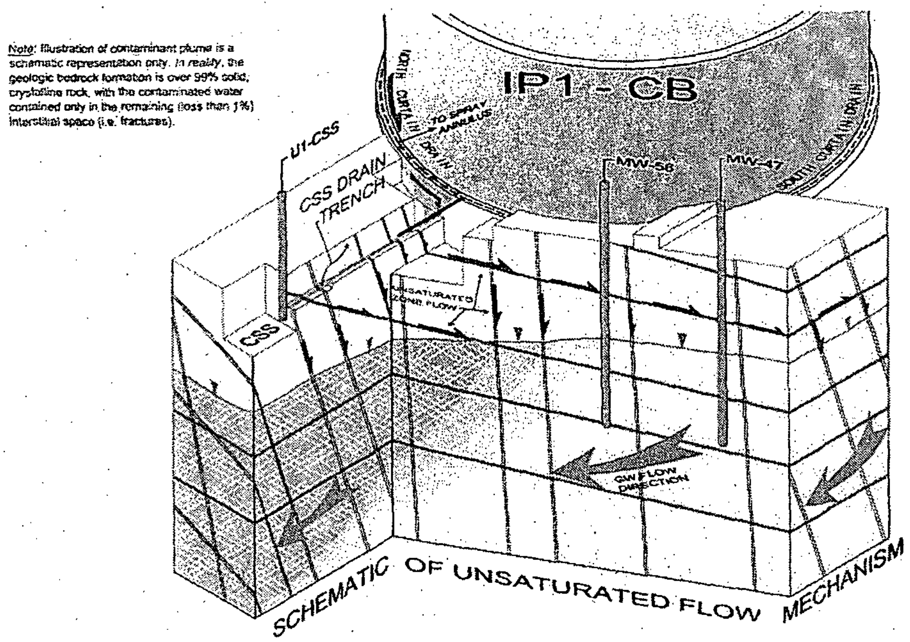
UNIT 1 NCD FLOW, U1-CSS GROUNDWATER ELEVATION AND PRECIPITATION RELATIONSHIPS

These hypothesized leakage paths are highlighted on **Figure 8.2**. Once leakage enters the trench, it should flow along the sloped bottom until it finds bedrock fractures through which to exfiltrate. This leakage will then flow through the unsaturated zone along the strike/dip of the fractures until it encounters the saturated zone, and thereafter will follow groundwater flow.

Because of these hypothesized, but probable conditions, we concluded that leakage has exited the trench and impacted groundwater. Impacts directly to the groundwater below the pipe trench are characterized by Strontium concentrations in monitoring well U1-CSS. In addition, source inputs to the groundwater from the trench are also envisioned to have occurred farther to the South, where the groundwater flow would then carry contamination to MW-57, thus explaining the Strontium concentrations found in that well[111]. While southerly flow in this area is inconsistent with groundwater flow direction, source inputs can migrate from the bedrock trench to the South in the *unsaturated* zone near the

[110] As noted above, the NCD discharge was rerouted into the Spray Annulus when the NCD was found to contain contaminants by the previous owner. Prior to this modification, the footing drain was routed to a 15-inch drain line collocated in the CSS pipe trench. The abandoned piping and permeable backfill still exist and likely act as an anthropogenic preferential flow path.
[111] Monitoring wells U1-CSS and MW-57 do not appear to be in the groundwater flow path of the primary Unit 1 "plume."

CSS, where the unsaturated zone is relatively deep[112]. This hypothesized unsaturated zone flow path is shown on **Figure 8.2,** as well as the schematic included below.



IP1-CSS TRENCH UNSATURATED ZONE FLOW MECHANISM

In addition, the construction details of the Superheater East wall may also channel saturated flow to the South, depending on variation in groundwater elevations. These less direct leakage inputs then establish the southern portion of the source area for the CSS trench flow path such that the groundwater flow carries the "plume" through monitoring well MW-57, thus explaining the Strontium found in samples collected from this well[113].

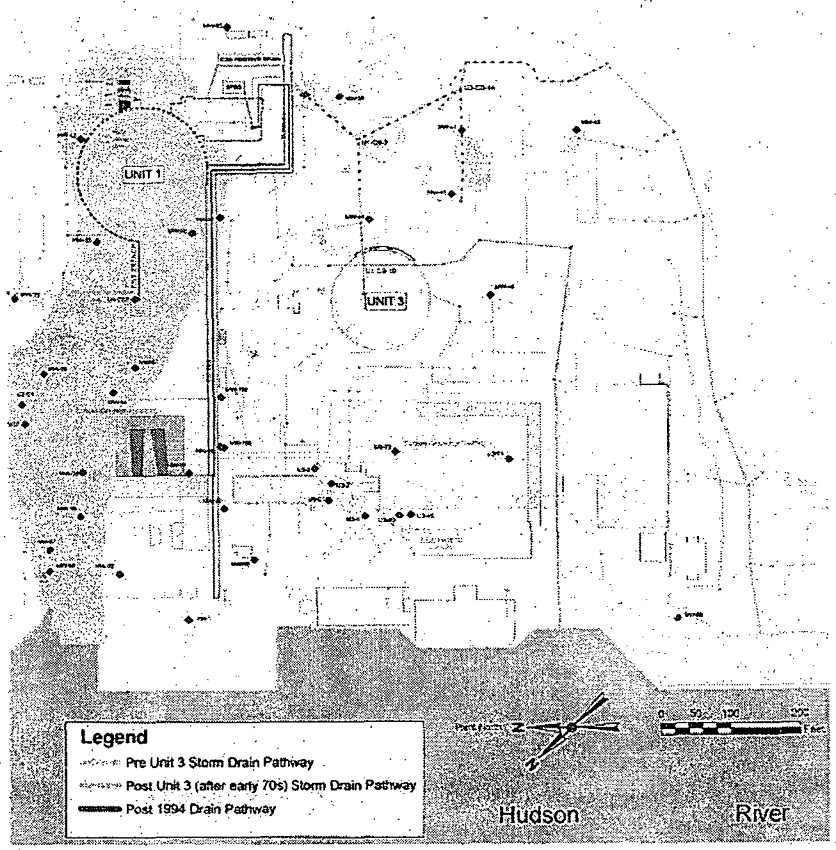
<u>Legacy IP1 Storm Drain Flow Path</u> – As summarized above, the CSB footing drain collects groundwater from the vicinity of the IP1-SFPs; this water has been documented to contain radionuclides. The contaminated water is then conveyed to the SFDS, located at the southern end of the CSB. In addition, historical events, including CSB sump tank overflows in Unit 1, have impacted the SFDS.

Prior to construction of Unit 3, water collected in the SFDS was pumped up to elevation 65 feet and discharged to the stormwater system on the South side of the Unit 1 CSB. The discharge was conveyed by these drains to the South towards catch basin U1-CB-9 (currently under the access ramp to Unit 3), and then West (U1 CB-10) under what is now the IP3-VC toward the Discharge Canal. This pathway was re-routed during construction of Unit 3 in the early 1970s to flow South from catch basin U1-CB-9, then further South towards catch basin U3-CB-A4 and subsequently to the Discharge Canal through the

---

[112] The hypothesized southerly flow of a portion of the trench leakage to the South through the unsaturated zone is consistent with: 1) the strike/dip direction of major joint sets found on Site; and 2) the groundwater flow path from the resulting unsaturated zone input to the wells which identified this Strontium flow path.
[113] This well appears to be located outside, and upgradient of, the primary Unit 1 Strontium flow path to the North.

E-Series storm drains. (See figure included below and **Figure 8.2** where these pathways are also highlighted.)



DIFFERING SPHERE FOUNDATION DRAIN SUMP DISCHARGE PATHWAYS OVER TIME

A recent inspection of the storm drain system, including smoke tests and water flushing, has revealed that a number of pipes along these sections have been compromised and are leaking. Strontium found in groundwater on the South side of the Unit 1 FSB, and upgradient of Unit 3, is coincident with the locations of these stormwater pipes. Therefore, we concluded that some of the contaminated water discharged into these pipes exfiltrated, and then migrated downward through the unsaturated zone and contaminated the groundwater, thus resulting in the "legacy" storm drain flow path[114] shown on **Figure 8.2**.

In 1994, this discharge route was changed again, when contamination was detected in the effluent from the Unit 1 SFDS. The pipe leading from the SFDS towards Unit 3 was capped, and discharges were thereafter routed directly to the Discharge Canal through a series of interior pipes as well as a radiation monitor. As such, the storm drain lines to the

---

[114] Three discrete isopleths have been drawn around MW-39, MW-41 and MW-43 given the measured concentrations greater than 2 pCi/L. However, it is expected that similar concentrations exist at other locations along the legacy piping alignment in addition to those shown on the figure. During the historic active discharge to the storm drains, it is expected that the individual leak areas would have resulted in commingling of the groundwater contamination into a single "plume" area. This "plume" would have then migrated downgradient across the Unit 3 area. With the cessation of discharge to the storm drains, the "plume" attenuated over time, leaving downgradient remnants which are still detectable as low level Strontium contamination in Unit 3 monitoring wells such as MW-44, 45 & 46, U3-T1 & 2, and U3-2.

South of Unit 1 no longer carry this contaminated water and they are therefore no longer an active source of contamination *to the groundwater*.

However, from a contaminant plume perspective, these historic releases still represent an ongoing legacy source of Strontium *in the groundwater* to the South side of Unit 1. This is because Strontium partitions from the water phase and adsorbs to solid materials, including subsurface soil and bedrock. The Strontium previously adsorbed to these subsurface materials then partitions back to, and continues to contaminate, the groundwater over time, even after the storm drain releases have been terminated.

As shown on **Figure 8.2**, low level residual evidence of this legacy pathway was identified in monitoring wells installed to South of Unit 1 during the course of the investigations proximate to potential sources associated with Unit 3. Strontium, Cesium and Tritium were detected in these wells at levels below the EPA drinking water standard. Three monitoring wells to the South of Unit 1 show "Legacy Storm Drain flow paths" drawn around them. These wells have yielded samples at one time/depth with Strontium concentrations greater than 2 pCi/L, or one-quarter of the Strontium-90 drinking water standard. While the actual extent of these Strontium concentrations is not known given that each has been drawn around a single point, they appear to be limited in extent (based on the data from the surrounding monitoring wells). It is also important to recognize that the specific locations of the historic releases from the storm drain lines are not known. In addition, once water has exfiltrated from the drain line, it moves generally downward in the unsaturated zone as controlled by the strike/dip direction of the specific bedrock fractures encountered. Therefore, legacy groundwater contamination does not have to be located immediately downgradient of the storm drain system (as exemplified by the Strontium found in MW-39 and tracer in MW-42). While three isopleths are shown on **Figure 8.2**, we believe it is possible that other areas in the general vicinity of this piping may exhibit similar groundwater concentrations. We have also concluded that the lower concentrations of Strontium detected in monitoring wells further downgradient, in the Unit 3 area, are also due to these historic, legacy storm drain releases.

9.0 GROUNDWATER CONTAMINATION FATE AND TRANSPORT

Strontium (the Unit 1 plume) and Tritium (the Unit 2 plume) are the radionuclides we used to map the groundwater contamination. The investigation focused on these two contaminants because they describe the relevant plume migration pathways, and the other Site groundwater contaminants are encompassed within these plumes.

While radionuclide contaminants have been detected at various locations on the Site, both the on-Site and off-Site analytical testing, as well as the groundwater elevation data, demonstrate that groundwater contaminants are not flowing off-Site and do not flow to the North, East or South. Groundwater flow and thus contaminant transport is West to the Hudson River via: 1) groundwater discharge directly to the river; 2) groundwater discharge to the cooling water canal, and 3) groundwater infiltration into storm drains, and then to the canal.

The primary source of groundwater Tritium contamination is the IP2-SFP. The resulting Unit 2 plume extends to the West, towards the river, as described in subsequent sections.

The source of the Strontium contamination is the IP1-SFPs. Previous conceptual models, based on information presented in prior reports, indicated that releases from the IP1-SFPs were likely captured through collection of groundwater from the Unit 1 foundation drain systems. However, based upon groundwater sampling and tracer test data, we now know that the Unit 1 foundation drain system, particularly the NCD, is not hydraulically containing *all* groundwater contamination in this area (see **Section 8.0**).

GZA's understanding of the Tritium source and Strontium source are discussed in more detail in **Section 8.0**. The plumes described on the figures in the following subsections are based on: 1) the isopleths bounding the maximum concentrations, as representative of "worst case conditions"[115] (**Figures 8.1** and **8.2**); and 2) the most recent laboratory data collected through August 2007, as representative of current conditions (**Figures 9.1, 9.2, 9.3** and **9.4**). While the figures showing upper bound isopleth concentrations do not show actual conditions, we believe these graphics are useful in developing an understanding of groundwater and radionuclide migration pathways.

In reviewing this section please note the plumes show our current understanding of how anthropogenic features influence groundwater flow patterns, in particular the various footing drains and backfill types used during construction. Also note that flow in the

---

[115] It is noted that these figures (**Figures 8.1** and **8.2**) do *not* show actual plumes; the isopleths present contoured upper bound concentrations for samples taken at *any time* and *any depth* at a particular location, rather than a 3-dimensional snapshot of concentrations at a single time. As such, these "plumes" are an overstatement of the contaminant levels existing at any time. It should also be noted that the lightest colored contour interval begins at one-quarter the USEPA drinking water standard. While drinking water standards do not apply to the Site (there are no drinking water wells on or proximate to the Site), they do provide a recognized, and highly conservative benchmark for comparison purposes). Lower, but positive, detections outside the colored contours are shown as colored data blocks. See figure for additional notes.

unsaturated zone plays an important role in both the timing of releases to the water table and in the spreading of contaminants.

Based upon the results of GZA's geostructural analysis, the extent of contaminated groundwater, the 72 hour Pumping Test, the tracer test and tidal response tests, we believe that the bedrock underneath the Site is sufficiently fractured and interconnected to allow the Site to be viewed as a non-homogenous and anisotropic porous media. Based on this finding, and because advection is the controlling transport mechanism, groundwater flow, and consequently contaminant migration in the saturated zone, is nearly perpendicular to groundwater contours on the scale of the Site.

9.1 AREAL EXTENT OF GROUNDWATER CONTAMINATION

Based on measured tracer velocities (4 to 9 feet per day; see **Section 7.4**), the limited distances between release areas and the river (typically less than 400 feet), the age of the plumes (years), and recent interdictions, we believe contaminant plumes have reached their maximum size and are currently decreasing in size. Consequently, our reporting in this section focuses on observed, "current" conditions (the summer of 2007). That is, we saw no need to mathematically predict future conditions.

9.2 DEPTH OF GROUNDWATER CONTAMINATION

Because of the location of Indian Point on the edge of the Hudson River, the width of the river, and the nature of contaminants of potential concern, groundwater flow patterns (and, consequently, contaminant pathways) are relatively shallow. Furthermore, as discussed in **Section 6.0**, the upper portion of the aquifer (typically, the upper 40 feet of the bedrock) has a higher average hydraulic conductivity than the deeper portions of the bedrock. Consequently, the center of mass of the contaminated groundwater is shallow.

Figures 9.1 and **9.2** are cross sections which show the approximate vertical distribution of Tritium and Strontium, near the center lines of the Unit 1 and Unit 2 plumes, in the summer of 2007 ("current conditions"). In reviewing these figures, note that Strontium was not found below a depth of 105 feet in MW-67. We attribute the low concentrations of Tritium below a depth of 200 feet at this location, at least in part, to the downward migration of Tritium during our investigations. For example, by necessity, well RW-1 was an open wellbore for a period of time[116] which allowed vertical groundwater migration, along an artificial preferred pathway, deeper than would occur along ambient flow paths.

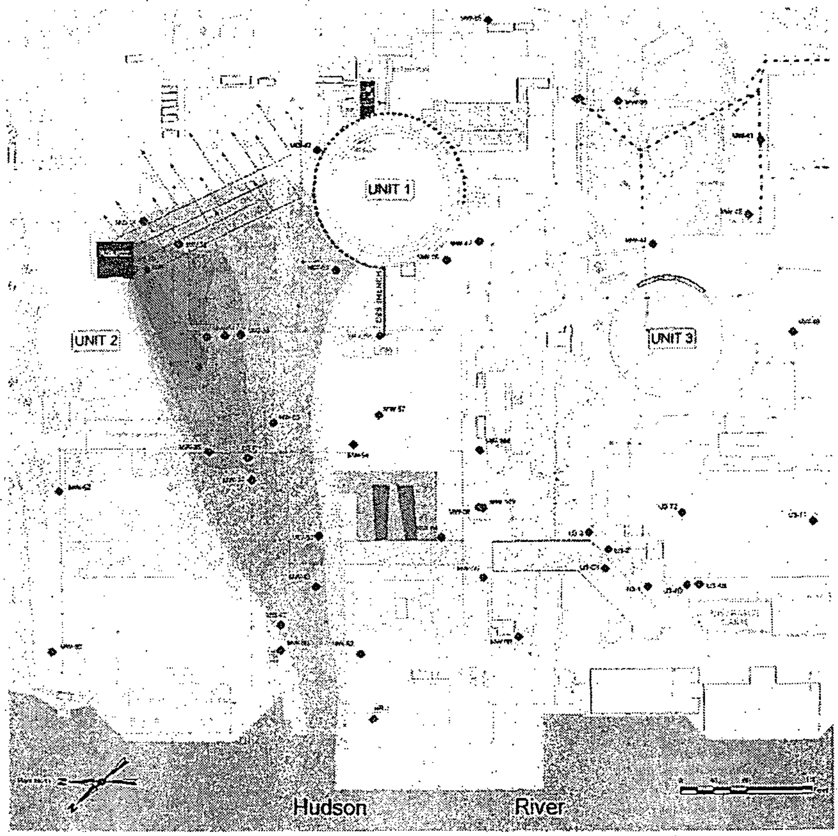
9.3 UNIT 2 TRITIUM PLUME BEHAVIOR

As shown on **Figures 8.1** and **9.3**, the Unit 2 plume exhibits Tritium concentrations originating at the IP2-SFP. The higher concentration isopleths are shown around the entire

---

[116] RW-1 is located immediately below the 2005 shrinkage crack leak (high Tritium concentrations in shallow groundwater). This well had remained as an open wellbore for periods of time in preparation for and during: 1) the drilling of the wellbore; 2) the packer testing; 3) the geophysical logging; and, 4) the Pumping Test. During these times, vertically downward gradients likely moved some Tritium to levels deeper than it would otherwise exist. When possible, this wellbore has been sealed over its entire length using a Flute Liner System.

pool area so as to include the location of the shrinkage crack leak in the South pool wall, the location of the 1992 leak on the East wall, and the location of the weld imperfection in the North wall of the IP2 Transfer Canal. We believe the core of the plume, as shown, is relatively narrow where Tritium flows downgradient (westerly) to MW-33 and MW-111 in the Transformer yard[117]. This delineation is based on: 1) the degree of connection[118] observed from MW-30 to MW-33 (as compared with that from MW-30 to MW-31 and/or MW-32) as being indicative of a zone of higher hydraulic conductivity limiting lateral dispersion; and 2) the localized increased thickness of the saturated soil in the vicinity of MW-111 (see **Figure 1.3**) which likely behaves as a local groundwater sink/source for westerly bedrock groundwater flow, prior to entering the associated backfill of the Discharge Canal.



BOUNDING UNIT 2 ACTIVITY ISOPLETHS

Tritium has been detected in MW-31 and MW-32, both of which are upgradient of the IP2-SFP. As evidenced by the tracer test (see **Section 7.0**) and hydraulic heads, this

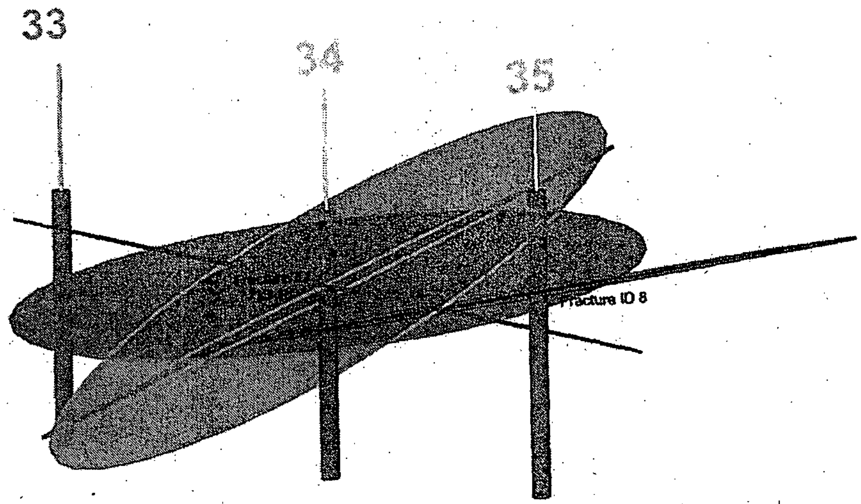
---

[117] The bedrock in this area was excavated via blasting to allow foundation construction. As such, the upper portions of the bedrock are likely highly fractured in this area. In addition, the pre-construction bedrock contours (see **Figure 1.3**) indicate that the particularly deep depression in the bedrock in the Transformer yard in the vicinity of MW-111 (filled with soil down to elevation 0 feet) was likely excavated to serve as a dewatering sump. The associated deeper blasting-induced fracturing and the saturated soil backfill are also likely to further increase the transmissivity in this area.

[118] The degree of connection is inferred based on both the similar static water levels in MW-30 and -33 (separated by over 100 feet), as contrasted to the much higher water levels in MW-31 and -32 located about 65 feet from MW-30, and the rapid change in water elevation in MW-30 in response to water level perturbations in MW-33 (e.g., during drilling/sampling), with little or no response in MW-31 and -32.

occurrence involves gravity flow along bedrock fractures in the unsaturated portion of the bedrock beneath the IP2-SFP. This unsaturated flow direction is consistent with the dominant foliations (which strike to the Northeast and dip to the Northwest). This behavior is shown on the figure by dashed arrows and the isometric insert (see **Section 8.1**). This mechanism also accounts for some of the Tritium found near Unit 1 and is also supported by the results of the tracer test (see **Section 7.3**). However, once the contaminated water enters the local groundwater flow field, it migrates via advection in a direction generally perpendicular to the groundwater contours (i.e., with the groundwater flow).

In the IP2-TY, the plume is drawn as more dispersive in response to the concentrations measured in MW-34 and -35 as well as the high degree of connection observed between MW-33, -34 and -35 along an orientation transverse to the general groundwater flow direction. See the figure below for a schematic of the three dimensional fracture orientations in this area that account for the observed lateral dispersion. In this general area, the Unit 2 plume is bounded to the South by MW-54 and to the North by MW-52.



Transmissive Fractures in MW-34 and MW-35
at Approximately Elevation 3

3 - DIMENSIONAL BEDROCK FRACTURE ORIENTATIONS

At the western boundary of IP2-TY, Tritium flows into the highly conductive soil backfill found along the eastern wall of the Discharge Canal (see **Figure 1.3**). This conclusion is supported by both the groundwater elevations and Tritium concentrations in MW-36.

The groundwater elevations with depth in MW-36 indicate that once in the Discharge Canal backfill, the groundwater flows downward below the canal wall and, subsequently, into both the Discharge Canal (lower water elevation in the canal) as well as under the canal through the bedrock fractures (see **Section 6.7.2.2** for an estimate of the relative flows to these two discharge locations). Once on the western side of the Discharge Canal, as evidenced by groundwater elevations and Tritium concentrations in MW-37, -49, and

-67, groundwater flow and Tritium migration is to the Hudson River, via both bedrock and unconsolidated material along the riverfront.

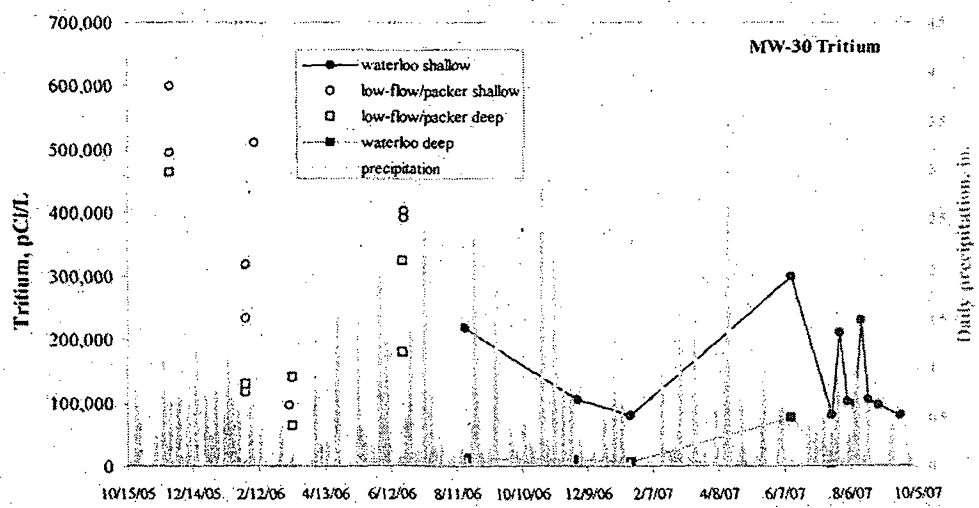
The specific flow path for the Tritium detected in MW-37-22 (located in the fill on the West side of the canal) is not certain. It is however associated with either: 1) upward groundwater flow into the backfill from the bedrock beneath the canal, as supported by the upward vertical hydraulic gradients; 2) groundwater flow into the blast rock fill on the West side of the canal, with northerly flow in the fill to, and around the North end of the canal and then southerly along the East side of the canal to MW-37; and/or 3) exfiltration from the stormwater piping between MH-4 and MH-4A into the fill on the western side of the canal, with a similar flow path as described in 2). See **Section 7.5** for additional information. Regardless of the upstream flow path to MW-37-22, the groundwater flow direction from this location is westerly toward the Hudson River. Also note that the exact pathway to this location does not change the results of the groundwater flux calculations to be used in radiologic dose impact assessments.

Both **Figures 8.1** and **9.3** show a southern component of flow as the Tritium migrates West towards the river. This pathway corresponds with the location of several East-West trending fractures zones and a fault zone. It is likely that this area is characterized by a zone of higher transmissivity that induces the contaminated groundwater to migrate as shown on these figures. We also note that it appears groundwater flow from higher elevations to the North also impedes a more northerly contaminant migration pattern.

9.3.1 Short Term Tritium Fluctuations

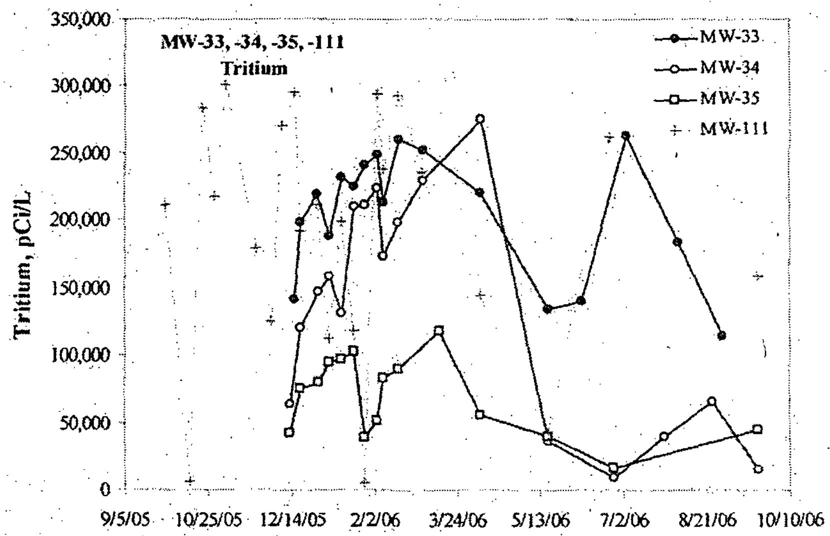
During our investigation, we observed short term fluctuating Tritium concentrations that we cannot reasonably attribute to a continuous release[119] (see **Table 5.1**). These fluctuations make drawing an accurate representation of a plume, on any single date, difficult because any single sample may not be representative of the overall water quality in proximity to the sampling location. In the case of Tritium associated with the IP2-FSB, we believe the fluctuations are associated with temporal variations in the release of Tritium-contaminated groundwater from the unsaturated zone to the water table. That is, we believe the unsaturated zone acts as an intermittent, ongoing source to the groundwater flow regime (see **Section 8.0**). The following graph shows the results of Tritium vs. time in samples collected from MW-30, located adjacent to the IP2-SFP.

[119] In addition, our review of sampling procedures and laboratory methods did not explain the variations observed in samples collected from monitoring well MW-30.



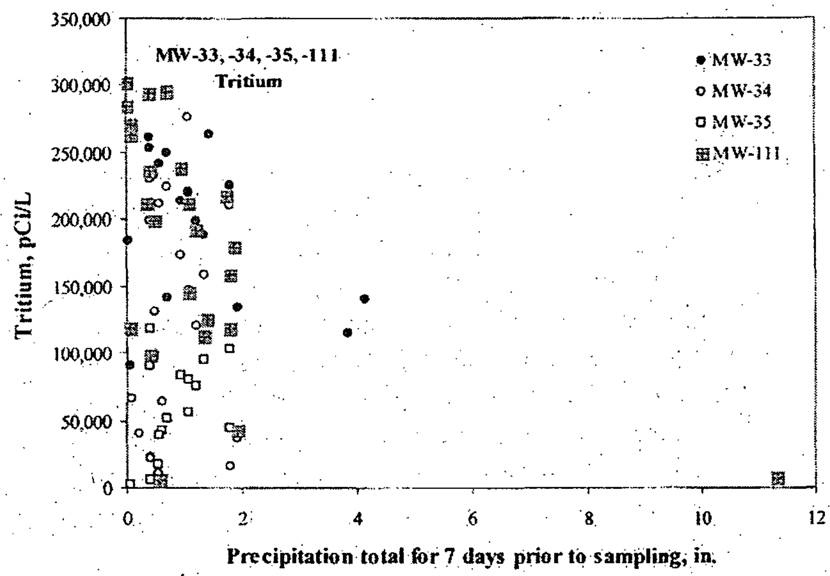
TRITIUM CONCENTRATIONS AND PRECIPITATION VS TIME FOR MW-30

Similar temporal variations in Tritium concentrations are observed in data generated by testing of samples downgradient of IP2-SFP at MW-33-34-35 and -111; see the following figure:



TRITIUM CONCENTRATIONS VS TIME FOR MW-33, -34, -35 AND -111

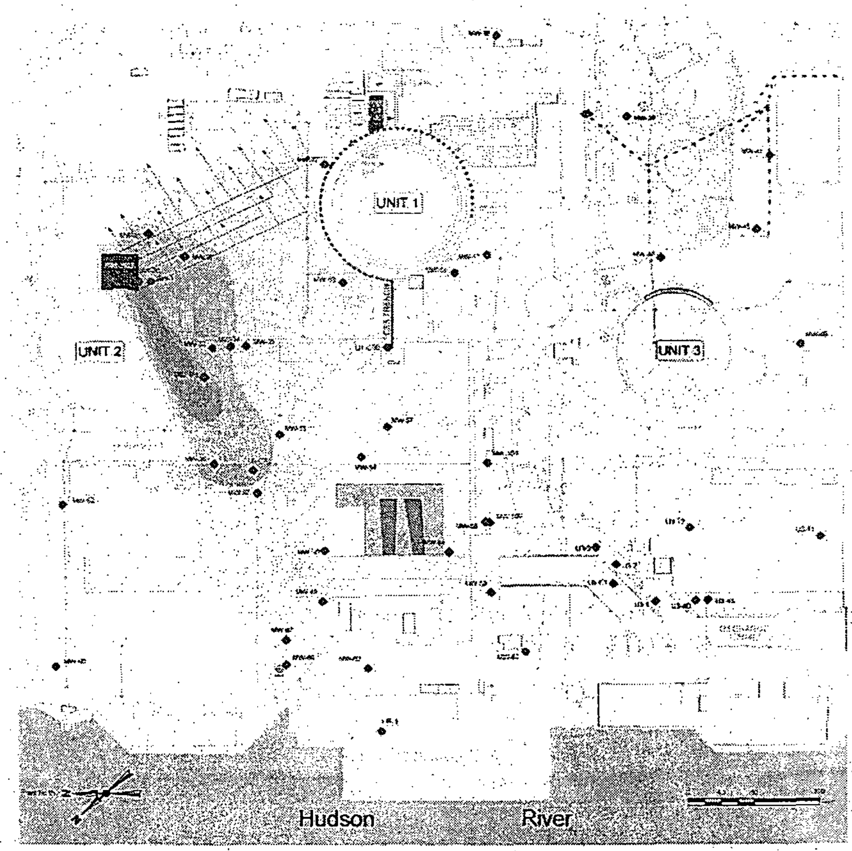
MW-111 is a shallow overburden well completed to a depth of 19 feet below ground surface (bgs). This well is located in a soil-filled bowl-shaped depression within the Transformer yard (see **Figure 1.3**). Consequently, the concentrations of Tritium in samples collected from MW-111 are more sensitive to precipitation (and the likely associated exfiltration from the proximate storm drain) than samples collected from other wells in this area (see above). In particular, note the substantial decrease in Tritium concentration as shown on the following graph, in samples collected after significant precipitation events in October 2005 and May 2006.



TRITIUM CONCENTRATIONS VS PRECIPTIATION

9.3.2 Long Term Variations in Tritium Concentrations

Recognizing the limitations posed by short term fluctuations, we constructed **Figure 9.3**, which shows the lateral extent of Tritium contamination in the late summer of 2007 ("current conditions").



CURRENT UNIT 2 PLUME

Our review of this figure, in conjunction with **Figure 8.1**[120] and **Table 5.1,** reveals the following:

- Despite interdictions, the lateral extent of the two plumes (i.e., the Tritium plume vs. the bounding isopleths) is similar. This indicates storage in the unsaturated zone remains important, and that previous releases did not generate significant groundwater mounding.
- The highest concentrations remain in the area of IP2-SFP. This is consistent with the observed relatively high (4 to 9 feet per day) groundwater transport velocities and an ongoing but smaller release from the unsaturated zone.
- Interdictions made at the IP2-SFP appear to have resulted in measurable reductions in Tritium groundwater concentrations over the entire Unit 2 plume length[121]. The larger reductions in Tritium concentrations are most evident in the source area, closer to the IP2-SFP (see table below).

ANALYSIS OF TRITIUM CONCENTRATIONS OVER TIME

Max. Observe (1) Tritium Concentrations (pCi/L)	Monitoring Well	Current (2) Tritium Concentrations (pCi/L)	Elapsed Time between Max. and Current Concentrations (days)	Current Conc. As Percent of Maximum
601,000	MW-30	92,000	657	15
302,000	MW-111	98,800	629	33
107,000*	RW-1	30,600	3	48
40,600	MW-31	37,700	39	93
44,400	MW-32	14,200	406	32
264,000	MW-33	23,000	390	9
276,000	MW-34	22,200	476	8
119,000	MW-35	5,950	510	5
55,200	MW-36	12,500	494	23
44,800	MW-37	6,680	400	72
3,980	MW-42	1,600	490	40
13,200	MW-53	8,050	346	61
13,100	MW-55	9,910	263	76
10,800	MW-50	4,500	427	42
9,100	MW-66**	9,100	0	100
4,860	MW-67**	4,860	0	100

* Sample obtained during Pumping Test.
** Only one sample analyzed.
(1) Any depth, any date at the indicated location.
(2) Maximum concentration, at any depth, reported during the last project sampling event at the indicated locations.

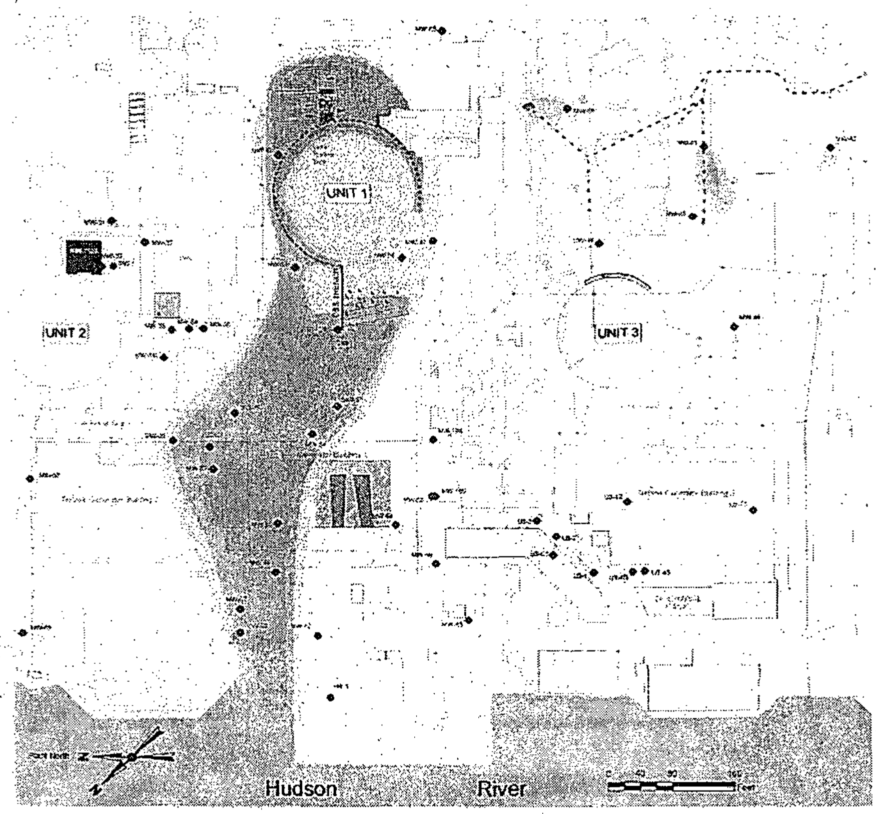
---

[120] When comparing the Unit 2 (Tritium) plume shown on **Figure 9.3** with the bounding isopleths presented on **Figure 8.1**, the analyses/methods used to develop the bounding isopleths need to be fully considered – please refer to **Section 8.0**.

[121] As based on monitoring well data over the plume length down to and across the Discharge Canal to MW-37, as well as the apparent migration velocity of Tritium in the groundwater observed on-Site. Data from monitoring wells downgradient of MW-37 have not been sampled over a sufficiently long period of time to confirm this conclusion. Further analysis of the plume behavior will be conducted as the Long Term Monitoring Plan data is developed over time.

9.4 UNIT 1 STRONTIUM PLUME BEHAVIOR

Figures 8.2 and **9.4** illustrate the migration paths for Strontium. These flow paths represent Strontium originating from an ongoing legacy leak(s) in the IP1-FHB (see **Section 8.0**). This leak explains the Strontium levels detected in MW-42. This well is located in close proximity to the NCD[122], with the upper screen spanning the elevation of the drain (elevation 33 feet) and the lower screen located approximately 35 feet below the drain elevation. This well exhibits upward vertical gradients from the bedrock into the overburden and the NCD. Therefore, a release through a crack in the Water Storage Pool wall (also forms the wall of the FHB), for example, would flow down through the backfill and into the drain where it would enter groundwater near monitoring well MW-42. However, as described in **Section 8.0**, the NCD is not 100% effective in hydraulically containing leaks from the IP1-SFPs. Contaminated pool water collected along the eastern portion of the NCD is released from the NCD via exfiltration as the groundwater elevations drop below elevation 33 feet towards the West; this is one source mechanism responsible for the Unit 1 Plume.



BOUNDING UNIT 1 ACTIVITY ISOPLETHS

---

[122] It is noted that MW-42 is screened in the bedrock slightly North of the drain. As such, it is located hydraulically upgradient of the drain. The drain should therefore form a sink between the potential leaks and the well, thus capturing contaminants from the FHB further South, with the well only encountering groundwater flowing from the North to the South towards the drain (i.e., the well should not sample groundwater in communication with IP1-FHB leaks). However, during rain events, it appears that the groundwater elevations at the drain can increase to a point where the groundwater flow direction is temporarily reversed (flows from the NCD northward past MW-42) due to the high inflows associated with storm drain leaks (storm drains being repaired, and/or taken out of service). This flow reversal can deposit Strontium on fracture surfaces around MW-42, which later enters the well during purging.

The easternmost portion of the overall Unit 1 plume is shown to exist below the entire IP1-SFPs. GZA termed this the eastern Unit 1 CB Flow Path. Strontium-contaminated groundwater in this area will migrate either to the NCD or the CSB drain, depending on where the specific release point is located relative to these drains.

As discussed in **Section 8.0**, the overall Unit 1 plume also extends to the West towards MW-47 and MW-56. GZA termed this the southwestern Unit 1 CB Flow Path. Once the contaminated water enters the groundwater on the South side of Unit 1, it flows either East to the CSB footing drain or to the Northwest towards Hudson River, depending on the hydraulic gradient at the location where the release reaches the water table.

In addition, we believe the bedrock trench that contained the Unit 1 Annulus-to-CSS drain creates a preferential pathway (through the backfill within the bedrock trench), further aiding the transport of Strontium-contaminated groundwater to the West. GZA termed this the Unit 1 CSS Trench Flow Path. Once leakage enters the trench, it should flow along the sloped bottom until it finds bedrock fractures through which it will exfiltrate. This leakage will then flow through the unsaturated zone along the strike/dip of the fractures until it encounters the saturated zone, and thereafter will follow groundwater flow. This pattern is illustrated on **Figure 9.4** by dashed arrows to the West of Unit 1. It results in a spreading of Strontium-contaminated groundwater, which then flows with groundwater to the Hudson River.

Figures 8.2 and **9.4** also show the Strontium contamination related to releases from legacy piping. These historic releases from the drain pipes are currently manifested as sporadic, low level detections of Strontium in groundwater wells (MW-39, -41 and -43) along the legacy piping. Note, as shown, this spatial distribution of contamination is not a result of groundwater contaminant transport to the South; rather it is a result of multiple release points along the piping. In summary, this contamination represents residual contamination which has attenuated and decayed over time, and will not result in further significant migration.

Once outside the drain capture zone, the Strontium migrates West towards the lower groundwater elevations measured in the IP2-TY and along the walls of the Discharge Canal along the southern end of the IP2-TB (MW-36, -55, -37, -49, -50 and -67) (see **Figures 8.2** and **9.4**). A more southerly track is not anticipated because: 1) the higher groundwater elevations measured in MW-58 and -59 just to the South of the IP1 TGB; and 2) the likely existence of low conductivity concrete backfill along the inside of the IP1-TB walls, its subbasement, discharge piping and eastern Discharge Canal wall (as contrasted with the much higher conductivity blast-rock backfill likely used in the IP2-TY and along the outside of the IP1-TGB walls as well as adjacent to the upgradient IP1 structures).

In addition, as discussed in **Section 6.0** and shown on **Figure 6.2**, there are North-South trending faults in the vicinity of MW-49, MW-61, and MW-66, which are characterized by clay-rich fault gouge[123]. In GZA's opinion (see **Section 6.4.5**), these zones of low hydraulic conductivity limit the southerly extent of contaminated groundwater. In addition, this area is characterized by the two discrete plumes (Tritium and Strontium) commingling and following the same flow path West towards the Hudson River. We attribute this flow pattern to a zone of higher transmissivity located between Units 1 and 2. Also note this area of higher flow is accounted for in our groundwater flux calculations.

The Unit 1 plume in the Transformer yard area is shown as widening due to Strontium concentrations detected in MW-111 and MW-36. This widening may reflect the increased thickness of the saturated zone soil deposits around MW-111, or the presence of high conductivity backfill around the Discharge Canal. This conclusion is supported by the hydraulic heads that indicate groundwater flow to the North along the canal as discussed above pursuant to the Unit 2 plume and the tracer test. West of the Discharge Canal, the Strontium pathways correspond to those described for the Unit 2 plume in **Section 9.3**.

9.4.1 Short Term Strontium Concentrations

As observed with Tritium, it appears that Strontium groundwater concentrations fluctuate, over short durations, more than can be reasonably explained[124] (see **Table 5.1**)by a continuous release at generally constant concentration. We attribute these fluctuations to variations in flows in the IP1-NCD, which are directly influenced by precipitation events (see **Section 8.2**). That is, we postulate that as flows in the drain vary, so do the concentrations and/or volumes of Strontium contaminated water being released.

9.4.2 Long Term Variations in Strontium Groundwater Variations

We used the results of the last sampling event to construct the current Unit 1 plume (see **Figure 9.4** and **Table 5.1**). In reviewing that figure (see below), note the overall configuration is similar to that of the bounded Unit 1 plume (see **Figure 8.2**[125]). The major difference between these plumes is the decrease in concentrations shown in the immediate vicinity of the IP1-SFP[126]. We attribute this decrease in Strontium concentrations to the increased rate of demineralization of the IP1-SFPs water (overall source of the plume).

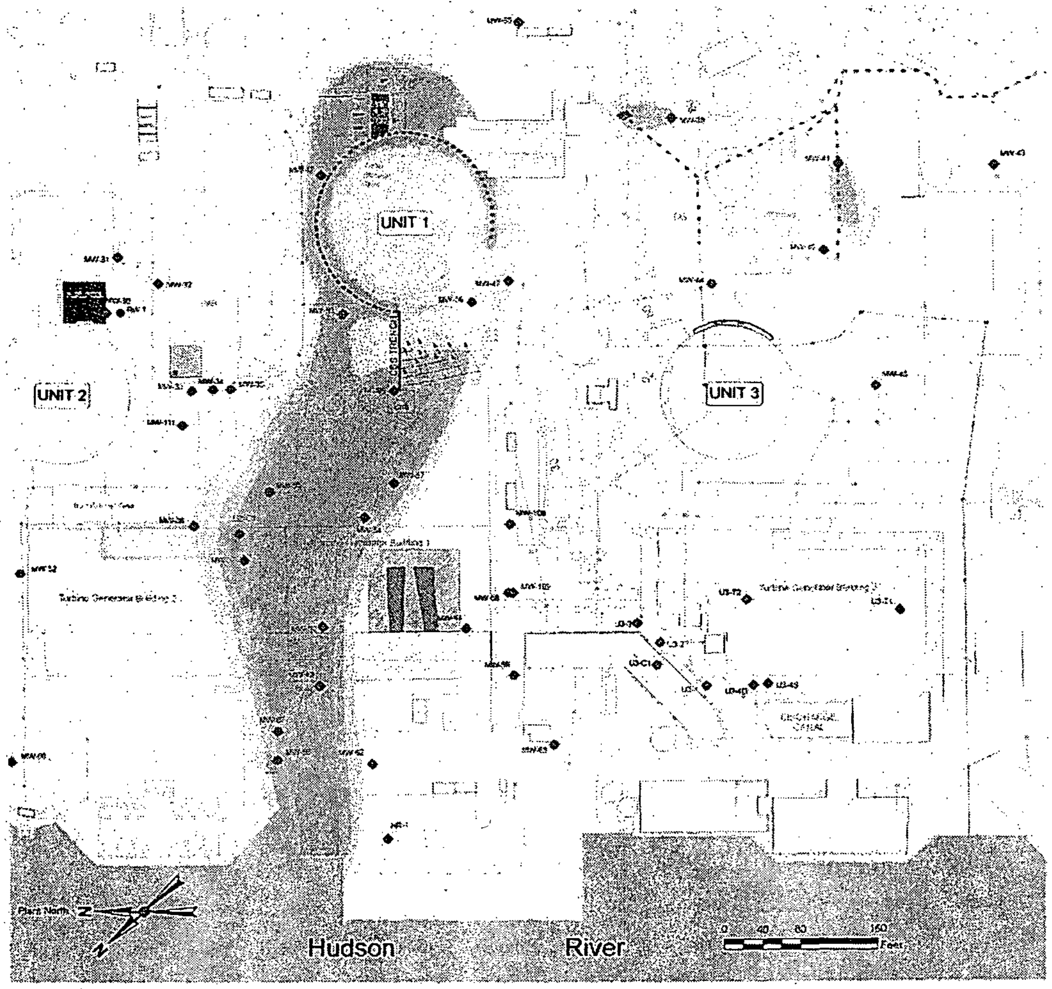
---

[123] This conclusion has been verified in the areas where the gouge was confirmed with split spoon sampling. See individual boring logs in **Appendix B** for further, more detailed, information.

[124] For example, our review of sampling procedures and laboratory methods did not explain the variations observed in samples collected from monitoring well MW-42.

[125] When comparing the Unit 1 (Strontium) plume shown on **Figure 9.4** with the bounding isopleths presented on **Figure 8.2**, the analyses/methods used to develop the bounding isopleths need to be fully considered – please refer to **Section 8.0**.

[126] It should be noted that the latest data just recently received (well after the report data-cut-off-date of August 31, 2007) for MW-42 shows an increase to 46 pCi/L. This increase, however, still remains within levels consistent with an overall reduction in concentrations in this area, as attributed to accelerated demineralization of the IP1-SFPs.



CURRENT UNIT 1 PLUME

However, because of the timing of the interdictions and, we believe, the slower groundwater transport rates for Strontium, overall the Unit 1 plume has not decayed to the extent the Unit 2 plume has decayed (see **Section 9.4.1**). In fact, due to what we attribute to short term Strontium fluctuations, at six of the well locations within the Unit 1 plume, the highest Strontium groundwater concentrations were observed during the last project sampling event (see the following table for additional detail). In reviewing both figures, note that they show what we believe are conservative estimates of the lateral distribution of the higher (25 pCi/L) Strontium groundwater concentrations.

ANALYSIS OF STRONTIUM CONCENTRATIONS OVER TIME

Max. Observed [1] Strontium Concentration (pCi/L)	Monitoring Well	Current [2] Strontium Concentration (pCi/L)	Elapsed Time between Max. and Current Concentrations (days)	Current Conc. As Percent of Maximum
110	MW-42	20.1	490	18 [3]
37	MW-53*	37	0	100
3.6	MW-47*	3.6	0	100
2.7	MW-56	2.4	332	89
26.8	UI-CSS*	26.8	0	100
21.9	MW-54	19.2	88	88
40.4	MW-55	34.0	263	84
45.5	MW-57	37.9	44	83
5.0	MW-36	2.3	483	46
29.8	MW-37	23.3	40	78
31	MW-50*	31	0	100
25.6	MW-49*	25.6	0	100
19.1	MW-67**	19.1	0	100**
6.2	MW-66**	6.2	0	100

* Current concentration is the maximum concentration of samples analyzed at this monitoring well.
** Only one sample analyzed.
(1) Any depth, any event, at the indicated location.
(2) Any depth, on the date of the last project sampling event, at the indicated location
(3) It should be noted that the latest data just recently received (well after the report data-cut-off-date of August 31, 2007) for MW-42 shows an increase to 46 pCi/L.

10.0 FINDINGS AND CONCLUSIONS

At no time have analyses of existing Site conditions yielded any indication of potential adverse environmental or health risk, as assessed by Entergy as well as the principal regulatory authorities. In fact, radiological assessments have consistently shown that the releases to the environment are a small percentage of regulatory limits, and no threat to public health or safety. In this regard, it is also important to note that the groundwater is not used as a source of drinking water on or near the Site.

Consistent with the purpose of the investigations, we have developed six major supporting conclusions which are described in the following subsections. Based on our findings and conclusions, we are recommending completion of source interdiction measures with Monitored Natural Attenuation as the preferred remedial measure. Refer to **Section 11.0** for more information, including our reasons for making this recommendation.

10.1 NATURE AND EXTENT OF CONTAMINANT MIGRATION

The primary groundwater radiological contaminants of interest are Tritium and Strontium. Other contaminants (Cesium-137, Nickel-63 and Cobalt-60) have been detected, but are limited to areas that have groundwater pathways dominated by Tritium and/or Strontium, and are accounted for in Entergy's dose calculations.

Groundwater contamination is limited to Indian Point's property and is not migrating off-property to the North, East or South. The contamination migrates with the Site groundwater from areas of higher heads to areas of lower heads along paths of least resistance, and ultimately discharges to the Hudson River to the West. This is supported by the bedrock geology, multi-level groundwater elevation data and the radiological results from analytical testing. The nearest drinking water reservoirs are located at distances and elevations which preclude impacts from contaminated groundwater from the Site and there is no nearby use of groundwater.

a. The Site is located over a portion of the aquifer basin where Site-wide ambient groundwater flow patterns, both shallow and deep, have been defined. These flows are towards the Site from higher elevations to the North, East and South. Groundwater flow on Site enters the Hudson River through: footing drains (which discharge to the Discharge Canal); the Discharge Canal; the storm drain system; or direct discharge. The results of over two years of investigations demonstrate that the off-Site groundwater migration to the South, as originally hypothesized by others prior to these investigations, is not occurring.
b. Surface water samples collected from the Algonquin Creek, the Trap Rock Quarry and from the drinking water reservoirs do not exhibit impacts from the Site.
c. The Hudson River is the regional groundwater sink for the area. We found no Site data, published information, or other reasons suggesting that groundwater would migrate beneath the river. To the contrary, based on the area's hydrogeologic setting and all available information, we are confident that groundwater beneath the Site discharges to the river.

d. Because of the hydraulic properties of the bedrock, the bedrock aquifer on-Site will not support large yields, or accept input of large volumes of water.
e. There are no identified off-Site uses of groundwater (extraction or injection) proximate to the Site that influence groundwater flow patterns on the Site. Furthermore, we have no reason to believe that potable or irrigation wells will be installed on or near the Site in the reasonably foreseeable future, in part because municipal water is available in the area.
f. Groundwater flow at the Site occurs in two distinct hydraulic regimes that are vertically connected, bedrock and overburden soils. Most of the groundwater flow and contaminants are found in the bedrock fractures. No evidence of large scale solution features exist in the rock cores obtained from any of the bedrock borings advanced at the Site; i.e., no open voids such as tunnels, caverns, caves, etc., sometimes referred to as "underground rivers," were found. Our on-Site investigatory findings are consistent with that expected for the Inwood Marble. Therefore, this work eliminates from concern solution feature flow associated with karst systems. The second regime is groundwater flow in the unconsolidated soil deposits. This includes groundwater found in native glacial and alluvial deposits, as well as groundwater flow in anthropogenic structures such as blast rock fill and utility trenches. These flow paths, while potentially complicating migration patterns, all terminate at the Hudson River.
g. While groundwater movement in the bedrock is controlled by fracture patterns, the high degree of fracturing allows groundwater flow to be effectively represented and modeled on a Site-wide scale using the well developed techniques derived for porous media[127].

10.2 SOURCES OF CONTAMINATION

The investigations identified two sources of radiological contamination. The IP1-SFPs and the IP2-SFP/Transfer Canal. The IP1-SFPs are the primary source of Strontium groundwater contamination, while the IP2-SFP is the primary source of Tritium groundwater contamination. No evidence of releases from Unit 3 have been identified during this investigation.

During the course of GZA's and Entergy's investigations, we have identified the sources of leakage associated with the IP2-SFP and Transfer Canal. These sources have been eliminated and/or controlled by Entergy. Specifically, Entergy has: 1) confirmed that the damage to the liner associated with the 1992 release was repaired by the prior owner and is no longer leaking; 2) installed a containment system (collection box) at the site of the leakage discovered in 2005, which precludes further release to the groundwater; and 3) identified a weld imperfection in the Transfer Canal liner that, once identified, was prevented from leaking further by draining the Transfer Canal. This weld imperfection was then subsequently repaired by Entergy (completed in mid December 07). Therefore, all identified leaks have been addressed. Water likely remains between the IP2-SFP stainless

---

[127] While fracture-specific numerical models exist, they are less well developed and less flexible than porous media-based models. The use of a porous media representation requires some level of approximation, particularly on small scales of tens of feet. However, the fracture flow models also require substantial approximations based on fracture statistics and are thus, more problematic at this Site than a porous model.

steel liner and the concrete walls, and thus additional active leaks can not be completely ruled out. However, if they exist at all, the data[128] indicate they must be very small and of little impact to the groundwater.

Our investigations also identified the source of all the Strontium contamination detected in groundwater beneath the Site as coming from the Unit 1 Fuel Pool Complex (IP1-SFPs). The IP1-SFPs were identified by the prior owner as leaking in the mid-1990's. All of the pools have been drained by Entergy except the West Pool, which currently contains the last 160 Unit 1 fuel assemblies remaining from prior plant operations. This plant was retired from service in 1974. Following detection of radionuclides associated with IP1-SFPs in the groundwater, Entergy, as part of their already planned fuel rod removal and complete pool drainage program, accelerated efforts to further reduce activity in the IP1-SFPs through demineralization..

The on-Site tracer test demonstrated that aqueous releases in the vicinity of IP2-SFP are stored *above the water table* in either: 1) unsaturated zone dead-end fractures; and/or 2) anthropogenic foundation details such as blast-rock backfill over a mud-mat (see **Section 8.1.2**). This impacted unsaturated zone water is then periodically released to the groundwater over time as driven, for example, by infiltration of precipitation. Consequently, subsequent releases *to the groundwater* can continue for significant durations after the initial leak has been terminated. In addition, the tracer studies further demonstrate that the migration rates for the Tritium plume *in the groundwater* can be slowed down as compared to the groundwater itself. This reduction in Tritium plume migration velocity occurs when impacted groundwater encounters, and becomes "entrapped" by dead-end fractures, both naturally occurring fractures and those created by excavation blasting during Site construction[129].

The radionuclides identified in the Unit 3 area are related to historic legacy leakage from IP1, and reflect what remains of the plume that has been naturally attenuating since approximately 1994. The pathway to the Unit 3 area was via the IP1-SFDS and then to the storm drain system which transverses along the southeastern portion of the Site; not via groundwater flow to the South (see **Section 8.2**). Exfiltration from this storm drain system had, in turn, resulted in contamination of the groundwater along the storm drain piping. The Sphere Foundation Drain Sump no longer discharges to the storm drain system and this legacy release pathway had therefore been terminated because the associated piping was capped in 1994.

---

[128] These data include: monitored water levels in the SFP, with variations accounted for based on refilling and evaporation volumes; the mass of Tritium migrating with groundwater is small; and the age of the water in the interstitial space.

[129] Once contaminants enter dead-end fractures, they no longer migrate with the groundwater flow. However, this "entrapped contamination" does re-enter the flow regime over time due to turbulent flow mixing at the fracture opening as well as diffusion.

10.3 GROUNDWATER CONTAMINANT TRANSPORT

Based on our assessment of the bedrock's hydraulic properties, the area's hydrogeologic setting, the properties of the contaminants, the age of the releases, interdictions made to eliminate or reduce release rates, and the distances between the source areas and the Hudson River, we believe the groundwater contaminant plumes have expanded to their maximum extent and are now decreasing in size. In this regard, the Unit 2 Tritium plume is decreasing faster than the Unit 1 Strontium plume, as anticipated. These conclusions are based on the data available which, given the aggressiveness with which Entergy implemented the investigations, is compressed in duration[130]. Therefore, ultimate confirmation of these conclusions will require monitoring over a number of years to allow ranges in seasonal variation to be adequately reflected in the monitoring data. During long term monitoring, GZA further anticipates that contaminant concentrations in individual monitoring wells will fluctuate over time (increasing at times as well as decreasing, as potentially related to precipitation events), and that a future short term increase in concentrations does *not*, in and of itself, indicate a new leak. In addition, it is also expected that some areas within the plumes will exhibit faster decay rates than others. Both behaviors are commonly observed throughout the industry with groundwater contamination sampling and analyses, and therefore, conclusions pursuant to plume behavior must be evaluated in the context of all of the Site-wide monitoring data. Overall, however, GZA believes that the continuing monitoring will demonstrate decreasing long term trends in groundwater contaminant concentrations over time given the source interdictions completed by Entergy. It is also further emphasized that even the *upper bound* Tritium and Strontium groundwater concentration isopleths presented on **Figures 8.1** and **8.2** result in releases to the river which are only a small percentage of the regulatory limits, which are of no threat to public health.

a. The major groundwater transport mechanism is advection. Sorption retards the migration of radiological contaminants other than Tritium relative to groundwater advection rates, while Tritium, within hydraulically interconnected fractures, can migrate at rates that approach the groundwater seepage velocity.
b. The Unit 2 contaminant plume is characterized by Tritium in the groundwater. Over the last two years, the highest Tritium concentrations in the Unit 2 plume have decreased (see **Table 5.1** and **Figures 8.1** and **9.3**). However, the center of mass of the Unit 2 plume is not rapidly migrating downgradient, and remains in proximity to the IP2-SFP. While a small active leak can not be ruled out completely, this behavior is also consistent with the identified role of unsaturated zone (above the water table) storage of historic releases, with precipitation-induced infusion of this entrapped water into the groundwater regime over time.
c. The Unit 1 contaminant plume is primarily characterized by Strontium concentrations in the groundwater, though near the physical pool area other isotopes are present as expected due to proximity. Over the last two years, the highest Strontium concentrations in the Unit 1 plume have decreased (**Table 5.1**). These decreases in concentration are consistent with a reduction in Strontium

[130] It is noted that a number of key monitoring installations have only recently been completed, and monitoring rounds spanning multiple seasons are not yet available.

concentrations in the Unit 1 West Fuel Pool via pool water recirculation through demineralization beds. While the physical leak(s) in this fuel pool still exist, the source term to the groundwater has been reduced through reduction in the contaminant concentrations in the leak water. It is noted, however, the Unit 1 Strontium decreases are more modest and are generally more limited to the immediate source area than that observed for Tritium at Unit 2. The slower rate of plume decay is not unanticipated give the adsorption properties of Strontium. Further planned interdictions include removal of the fuel rods and draining of the pool water, which will permanently eliminate the West Fuel Pool as well as the entire IP1-SFP complex as a source of contamination to the groundwater. With elimination of this source, natural attenuation will reduce Strontium concentrations in the Unit 1 plume over time.

10.4 GROUNDWATER MASS FLUX CALCULATIONS

During the project (over the past two years), as testing progressed and more information became available, we refined methods to calculate the groundwater flux and associated radiological activity to the Hudson River. As described below, we have developed a procedure which is scientifically sound, relatively straight-forward, and appropriately conservative. Groundwater flow rates are provided to Entergy, who computes the radiological dose impact.

a. Migration of radionuclides to the river is computed based on groundwater flow rates, in combination with contaminant concentrations within the flow regime. This information is then used in surface water models to compute radiological contaminant concentrations in the river and thus potential dose to receptors.
b. To assess the validity of the precipitation mass balance method used to date for computing groundwater flux across the Site, GZA also performed groundwater flux computations using an independent method based on Darcy's Law. Thus, the results from two widely accepted groundwater flow calculation methods were compared against each other. The first, the precipitation mass balance method, is a "top-down" procedure based on precipitation-driven water balance analyses. The second, based on Darcy's Law, is a "bottom-up" method using hydraulic conductivity and flow gradient measurements. These two methods resulted in estimated groundwater flow values which were in agreement, providing a high degree of confidence in the values obtained relative to their impact on subsequent dose computations and risk analyses.
c. The original groundwater flux computations were developed for two separate areas of the Site. The northernmost area included both the Unit 2 and Unit 1 plumes. The southernmost area encompassed Unit 3. This bifurcation of the Site was established given: 1) the co-location of the Unit 2 plume and the Unit 1 plume near the western boundary of the Site just upgradient of the river; 2) the much lower contaminant concentrations in the Unit 3 area; and 3) the amount of data available at that time. Current data, derived from a greater number of groundwater elevation and sampling points than reflected in earlier data, show the Site can be divided into six separate areas. The computations were further separated into shallow and deep flow regimes given: 1) the generally higher hydraulic conductivity in the shallow

portion of the bedrock, and 2) the generally more elevated contaminant concentrations in the shallow flow regime.

d. The groundwater contaminant concentrations used for the radiological dose computations were obtained primarily from the analysis of samples taken from the recently completed multi-level wells specifically installed for this purpose. These wells are located downgradient of the Unit 2 and Unit 1 infrastructure[131] and are positioned within the plumes and just upgradient of where the groundwater discharges to the river and Discharge Canal. The multi-level nature of these wells allows the groundwater to be sampled over at least five separate elevations in the bedrock, in addition to the overburden layer above. Sampling zones specifically targeted the most pervious depths within the bedrock boreholes. As such, the groundwater samples encompass the full depth of the contaminant plume, from the upper soil zones to depths where the contaminant concentrations have fallen off to insignificant levels. The high number of samples over the depth of the plume provides a higher degree of confidence that the significant flow zones are accounted for. The high number of vertical sampling zones also provides a higher level of redundancy relative to the longevity and efficacy of the monitoring network over time.

10.5 GROUNDWATER MONITORING

The current groundwater well and footing drain monitoring network is consistent with the objectives of the NEI Groundwater Protection Initiative[132]. Wells have been installed and are currently being monitored to both detect and characterize current and potential future groundwater contaminant migration to the river, as well as, in concert with specific footing drain monitoring, provide earlier detection of potential future leaks associated with the existing infrastructure.

a. The network of 59 monitoring well locations and over 140 sampling intervals/locations, has allowed us to identify groundwater flow patterns. A subset of this network will provide an adequate long term monitoring system.
b. Existing and potential sources have been identified, and monitoring is in place to both evaluate current conditions and identify future releases, should they occur.
c. The nature and extent of contamination is known and reporting requirements are in place.

10.6 COMPLETENESS

Investigations at the Site have been broad, comprehensive, and rigorous. Major components of the field studies include: detailed acquisition of geologic information; automated long duration collection of piezometric data; vigorous source area

[131] The multi-level sampling network is concentrated in the Unit 2 and Unit 1 areas given that this is where contaminant concentrations are by far the highest. The individual monitoring wells located downgradient of Unit 3 are judged sufficient for computations in this area given the low contaminant concentrations measured, even in the typically more contaminated shallow flow regime.

[132] NEI developed a set of procedures/goals for nuclear plants to assess the potential for releases of radionuclides to potentially migrate off-Site.

identification; comprehensive aquifer property testing, including performance of a full scale Pumping Test; and large-scale confirmatory contaminant transport testing, in the form of an extensive tracer test. The results of this systematic testing program are in agreement with conditions anticipated by our Conceptual Site Model. Based on our review of findings, we have concluded that the field studies conducted at the Site have addressed the study objectives.

a. There is no need to monitor groundwater at off-Site locations. The density and spacing of on-Site monitoring wells is adequate to: 1) demonstrate that contaminated groundwater is migrating to the Hudson River to the West, and not migrating off of the property to the North, East or South; 2) monitor the anticipated attenuation of contaminant concentrations; 3) identify future releases, should they occur; and 4) provide the data required to compute radiological dose impact.
b. Hydraulic conductivity is the most important aquifer property. We have completed more than 245 hydraulic conductivity tests, including a full-scale Pumping Test. Therefore, we believe no future aquifer testing is required. In addition, the contaminant plumes have reached their maximum spatial extent. Therefore, there is no need for contaminant transport modeling.
c. The sources of releases to the groundwater have been identified. In addition to monitoring, actions have been taken to reduce or eliminate these releases. Therefore, we believe no future source characterization is required.
d. All information indicates Monitored Natural Attenuation is the appropriate remedial response and is GZA's recommended approach (see **Section 11.0**). The existing monitoring network will serve this remedial approach. Therefore, no design phase studies are required.

11.0 RECOMMENDATIONS

Based upon the comprehensive groundwater investigation and other work performed by Entergy, GZA recommends the following:

1. Repair the identified Unit 2 Transfer Canal liner weld imperfection (completed mid December 2007);
2. Continue source term reduction in the Unit 1 pool via the installed demineralization system;
3. Remove the remaining Unit 1 fuel and drain the pools; and
4. Implement long term monitoring consistent with monitored natural attenuation, property boundary monitoring, future potential leak identification, and support of ongoing dose assessment.

It is GZA's opinion that our investigations have characterized the hydrogeology and radiochemistry of the groundwater regime at the Site. Therefore, we are not recommending further subsurface investigations (see **Section 10.0**). Based upon the findings and conclusions from these investigations, as well as other salient Site operational information, we recommend the completion of source interdiction measures with Monitored Natural Attenuation (MNA) as the remediation technology at the Site. In no small part, this recommendation is made because of the low potential for risk associated with groundwater plume discharge to the Hudson River.

Monitored Natural Attenuation is defined by the United States Environmental Protection Agency as the reliance on natural attenuation processes (within the context of a carefully controlled and monitored clean up approach) to achieve Site-specific remedial objectives within a time frame that is reasonable compared to other methods. The "natural attenuation processes" that are at work in the remediation approach at this Site include a variety of physical, chemical and radiological processes that act without human intervention to reduce the activity, toxicity, mobility, volume, or concentration of contaminants in soil and groundwater. These primarily include radiological decay, dispersion, and sorption.

MNA is typically used in conjunction with active remediation measures (e.g., source control), or as a follow-up to active remediation measures that have already been implemented. At IPEC, active remedial measures *already implemented* include elimination (e.g., repair of the Unit 2 1990 liner leak and repair of Transfer Canal weld imperfection in mid-December 2007) and/or control (e.g., installation of a collection box to capture moisture from the IP2 shrinkage cracks) of active leaks, and reduction of the source term in the Unit 1 fuel storage pool through demineralization, with subsequent planned removal of the source term (fuel rods) followed by complete draining of the IP1-SFPs.

<u>Remediation</u>

1. Our recommendation of MNA principles includes source term contaminant reduction as an integral part of this remediation strategy. Data demonstrating plume concentration reductions over time, as considered along with other salient

Site information, are consistent with a conclusion that the interdiction efforts to date (both current and in the past) have resulted in: 1) termination of the identified Tritium leaks in the IP2-SFP; 2) identification of an imperfection in a Unit 2 Transfer Canal weld which has been repaired; 3) reduction in IP1-SFP contaminant concentrations; and 4) elimination of Sphere Foundation Drain Sump discharges to the storm drain piping East of Unit 3. As such, these interdictions have resulted in the elimination and/or control of identified sources of contamination to the groundwater, as required:

a. Over the last two years, the highest Tritium concentrations in the Unit 2 plume have decreased. These data are consistent with a conclusion that the leaks responsible for the currently monitored Tritium plume are related primarily to the previously repaired 1992 legacy liner leak and the imperfection in the Transfer Canal weld. With the implemented physical containment of the associated 2005 "concrete wall crack leaks" and the repair of the Transfer Canal liner, the source of contamination to the groundwater has been reduced and controlled.
b. Over the last two years, the highest radionuclide concentrations in the Unit 1 plume have decreased. These decreases are consistent with a reduction in the concentrations in the Unit 1 West Fuel Pool via pool water recirculation through demineralization beds. While the physical leak(s) in this fuel pool still exist, the source term to the groundwater has been reduced due to treatment of the source water. Further planned interdictions include removal of the fuel rods and draining of the pool water, which will permanently eliminate the West Fuel Pool as a source of contamination to the groundwater.
c. The Unit 1 plume in the Unit 3 area has been attributed to a historic legacy discharge from the Sphere Foundation Drain Sump (SFDS) through the storm drain system which traverses along the southeastern portion of the Site. Leaks from this storm drain system have, in turn, resulted in past contamination of the groundwater along the storm drains, with subsequent groundwater migration westward, through Unit 3 toward the river. The SFDS no longer discharges to the storm drain and the Strontium concentrations in the Unit 3 groundwater have decreased to low levels, consistent with natural attenuation processes.

2. GZA selected Monitored Natural Attenuation as the remediation strategy because:

a. Interdiction measures undertaken and planned to date have, or are expected to, eliminate/control active sources of groundwater contamination.
b. Groundwater flow at the Site precludes off-Site migration of contaminated groundwater to the North, South or East.
c. Consistent with the Conceptual Site Model, no contaminants have been detected above regional background in any of the off-Site monitoring locations or drinking water supply systems in the region.
d. The only on-Site exposure route for the documented contamination is through direct exposure. Because the majority of the Site is capped by

impermeable surfaces, there is no uncontrolled direct contact with contaminants.

e. Our studies indicate that under existing conditions, the spatial extent of the groundwater plume will decrease with time.
f. Groundwater is not used as a source of drinking water on the Site or in the immediate vicinity of the Site, and there is no reason to believe that this practice will change in the foreseeable future.
g. Groundwater associated with the Unit 1 foundation drainage systems is captured and treated to reduce contaminants prior to discharge to the Discharge Canal, consistent with ALARA principles.
h. At the locations where contaminated groundwater discharges to the Hudson River, the concentrations have been, and will continue to be, reduced by sorption, hydrodynamic dispersion and radiological decay. No detections of contaminants associated with plant operations have been found in the Hudson River or biota sampled as part of the required routine environmental sampling.
i. More aggressive technologies would alter groundwater flow patterns and, therefore, in our opinion, offer no clear advantages.

Long Term Monitoring

1. The second primary requirement for implementation of MNA is a demonstration that contaminant migration is consistent with the Conceptual Site Model. In particular, rigorous monitoring is required to demonstrate reductions in source area contamination, reductions in plume contaminant concentrations, and reduction in contaminant discharge to the river over time. The initial implementation stages of this monitoring process were begun nearly two years ago as part of the investigations summarized herein. As outlined above, reductions in maximum groundwater plume contaminant concentrations have already been documented. The elements for long term monitoring, consistent with the objectives of the NEI Groundwater Protection Initiative, are in place. We further note:

   a. Groundwater wells have specifically been installed, and are currently being monitored, to both detect and characterize current and potential future off-Site groundwater contaminant migration to the river. Additional wells have also been installed for monitoring of other Site property boundaries.
   b. Monitoring wells have also been installed just downgradient of identified critical Structures, Systems and Components (SSCs). These wells, in concert with specific footing drain monitoring, provide earlier detection of potential future leaks associated with the power generating units than would be possible with boundary wells alone.
   c. Monitoring wells have been strategically placed to monitor the behavior of the plumes identified on the Site.
   d. MW-38 and MW-48 should be excluded from the monitoring plan as samples from these wells are generally indicative of a mixed groundwater

and Discharge Canal/river water condition and, therefore, are not completely groundwater specific[133].

e. The long term monitoring plan should include action levels, which if exceeded, trigger further analysis and/or investigations, potentially leading to implementation of an interdiction plan, if required.
f. A number of individual vertical sampling zones were included in nearly all the monitoring well installations, particularly within the contaminant plumes and at the location of plume discharge to the river. These individual vertical monitoring zones provide a significant level of vertical resolution and also provide a substantial degree of redundancy relative to the longevity and efficacy of the monitoring network over time[134].
g. While previous and current dose calculations are both reasonable and conservative, we recommend that, with the accumulation of additional Site-specific hydrogeologic information, the calculations be modified to incorporate Site-specific transmissivities and groundwater gradients. Entergy has agreed that Site-specific model information will be utilized in the next NRC required annual assessment of dose from this pathway. Our specific recommendations (which will include additional trend information in early 2008) will be provided under separate cover for Entergy's incorporation to support the annual report.

[133] See **Section 6.6.3** for further discussion pursuant to this conclusion.

[134] The level of redundancy designed into the long term monitoring network anticipates and allows for the loss of a number of monitoring zones without significant impact to the adequacy of the monitoring system.

TABLE 4.1
SUMMARY OF WELL LOCATIONS AND INSTALLATION DEPTHS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS [1]		
									TOP	CENTER	BOTTOM
MW-30-69	604885.30	462996.83	77.50	75.66	87.20	51.70	11/11/05	11/19/05	8.4	6.4	4.4
30-71[2]									8.4	4.9	4.4
30-82[2]									-1.6	-6.6	-9.6
30-84									-1.6	-8.1	-9.6
MW-31-49	604924.22	462969.84	77.45	75.64	88.15	75.74	12/20/05	2/14/06	40.8	26.8	26.3
31-63									20.3	12.3	11.8
31-85									5.8	-9.2	-9.7
MW-32-62	604876.03	462953.48	78.90	77.13	200.00	71.40	12/21/05	1/13/06	30.3	15.3	14.8
32-92									-5.2	-15.2	-15.7
32-140									-42.7	-62.7	-63.2
32-165									-69.2	-87.7	-89.2
32-196									-95.2	-119.2	-120.7
MW-33	604767.86	462995.54	18.88	18.62	30.21	12.38	12/12/05	12/14/05		2.9	
MW-34	604755.31	462976.79	18.48	18.07	30.00	14.98	12/8/05	12/13/05		2.0	
MW-35	604744.19	462962.18	18.60	18.44	29.70	10.60	12/6/05	12/20/05		3.6	
MW-36-24	604657.59	463090.60	11.80	11.60	54.00	-12.20	1/24/06	2/1/06	5.2	-4.3	-13.8
36-41				11.75					-20.2	-25.2	-30.2
36-52				11.67					-34.4	-37.9	-41.4
MW-37-22	604604.87	463075.37	15.02	14.85	57.00	-9.98	2/9/06	2/22/06	6.7	-0.8	-8.3
37-32				14.79					-11.8	-14.8	-17.8
37-40				14.96					-22.9	-24.2	-25.4
37-57				14.79					-34.7	-38.2	-41.7
MW-38	603810.21	462505.68	14.34	14.00	40.00	NA	12/1/05		12.0	-6.5	-25.0
MW-39-67	604676.87	462425.51	81.83	79.99	200.00	57.33	2/10/06	2/21/06	15.0	13.0	9.5
39-84									0.5	-3.5	-5.0
39-100[2]									-13.0	-20.0	-23.0
39-102									-13.0	-21.5	-22.0
39-124									-35.0	-44.0	-46.5
39-183									-89.5	-102.5	-106.0
39-195									-113.0	-115.0	-118.5
MW-40-24[2]	603899.35	461950.51	74.95	73.16	200.00	69.95	1/30/06	2/6/06	55.0	49.0	38.0
40-27									55.0	46.5	38.0
40-46									29.0	27.0	19.5
40-81									8.5	-7.5	-11.0
40-100									-20.0	-27.0	-33.5
40-127									-52.0	-54.0	-63.5
40-162									-85.5	-88.5	-117.0
MW-41-13	604531.11	462318.68	54.87	0.00	65.00	40.00	2/23/06	3/2/06	54.7	48.2	41.7
41-40				54.13					35.2	23.2	11.2
41-63				54.13					0.5	-4.5	-9.5
MW-42-49	604857.50	462750.33	69.71	69.42	80.00	44.71	3/16/06	3/22/06	42.7	31.2	19.7
42-78				69.52				3/21/06	2.1	-3.9	-9.9
MW-43-28	604429.78	462192.60	48.76	48.02	65.00	16.30	1/24/06	3/1/06	41.8	29.8	17.8
43-62				47.82				3/1/06	7.4	-5.1	-17.6

See Page 4 for Notes

TABLE 4.1
SUMMARY OF WELL LOCATIONS AND INSTALLATION DEPTHS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS [1]		
									TOP	CENTER	BOTTOM
MW-44-67	604516.43	462499.91	93.52	93.02	105.00	62.52	3/10/06	3/15/06	43.5	34.5	25.5
44-102				93.09				3/15/06	18.0	4.0	-10.0
MW-45-42	604471.96	462385.52	53.66	53.20	65.00	38.66	3/22/06	3/29/06	28.3	19.3	10.3
45-61				53.10				3/29/06	2.9	-4.4	-11.6
MW-46	604328.72	462431.26	18.08	16.97	31.50	18.08	2/14/06	2/22/06	0.0	7.6	0.0
MW-47-56	604651.13	462664.08	70.32	69.81	80.00	57.32	3/3/06	2/24/06	39.4	25.9	12.4
47-80				69.74				3/14/06	1.8	-4.2	-10.2
MW-48-23	603473.78	462015.66	15.39	14.76	40.00	-9.60	1/27/06	2/2/06	9.1	-0.4	-9.9
48-37				15.07					-16.4	-20.4	-24.4
MW-49-26	604445.56	463080.21	14.58	14.17	65.00	-8.42	3/16/06	3/17/06	0.4	-5.6	-11.6
49-42	604446.12	463078.45	14.63	14.22				3/20/06	-16.5	-23.5	-30.5
49-65				14.46				3/20/06	-41.0	-46.0	-51.0
MW-50-42	604494.30	463039.18	14.92	14.45	67.00	-7.78	3/13/06	3/13/06	-6.5	-17.5	-28.5
50-66				14.61					-44.1	-47.6	-51.1
MW-51-40	604275.34	461822.43	69.64	67.72	200.00	53.64	3/28/06	3/27/06	38.0	28.0	23.5
51-79									4.5	-11.0	-13.5
51-102[2]									-33.5	-34.5	-43.5
51-104									-33.5	-36.0	-43.5
51-135									-62.5	-67.5	-76.0
51-163									-87.0	-95.0	-98.5
51-189									-116.5	-121.5	-130.0
MW-52-11	604733.05	463253.94	16.77	16.28	12.00	NA[3]	3/21/06	3/21/06	15.3	9.8	4.3
52-18	604733.54	463254.34	16.77	16.37	200.00	3.77			16.3	-2.6	-13.7
52-48									-31.7	-33.1	-39.7
52-64									-42.7	-49.1	-55.2
52-118[2]									-94.2	-102.6	-107.2
52-122									-94.2	-107.1	-107.2
52-162									-138.2	-146.6	-147.7
52-181									-154.7	-166.1	-181.7
MW-53-82	604732.60	462822.15	70.26	69.93	125.00	40.26	6/29/06	6/30/06	10.1	-2.4	-14.9
53-120				70.06					-26.5	-39.5	-52.5
MW-54-35[2]	604554.25	462935.57	14.99	13.09	206.00	-1.81	8/30/06	9/7/06	-15.9	-21.9	-28.9
54-37									-15.9	-23.4	-28.9
54-58									-38.4	-44.4	-50.9
54-123									-102.9	-109.9	-112.9
54-144									-121.9	-130.9	-142.4
54-173									-157.4	-159.4	-168.9
54-190									-171.9	-176.9	-190.4
MW-55-24	604635.96	462996.42	18.25	17.77	77.50	8.75	8/11/06	8/14/06	5.7	-0.8	-7.3
55-35				17.77					-10.2	-14.2	-18.2
55-54				17.77					-24.3	-30.8	-37.3
MW-56-53	604658.09	462708.49	70.26	69.32	88.50	41.26	8/29/06	8/30/06	22.3	17.8	13.3
56-83				69.21					4.0	-5.5	-15.0

See Page 4 for Notes

TABLE 4.1
SUMMARY OF WELL LOCATIONS AND INSTALLATION DEPTHS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS[1]		
									TOP	CENTER	BOTTOM
MW-57-11	604562.36	462888.55	14.98	14.73	47.00	9.48	7/12/06	7/13/06	11.6	7.1	2.6
57-20				14.75					0.1	-2.9	-5.9
57-45				14.81					-13.8	-22.5	-31.3
MW-58-26	604400.31	462864.26	14.57	14.23	72.00	-0.43	7/12/06	7/13/06	0.0	-7.0	-14.0
58-65				14.14					-33.5	-43.0	-52.5
MW-59-32	604330.15	462912.91	14.52	14.41	77.00	1.52	9/8/06	10/3/06	-5.2	-11.7	-18.2
59-45				13.90					-19.4	-25.9	-32.4
59-68				14.23					-37.1	-46.1	-55.1
MW-60-35	604585.60	463381.26	14.31	12.48	200.00	5.81	10/23/06	10/24/06	-12.4	-22.4	-26.9
60-53									-32.9	-40.9	-46.9
60-55[2]									-32.9	-42.4	-46.9
60-72									-53.9	-59.9	-66.4
60-135									-112.4	-122.4	-128.9
60-154									-134.9	-141.9	-152.4
60-176									-158.4	-163.4	-187.9
MW-62-18			14.69	12.81	38.30	NA	8/17/06	10/5/06	6.7	-1.8	-10.3
62-37									-30.3	-33.5	-36.6
62-52[2]	604350.80	463086.79	14.69	12.82	201.00	-22.31			-36.8	-38.8	-41.3
62-53									-36.8	-40.3	-41.3
62-71									-48.3	-58.3	-69.8
62-92									-75.8	-78.8	-86.3
62-138									-113.3	-125.3	-130.8
62-181[2]									-164.8	-167.8	-185.8
62-182									-164.8	-169.3	-185.8
MW-63-18	604252.14	462968.86	14.18	13.06	35.00	NA	8/17/06	9/22/06	7.1	0.6	-5.9
63-34									-27.1	-30.6	-34.1
63-50	604251.28	462970.42	14.18	12.32	201.00	-17.82			-29.2	-37.2	-45.7
63-91[2]									-69.2	-78.2	-88.2
63-93									-69.2	-80.7	-88.2
63-112									-94.2	-99.2	-99.7
63-121									-105.7	-108.7	-115.2
63-163									-138.2	-150.2	-152.7
63-174									-155.7	-161.7	-178.7
MW-65-48	604851.98	462489.68	69.72	68.86	83.00	34.72	8/21/06	8/23/06	33.9	26.4	18.9
65-80									10.8	-1.7	-14.2
MW-66-21	604408.77	463146.34	14.12	13.41	37.00	-23.48	11/17/06	12/5/06	8.0	0.0	-8.0
66-36									-16.0	-19.5	-23.0
MW-67-39	604426.67	463127.06	14.36	12.51	349.25	-18.64	6/5/07	6/8/07	-15.8	-25.8	-41.3
67-105									-77.3	-92.3	-97.8
67-173									-151.8	-159.8	-175.3
67-219									-196.3	-206.3	-216.8
67-276									-237.8	-262.8	-268.3
67-323									-304.8	-309.8	-317.8
67-340									-322.3	-327.3	-334.8

See Page 4 for Notes

TABLE 4.1
SUMMARY OF WELL LOCATIONS AND INSTALLATION DEPTHS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS [1]		
									TOP	CENTER	BOTTOM
MW-101	Not surveyed		133.86	133.86	15.00	NA	2/7/00	2/7/00	129.9	124.4	118.9
MW-103	Not surveyed		143.44	146.74	26.30	7.00	2/9/00	2/9/00	133.1	125.1	117.1
MW-104	Not surveyed		140.50	140.50	30.00	136.00	2/10/00	2/10/00	131.5	121.0	110.5
MW-105	Not surveyed		135.73	138.51	20.00	NA	2/10/00	2/10/00	131.7	123.7	115.7
MW-107	605014.18	461922.70	140.06	142.76	35.00	NA	2/15/00	2/15/00	126.1	115.6	105.1
MW-108	604454.15	462819.57	14.48	14.23	11.67	NA	2/21/00	2/21/00	12.8	7.8	2.8
MW-109	604396.85	462860.95	14.55	14.25	11.91	NA	2/25/00	2/25/00	12.6	7.6	2.6
MW-110	Not surveyed		134.55	137.72	29.50	126.55	2/25/00	2/25/00	121.1	113.6	106.1
MW-111	604735.19	463023.59	18.93	18.38	16.92	0.90	2/24/00	2/24/00	7.0	4.2	1.5
MW-112	604888.09	461578.48	136.77	36.77	24.00	126.77	2/26/00	2/26/00	128.8	120.8	112.8
RW-1	604879.23	463006.67	77.50	75.82	138.50	51.30	7/28/06	8/1/06			
U3-1	604197.32	462762.55	13.50	13.50	19.00	NA	4/11/96	4/11/96	7.5	1.0	-5.5
U3-2	604262.35	462772.31	14.16	14.11	14.70	NA	Not available [4]		10.5	5.0	-0.5
U3-3	604293.07	462778.30	14.85	14.60	14.70	NA	4/9/96	4/9/96	11.1	5.6	0.1
U3-4D	604167.66	462723.77	14.82	14.52	34.00	-3.78	12/15/97	12/15/97	-10.2	-14.7	-19.2
U3-4S	604158.88	462711.07	14.65	13.94	17.35	-2.65	12/12/97	12/12/97	8.3	2.8	-2.7
U3-T1	604132.98	462555.03	3.27	8.51	1.20	NA	12/12/97	12/12/97	0.0	2.5	0.0
U3-T2	604240.59	462673.84	3.26	8.51	1.60	NA	12/12/97	12/12/97	0.0	2.5	0.0
I-2	605072.45	463218.16	80.92	82.23	40.00	NA	4/8/03	4/8/03	53.8	48.0	42.2
U1-CSS	604631.14	462827.29	15.09	20.07	Not avaialbe [5]						

NOTES: [shaded box] well screen in unconsolidated deposit {soil backfill/natural soil}
[unshaded box] well screen in consolicated {bedrock}

1. Elevations of sampling ports in waterloo systems or sand packed zone in wells. Low flow sampling locations are given for open rock holes when available.
2. Redundant sampling ports within single sampling zones.
3. Rock surface not encountered.
4. U3-2 is a legacy well installed by Foster Wheeler Env Co. No dates for installation provided.
5. No construction details of U1-CSS were provided to GZA.

TABLE 4.1
SUMMARY OF WELL LOCATIONS AND INSTALLATION DEPTHS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS [1]		
									TOP	CENTER	BOTTOM
MW-30-69	604885.30	462996.83	77.50	75.66	87.20	51.70	11/11/05	11/19/05	8.4	6.4	4.4
30-71[2]									8.4	4.9	4.4
30-82[2]									-1.6	-6.6	-9.6
30-84									-1.6	-8.1	-9.6
MW-31-49	604924.22	462969.84	77.45	75.64	88.15	75.74	12/20/05	2/14/06	40.8	26.8	26.3
31-63									20.3	12.3	11.8
31-85									5.8	-9.2	-9.7
MW-32-62	604876.03	462953.48	78.90	77.13	200.00	71.40	12/21/05	1/13/06	30.3	15.3	14.8
32-92									-5.2	-15.2	-15.7
32-140									-42.7	-62.7	-63.2
32-165									-69.2	-87.7	-89.2
32-196									-95.2	-119.2	-120.7
MW-33	604767.86	462995.54	18.88	18.62	30.21	12.38	12/12/05	12/14/05		2.9	
MW-34	604755.31	462976.79	18.48	18.07	30.00	14.98	12/8/05	12/13/05		2.0	
MW-35	604744.19	462962.18	18.60	18.44	29.70	10.60	12/6/05	12/20/05		3.6	
MW-36-24	604657.59	463090.60	11.80	11.60	54.00	-12.20	1/24/06	2/1/06	5.2	-4.3	-13.8
36-41				11.75					-20.2	-25.2	-30.2
36-52				11.67					-34.4	-37.9	-41.4
MW-37-22	604604.87	463075.37	15.02	14.85	57.00	-9.98	2/9/06	2/22/06	6.7	-0.8	-8.3
37-32				14.79					-11.8	-14.8	-17.8
37-40				14.96					-22.9	-24.2	-25.4
37-57				14.79					-34.7	-38.2	-41.7
MW-38	603810.21	462505.68	14.34	14.00	40.00	NA	12/1/05		12.0	-6.5	-25.0
MW-39-67	604676.87	462425.51	81.83	79.99	200.00	57.33	2/10/06	2/21/06	15.0	13.0	9.5
39-84									0.5	-3.5	-5.0
39-100[2]									-13.0	-20.0	-23.0
39-102									-13.0	-21.5	-22.0
39-124									-35.0	-44.0	-46.5
39-183									-89.5	-102.5	-106.0
39-195									-113.0	-115.0	-118.5
MW-40-24[2]	603899.35	461950.51	74.95	73.16	200.00	69.95	1/30/06	2/6/06	55.0	49.0	38.0
40-27									55.0	46.5	38.0
40-46									29.0	27.0	19.5
40-81									8.5	-7.5	-11.0
40-100									-20.0	-27.0	-33.5
40-127									-52.0	-54.0	-63.5
40-162									-85.5	-88.5	-117.0
MW-41-13	604531.11	462318.68	54.87	0.00	65.00	40.00	2/23/06	3/2/06	54.7	48.2	41.7
41-40				54.13					35.2	23.2	11.2
41-63				54.13					0.5	-4.5	-9.5
MW-42-49	604857.50	462750.33	69.71	69.42	80.00	44.71	3/16/06	3/22/06	42.7	31.2	19.7
42-78				69.52				3/21/06	2.1	-3.9	-9.9
MW-43-28	604429.78	462192.60	48.76	48.02	65.00	16.30	1/24/06	3/1/06	41.8	29.8	17.8
43-62				47.82				3/1/06	7.4	-5.1	-17.6

See Page 4 for Notes

TABLE 4.1
SUMMARY OF WELL LOCATIONS AND INSTALLATION DEPTHS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS [1]		
									TOP	CENTER	BOTTOM
MW-44-67	604516.43	462499.91	93.52	93.02	105.00	62.52	3/10/06	3/15/06	43.5	34.5	25.5
44-102				93.09				3/15/06	18.0	4.0	-10.0
MW-45-42	604471.96	462385.52	53.66	53.20	65.00	38.66	3/22/06	3/29/06	28.3	19.3	10.3
45-61				53.10				3/29/06	2.9	-4.4	-11.6
MW-46	604328.72	462431.26	18.08	16.97	31.50	18.08	2/14/06	2/22/06	0.0	7.6	0.0
MW-47-56	604651.13	462664.08	70.32	69.81	80.00	57.32	3/3/06	2/24/06	39.4	25.9	12.4
47-80				69.74				3/14/06	1.8	-4.2	-10.2
MW-48-23	603473.78	462015.66	15.39	14.76	40.00	-9.60	1/27/06	2/2/06	9.1	-0.4	-9.9
48-37				15.07					-16.4	-20.4	-24.4
MW-49-26	604445.56	463080.21	14.58	14.17	65.00	-8.42	3/16/06	3/17/06	0.4	-5.6	-11.6
49-42	604446.12	463078.45	14.63	14.22				3/20/06	-16.5	-23.5	-30.5
49-65				14.46				3/20/06	-41.0	-46.0	-51.0
MW-50-42	604494.30	463039.18	14.92	14.45	67.00	-7.78	3/13/06	3/13/06	-6.5	-17.5	-28.5
50-66				14.61					-44.1	-47.6	-51.1
MW-51-40	604275.34	461822.43	69.64	67.72	200.00	53.64	3/28/06	3/27/06	38.0	28.0	23.5
51-79									4.5	-11.0	-13.5
51-102[2]									-33.5	-34.5	-43.5
51-104									-33.5	-36.0	-43.5
51-135									-62.5	-67.5	-76.0
51-163									-87.0	-95.0	-98.5
51-189									-116.5	-121.5	-130.0
MW-52-11	604733.05	463253.94	16.77	16.28	12.00	NA[3]	3/21/06	3/21/06	15.3	9.8	4.3
52-18	604733.54	463254.34	16.77	16.37	200.00	3.77			16.3	-2.6	-13.7
52-48									-31.7	-33.1	-39.7
52-64									-42.7	-49.1	-55.2
52-118[2]									-94.2	-102.6	-107.2
52-122									-94.2	-107.1	-107.2
52-162									-138.2	-146.6	-147.7
52-181									-154.7	-166.1	-181.7
MW-53-82	604732.60	462822.15	70.26	69.93	125.00	40.26	6/29/06	6/30/06	10.1	-2.4	-14.9
53-120				70.06					-26.5	-39.5	-52.5
MW-54-35[2]	604554.25	462935.57	14.99	13.09	206.00	-1.81	8/30/06	9/7/06	-15.9	-21.9	-28.9
54-37									-15.9	-23.4	-28.9
54-58									-38.4	-44.4	-50.9
54-123									-102.9	-109.9	-112.9
54-144									-121.9	-130.9	-142.4
54-173									-157.4	-159.4	-168.9
54-190									-171.9	-176.9	-190.4
MW-55-24	604635.96	462996.42	18.25	17.77	77.50	8.75	8/11/06	8/14/06	5.7	-0.8	-7.3
55-35				17.77					-10.2	-14.2	-18.2
55-54				17.77					-24.3	-30.8	-37.3
MW-56-53	604658.09	462708.49	70.26	69.32	88.50	41.26	8/29/06	8/30/06	22.3	17.8	13.3
56-83				69.21					4.0	-5.5	-15.0

See Page 4 for Notes

TABLE 4.1
SUMMARY OF WELL LOCATIONS AND INSTALLATION DEPTHS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS [1]		
									TOP	CENTER	BOTTOM
MW-57-11	604562.36	462888.55	14.98	14.73	47.00	9.48	7/12/06	7/13/06	11.6	7.1	2.6
57-20				14.75					0.1	-2.9	-5.9
57-45				14.81					-13.8	-22.5	-31.3
MW-58-26	604400.31	462864.26	14.57	14.23	72.00	-0.43	7/12/06	7/13/06	0.0	-7.0	-14.0
58-65				14.14					-33.5	-43.0	-52.5
MW-59-32	604330.15	462912.91	14.52	14.41	77.00	1.52	9/8/06	10/3/06	-5.2	-11.7	-18.2
59-45				13.90					-19.4	-25.9	-32.4
59-68				14.23					-37.1	-46.1	-55.1
MW-60-35	604585.60	463381.26	14.31	12.48	200.00	5.81	10/23/06	10/24/06	-12.4	-22.4	-26.9
60-53									-32.9	-40.9	-46.9
60-55[2]									-32.9	-42.4	-46.9
60-72									-53.9	-59.9	-66.4
60-135									-112.4	-122.4	-128.9
60-154									-134.9	-141.9	-152.4
60-176									-158.4	-163.4	-187.9
MW-62-18			14.69	12.81	38.30	NA	8/17/06	10/5/06	6.7	1.8	-10.3
62-37									-30.3	-33.5	-36.6
62-52[2]	604350.80	463086.79	14.69	12.82	201.00	-22.31			-36.8	-38.8	-41.3
62-53									-36.8	-40.3	-41.3
62-71									-48.3	-58.3	-69.8
62-92									-75.8	-78.8	-86.3
62-138									-113.3	-125.3	-130.8
62-181[2]									-164.8	-167.8	-185.8
62-182									-164.8	-169.3	-185.8
MW-63-18	604252.14	462968.86	14.18	13.06	35.00	NA	8/17/06	9/22/06	7.1	0.6	-5.9
63-34									-27.1	-30.6	-34.1
63-50	604251.28	462970.42	14.18	12.32	201.00	-17.82			-29.2	-37.2	-45.7
63-91[2]									-69.2	-78.2	-88.2
63-93									-69.2	-80.7	-88.2
63-112									-94.2	-99.2	-99.7
63-121									-105.7	-108.7	-115.2
63-163									-138.2	-150.2	-152.7
63-174									-155.7	-161.7	-178.7
MW-65-48	604851.98	462489.68	69.72	68.86	83.00	34.72	8/21/06	8/23/06	33.9	26.4	18.9
65-80									10.8	-1.7	-14.2
MW-66-21	604408.77	463146.34	14.12	13.41	37.00	-23.48	11/17/06	12/5/06	8.0	0.0	-8.0
66-36									-16.0	-19.5	-23.0
MW-67-39	604426.67	463127.06	14.36	12.51	349.25	-18.64	6/5/07	6/8/07	-15.8	-25.8	-41.3
67-105									-77.3	-92.3	-97.8
67-173									-151.8	-159.8	-175.3
67-219									-196.3	-206.3	-216.8
67-276									-237.8	-262.8	-268.3
67-323									-304.8	-309.8	-317.8
67-340									-322.3	-327.3	-334.8

See Page 4 for Notes

TABLE 4.1
SUMMARY OF WELL LOCATIONS AND INSTALLATION DEPTHS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	EAST COORDINATES	NORTH COORDINATES	GROUND SURFACE ELEVATION	WELLHEAD ELEVATION	DEPTH OF BORING	BEDROCK SURFACE ELEVATION	DATE DRILLING COMPLETED	DATE DEVELOPED	SAMPLE ZONE ELEVATIONS [1]		
									TOP	CENTER	BOTTOM
MW-101	Not surveyed		133.86	133.86	15.00	NA	2/7/00	2/7/00	129.9	124.4	118.9
MW-103	Not surveyed		143.44	146.74	26.30	7.00	2/9/00	2/9/00	133.1	125.1	117.1
MW-104	Not surveyed		140.50	140.50	30.00	136.00	2/10/00	2/10/00	131.5	121.0	110.5
MW-105	Not surveyed		135.73	138.51	20.00	NA	2/10/00	2/10/00	131.7	123.7	115.7
MW-107	605014.18	461922.70	140.06	142.76	35.00	NA	2/15/00	2/15/00	126.1	115.6	105.1
MW-108	604454.15	462819.57	14.48	14.23	11.67	NA	2/21/00	2/21/00	12.8	7.8	2.8
MW-109	604396.85	462860.95	14.55	14.25	11.91	NA	2/25/00	2/25/00	12.6	7.6	2.6
MW-110	Not surveyed		134.55	137.72	29.50	126.55	2/25/00	2/25/00	121.1	113.6	106.1
MW-111	604735.19	463023.59	18.93	18.38	16.92	0.90	2/24/00	2/24/00	7.0	4.2	1.5
MW-112	604888.09	461578.48	136.77	36.77	24.00	126.77	2/26/00	2/26/00	128.8	120.8	112.8
RW-1	604879.23	463006.67	77.50	75.82	138.50	51.30	7/28/06	8/1/06			
U3-1	604197.32	462762.55	13.50	13.50	19.00	NA	4/11/96	4/11/96	7.5	1.0	-5.5
U3-2	604262.35	462772.31	14.16	14.11	14.70	NA	Not available [4]		10.5	5.0	-0.5
U3-3	604293.07	462778.30	14.85	14.60	14.70	NA	4/9/96	4/9/96	11.1	5.6	0.1
U3-4D	604167.66	462723.77	14.82	14.52	34.00	-3.78	12/15/97	12/15/97	-10.2	-14.7	-19.2
U3-4S	604158.88	462711.07	14.65	13.94	17.35	-2.65	12/12/97	12/12/97	8.3	2.8	-2.7
U3-T1	604132.98	462555.03	3.27	8.51	1.20	NA	12/12/97	12/12/97	0.0	2.5	0.0
U3-T2	604240.59	462673.84	3.26	8.51	1.60	NA	12/12/97	12/12/97	0.0	2.5	0.0
I-2	605072.45	463218.16	80.92	82.23	40.00	NA	4/8/03	4/8/03	53.8	48.0	42.2
U1-CSS	604631.14	462827.29	15.09	20.07	Not avaialbe [5]						

NOTES:
(shaded box) well screen in unconsolidated deposit {soil backfill/natural soil}
(unshaded box) well screen in consolicated {bedrock}

1. Elevations of sampling ports in waterloo systems or sand packed zone in wells. Low flow sampling locations are given for open rock holes when available.
2. Redundant sampling ports within single sampling zones.
3. Rock surface not encountered.
4. U3-2 is a legacy well installed by Foster Wheeler Env Co. No dates for installation provided.
5. No construction details of U1-CSS were provided to GZA.

TABLE 4.2
WELL NOMENCLATURE
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

ORIGINAL NOMENCLATURE	NEW DESIGNATION
MW-30-74	MW-30-69
MW-30-75	MW-30-71
MW-30-87	MW-30-82
MW-30-88	MW-30-84
MW-31-53	MW-31-49
MW-31-67	MW-31-63
MW-31-89	MW-31-85
MW-36-26	MW-36-24
MW-36-41	MW-36-40
MW-36-53	MW-36-52
MW-37-22	MW-37-22
MW-37-32	MW-37-32
MW-37-40	MW-37-40
MW-37-57	MW-37-57
MW-39-69	MW-39-67
MW-39-85	MW-39-84
MW-39-102	MW-39-100
MW-39-103	MW-39-102
MW-39-126	MW-39-124
MW-39-184	MW-39-183
MW-39-197	MW-39-195
MW-40-26	MW-40-24
MW-40-28	MW-40-27
MW-40-48	MW-40-46
MW-40-82	MW-40-81
MW-40-102	MW-40-100
MW-40-129	MW-40-127
MW-40-163	MW-40-162
MW-41-15	MW-41-13
MW-41-42	MW-41-40
MW-41-64	MW-41-63
MW-42-51	MW-42-49
MW-42-79	MW-42-78
MW-43-28	MW-43-28
MW-43-62	MW-43-62
MW-44-67	MW-44-67
MW-44-104	MW-44-102
MW-45-43	MW-45-42
MW-45-62	MW-45-61

See Page 3 for Notes

TABLE 4.2
WELL NOMENCLATURE
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

ORIGINAL NOMENCLATURE	NEW DESIGNATION
MW-47-56	MW-47-56
MW-47-80	MW-47-80
MW-48-23	MW-48-23
MW-48-38	MW-48-37
MW-49-25	MW-49-26
MW-49-42	MW-49-42
MW-49-65	MW-49-65
MW-50-42	MW-50-42
MW-50-67	MW-50-66
MW-51-42	MW-51-40
MW-51-81	MW-51-79
MW-51-104	MW-51-102
MW-51-106	MW-51-104
MW-51-137	MW-51-135
MW-51-165	MW-51-163
MW-51-191	MW-51-189
MW-51-42	MW-51-40
MW-51-81	MW-51-79
MW-51-104	MW-51-102
MW-51-106	MW-51-104
MW-51-137	MW-51-135
MW-51-165	MW-51-163
MW-51-191	MW-51-189
MW-52-12	MW-52-11
MW-52-19	MW-52-18
MW-52-50	MW-52-48
MW-52-66	MW-52-64
MW-52-119	MW-52-118
MW-52-124	MW-52-122
MW-52-163	MW-52-162
MW-52-183	MW-52-181
MW-53-80	MW-53-82
MW-53-120	MW-53-120
MW-54-37	MW-54-35
MW-54-38	MW-54-37
MW-54-59	MW-54-58
MW-54-125	MW-54-123
MW-54-146	MW-54-144
MW-54-174	MW-54-173
MW-54-192	MW-54-190

TABLE 4.2
WELL NOMENCLATURE
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

ORIGINAL NOMENCLATURE	NEW DESIGNATION
MW-55-24	MW-55-24
MW-55-35	MW-55-35
MW-55-54	MW-55-54
MW-56-54	MW-56-53
MW-56-85	MW-56-83
MW-57-11	MW-57-11
MW-57-20	MW-57-20
MW-57-45	MW-57-45
MW-58-26	MW-58-26
MW-58-65	MW-58-65
MW-59-31	MW-59-32
MW-59-45	MW-59-45
MW-59-68	MW-59-68
MW-60-37	MW-60-35
MW-60-55	MW-60-53
MW-60-57	MW-60-55
MW-60-74	MW-60-72
MW-60-137	MW-60-135
MW-60-156	MW-60-154
MW-60-178	MW-60-176
MW-62-15	MW-62-18
MW-62-38	MW-62-37
MW-62-54	MW-62-52
MW-62-55	MW-62-53
MW-62-73	MW-62-71
MW-62-94	MW-62-92
MW-62-140	MW-62-138
MW-62-182	MW-62-181
MW-62-184	MW-62-182
MW-63-19	MW-63-18
MW-63-35	MW-63-34
MW-63-51	MW-63-50
MW-63-92	MW-63-91
MW-63-95	MW-63-93
MW-63-113	MW-63-112
MW-63-123	MW-63-121
MW-63-164	MW-63-163
MW-63-176	MW-63-174

NOTES: Names of multi-level wells have been changed to relay approximate (within 1/2 ft) depth to bottom from top of well casing

Names of waterloo sampling intervals have been changed to relay approximate (within 1/2 ft) depth to top of sampling port from top of well casing.

Names of single interval wells have not been changed.

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft		ALTERATIONS (DATE)
				surveyed	measured	
MW-30	NS [1]		51.7 [2]			
	Nov 2006	78.470	72.690	5.780	NM [3]	
	Feb 2007	78.057	NS	NS	NM	casing cut (Jan 31, 2007)
	Mar 2007	75.660	NS	NS	NM	2.39' casing cut (Feb 15, 2007)
MW-31	Dec 2005	79.593	NS	NS	NM	
	May 2007	75.641	77.447	-1.806	NM	casing cut for well vault installation (Sept 12, 2006)
MW-32	Dec 2005	78.339	78.939	-0.600	-0.6	
	May 2007	77.126	78.898	-1.772	NM	casing cut for well vault installation (Sept 13, 2006)
MW-33	Dec 2005	18.619	18.879 [4]	-0.260	-0.26	
MW-34	Dec 2005	18.071	18.481 [4]	-0.410	-0.41	
MW-35	Dec 2005	18.444	18.604 [4]	-0.160	-0.16	
MW-36-24	Mar 2006	11.393	NS	NS	-0.33	
	May 2007	11.598	11.799	-0.201	NM	pvc coupling attached for pneumatic slug testing (May 9, 2007)
MW-36-35	Mar 2006	11.604	NS	NS	NM	
	May 2007	11.754	11.799	-0.045	-0.19	pvc coupling attached for pneumatic slug testing (Jan 3, 2007)
MW-36-52	Mar 2006	11.492	NS	NS	NM	
	May 2007	11.670	11.799	-0.129	-0.06	pvc coupling attached for pneumatic slug testing (Jan 3, 2007)
MW-37-22	Mar 2006	14.784	14.964	NS	-0.18	
	May 2007	14.852	15.021	-0.169	NM	
MW-37-32	Mar 2006	14.725	NS	NS	NM	
	May 2007	14.791	15.021	-0.230	-0.24	pvc coupling attached for pneumatic slug testing (Jan 3, 2007)
MW-37-40	Mar 2006	14.790	NS	NS	NM	
	May 2007	14.962	15.021	-0.059	-0.06	pvc coupling attached for pneumatic slug testing (Jan 3, 2007)
	June 2007	14.852	15.021	-0.169	NM	pvc coupling removed (June 12, 2007)

See Page 6 for Notes

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft		ALTERATIONS (DATE)
				surveyed	measured	
MW-37-57	Mar 2006	14.723	NS	NS	NM	
	May 2007	14.788	15.021	-0.233	-0.25	pvc coupling attached for pneumatic slug testing (Jan 3, 2007)
MW-38	Dec 2005	13.990	14.350	NS	-0.36	
	May 2007	13.999	14.342	-0.343	NM	
MW-39	Mar 2006	81.452	81.864	-0.412	NM	
	Jan 2007	79.992	81.827	-1.835	NM	casing cut for well vault installation (Sept 19, 2006)
MW-40	Mar 2006	74.758	74.987	-0.229	NM	
	Jan 2007	73.164	74.948	-1.784	-1.83	casing cut for well vault installation (Nov 8, 2006)
MW-41-13	Apr 2006	NS	54.870	NS	NM	
MW-41-40	Apr 2006	54.130	54.870	-0.740	NM	
MW-41-63	Apr 2006	54.130	54.870	-0.740	NM	
MW-42-49	Apr 2006	69.419	69.714	-0.295	-0.22	
MW-42-78	Apr 2006	69.524	69.714	-0.190	-0.19	
MW-43-28	Mar 2006	48.021	48.761	-0.740	NM	
MW-43-62	Mar 2006	47.821	48.761	-0.940	NM	
MW-44-67	Apr 2006	93.020	93.520	-0.500	NM	
MW-44-102	Apr 2006	92.960	93.520	-0.560	NM	
	NS	93.090	93.520	-0.430	-0.43	pvc coupling attached for pneumatic slug testing (May 7, 2007)
MW-45-42	Apr 2006	53.196	53.662	-0.466	-0.46	
MW-45-61	Apr 2006	53.097	53.662	-0.565	NM	
	NS	53.217	53.662	-0.445	-0.445	pvc coupling attached for pneumatic slug testing (May 7, 2007)
MW-46	Apr 2006	16.970	18.080	-1.110	-1.1	
MW-47-56	Apr 2006	69.805	70.321	-0.516	-0.5	
MW-47-80	Apr 2006	69.742	70.321	-0.579	-0.57	

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft		ALTERATIONS (DATE)
				surveyed	measured	
MW-48-23	Mar 2006	14.762	15.394	-0.632	-0.63	
	May 2007	14.759	15.387	-0.628	NM	
MW-48-37	Mar 2006	14.765	15.394 [5]	-0.629	-0.33	
	May 2007	15.069	15.387	-0.318	NM	
	NS	15.189	15.387	-0.198	-0.198	pvc coupling attached for pneumatic slug testing (May 25, 2007)
MW-49-26	Apr 2006	14.191	14.655	-0.464	-0.42	
	May 2007	14.171	14.582	-0.411	NM	
MW-49-42	Apr 2006	14.133	14.655	-0.522	-0.54	
	May 2007	14.223	14.628	-0.405	NM	pvc coupling attached for pneumatic slug testing (May 9, 2007)
MW-49-65	Apr 2006	14.372	14.655	-0.283	-0.26	
	May 2007	14.457	14.628	-0.171	-0.17	pvc coupling attached for pneumatic slug testing (May 4, 2007)
MW-50-42	Apr 2006	14.432	14.923	-0.491	-0.59	
	May 2007	14.453	14.923	NS	-0.47	pvc coupling attached for pneumatic slug testing (May 7, 2007)
MW-50-66	Apr 2006	14.614	14.923	-0.309	-0.32	
MW-51	Apr 2006	69.340	69.620	-0.280	NM	
	Jan 2007	67.723	69.639	-1.916	-1.83	casing cut for well vault installation (Nov 9, 2006)
MW-52	Apr 2006	16.370	16.766	-0.396	NM	
	NS	14.916	16.766	NS	-1.85	casing cut for well vault installation (Oct 17, 2006)
MW-52-11	Apr 2006	16.283	16.766	-0.483	-1.8	
MW-53-82	Nov 2006	69.930	70.260	-0.330	-0.32	
MW-53-120	Nov 2006	70.060	70.260	-0.200	NM	
	NS	70.190	70.260	NS	-0.13	pvc coupling attached for pneumatic slug testing (Dec 28, 2006)
MW-54	Nov 2006	14.760	14.990	-0.230	NM	
	NS	13.090	14.990	NS	-1.9	casing cut

See Page 6 for Notes

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft		ALTERATIONS (DATE)
				surveyed	measured	
MW-55-24	Nov 2006	17.670	18.250	-0.580	NM	ground surface measurements taken from top of manhole
	NS	17.770	18.250	NS	-0.48	pvc coupling attached for pneumatic slug testing (Dec 27, 2006)
MW-55-35	Nov 2006	17.670	18.250	-0.580	NM	ground surface measurements taken from top of manhole
	NS	17.770	18.250	NS	-0.48	pvc coupling attached for pneumatic slug testing (Dec 27, 2006)
MW-55-54	Nov 2006	17.680	18.250	-0.570	NM	ground surface measurements taken from top of manhole
	NS	17.770	18.250	NS	-0.48	pvc coupling attached for pneumatic slug testing (Dec 27, 2006)
MW-56	Nov 2006	68.560	70.260	-1.700	-1.76	elevation for 4" well casing prior to pvc riser installation
MW-56-53	Jan 2007	69.322	70.258	-0.936	-0.97	
MW-56-83	Jan 2007	69.207	70.258	-1.051	-1.09	
MW-57-11	Nov 2006	14.630	14.980	-0.350	NM	
	NS	14.730	14.980	NS	-0.25	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-57-20	Nov 2006	14.610	14.980	-0.370	NM	
	NS	14.750	14.980	NS	-0.23	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-57-45	Nov 2006	14.640	14.980	-0.340	NM	
	NS	14.810	14.980	NS	-0.17	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-58-26	Nov 2006	14.230	14.570	-0.340	-0.35	
MW-58-65	Nov 2006	14.140	14.570	-0.430	NM	
	NS	14.250	14.570	NS	-0.32	pvc coupling attached for pneumatic slug testing (Jan 2, 2007)
MW-59-32	Nov 2006	14.310	14.520	-0.210	NM	
	NS	14.410	14.520	NS	-0.11	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-59-45	Nov 2006	13.930	14.520	-0.590	NM	
	NS	13.900	14.520	NS	-0.62	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-59-68	Nov 2006	14.150	14.520	-0.370	NM	
	NS	14.230	14.520	NS	-0.29	pvc coupling attached for pneumatic slug testing (Dec 26, 2006)
MW-60	Nov 2006	12.480	14.310	-1.830	-1.85	

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft		ALTERATIONS (DATE)
				surveyed	measured	
MW-62	Nov 2006	12.820	14.690	-1.870	-1.86	
MW-62-18	NS	12.810	14.690	NS	-1.88	
MW-62-37	NS	12.810	14.690	NS	-1.88	
MW-63	Jan 2007	12.315	14.178	-1.863	-1.85	
MW-63-18	Jan 2007	13.059	14.178	-1.119	-1.16	
MW-63-34	Jan 2007	13.059	14.178	-1.119	-1.16	
MW-65	Nov 2006	69.720	70.260	-0.540	NM	elevation for 4" well casing prior to pvc riser installation
MW-65-48	Jan 2007	68.856	69.723	-0.867	-0.93	
MW-65-80	Jan 2007	68.841	69.723	-0.882	NM	pvc coupling attached for pneumatic slug testing (Dec 28, 2007)
MW-66	Jan 2007	12.155	14.021	-1.866	NM	
MW-66-21	Sept 2007	13.407	14.122	-0.715	NM	
MW-66-36	Sept 2007	13.364	14.122	-0.758	NM	
MW-67	Sept 2007	12.511	14.356	-1.845	NM	
MW-107	Dec 2005	142.757	140.061	2.696	NM	
MW-108	Dec 2005	14.230	NS	NS	-0.25	
MW-109	Dec 2005	14.254	NS	NS	-0.3	
MW-111	Dec 2005	19.385	NS	NS	NM	casing cut approx 1 ft (Mar 20, 2006)
	Nov 2006	18.380	18.930	-0.550	-0.59	casing cut and new manhole installed (Nov 2006)
MW-112	Dec 2005	36.773	NS	NS	NM	
U3-1[6]	Dec 2005	13.495	NS	NS	NM	
U3-2	Dec 2005	14.114	14.164	NS	-0.05	
U3-3	Dec 2005	14.599	14.849	NS	-0.25	
U3-4D	Dec 2005	14.519	14.819	NS	-0.3	
U3-4S	Dec 2005	13.943	14.653	NS	-0.71	
U3-T1	Mar 2006	8.518	3.267	5.251	5.15	

See Page 6 for Notes

TABLE 4.3
WELL HEAD ELEVATION CHANGES
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	MONTH SURVEYED	TOC EL. ft	GS EL. ft	Distance from GS to TOC, ft surveyed	Distance from GS to TOC, ft measured	ALTERATIONS (DATE)
U3-T2	Mar 2006	8.512	3.259	5.253	5.15	
I-2	Nov 2006	82.230	80.920	1.310	NM	
HR-1	Apr 2006	18.517	NS	NS	NM	
	May 2007	18.496	14.994	3.502	NM	
OUT-1	Apr 2006	11.910	NS	NS	NM	
	Jan 2007	11.901	8.188	3.713	3.65	
	May 2007	11.891	8.204	3.687	NM	
U3-C1	Jan 2007	18.069	14.981	3.088	NM	
	May 2007	18.060	15.003	3.057	NM	
U2-C1	Apr 2006	15.054	12.054	3.000	3.0	
	May 2007	15.054	12.031	3.023	NM	
RW-1	Nov 2006	81.280	72.690	8.590	NM	
	Feb 2007	76.518	72.738	NS	3.78	casing cut 4.3' (Jan 31, 2007)
	Mar 2007	75.822	NS	NS	NM	casing cut 0.69' (Feb 15, 2007)
U1-CSS	May 2007	20.073	15.088	4.985	5.0	
MH-3	Mar 2006	14.847	NA	NA	NA	
MH-4	Mar 2006	16.949	NA	NA	NA	
MH-4A	Mar 2006	12.707	NA	NA	NA	
MH-5	Nov 2006	18.540	NA	NA	NA	

NOTES: All elevations are above NGVD29.

1. NS: Not Surveyed
2. From Con. Ed. Co. DWG A200002, "Details of excavation"
3. NM: Not Measured
4. Ground surface measurements taken from top of manhole
5. Surveyor error
6. Road box in a sinkhole. Ground surface location is unclear.

See Page 6 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft²/d	TEST METHOD	METHOD OF ANALYSIS
MW-30	10	5	1.8	8.5	Packered rising slug	Hvorslev[4]
	7	2	1.0	4.8	Packered rising slug	Hvorslev
	3	-1	0.0048	0.02	Packered rising slug	Hvorslev
	-1	-10	0.00071	0.0	Packered rising slug	Hvorslev
MW-31	45	36	0.17	1.4	Packered rising slug	Hvorslev
	37	28	29	250.0	Packered extraction	Unconfined Theis[5]
	29	20	1.7	14.6	Packered rising slug	Hvorslev
	21	12	0.50	4.3	Packered rising slug	Hvorslev
	14	5	0.31	2.7	Packered rising slug	Hvorslev
	6	-3	0.34	2.9	Packered rising slug	Hvorslev
	0	-11	0.20	2.1	Packered rising slug	Hvorslev
MW-32	8	-2	0.016	0.2	Packered rising slug	Hvorslev
	-2	-12	0.31	3.1	Packered rising slug	Hvorslev
	-39	-49	0.30	3.0	Packered rising slug	Hvorslev
	-53	-63	1.0	9.6	Packered rising slug	Hvorslev
	-70	-80	0.41	4.1	Packered rising slug	Hvorslev
	-92	-102	1.1	10.5	Packered rising slug	Hvorslev
	-97	-107	0.15	1.5	Packered rising slug	Hvorslev
	-107	-117	0.36	3.6	Packered rising slug	Hvorslev
MW-33	9	-11	0.55	11.3	Rising slug	Hvorslev
MW-34	9	-12	0.45	9.5	Rising slug	Hvorslev
MW-35	12	-12	0.47	11.0	Rising slug	Hvorslev
MW-36-41	-20	-30	0.24	2.4	Rising slug	Hvorslev
			0.10	1.0	Pneumatic slug	Hvorslev
36-52	-34	-41	0.12	0.8	Rising slug	Hvorslev
			0.095	0.7	Pneumatic slug	Hvorslev
MW-37-32	-12	-18	26	141.7	Rising slug	Hvorslev
37-40	-23	-25	0.0047	0.0	Pneumatic slug	Hvorslev
37-57	-35	-42	2.5	17.4	Rising slug	Hvorslev
			1.1	7.7	Pneumatic slug	Hvorslev
MW-38	12	-25	22	811.0	Specific capacity	Walton[6]
MW-39	23	13	12	122.0	Packered extraction	Unconfined Theis
	12	2	0.6	5.7	Packered rising slug	Hvorslev
	2	-8	1.5	15.0	Packered rising slug	Hvorslev
			2.5	25.0	Packered extraction	Unconfined Theis
	-7	-17	0.51	5.1	Packered rising slug	Hvorslev
	-18	-28	13	128.0	Packered extraction	Unconfined Theis
	-37	-47	2.3	23.0	Packered rising slug	Hvorslev
			2.3	23.0	Packered extraction	Unconfined Theis
	-47	-57	0.016	0.2	Packered rising slug	Hvorslev
	-57	-67	0.067	0.7	Packered rising slug	Hvorslev
	-70	-80	0.019	0.2	Packered rising slug	Hvorslev
	-83	-93	0.0045	0.0	Packered rising slug	Hvorslev
	-93	-103	0.58	5.8	Packered rising slug	Hvorslev
	-103	-113	0.69	6.9	Packered rising slug	Hvorslev

 See Page 7 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE[1] EL., ft		K[2] ft/d	T[3] ft^2/d	TEST METHOD	METHOD OF ANALYSIS
MW-40	57	47	7.4	74.0	Packered extraction	Unconfined Theis
	47	37	1.1	10.7	Packered rising slug	Hvorslev
	41	31	0.64	6.4	Packered rising slug	Hvorslev
	31	21	0.10	1.0	Packered rising slug	Hvorslev
	23	13	0.088	0.9	Packered rising slug	Hvorslev
	12	2	0.14	1.4	Packered rising slug	Hvorslev
	-5	-15	0.20	2.0	Packered rising slug	Hvorslev
	-20	-30	0.27	2.7	Packered rising slug	Hvorslev
	-52	-62	0.23	2.3	Packered rising slug	Hvorslev
	-71	-81	0.31	3.1	Packered rising slug	Hvorslev
	-85	-95	0.092	0.9	Packered rising slug	Hvorslev
	-103	-113	0.035	0.4	Packered rising slug	Hvorslev
MW-41-40	35	11	0.036	0.9	Rising slug	Hvorslev
41-63	0	-10	22	219.0	Rising slug	Hvorslev
MW-42-49	43	20	0.57	13.0	Extraction	Unconfined Theis
			0.52	12.0	Rising slug	Hvorslev
42-78	2	-10	2.0	23.6	Rising slug	Hvorslev
MW-43-28	42	18	0.45	10.8	Rising slug	Hvorslev
43-62	7	-18	0.16	4.0	Extraction	Unconfined Theis
			0.031	0.8	Rising slug	Hvorslev
MW-44-67	58	25	1.0	10.0	Specific capacity	Walton
44-102	18	-10	0.092	2.6	Pneumatic slug	Hvorslev
MW-45-42	28	10	0.0050	0.1	Extraction	Unconfined Theis
45-61	3	-12	0.20	2.9	Pneumatic slug	Hvorslev
MW-46	12.8	-12.9	0.10	2.6	Rising slug	Hvorslev
MW-47-80	2	-10	1.4	16.4	Rising slug	Hvorslev
MW-48-23	9	-10	4.1	77.0	Specific capacity	Walton
48-37	-16	-24	2.5	20.0	Pneumatic slug	Hvorslev
MW-49-42	-16	-30	6.2	86.8	Pneumatic slug	Hvorslev
49-65	-41	-51	6.2	62.0	Pneumatic slug	Hvorslev
MW-50-42	-6	-28	3.2	70.4	Pneumatic slug	Hvorslev
50-66	-44	-51	0.14	1.0	Specific capacity	Walton
			0.24	1.7	Rising slug	Hvorslev

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft^2/d	TEST METHOD	METHOD OF ANALYSIS
MW-51	42	-127	0.059	10.0	Specific capacity	Walton
	31	40	0.17	1.6	Packered rising slug	Hvorslev
	20	30	0.39	3.8	Packered rising slug	Hvorslev
	10	19	0.066	0.6	Packered rising slug	Hvorslev
	-5	4	0.073	0.7	Packered rising slug	Hvorslev
	-18	-8	0.075	0.7	Packered rising slug	Hvorslev
	-29	-19	0.22	2.1	Packered rising slug	Hvorslev
	-40	-31	0.16	1.5	Packered rising slug	Hvorslev
	-50	-40	0.38	3.7	Packered rising slug	Hvorslev
	-61	-51	0.036	0.4	Packered rising slug	Hvorslev
	-72	-62	0.082	0.8	Packered rising slug	Hvorslev
	-84	-74	0.052	0.5	Packered rising slug	Hvorslev
	-94	-85	0.075	0.7	Packered rising slug	Hvorslev
	-98	-88	0.15	1.5	Packered rising slug	Hvorslev
	-114	-104	0.14	1.3	Packered rising slug	Hvorslev
	-125	-115	0.19	1.8	Packered rising slug	Hvorslev
MW-52	6	-183	0.011	2.0	Specific capacity	Walton
	4	-5	0.40	3.9	Packered rising slug	Hvorslev
	-2	-11	0.00069	0.0	Packered rising slug	Hvorslev
	-11	-21	0.0010	0.0	Packered rising slug	Hvorslev
	-22	-32	0.0013	0.0	Packered rising slug	Hvorslev
	-33	-43	0.10	1.0	Packered rising slug	Hvorslev
	-43	-53	0.0021	0.0	Packered rising slug	Hvorslev
	-52	-62	0.0018	0.0	Packered rising slug	Hvorslev
	-60	-69	0.025	0.2	Packered rising slug	Hvorslev
	-72	-82	0.15	1.5	Packered rising slug	Hvorslev
	-84	-93	0.16	1.6	Packered rising slug	Hvorslev
	-99	-108	0.13	1.3	Packered rising slug	Hvorslev
	-116	-126	0.084	0.8	Packered rising slug	Hvorslev
	-127	-136	0.13	1.3	Packered rising slug	Hvorslev
	-142	-151	0.14	1.4	Packered rising slug	Hvorslev
	-152	-161	0.064	0.6	Packered rising slug	Hvorslev
	-163	-172	0.031	0.3	Packered rising slug	Hvorslev
MW-53-82	10	-15	0.76	19.0	Extraction	Unconfined Theis
53-120	-30	-50	0.15	3.0	Pneumatic slug	Hvorslev

See Page 7 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft²/d	TEST METHOD	METHOD OF ANALYSIS
MW-54	-172	-191	1.5	28.1	Packered rising slug	Hvorslev
	-167	-191	1.0	24.0	Packered extraction	Unconfined Theis
	-157	-167	2.5	24.3	Packered rising slug	Hvorslev
			3.1	30.0	Packered extraction	Unconfined Theis
	-142	-152	1.1	10.3	Packered rising slug	Hvorslev
	-131	-141	1.9	18.5	Packered rising slug	Hvorslev
			1.6	16.0	Packered extraction	Unconfined Theis
	-122	-131	2.8	26.3	Packered rising slug	Hvorslev
			1.9	18.0	Packered extraction	Unconfined Theis
	-105	-115	2.5	23.8	Packered rising slug	Hvorslev
			1.3	13.0	Packered extraction	Unconfined Theis
	-96	-105	0.6	5.8	Packered rising slug	Hvorslev
	-86	-96	0.45	4.3	Packered rising slug	Hvorslev
	-69	-78	0.30	2.9	Packered rising slug	Hvorslev
	-59	-69	0.17	1.7	Packered rising slug	Hvorslev
	-49	-59	0.28	2.7	Packered rising slug	Hvorslev
	-40	-49	0.40	3.9	Packered rising slug	Hvorslev
	-30	-40	0.69	6.7	Packered rising slug	Hvorslev
	-20	-30	0.69	6.7	Packered rising slug	Hvorslev
	-9	-19	0.47	4.6	Packered rising slug	Hvorslev
	-6	-9	0.22	0.8	Packered rising slug	Hvorslev
MW-55-24	5.72	-7.28	0.71	9.2	Pneumatic slug	Hvorslev
55-35	-10.18	-18.18	2.5	20.0	Pneumatic slug	Hvorslev
55-54	-24.33	-37.33	3.8	49.1	Pneumatic slug	Hvorslev
MW-56-83	3.987	-15.013	3.9	58.1	Pneumatic slug	Hvorslev
MW-57-11	10	2.6	0.38	2.7	Pneumatic slug	Hvorslev
57-20	0.13	-5.87	3.4	20.5	Pneumatic slug	Hvorslev
57-45	-13.77	-31.27	0.90	15.8	Pneumatic slug	Hvorslev
MW-58-26	0.02	-13.98	0.36	5.0	Extraction	Unconfined Theis
58-65	-33.54	-52.54	1.0	19.0	Pneumatic slug	Hvorslev
MW-59-32	-5.17	-18.17	5.9	77.2	Pneumatic slug	Hvorslev
59-45	-19.35	-32.35	1.9	24.3	Pneumatic slug	Hvorslev
59-68	-37.09	-55.09	0.2	4.2	Pneumatic slug	Hvorslev
MW-60	-174	-188	0.042	0.6	Packered rising slug	Hvorslev
	-158	-168	0.010	0.1	Packered rising slug	Hvorslev
	-147	-157	0.10	0.9	Packered rising slug	Hvorslev
	-137	-147	0.54	5.2	Packered rising slug	Hvorslev
	-121	-130	0.29	2.8	Packered rising slug	Hvorslev
	-101	-111	0.022	0.2	Packered rising slug	Hvorslev
	-85	-95	0.12	1.2	Packered rising slug	Hvorslev
	-74	-84	0.27	2.6	Packered rising slug	Hvorslev
	-55	-64	0.40	3.9	Packered rising slug	Hvorslev
	-36	-46	0.83	8.1	Packered rising slug	Hvorslev
	-20	-30	0.064	0.6	Packered rising slug	Hvorslev
	1	-15	0.00066	0.0	Packered rising slug	Hvorslev

See Page 7 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft²/d	TEST METHOD	METHOD OF ANALYSIS
MW-62	-172	-186	0.37	5.2	Packered rising slug	Hvorslev
	-162	-172	0.72	7.0	Packered rising slug	Hvorslev
	-154	-163	0.34	3.3	Packered rising slug	Hvorslev
	-143	-153	0.042	0.4	Packered rising slug	Hvorslev
	-133	-142	0.091	0.9	Packered rising slug	Hvorslev
	-120	-130	0.24	2.3	Packered rising slug	Hvorslev
	-102	-112	0.22	2.2	Packered rising slug	Hvorslev
	-92	-102	0.076	0.7	Packered rising slug	Hvorslev
	-83	-92	0.060	0.6	Packered rising slug	Hvorslev
	-66	-76	0.050	0.5	Packered rising slug	Hvorslev
	-48	-58	0.0080	0.1	Packered rising slug	Hvorslev
	-37	-47	0.0072	0.1	Packered rising slug	Hvorslev
62-37	-30	-37	3.0	18.0	Pneumatic slug	Hvorslev
MW-63	-172	-187	1.4	21.5	Packered rising slug	Hvorslev
	-151	-161	0.39	3.8	Packered rising slug	Hvorslev
	-141	-151	0.46	4.5	Packered rising slug	Hvorslev
	-131	-141	0.044	0.4	Packered rising slug	Hvorslev
	-109	-119	0.30	2.9	Packered rising slug	Hvorslev
	-96	-106	1.0	9.7	Packered rising slug	Hvorslev
	-86	-96	0.090	0.9	Packered rising slug	Hvorslev
	-74	-84	1.1	10.7	Packered rising slug	Hvorslev
	-64	-74	1.9	17.9	Packered rising slug	Hvorslev
	-57	-67	0.43	4.2	Packered rising slug	Hvorslev
	-47	-56	0.29	2.8	Packered rising slug	Hvorslev
	-36	-46	0.87	8.4	Packered rising slug	Hvorslev
	-22	-36	0.80	11.2	Packered rising slug	Hvorslev
			6.9	96.0	Packered extraction	Unconfined Theis
63-34	-27	-34	48	336.0	Pneumatic slug	Hvorslev
MW-65-48	34	19	0.27	4.0	Extraction	Unconfined Theis
65-80	11	-14	0.39	9.8	Pneumatic slug	Hvorslev
MW-66	-168	-186	0.42	7.6	Packered rising slug	Hvorslev
	-158	-168	0.21	2.0	Packered rising slug	Hvorslev
	-148	-158	0.17	1.6	Packered rising slug	Hvorslev
	-138	-148	0.14	1.4	Packered rising slug	Hvorslev
	-128	-138	0.07	0.7	Packered rising slug	Hvorslev
	-117	-127	1.4	14.0	Packered extraction	Unconfined Theis
	-95	-105	1.5	14.3	Packered rising slug	Hvorslev
	-83	-93	0.050	0.5	Packered rising slug	Hvorslev
	-70	-80	0.18	1.7	Packered rising slug	Hvorslev
	-49	-59	0.040	0.4	Packered rising slug	Hvorslev
	-29	-39	0.090	0.9	Packered rising slug	Hvorslev
	-24	-38	6.5	90.9	Packered extraction	Unconfined Theis

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft^2/d	TEST METHOD	METHOD OF ANALYSIS
MW-67	-317	-335	1.1	20.0	Packered rising slug	Hvorslev
			1.3	24.6	Packered extraction recovery	Hvorslev
	-305	-335	1.0	28.9	Packered rising slug	Hvorslev
			0.77	23.2	Packered extraction recovery	Hvorslev
	-301	-316	0.74	11.0	Packered rising slug	Hvorslev
			0.66	9.8	Packered extraction recovery	Hvorslev
	-294	-309	0.25	3.7	Packered extraction recovery	Hvorslev
	-282	-297	0.87	12.9	Packered extraction recovery	Hvorslev
	-270	-285	0.41	6.1	Packered extraction recovery	Hvorslev
	-243	-258	3.4	49.6	Packered extraction recovery	Hvorslev
	-235	-250	2.1	31.1	Packered extraction recovery	Hvorslev
	-219	-234	0.45	6.7	Packered rising slug	Hvorslev
			0.45	6.7	Packered extraction recovery	Hvorslev
	-202	-217	0.91	13.5	Packered rising slug	Hvorslev
			1.0	14.5	Packered extraction recovery	Hvorslev
	-186	-201	0.29	4.3	Packered rising slug	Hvorslev
			0.29	4.3	Packered extraction recovery	Hvorslev
	-156	-171	0.16	2.3	Packered rising slug	Hvorslev
			0.15	2.2	Packered extraction recovery	Hvorslev
	-138	-153	0.14	2.0	Packered rising slug	Hvorslev
			0.12	1.8	Packered extraction recovery	Hvorslev
	-119	-133	0.16	2.4	Packered rising slug	Hvorslev
			0.53	7.8	Packered extraction recovery	Hvorslev
	-115	-130	0.22	3.3	Packered rising slug	Hvorslev
			0.21	3.1	Packered extraction recovery	Hvorslev
	-115	-130	0.34	5.0	Packered extraction recovery	Hvorslev
	-104	-119	0.20	3.0	Packered extraction recovery	Hvorslev
	-86	-100	0.82	12.1	Packered rising slug	Hvorslev
			1.0	14.2	Packered extraction recovery	Hvorslev
	-71	-86	0.27	4.0	Packered rising slug	Hvorslev
			0.27	4.0	Packered extraction recovery	Hvorslev
	-58	-72	0.049	0.7	Packered extraction recovery	Hvorslev
	-42	-56	0.022	0.3	Packered extraction recovery	Hvorslev
	-32	-47	0.045	0.7	Packered extraction recovery	Hvorslev
	-25	-40	0.93	13.8	Packered rising slug	Hvorslev
	-18	-33	1.1	17.0	Packered rising slug	Hvorslev
MW-109	6	2	76	301.0	Specific capacity	Cooper-Jacob [7]
MW-111	5	0	3.5	19.3	Rising slug	Hvorslev
U3-3	6	0	2.5	15.0	Extraction	Unconfined Theis
U3-4D	-10	-19	0.44	4.0	Specific capacity	Walton

See Page 7 for Notes

TABLE 4.4
HYDRAULIC CONDUCTIVITY SUMMARY
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	TEST ZONE [1] EL., ft		K [2] ft/d	T [3] ft^2/d	TEST METHOD	METHOD OF ANALYSIS
U3-4S	5	-3	39	333.0	Extraction	Unconfined Theis
I-2	54	42	0.08	0.9	Rising slug	Hvorslev

NOTES: [shaded box] well screen in unconsolidated deposit {soil backfill/natural soil}
[open box] well screen in consolicated {bedrock}

All elevations are above NGVD29.

1. Submerged parts of sand packed zones in wells. Packered or submerged zones for open rock holes.
2. Hydraulic conductivity
3. Transmissivity. Calculated by multiplying K with test zone interval.
4. Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, Mississippi, pp. 1-50.
5. Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.
6. Walton, W. C., 1970. Groundwater resource evaluation: New York, McGraw-Hill.
7. Cooper, H.H. and C.E. Jacob, 1946. A generalized graphical method for evaluating formation constants and summarizing well field history, Am. Geophys. Union Trans.

TABLE 4.5
TRANSDUCER INFORMATION
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	DIAPHRAGM DEPTH ft below toc	DIAPHRAGM EL. ft msl	TRANSDUCER MAKE	PRESSURE RANGE psi	ACCURACY % full scale	ACCURACY ft H_2O[1]
MW-30-69	68.8	6.9	Geokon	10	0.10	0.023
MW-30-71	70.3	5.4	Geokon	10	0.10	0.023
MW-30-82	81.8	-6.1	Geokon	10	0.10	0.023
MW-30-84	83.3	-7.6	Geokon	10	0.10	0.023
MW-31-49	48.3	27.3	Geokon	10	0.10	0.023
MW-31-63	63.0	12.6	Geokon	50	0.10	0.115
MW-31-85	84.5	-8.9	Geokon	50	0.10	0.115
MW-32-62[2]	59.5	17.6	Geokon	10	0.10	0.023
MW-32-92[2]	90.2	-13.1	Geokon	50	0.10	0.115
MW-32-140[2]	137.7	-60.6	Geokon	50	0.10	0.115
MW-32-165[2]	162.7	-85.6	Geokon	50	0.10	0.115
MW-32-196[2]	194.5	-117.4	Geokon	100	0.10	0.231
MW-32-48[3]	48.0	29.1	Geokon	50	0.10	0.115
MW-32-59[3]	58.0	19.1	Geokon	50	0.10	0.115
MW-32-85[3]	85.0	-7.9	Geokon	50	0.10	0.115
MW-32-131[3]	130.5	-53.4	Geokon	50	0.10	0.115
MW-32-149[3]	149.0	-71.9	Geokon	50	0.10	0.115
MW-32-173[3]	172.5	-95.4	Geokon	100	0.10	0.231
MW-32-190[3]	190.0	-112.9	Geokon	100	0.10	0.231
MW-33	variable[4]		In-Situ MiniTroll	30	0.10	0.069
MW-34	variable		In-Situ MiniTroll	30	0.10	0.069
MW-35	variable		In-Situ MiniTroll	30	0.10	0.069
MW-36-24	variable		In-Situ MiniTroll	30	0.10	0.069
MW-36-41	variable		In-Situ MiniTroll	30	0.10	0.069
MW-36-52	variable		In-Situ MiniTroll	30	0.10	0.069
MW-37-22	variable		In-Situ MiniTroll	30	0.10	0.069
MW-37-32	variable		In-Situ MiniTroll	30	0.10	0.069
MW-37-40	variable		In-Situ MiniTroll	30	0.10	0.069
MW-37-57	variable		In-Situ MiniTroll	30	0.10	0.069
MW-38	variable		In-Situ MiniTroll	30	0.10	0.069
MW-39-67	66.7	13.3	Geokon	50	0.10	0.115
MW-39-84	83.0	-3.0	Geokon	25	0.10	0.058
MW-39-100	99.5	-19.5	Geokon	25	0.10	0.058
MW-39-102	101.2	-21.2	Geokon	50	0.10	0.115
MW-39-124	123.7	-43.7	Geokon	50	0.10	0.115
MW-39-183	182.2	-102.2	Geokon	50	0.10	0.115
MW-39-195	194.7	-114.7	Geokon	100	0.10	0.231
MW-40-24	23.9	49.3	Geokon	50	0.10	0.115
MW-40-27	26.2	47.0	Geokon	10	0.10	0.023
MW-40-46	45.7	27.5	Geokon	25	0.10	0.058
MW-40-81	80.2	-7.0	Geokon	25	0.10	0.058
MW-40-100	99.9	-26.7	Geokon	50	0.10	0.115
MW-40-127	126.9	-53.7	Geokon	50	0.10	0.115
MW-40-162	161.4	-88.2	Geokon	100	0.10	0.231
MW-41-40	variable		In-Situ MiniTroll	30	0.10	0.069
MW-41-63	variable		In-Situ MiniTroll	30	0.10	0.069
MW-42-49	variable		In-Situ MiniTroll	30	0.10	0.069
MW-42-78	variable		In-Situ MiniTroll	30	0.10	0.069
MW-43-28	variable		In-Situ MiniTroll	30	0.10	0.069
MW-43-62	variable		In-Situ MiniTroll	30	0.10	0.069
MW-44-67	variable		In-Situ MiniTroll	30	0.10	0.069
MW-44-102	variable		In-Situ MiniTroll	30	0.10	0.069

See Page 3 for Notes

TABLE 4.5
TRANSDUCER INFORMATION
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	DIAPHRAGM DEPTH ft below toc	DIAPHRAGM EL. ft msl	TRANSDUCER MAKE	PRESSURE RANGE psi	ACCURACY % full scale	ACCURACY ft H_2O[1]
MW-45-42	variable		In-Situ MiniTroll	30	0.10	0.069
MW-45-61	variable		In-Situ MiniTroll	30	0.10	0.069
MW-46	variable		In-Situ MiniTroll	30	0.10	0.069
MW-47-56	variable		In-Situ MiniTroll	30	0.10	0.069
MW-47-80	variable		In-Situ MiniTroll	30	0.10	0.069
MW-48-23	variable		In-Situ MiniTroll	30	0.10	0.069
MW-48-37	variable		In-Situ MiniTroll	30	0.10	0.069
MW-49-26	variable		In-Situ MiniTroll	30	0.10	0.069
MW-49-42	variable		In-Situ MiniTroll	30	0.10	0.069
MW-49-65	variable		In-Situ MiniTroll	30	0.10	0.069
MW-50-42	variable		In-Situ MiniTroll	30	0.10	0.069
MW-50-66	variable		In-Situ MiniTroll	30	0.10	0.069
MW-51-40	39.4	28.3	Geokon	50	0.10	0.115
MW-51-79	78.2	-10.5	Geokon	25	0.10	0.058
MW-51-102	101.9	-34.2	Geokon	50	0.10	0.115
MW-51-104	103.4	-35.7	Geokon	50	0.10	0.115
MW-51-135	134.9	-67.2	Geokon	50	0.10	0.115
MW-51-163	162.4	-94.7	Geokon	100	0.10	0.231
MW-51-189	188.9	-121.2	Geokon	100	0.10	0.231
MW-52-11	variable		In-Situ MiniTroll	30	0.10	0.069
MW-52-18	17.2	-2.3	Geokon	50	0.10	0.115
MW-52-48	47.5	-32.6	Geokon	25	0.10	0.058
MW-52-64	63.7	-48.8	Geokon	50	0.10	0.115
MW-52-118	117.2	-102.3	Geokon	50	0.10	0.115
MW-52-122	121.7	-106.8	Geokon	50	0.10	0.115
MW-52-162	161.2	-146.3	Geokon	100	0.10	0.231
MW-52-181	180.7	-165.8	Geokon	100	0.10	0.231
MW-53-82	variable		In-Situ MiniTroll	30	0.10	0.069
MW-53-120	variable		In-Situ MiniTroll	30	0.10	0.069
MW-54-35	34.7	-21.6	Geokon	50	0.10	0.115
MW-54-37	36.2	-23.1	Geokon	50	0.10	0.115
MW-54-58	57.2	-44.1	Geokon	50	0.10	0.115
MW-54-123	122.7	-109.6	Geokon	50	0.10	0.115
MW-54-144	143.7	-130.6	Geokon	50	0.10	0.115
MW-54-173	172.2	-159.1	Geokon	100	0.10	0.231
MW-54-190	189.7	-176.6	Geokon	100	0.10	0.231
MW-55-24	variable		In-Situ MiniTroll	30	0.10	0.069
MW-55-35	variable		In-Situ MiniTroll	30	0.10	0.069
MW-55-54	variable		In-Situ MiniTroll	30	0.10	0.069
MW-56-53	variable		In-Situ MiniTroll	30	0.10	0.069
MW-56-83	variable		In-Situ MiniTroll	30	0.10	0.069
MW-57-11	variable		In-Situ MiniTroll	30	0.10	0.069
MW-57-20	variable		In-Situ MiniTroll	30	0.10	0.069
MW-57-45	variable		In-Situ MiniTroll	30	0.10	0.069
MW-58-26	variable		In-Situ MiniTroll	30	0.10	0.069
MW-58-65	variable		In-Situ MiniTroll	30	0.10	0.069
MW-59-32	variable		In-Situ MiniTroll	30	0.10	0.069
MW-59-45	variable		In-Situ MiniTroll	30	0.10	0.069
MW-59-68	variable		In-Situ MiniTroll	30	0.10	0.069
MW-60-35	34.6	-22.1	Geokon	50	0.10	0.115
MW-60-53	52.9	-40.4	Geokon	25	0.10	0.058
MW-60-55	54.4	-41.9	Geokon	25	0.10	0.058
MW-60-72	72.1	-59.6	Geokon	50	0.10	0.115
MW-60-135	134.6	-122.1	Geokon	50	0.10	0.115
MW-60-154	154.1	-141.6	Geokon	100	0.10	0.231
MW-60-176	175.6	-163.1	Geokon	100	0.10	0.231

See Page 3 for Notes

TABLE 4.5
TRANSDUCER INFORMATION
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	DIAPHRAGM DEPTH ft below toc	DIAPHRAGM EL. ft msl	TRANSDUCER MAKE	PRESSURE RANGE psi	ACCURACY % full scale	ACCURACY ft H_2O[1]
MW-62-18	variable		In-Situ MiniTroll	30	0.10	0.069
MW-62-37	variable		In-Situ MiniTroll	30	0.10	0.069
MW-62-52	51.3	-38.5	Geokon	50	0.10	0.115
MW-62-53	52.8	-40.0	Geokon	50	0.10	0.115
MW-62-71	70.8	-58.0	Geokon	50	0.10	0.115
MW-62-92	91.3	-78.5	Geokon	50	0.10	0.115
MW-62-138	137.8	-125.0	Geokon	50	0.10	0.115
MW-62-181	180.3	-167.5	Geokon	100	0.10	0.231
MW-62-182	181.8	-169.0	Geokon	100	0.10	0.231
MW-63-18	variable		In-Situ MiniTroll	30	0.10	0.069
MW-63-35	variable		In-Situ MiniTroll	30	0.10	0.069
MW-63-50	49.2	-36.9	Geokon	50	0.10	0.115
MW-63-91	90.2	-77.9	Geokon	50	0.10	0.115
MW-63-93	92.7	-80.4	Geokon	50	0.10	0.115
MW-63-112	111.2	-98.9	Geokon	50	0.10	0.115
MW-63-121	120.7	-108.4	Geokon	50	0.10	0.115
MW-63-163	162.2	-149.9	Geokon	100	0.10	0.231
MW-63-174	173.7	-161.4	Geokon	100	0.10	0.231
MW-65-48	variable		In-Situ MiniTroll	30	0.10	0.069
MW-65-80	variable		In-Situ MiniTroll	30	0.10	0.069
MW-66-21	variable		In-Situ MiniTroll	30	0.10	0.069
MW-66-36	variable		In-Situ MiniTroll	30	0.10	0.069
MW-67-39	38.0	-25.5	Geokon	50	0.10	0.115
MW-67-105	104.5	-92.0	Geokon	50	0.10	0.115
MW-67-173	172.0	-159.5	Geokon	100	0.10	0.231
MW-67-219	218.5	-206.0	Geokon	100	0.10	0.231
MW-67-276	275.0	-262.5	Geokon	100	0.10	0.231
MW-67-323	322.0	-309.5	Geokon	145	0.10	0.334
MW-67-340	339.5	-327.0	Geokon	145	0.10	0.334
MW-107	variable		In-Situ MiniTroll	30	0.10	0.069
MW-108	variable		In-Situ MiniTroll	30	0.10	0.069
MW-109	variable		In-Situ MiniTroll	30	0.10	0.069
MW-111	variable		In-Situ MiniTroll	30	0.10	0.069
U3-1	variable		In-Situ MiniTroll	30	0.10	0.069
U3-2	variable		In-Situ MiniTroll	30	0.10	0.069
U3-3	variable		In-Situ MiniTroll	30	0.10	0.069
U3-4S	variable		In-Situ MiniTroll	30	0.10	0.069
U3-4D	variable		In-Situ MiniTroll	30	0.10	0.069
U3-T1	variable		In-Situ MiniTroll	30	0.10	0.069
U3-T2	variable		In-Situ MiniTroll	30	0.10	0.069
I-2	variable		In-Situ MiniTroll	30	0.10	0.069
U1-CSS	variable		Geokon	10	0.10	0.023

NOTES:
All elevations are above NGVD29.
1. 0.1% of full scale
2. Transducer installation data for MW-32 Waterloo System configuration in place prior to September 2007.
3. Transducer installation data for MW-32 Waterloo System configuration as re-installed in September 2007 (see Appendix D for further information).
4. "Variable" indicates that the transducer has been positioned at different elevations over time (see Appendix M for further information).

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-30-69	6.4	8/18/06	220,000	ND[2]	ND	NA[3]	ND
		11/29/06	106,000	2.5	3,130	ND	ND
		1/16/07	81,700	ND	ND	NA	ND
		6/12/07	297,000	ND	ND	ND	ND
		7/18/07	82,100	NA	NA	NA	NA
		7/25/07	232,000	ND	ND	NA	ND
		8/1/07	103,000	NA	NA	NA	NA
		8/8/07	99,600	NA	NA	NA	NA
		8/15/07	233,000	NA	NA	NA	NA
		8/21/07	107,000	NA	NA	NA	NA
		8/30/07	98,000	NA	NA	NA	NA
		9/7/07	97,900	NA	NA	NA	NA
		9/13/07	93,100	NA	NA	NA	NA
		9/19/07	92,000	NA	NA	NA	NA
30-84	-8.1	8/22/06	12,500	ND	ND	NA	ND
		11/29/06	10,100	ND	294	ND	ND
		1/17/07	7,330	ND	ND	NA	ND
		6/12/07	7,790	ND	ND	ND	ND
		7/18/07	4,800	NA	NA	NA	NA
		7/25/07	5,020	ND	ND	NA	ND
MW-31-49	26.3	11/27/06	298	ND	70	ND	ND
		1/18/07	1,200	ND	ND	NA	ND
		6/12/07	1,480	ND	ND	ND	ND
		8/2/07	11,900	ND	88.3	NA	ND
		9/11/07	6,980	ND	ND	NA	ND
31-63	12.3	11/27/06	6,890	ND	199	ND	ND
		1/18/07	14,100	ND	ND	NA	ND
		6/12/07	5,000	ND	ND	ND	ND
		8/2/07	40,600	ND	ND	NA	ND
		9/11/07	37,700	ND	ND	NA	ND
31-85	-9.2	11/27/06	462	ND	152	ND	ND
		1/18/07	2,660	ND	ND	NA	ND
		6/12/07	317	ND	ND	ND	ND
		8/2/07	2,690	ND	ND	NA	ND
		9/11/07	4,320	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-32-62	15.3	1/19/07	7,670	ND	ND	NA	ND
		6/28/07	24,000	ND	ND	NA	ND
		8/13/07	14,200	ND	ND	NA	ND
32-92	-15.2	1/19/07	11,200	ND	ND	NA	ND
		6/28/07	5,420	ND	ND	NA	ND
		8/13/07	5,700	ND	ND	NA	ND
32-140	-62.7	1/19/07	11,300	ND	ND	NA	ND
		6/28/07	302	ND	ND	NA	ND
		8/13/07	ND	ND	ND	NA	ND
32-160[4]	-82.7	1/19/07	10,500	ND	NA	NA	NA
32-165	-87.7	6/28/07	581	ND	ND	NA	ND
		8/13/07	493	ND	ND	NA	ND
32-196	-118.0	1/19/07	11,300	ND	ND	NA	ND
		6/28/07	2,410	ND	ND	NA	ND
		8/13/07	1,720	ND	ND	NA	ND
MW-33	-0.35	12/15/05	142,000	NA	NA	NA	NA
		12/19/05	199,000	NA	NA	NA	NA
		12/29/05	220,000	NA	NA	NA	NA
		1/6/06	189,000	NA	NA	NA	NA
		1/13/06	232,000	NA	NA	NA	NA
		1/20/06	226,000	NA	NA	NA	NA
		1/27/06	242,000	NA	NA	NA	NA
		2/3/06	250,000	NA	NA	NA	NA
		2/7/06	214,000	ND	NA	NA	NA
		2/16/06	261,000	NA	NA	NA	NA
		3/3/06	253,000	NA	NA	NA	NA
		4/7/06	221,000	NA	NA	NA	NA
		5/17/06	135,000	ND	ND	NA	ND
		6/7/06	141,000	0.7	ND	NA	ND
		7/3/06	264,000	ND	ND	NA	ND
		8/4/06	184,000	NA	ND	NA	ND
		8/30/06	115,000	NA	ND	NA	ND
	2.9[5]	6/15/07	90,600	ND	ND	ND	ND
		8/3/07	23,000	ND	ND	NA	ND

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-34	-0.38	12/13/05	63,900	NA	NA	NA	NA
		12/19/05	121,000	NA	NA	NA	NA
		12/29/05	147,000	NA	NA	NA	NA
		1/6/06	159,000	NA	NA	NA	NA
		1/13/06	131,000	NA	NA	NA	NA
		1/20/06	211,000	NA	NA	NA	NA
		1/27/06	212,000	NA	NA	NA	NA
		2/3/06	224,000	NA	NA	NA	NA
		2/7/06	174,000	ND	NA	NA	NA
		2/16/06	199,000	NA	NA	NA	NA
		3/3/06	230,000	NA	NA	NA	NA
		4/7/06	276,000	NA	NA	NA	NA
		5/17/06	36,400	ND	ND	NA	ND
		6/26/06	10,500	ND	ND	NA	ND
		7/26/06	40,700	ND	ND	NA	ND
		8/24/06	66,900	NA	ND	NA	ND
		9/21/06	16,100	ND	ND	NA	ND
	2.0[5]	8/3/07	22,200	ND	ND	NA	ND
MW-35	-0.4	12/13/05	42,300	NA	NA	NA	NA
		12/19/05	76,000	NA	NA	NA	NA
		12/29/05	80,500	NA	NA	NA	NA
		1/6/06	95,400	NA	NA	NA	NA
		1/13/06	97,800	NA	NA	NA	NA
		1/20/06	104,000	NA	NA	NA	NA
		1/27/06	38,700	NA	NA	NA	NA
		2/3/06	51,400	NA	NA	NA	NA
		2/7/06	84,400	ND	NA	NA	NA
		2/16/06	90,400	NA	NA	NA	NA
		3/3/06	119,000	NA	NA	NA	NA
		4/7/06	56,200	NA	NA	NA	NA
		5/17/06	40,700	ND	ND	NA	ND
		6/26/06	17,400	ND	ND	NA	ND
		9/21/06	45,300	ND	ND	NA	ND
	3.6[5]	6/15/07	2,030	ND	46.6	ND	ND
		8/3/07	5,950	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-36-24	-4.3	2/7/06	NA	1.3	NA	NA	NA
		2/27/06	30,400	NA	NA	NA	NA
		3/23/06	34,200	1.0	ND	64.1	ND
		4/5/06	NA	1.6	NA	NA	NA
		6/5/06	202	ND	ND	NA	ND
		8/28/06	245	NA	ND	NA	ND
		6/27/07	ND	ND	ND	NA	ND
		8/8/07	ND	ND	ND	ND	ND
MW-36-41	-25.2	2/10/06	47,500	NA	NA	NA	NA
		2/27/06	45,800	NA	NA	NA	NA
		3/24/06	55,200	3.5	ND	48.7	ND
		4/5/06	NA	3.5	NA	NA	NA
		6/5/06	20,500	2.3	ND	NA	ND
		8/28/06	20,100	NA	ND	NA	ND
	-25.2[5]	6/27/07	6,110	2.2	ND	NA	ND
MW-36-52	-37.9	2/10/06	22,400	NA	NA	NA	NA
		2/27/06	25,700	NA	NA	NA	NA
		3/24/06	26,800	4.1	ND	ND	ND
		4/5/06	NA	5.0	NA	NA	NA
		6/5/06	24,000	4.4	ND	NA	ND
		8/28/06	14,100	NA	ND	NA	ND
		6/27/07	10,100	2.6	ND	NA	ND
	-38.2[5]	8/8/07	12,500	2.3	ND	ND	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-37-22	-1.5	2/24/06	10,700	NA	NA	NA	NA
		2/28/06	12,800	2.4	ND	42.4	ND
		3/10/06	23,200	4.7	ND	20.8	ND
		3/27/06	34,900	4.1	ND	54.3	ND
		6/27/06	10,500	9.6	ND	NA	ND
		9/29/06	7,370	14.2	ND	NA	ND
	-2.0[5]	6/27/07	4,050	14.9	ND	NA	ND
		8/7/07	2,790	18.3	ND	NA	ND
MW-37-32	-14.8	2/24/06	30,100	NA	NA	NA	NA
		2/28/06	28,600	18.2	ND	34.1	ND
		3/10/06	28,300	15.2	ND	ND	ND
		3/27/06	13,900	19.5	ND	ND	ND
		6/27/06	7,920	29.8	ND	NA	ND
		9/29/06	11,500	15.3	ND	NA	ND
	-14.0[5]	6/27/07	3,130	18.5	ND	NA	ND
		8/7/07	3,810	18.9	ND	NA	ND
MW-37-40	-24.2	2/24/06	16,800	NA	NA	NA	NA
		2/28/06	14,700	4.9	ND	56.5	ND
		3/10/06	17,000	13.5	ND	ND	ND
		3/27/06	15,600	11.1	ND	ND	ND
	-24.0[5]	6/27/07	14,200	24.4	ND	NA	ND
		8/7/07	5,850	9.8	ND	NA	ND
MW-37-57	-38.2	2/24/06	16,000	NA	NA	NA	NA
		2/28/06	13,300	22.7	ND	29.1	ND
		3/10/06	19,100	22.9	ND	ND	ND
		3/27/06	15,900	16.5	ND	ND	ND
		6/27/06	44,800	27.3	ND	NA	ND
		9/29/06	10,500	18.1	ND	NA	ND
	-40.0[5]	6/27/07	5,890	24.2	ND	NA	ND
		8/7/07	6,680	23.3	ND	NA	ND

 See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-38	-11.1	12/8/05	985	ND	ND	NA	ND
		12/30/05	ND	NA	ND	NA	ND
		1/10/06	1,010	NA	ND	NA	ND
		1/19/06	758	NA	ND	NA	ND
		1/25/06	1,440	NA	ND	NA	ND
		2/1/06	ND	NA	ND	NA	ND
		2/8/06	ND	ND	ND	NA	ND
		2/16/06	ND	NA	ND	NA	ND
		2/23/06	2,630	NA	ND	NA	ND
		3/3/06	ND	NA	ND	NA	ND
		5/22/06	759	ND	ND	NA	ND
		6/21/06	916	ND	ND	ND	ND
		7/6/06	593	ND	ND	NA	ND
		8/7/06	215	ND	ND	ND	ND
		9/5/06	353	ND	ND	NA	ND
		11/22/06	ND	ND	ND	NA	ND
		2/12/07	2,240	ND	2.7	NA	ND
		8/16/07	604	ND	ND	NA	ND
MW-39-67	12.7	5/22/07	473	2.8	ND	ND	ND
		8/7/07	325	4.8	ND	NA	ND
39-84	-3.8	5/22/07	591	1.7	ND	ND	ND
		8/7/07	252	0.8	ND	NA	ND
39-102	-21.8	5/22/07	805	1.3	ND	ND	ND
		8/7/07	321	ND	ND	NA	ND
39-124	-44.3	5/22/07	261	ND	ND	ND	ND
		8/7/07	192	ND	ND	NA	ND
39-183	-102.8	5/22/07	247	ND	ND	ND	ND
		8/7/07	ND	ND	ND	NA	ND
39-195	-115.3	5/22/07	255	1.3	ND	ND	ND
		8/7/07	200	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-40-27	48.7	6/5/07	ND	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
40-46	26.7	6/5/07	ND	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
40-81	-7.8	6/5/07	ND	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
40-100	-27.3	6/5/07	176	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
40-127	-54.3	6/5/07	187	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
40-162	-88.8	6/5/07	ND	ND	ND	NA	ND
		7/23/07	ND	ND	ND	NA	ND
MW-41-40	20.5	4/12/06	726	2.6	ND	NA	ND
		5/25/06	607	5.2	ND	NA	ND
		6/12/06	676	3.6	ND	NA	ND
		7/14/06	983	7.0	ND	NA	ND
		8/16/06	447	NA	ND	NA	ND
		11/13/06	425	4.6	ND	ND	ND
	18.9[5]	6/19/07	3,910	6.0	ND	ND	ND
		8/14/07	380	6.0	ND	NA	ND
41-63	-4.6	4/12/06	701	5.5	ND	NA	ND
		5/25/06	361	5.2	ND	NA	ND
		6/12/06	268	0.8	ND	NA	ND
		7/18/06	243	2.2	ND	NA	ND
		8/16/06	356	NA	ND	NA	ND
		11/13/06	157	2.1	ND	ND	ND
	-6.1[5]	6/20/07	552	7.1	ND	ND	ND
		8/14/07	547	3.6	ND	NA	ND

 See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-42-41[6]	28.7	3/31/06	5,400	NA	6,890	NA	NA
		4/7/06	2,880	95.9	48,900	3,190	56.2
		7/21/06	3,580	13	8,290	NA	ND
		9/18/06	1,840	NA	17,700	NA	ND
		11/17/06	2,260	10	6,950	131	ND
42-43[6]	26.7	3/31/06	4,870	NA	6,950	NA	NA
		4/7/06	2,370	93.5	50,000	3,600	40.2
		7/21/06	3,050	12.8	8,890	NA	ND
		9/18/06	1,280	NA	22,600	NA	ND
		11/16/06	2,650	14.9	8,620	228	3.2
42-46[6]	24.2	3/31/06	4,830	NA	8,620	NA	NA
		4/7/06	2,510	110	47,300	4,730	ND
		7/21/06	2,320	10.9	7,860	NA	ND
		9/15/06	1,100	NA	22,600	NA	ND
		11/16/06	2,310	11.4	7,250	249	ND
42-48[6]	21.7	3/31/06	4,600	NA	7,250	NA	NA
		4/7/06	3,980	73.7	53,100	5,120	ND
		7/20/06	2,800	15.2	9,330	NA	ND
		9/15/06	621	NA	38,900	NA	65.3
		11/16/06	1,980	10.6	6,920	207	ND
MW-42-49	27.1	3/23/06	2,630	51.9	102,000	NA	194
		3/31/06	2,490	21.0	6,550	NA	ND
		4/7/06	2,510	109	81,100	2,220	88.1
	23.7[5]	6/18/07	1,340	77.3	19,000	1,030	ND
		8/2/07	1,500	50.2	24,800	805	ND
		8/17/07	1,600	20.1	19,600	526	ND
42-78	-4.3	3/24/06	1,280	ND	4,460	NA	ND
		4/7/06	792	ND	1,980	36.6	ND
	-4.3[5]	6/18/07	378	ND	62.8	ND	ND
		7/27/07	319	ND	ND	ND	ND
		8/17/07	461	ND	45.1	ND	ND
MW-43-28	25.3	4/12/06	346	ND	ND	NA	ND
		5/25/06	ND	2.7	ND	NA	ND
		6/12/06	230	ND	ND	NA	ND
		7/12/06	ND	ND	ND	NA	ND
		8/16/06	260	NA	ND	NA	ND
	25.8[5]	6/18/07	278	1.1	ND	ND	ND
		8/13/07	ND	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
43-62	-2.2	4/12/06	200	ND	ND	NA	ND
		5/25/06	ND	ND	ND	NA	ND
		6/12/06	ND	1.3	ND	NA	ND
		7/12/06	ND	ND	ND	NA	ND
		8/16/06	ND	NA	ND	NA	ND
	-5.2[5]	6/19/07	ND	0.9	ND	ND	ND
		8/13/07	ND	ND	ND	NA	ND
MW-44-67	31.1	3/28/06	338	ND	ND	NA	ND
		5/24/06	237	0.7	ND	NA	ND
		7/20/06	892	ND	35.4	NA	ND
	30.5[5]	6/29/07	268	ND	ND	NA	ND
		8/14/07	417	ND	ND	NA	ND
44-102	2.5	6/13/06	253	ND	ND	NA	ND
		7/20/06	316	ND	ND	NA	ND
		8/4/06	761	NA	ND	NA	ND
		9/13/06	267	NA	ND	NA	ND
	13.5[5]	6/19/07	298	ND	ND	ND	ND
		8/14/07	284	ND	ND	NA	ND
MW-45-42	19.2	4/4/06	518	0.9	ND	NA	ND
		5/25/06	1,820	ND	ND	NA	ND
		6/12/06	2,270	1.0	ND	NA	ND
		7/14/06	419	ND	ND	NA	ND
		8/11/06	3,160	NA	ND	NA	ND
		9/13/06	4,150	NA	ND	NA	ND
		11/13/06	525	ND	ND	ND	ND
	16.7[5]	6/21/07	2,320	ND	ND	ND	ND
		8/15/07	1,160	ND	ND	NA	ND
45-61	-4.1	4/4/06	298	ND	ND	NA	ND
		5/25/06	1,710	ND	ND	NA	ND
		6/12/06	1,020	ND	ND	NA	ND
		7/20/06	372	ND	ND	NA	ND
		8/11/06	1,350	NA	ND	NA	ND
		9/13/06	1,450	NA	ND	NA	ND
		11/13/06	957	1.7	ND	ND	ND
	-4.3[5]	6/21/07	1,470	ND	ND	ND	ND
		8/15/07	1,500	ND	ND	NA	ND
MW-46	0.0	4/12/06	1,380	0.6	ND	NA	ND
		5/24/06	623	ND	ND	NA	ND
		6/13/06	ND	ND	ND	NA	ND
		7/12/06	786	ND	ND	NA	ND
		8/4/06	1,150	NA	ND	NA	ND
		9/13/06	1,470	NA	ND	NA	ND
	7.6[5]	6/14/07	3,430	ND	ND	ND	ND
		8/1/07	662	ND	ND	NA	ND

 See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-47-56	17.1	4/13/06	760	2.3	ND	NA	ND
		7/18/06	ND	ND	ND	NA	ND
	18.3[5]	6/20/07	529	0.6	ND	ND	ND
		8/10/07	270	ND	ND	NA	ND
47-80	-3.7	4/13/06	2,330	2.7	ND	NA	ND
		7/18/06	1,870	2.9	ND	NA	ND
	-1.7[5]	6/19/07	2,360	3.3	ND	ND	ND
		8/10/07	3,510	3.6	ND	NA	ND
MW-48-23	-5.0	2/8/06	ND	ND	ND	NA	ND
		4/12/06	ND	ND	ND	NA	ND
		4/27/06	238	ND	ND	NA	ND
		5/22/06	755	ND	ND	NA	ND
		6/9/06	737	ND	ND	ND	ND
		7/6/06	ND	ND	ND	NA	ND
		8/8/06	ND	ND	ND	NA	ND
		9/5/06	740	ND	ND	NA	ND
		11/22/06	ND	ND	ND	NA	ND
		2/9/07	272	ND	ND	NA	ND
		8/16/07	393	ND	ND	NA	ND
48-37	-20.6	2/10/06	ND	NA	ND	NA	ND
		4/12/06	ND	ND	ND	NA	ND
		4/27/06	ND	ND	ND	NA	ND
		5/22/06	ND	ND	ND	NA	ND
		6/9/06	ND	2.1	ND	ND	ND
		7/6/06	ND	ND	ND	NA	ND
		8/8/06	ND	ND	ND	NA	ND
		9/5/06	573	ND	ND	NA	ND
		11/22/06	ND	ND	ND	NA	ND
		2/9/07	ND	ND	ND	NA	ND
		8/16/07	ND	ND	ND	NA	ND
MW-49-26	-4.4	3/22/06	15,400	18.4	ND	NA	ND
		5/19/06	14,200	9.0	ND	NA	ND
		6/6/06	14,000	14.1	ND	NA	ND
		7/7/06	10,000	12.6	ND	NA	ND
		8/1/06	13,700	NA	ND	36.7	ND
		8/28/06	11,000	NA	ND	NA	ND
		11/15/06	6,390	15.5	ND	ND	ND
	-5.4[5]	6/26/07	7,760	12.7	ND	ND	ND
		8/9/07	6,720	14.3	ND	ND	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE[1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
49-42	-23.4	3/22/06	11,300	19.4	ND	NA	ND
		5/19/06	9,390	12.0	ND	NA	ND
		6/6/06	8,280	16.3	ND	NA	ND
		7/7/06	5,850	19.2	ND	NA	ND
		8/1/06	8,800	NA	ND	ND	ND
		8/28/06	8,690	NA	ND	NA	ND
		11/15/06	6,190	21.1	ND	ND	ND
	-22.4[5]	6/26/07	4,440	20.8	ND	ND	ND
		8/9/07	4,300	25.6	ND	ND	ND
49-65	-45.4	3/22/06	5,430	18.5	ND	NA	ND
		5/19/06	5,750	11.3	ND	NA	ND
		6/6/06	4,320	17.2	ND	NA	ND
		7/7/06	4,630	15.6	ND	NA	ND
		8/1/06	5,760	NA	ND	ND	ND
		8/28/06	5,540	NA	ND	NA	ND
		11/15/06	3,040	19.2	ND	ND	ND
	-46.4[5]	6/26/07	2,620	15.8	ND	ND	ND
		8/9/07	2,410	20.8	ND	ND	ND
MW-50-42	-27.1	3/22/06	9,750	19.3	ND	ND	ND
		5/19/06	4,590	19.5	ND	NA	ND
		6/7/06	479	3.9	ND	NA	ND
		7/3/06	398	3.5	ND	NA	ND
		8/1/06	1,410	NA	ND	ND	ND
		8/28/06	311	NA	ND	NA	ND
		11/15/06	1,700	11.3	7.2	ND	ND
	-12.1[5]	6/26/07	215	11.6	ND	ND	ND
		7/26/07	ND	19.4	ND	ND	ND
50-66	-52.1	3/22/06	6,810	25.5	ND	ND	ND
		5/19/06	10,800	19.5	ND	NA	ND
		6/7/06	10,500	19.8	ND	NA	ND
		7/3/06	8,620	25.3	ND	NA	ND
		8/1/06	7,930	NA	ND	ND	ND
		8/28/06	6,770	NA	ND	NA	ND
		11/15/06	5,050	21.5	ND	ND	ND
	-45.1[5]	6/26/07	4,210	29.3	ND	ND	ND
		7/26/07	4,500	31.0	ND	ND	ND

 See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-51-40	27.8	5/30/07	198	ND	ND	NA	ND
		7/24/07	223	ND	ND	NA	ND
51-79	-11.2	5/30/07	ND	ND	ND	NA	ND
		7/24/07	ND	ND	ND	NA	ND
51-104	-34.7	5/30/07	ND	ND	ND	NA	ND
		7/24/07	ND	ND	ND	NA	ND
51-135	-67.7	5/30/07	ND	ND	ND	NA	ND
		7/24/07	ND	ND	ND	NA	ND
51-163	-95.2	5/30/07	ND	ND	ND	NA	ND
		7/24/07	ND	ND	ND	NA	ND
51-189	-121.7	5/30/07	187	ND	ND	NA	ND
		7/24/07	ND	ND	ND	NA	ND
MW-52-11	5.2	6/20/07	ND	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND
52-18	-1.5	5/24/07	ND	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND
52-48	-32.0	5/24/07	ND	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND
52-64	-48.0	5/24/07	ND	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND
52-122	-106.0	5/24/07	ND	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND
52-162	-145.5	5/24/07	282	ND	ND	ND	ND
		8/6/07	211	ND	ND	NA	ND
52-181	-165.0	5/24/07	248	ND	ND	ND	ND
		8/6/07	ND	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE[1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-53-82	-2.4	8/23/06	13,200	6.7	ND	ND	ND
		11/9/06	454	ND	ND	ND	ND
	-4.7[5]	6/22/07	8,680	4.0	ND	ND	ND
		8/9/07	776	ND	ND	ND	ND
53-120	-39.5	8/30/06	4,420	NA	ND	NA	ND
		11/9/06	7,900	24.7	ND	27.1	ND
	-34.7[5]	6/22/07	9,610	35.7	7.9	17.3	ND
		8/9/07	8,050	37.0	ND	ND	ND
MW-54-37	-23.7	5/3/07	801	12.5	ND	ND	ND
		7/31/07	888	5.3	ND	ND	ND
54-58	-44.7	5/3/07	760	2.2	ND	ND	ND
		7/31/07	693	1.8	ND	ND	ND
54-123	-110.2	5/3/07	1,110	21.9	4.21	ND	ND
		7/31/07	963	13.5	ND	ND	ND
54-144	-131.2	5/3/07	1,340	16.1	ND	ND	ND
		7/31/07	1,890	19.2	ND	ND	ND
54-173	-159.7	5/3/07	1,900	20.9	ND	ND	ND
		7/31/07	2,080	14.5	ND	ND	ND
54-190	-177.2	5/3/07	1,870	19.5	ND	ND	ND
		7/31/07	2,250	17.9	ND	ND	ND
MW-55-24	-0.8	11/9/06	2,000	16.6	ND	ND	ND
	2.3[5]	6/28/07	3,080	32.5	ND	NA	ND
		8/2/07	2,710	23.1	ND	ND	ND
55-35	-14.2	11/9/06	9,040	40.4	ND	ND	ND
	-13.8[5]	6/28/07	3,090	32.5	ND	NA	ND
		8/2/07	3,680	34.0	ND	ND	ND
55-54	-30.8	11/9/06	13,100	22.8	ND	ND	ND
	-28.8[5]	6/28/07	10,400	24.7	ND	NA	ND
		8/2/07	9,910	22.2	ND	ND	ND
MW-56-53	17.8	1/4/07	780	ND	13.6	ND	ND
	18.3[5]	6/26/07	289	ND	ND	ND	ND
		8/10/07	216	ND	ND	NA	ND
56-83	-5.5	9/8/06	540	2.7	ND	NA	ND
		11/9/06	165	ND	ND	ND	ND
		1/4/07	1,280	2.3	11.8	ND	ND
	-3.7[5]	6/22/07	1,850	1.9	ND	ND	ND
		8/10/07	1,490	2.4	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-57-11	5.0[5]	6/22/07	4,610	45.5	ND	22.4	ND
		8/6/07	4,090	37.9	ND	ND	ND
57-20	-4.0[5]	6/22/07	1,650	2.0	ND	ND	ND
		8/6/07	966	1.2	ND	ND	ND
57-45	-25.0[5]	8/24/06	4,060	18.8	ND	ND	ND
		6/22/07	955	1.9	ND	ND	ND
		8/6/07	740	2.6	ND	ND	ND
MW-58-26	-7.0	11/16/06	ND	ND	72.7	ND	ND
		1/5/07	260	ND	ND	ND	ND
	-5.4[5]	6/21/07	597	1.0	ND	ND	ND
		7/31/07	856	1.0	ND	NA	ND
58-65	-43.0	11/16/06	ND	ND	ND	ND	ND
		1/5/07	550	ND	ND	ND	ND
	-39.4[5]	6/21/07	315	ND	ND	ND	ND
		7/31/07	342	ND	ND	NA	ND
MW-59-32	-11.7	11/16/06	ND	ND	ND	ND	ND
		1/5/07	ND	ND	ND	ND	ND
	-12.5[5]	6/21/07	467	ND	ND	ND	ND
		7/31/07	169	ND	ND	NA	ND
59-45	-25.9	11/16/06	ND	ND	37.4	ND	ND
		1/5/07	ND	ND	149	ND	ND
	-27.5[5]	6/21/07	754	ND	ND	ND	ND
		7/31/07	249	ND	ND	NA	ND
59-68	-46.1	11/16/06	ND	ND	115	ND	ND
		1/5/07	ND	ND	67.6	ND	ND
	-43.5[5]	6/21/07	590	ND	ND	ND	ND
		7/31/07	819	ND	ND	NA	ND
MW-60-35	-22.7	5/8/07	ND	ND	ND	ND	ND
		7/27/07	761	ND	ND	NA	ND
60-53	-41.7	5/8/07	ND	ND	ND	ND	ND
		7/27/07	ND	ND	ND	NA	ND
60-72	-60.2	5/8/07	ND	ND	ND	ND	ND
		7/27/07	ND	ND	ND	NA	ND
60-135	-122.7	5/8/07	ND	ND	ND	ND	ND
		7/27/07	392	ND	ND	NA	ND
60-154	-142.2	5/8/07	ND	ND	ND	ND	ND
		7/27/07	462	ND	ND	NA	ND
60-176	-163.7	5/8/07	530	ND	ND	ND	ND
		7/27/07	849	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-62-18	-1.8	5/17/07	452	ND	ND	ND	ND
		7/26/07	508	ND	ND	NA	ND
62-37	-33.5	5/17/07	297	ND	ND	ND	ND
		7/26/07	250	ND	ND	NA	ND
62-53	-40.5	5/10/07	393	ND	ND	ND	ND
		7/26/07	345	ND	ND	NA	ND
62-71	-58.5	5/10/07	502	ND	ND	ND	ND
		7/26/07	ND	ND	ND	NA	ND
62-92	-79.0	5/10/07	700	ND	ND	ND	ND
		7/26/07	437	ND	ND	NA	ND
62-138	-125.5	5/10/07	455	0.8	ND	ND	ND
		7/26/07	538	ND	ND	NA	ND
62-182	-169.5	5/10/07	541	ND	ND	ND	ND
		7/26/07	417	ND	ND	NA	ND
MW-63-18	0.6	5/18/07	230	ND	ND	ND	ND
		7/30/07	200	ND	ND	NA	ND
63-34	-30.6	5/18/07	228	ND	ND	ND	ND
		7/30/07	280	ND	ND	NA	ND
63-50	-37.4	5/15/07	326	ND	ND	ND	ND
		7/25/07	225	ND	ND	NA	ND
63-93	-80.9	5/15/07	281	ND	ND	ND	ND
		7/25/07	237	ND	ND	NA	ND
63-112	-99.4	5/15/07	424	ND	ND	ND	ND
		7/25/07	269	ND	ND	NA	ND
63-121	-108.9	5/15/07	311	ND	ND	ND	ND
		7/25/07	296	ND	ND	NA	ND
63-163	-150.4	5/15/07	578	ND	ND	ND	ND
		7/25/07	479	ND	ND	NA	ND
63-174	-161.9	5/15/07	593	ND	ND	ND	ND
		7/25/07	528	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-65-48	26.4	1/4/07	208	ND	ND	ND	ND
65-80	-1.7	9/8/06	ND	ND	ND	NA	ND
		1/4/07	183	ND	ND	ND	ND
MW-66-21	0.0	7/30/07	3,570	1.8	ND	NA	ND
66-36	-19.5	7/30/07	9,100	6.2	ND	NA	ND
MW-67-39	-29.5	8/31/07	4,860	18.6	ND	NA	ND
67-105	-88.5	8/31/07	1,860	1.1	ND	NA	ND
67-173	-164.5	8/31/07	1,050	ND	ND	NA	ND
67-219	-207.5	8/31/07	1,250	ND	ND	NA	ND
67-276	-254.0	8/31/07	679	ND	ND	NA	ND
67-323	-311.0	8/31/07	313	ND	ND	NA	ND
67-340	-329.5	8/31/07	369	ND	ND	NA	ND
MW-101	124.4	12/8/05	ND	ND	ND	NA	ND
		6/8/06	ND	ND	ND	NA	ND
MW-103	125.1	6/8/06	170	ND	ND	NA	ND
MW-105	123.7	12/8/05	ND	ND	ND	NA	ND
		6/8/06	ND	ND	ND	NA	ND
MW-107	111.0	9/28/05	ND	NA	ND	NA	ND
		12/8/05	ND	ND	ND	NA	ND
		4/18/06	ND	ND	ND	NA	ND
		6/6/06	ND	ND	ND	NA	ND
	110.1[5]	7/23/07	ND	ND	ND	NA	ND
MW-108	6.2	9/29/05	ND	NA	ND	NA	ND
		11/3/05	ND	NA	ND	NA	ND
		5/13/06	278	ND	ND	NA	ND
MW-109	6.1	9/29/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		5/13/06	339	ND	ND	NA	ND
MW-110	113.6	6/8/06	225	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
MW-111	4.8	9/29/05	212,000	NA	ND	NA	ND
		10/14/05	6,810	NA	NA	NA	NA
		10/21/05	284,000	NA	NA	NA	NA
		10/28/05	218,000	NA	NA	NA	NA
		11/4/05	302,000	NA	NA	NA	NA
		11/22/05	180,000	NA	NA	NA	NA
		12/2/05	125,000	NA	NA	NA	NA
		12/8/05	271,000	NA	NA	NA	NA
		12/15/05	296,000	NA	NA	NA	NA
		12/19/05	192,000	NA	NA	NA	NA
		12/29/05	212,000	NA	NA	NA	NA
		1/6/06	113,000	NA	NA	NA	NA
		1/13/06	199,000	NA	NA	NA	NA
		1/20/06	119,000	NA	NA	NA	NA
		1/27/06	5,780	NA	NA	NA	NA
		2/3/06	295,000	NA	NA	NA	NA
		2/7/06	238,000	1.2	NA	NA	NA
		2/16/06	294,000	NA	NA	NA	NA
		3/3/06	236,000	NA	NA	NA	NA
		4/7/06	145,000	NA	NA	NA	NA
		5/17/06	43,100	2.5	ND	NA	ND
		6/23/06	262,000	ND	ND	NA	ND
		9/21/06	159,000	ND	ND	NA	ND
	2.4[5]	6/15/07	119,000	1.0	ND	ND	ND
		8/3/07	98,800	1.0	ND	NA	ND
MW-112	120.8	6/8/06	ND	ND	ND	NA	ND
RW-1	-30.0	10/25/06 11:37	64,100	ND	ND	NA	ND
		10/25/06 14:15	29,500	ND	ND	NA	ND
		10/31/06 12:27	107,000	ND	ND	NA	ND
		10/31/06 15:55	26,300	ND	ND	NA	ND
		10/31/06 20:00	18,900	ND	ND	NA	ND
		11/1/06 12:00	18,400	ND	ND	NA	ND
		11/2/06 12:00	24,000	ND	ND	NA	ND
		11/3/06 9:00	30,600	ND	ND	NA	ND
I2	48.0	5/13/06	ND	ND	ND	NA	NA

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
U3-1	-0.7	10/6/05	417	NA	ND	NA	ND
		10/21/05	ND	NA	ND	NA	ND
		10/28/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		11/10/05	ND	NA	ND	NA	ND
		11/18/05	ND	NA	ND	NA	ND
		12/2/05	ND	NA	ND	NA	ND
		12/15/05	ND	NA	ND	NA	ND
		12/30/05	ND	NA	ND	NA	ND
		1/12/06	744	NA	ND	NA	ND
		2/15/06	ND	NA	NA	NA	NA
		3/16/06	763	ND	ND	NA	ND
		6/22/06	755	ND	ND	NA	ND
U3-2	2.4	10/6/05	960	NA	ND	NA	ND
		10/21/05	ND	NA	ND	NA	ND
		10/28/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		11/10/05	ND	NA	ND	NA	ND
		11/18/05	ND	NA	ND	NA	ND
		12/2/05	ND	NA	ND	NA	ND
		12/15/05	ND	NA	ND	NA	ND
		12/28/05	ND	NA	ND	NA	ND
		1/12/06	ND	NA	ND	NA	ND
		2/15/06	ND	NA	NA	NA	NA
		3/16/06	282	ND	ND	NA	ND
		6/22/06	197	1.4	ND	NA	ND
U3-3	4.2	10/6/05	439	NA	ND	NA	ND
		10/21/05	ND	NA	ND	NA	ND
		10/28/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		11/10/05	471	NA	ND	NA	ND
		11/18/05	ND	NA	ND	NA	ND
		12/2/05	ND	NA	ND	NA	ND
		12/15/05	ND	NA	ND	NA	ND
		12/30/05	ND	NA	ND	NA	ND
		1/13/06	ND	NA	ND	NA	ND
		2/15/06	ND	NA	NA	NA	NA
		3/16/06	263	ND	ND	NA	ND
		6/22/06	179	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
U3-4D	-14.7	10/16/05	ND	NA	ND	NA	ND
		10/21/05	ND	NA	ND	NA	ND
		10/28/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		11/10/05	ND	NA	ND	NA	ND
		11/18/05	ND	NA	ND	NA	ND
		11/22/05	ND	NA	NA	NA	NA
		12/2/05	ND	NA	ND	NA	ND
		12/15/05	ND	NA	ND	NA	ND
		12/30/05	ND	NA	ND	NA	ND
		1/12/06	573	NA	ND	NA	ND
		2/15/06	ND	NA	NA	NA	NA
		4/26/06	575	ND	ND	NA	ND
		6/22/06	710	ND	ND	NA	ND
U3-T1	3.2	10/7/05	1,590	NA	ND	NA	ND
		10/21/05	ND	NA	ND	NA	ND
		10/28/05	ND	NA	ND	NA	ND
		11/4/05	ND	NA	ND	NA	ND
		11/10/05	563	NA	ND	NA	ND
		11/18/05	ND	NA	ND	NA	ND
		12/2/05	498	NA	ND	NA	ND
		12/15/05	ND	NA	ND	NA	ND
		12/30/05	529	NA	ND	NA	ND
		1/12/06	787	NA	ND	NA	ND
		2/15/06	ND	NA	NA	NA	NA
		3/16/06	1,260	ND	ND	NA	ND
		5/26/06	732	1.3	ND	NA	ND
		7/12/06	684	ND	ND	NA	ND
		8/15/06	766	ND	ND	NA	ND
	2.5[5]	6/12/07	506	ND	ND	ND	ND
		8/1/07	490	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
U3-T2	2.9	10/7/05	703	NA	ND	NA	ND
		10/21/05	1,470	NA	ND	NA	ND
		10/28/05	1,280	NA	ND	NA	ND
		11/4/05	1,190	NA	ND	NA	ND
		11/10/05	1,640	NA	ND	NA	ND
		11/18/05	1,130	NA	ND	NA	ND
		12/2/05	1,330	NA	ND	NA	ND
		12/15/05	1,290	NA	ND	NA	ND
		12/30/05	1,690	NA	ND	NA	ND
		1/6/06	2,420	NA	ND	NA	ND
		1/13/06	1,780	NA	ND	NA	ND
		1/20/06	1,750	NA	ND	NA	ND
		1/25/06	2,320	NA	ND	NA	ND
		2/1/06	2,130	NA	ND	NA	ND
		2/17/06	ND	NA	NA	NA	NA
		3/16/06	1,690	ND	ND	NA	ND
		5/26/06	1,900	1.5	ND	NA	ND
		7/12/06	1,830	ND	ND	NA	ND
		8/15/06	1,580	NA	ND	NA	ND
	2.5[5]	6/12/07	1,450	ND	ND	ND	ND
		8/1/07	1,250	ND	ND	NA	ND
U1-CSS	6.1	1/30/07	1,760	19.5	ND	ND	ND
		2/27/07	4,320	13.8	ND	ND	ND
		6/13/07	1,530	14.5	ND	ND	ND
		8/6/07	2,800	26.8	ND	NA	ND
LAF-1	38.3	12/6/05	ND	NA	ND	NA	ND
		6/6/06	ND	ND	ND	ND	ND
		9/19/06	ND	ND	ND	NA	ND
		12/4/06	ND	ND	ND	ND	ND
		3/7/07	ND	ND	ND	ND	ND
		6/7/07	ND	1.1	ND	NA	ND
		9/10/07	ND	ND	ND	NA	ND
LAF-2	-22.3	6/6/06	ND	ND	ND	ND	ND
		9/19/06	ND	ND	ND	NA	ND
		12/4/06	ND	ND	NA	ND	ND
		3/7/07	ND	ND	ND	NA	ND
		6/7/07	ND	ND	ND	NA	ND

See Page 21 for Notes

TABLE 5.1
GROUNDWATER ANALYTICAL DATA
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

Well ID	SAMPLE ZONE [1] CENTER ELEVATION, FT	SAMPLE COLLECTION DATE	ANALYSIS RESULTS				
			H-3 pCi/L	Sr-90 pCi/L	Cs-137 pCi/L	Ni-63 pCi/L	Co-60 pCi/L
LAF-3	46.5	12/6/05	ND	NA	ND	NA	ND
		6/6/06	ND	ND	ND	ND	ND
		9/19/06	ND	ND	ND	NA	ND
		12/4/06	ND	ND	ND	ND	ND
		3/7/07	ND	ND	ND	NA	ND
		6/7/07	ND	ND	ND	NA	ND
		9/10/07	ND	ND	ND	NA	ND

well screen in unconsolidated deposit {soil backfill/natural soil}
well screen in consolidated {bedrock}

NOTES:
All elevations are above NGVD29.
1. Either the center of the screen/sampling ports (wells) or the midpoint of submerged part (open holes).
2. ND: Not detected above laboratory minimum detection limits
3. NA: Not Analyzed
4. Sampling port location changed since Feb. 07
5. Samples were taken using the low-flow sampling method at given elevations.
6. Suffix of Well ID displayed is representative of sampling depth within the screened well MW42-49.
7. This table contains data for completed well installations only.

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-30-69	11.8	-	-	12.5	-	-	11.8	-	-
MW-30-84	12.8	-	-	13.2	-	-	11.7	-	-
MW-31-49	44.1	-	-	48.0	-	-	39.1	-	-
MW-31-63	41.6	-	-	45.6	-	-	38.1	-	-
MW-31-85	39.6	-	-	43.6	-	-	36.9	-	-
MW-32-62	42.8	-	-	46.6	-	-	38.4	-	-
MW-32-92	10.3	-	-	11.0	-	-	10.3	-	-
MW-32-140	13.1	-	-	13.1	-	-	12.4	-	-
MW-32-165	8.2	-	-	8.3	-	-	7.6	-	-
MW-32-196	6.7	-	-	7.0	-	-	6.3	-	-
MW-33	10.1	-	-	10.7	-	-	9.1	-	-
MW-34	9.9	-	-	10.8	-	-	9.1	-	-
MW-35	10.0	-	-	11.2	-	-	9.4	-	-
MW-36-24	8.9	-	-	7.1	-	-	7.0	-	-
MW-36-41	8.4	8.5	8.2	7.2	7.2	7.2	7.1	7.2	7.1
MW-36-52	7.5	7.4	7.4	6.7	6.7	6.7	6.6	6.7	6.5
MW-37-22	5.4	5.48	5.51	4.9	5.1	4.7	4.1	4.2	3.9
MW-37-32	5.6	5.52	5.51	5.0	5.0	5.0	4.2	4.3	4.1
MW-37-40	5.4	-	-	4.9	-	-	4.1	-	-
MW-37-57	7.2	7.17	7.07	6.2	6.2	6.1	5.4	5.5	5.3
MW-38	4.1	4.13	3.01	3.0	3.8	2.1	1.9	2.5	1.2

See Page 7 for Notes

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-39-67	24.9	-	-	31.1	-	-	24.1	-	-
MW-39-84	24.7	-	-	30.9	-	-	23.9	-	-
MW-39-100	25.0	-	-	31.0	-	-	24.0	-	-
MW-39-124	24.0	-	-	30.1	-	-	23.1	-	-
MW-39-183	18.6	-	-	29.8	-	-	22.8	-	-
MW-39-195	22.7	-	-	28.5	-	-	21.5	-	-
MW-40-24	59.4	-	-	62.9	-	-	58.6	-	-
MW-40-46	58.1	-	-	61.7	-	-	57.4	-	-
MW-40-81	55.0	-	-	58.6	-	-	54.3	-	-
MW-40-100	53.1	-	-	56.8	-	-	52.5	-	-
MW-40-127	52.4	-	-	56.2	-	-	51.9	-	-
MW-40-162	49.4	-	-	53.6	-	-	49.3	-	-
MW-41-13	DRY	-	-	DRY	-	-	DRY	-	-
MW-41-40	29.9	-	-	34.5	-	-	30.0	-	-
MW-41-63	25.9	-	-	31.5	-	-	27.0	-	-
MW-42-49	34.5	-	-	34.9	-	-	34	-	-
MW-42-78	35.6	-	-	36.0	-	-	35	-	-
MW-43-28	32.8			34.1			32.4		
MW-43-62	30.9	-	-	31.8	-	-	31.3	-	-
MW-44-67	33.4	-	-	37.3	-	-	33.1	-	-
MW-44-102	23.1	-	-	24.1	-	-	19.9	-	-
MW-45-42	26.4	-	-	33.1	-	-	26.3	-	-
MW-45-61	25.7	-	-	32.0	-	-	25.2	-	-

See Page 7 for Notes

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-46	12.8	-	-	14.2	-	-	11.7	-	-
MW-47-56	21.8	-	-	27.2	-	-	21.4	-	-
MW-47-80	22.3	-	-	27.2	-	-	21.4	-	-
MW-48-23	1.5	2.26	-0.08	1.4	2.7	0.1	0.2	1.0	-0.8
MW-48-37	2.0	2.42	0.64	2.1	3.0	1.1	0.7	1.1	0.1
MW-49-26	1.6	1.47	1.04	1.4	2.3	0.4	0.6	1.1	0.1
MW-49-42	1.1	1.34	0.31	1.7	2.3	1.2	0.9	1.7	0.1
MW-49-65	1.5	1.37	0.89	1.8	2.2	1.5	1.0	1.6	0.6
MW-50-42	7.2	7.34	7.24	5.9	6.1	5.7	4.8	5.1	4.8
MW-50-66	4.4	4.46	3.71	3.9	4.3	3.5	2.8	3.3	2.2
MW-51-40	50.6	-	-	53.3	-	-	51.3	-	-
MW-51-79	41.8	-	-	45.6	-	-	43.6	-	-
MW-51-102	37.8	-	-	39.7	-	-	37.7	-	-
MW-51-135	39.1	-	-	41.3	-	-	39.3	-	-
MW-51-163	35.4	-	-	37.0	-	-	35.0	-	-
MW-51-189	30.7	-	-	32.1	-	-	30.1	-	-
MW-52-11	6.0	-	-	6.4	-	-	5.7	-	-
MW-52-18	6.6	-	-	6.7	6.7	6.7	6.0	6.0	6.0
MW-52-48	7.1	7.02	7.08	7.2	7.2	7.2	6.6	6.7	6.5
MW-52-64	6.0	6.0	6.0	6.1	6.1	6.1	5.2	5.2	5.2
MW-52-118	5.4	5.27	5.34	5.5	5.5	5.5	4.9	4.9	4.9
MW-52-122	5.3	5.20	5.25	5.3	5.3	5.3	4.8	4.8	4.8
MW-52-162	1.2	1.04	0.67	0.8	1.0	0.5	0.6	0.9	0.1
MW-52-181	0.9	0.82	0.41	0.6	0.8	0.3	0.3	0.6	-0.3
MW-53-82	9.8	-	-	11.7	-	-	8.7	-	-
MW-53-120	9.9	-	-	10.9	-	-	7.9	-	-

See Page 7 for Notes

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-54-37	7.7	7.61	7.52	9.7	9.8	9.6	5.3	5.4	5.1
MW-54-58	7.0	6.99	6.86	9.0	9.1	8.9	4.7	4.8	4.5
MW-54-123	6.0	5.96	5.69	7.9	8.1	7.7	3.6	3.8	3.3
MW-54-144	9.1	9.2	8.9	11.1	11.3	10.9	6.7	7.0	6.4
MW-54-173	5.5	5.46	5.17	7.4	7.6	7.3	3.0	3.3	2.7
MW-54-190	5.4	5.36	5.08	7.3	7.5	7.2	3.0	3.2	2.9
MW-55-24	8.6	8.6	8.6	8.2	8.3	8.1	6.7	6.7	6.6
MW-55-35	8.2	8.13	8.10	8.2	8.2	8.1	6.7	6.8	6.6
MW-55-54	8.6	8.52	8.47	7.9	7.9	7.9	6.4	6.5	6.4
MW-56-53	21.0	-	-	26.0	-	-	20.3	-	-
MW-56-83	21.1	-	-	24.4	-	-	18.7	-	-
MW-57-11	9.6	9.59	9.57	11.1	11.1	11.0	7.5	7.6	7.5
MW-57-20	9.4	9.40	9.38	10.8	10.8	10.8	7.2	7.2	7.2
MW-57-45	9.2	9.11	9.08	10.4	10.4	10.4	6.8	6.8	6.8
MW-58-26	8.2	8.04	8.03	8.3	8.4	8.2	4.9	5.0	4.8
MW-58-65	6.3	6.32	6.03	7.5	7.6	7.4	4.1	4.3	3.9
MW-59-32	1.8	1.46	1.06	1.6	2.1	0.9	1.7	2.0	0.9
MW-59-45	2.0	1.9	1.1	1.9	2.9	0.8	2.0	2.7	1.0
MW-59-68	4.2	4.53	2.91	2.3	2.9	1.4	3.4	4.4	2.3

See Page 7 for Notes

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-60-35	2.6	2.55	2.19	2.9	3.1	2.5	2.2	2.5	1.7
MW-60-53	0.3	0.45	-0.63	0.4	0.9	-0.2	-0.3	1.0	-1.2
MW-60-72	1.5	1.70	0.74	1.7	2.2	0.8	1.0	1.4	0.4
MW-60-135	1.7	1.89	0.94	1.9	2.3	1.4	1.2	1.9	0.4
MW-60-154	0.9	0.94	0.08	1.0	1.4	0.5	0.3	0.7	-0.1
MW-60-176	0.2	0.93	-0.48	0.7	1.4	0.1	0.0	0.7	-0.4
MW-62-18	1.2	2.2	0.3	NA[8]			NA		
MW-62-37	1.4	2.1	0.6	1.4	1.8	0.7	-0.2	0.1	-0.7
MW-62-53	1.5	1.15	0.95	1.6	2.0	0.9	0.9	1.2	0.5
MW-62-71	1.1	1.54	0.89	1.7	2.1	1.2	1.0	1.6	0.2
MW-62-92	1.3	1.84	1.07	2.0	2.3	1.5	1.3	1.9	1.2
MW-62-138	2.1	2.19	1.40	2.3	2.6	1.8	1.6	2.0	1.2
MW-62-181	1.9	2.07	1.33	2.2	2.7	1.6	1.5	1.9	1.1
MW-63-18	1.2	2.00	0.14	NA			NA		
MW-63-34	1.3	2.03	0.51	NA			NA		
MW-63-50	1.6	1.51	0.86	1.7	2.1	1.1	1.0	1.5	0.2
MW-63-91	2.0	1.91	1.16	2.0	2.3	1.5	1.3	1.8	0.4
MW-63-112	0.7	0.80	0.03	0.9	1.4	0.2	0.2	0.6	-0.4
MW-63-121	1.7	2.39	1.41	2.4	3.0	1.4	1.7	2.1	1.1
MW-63-163	1.4	1.47	0.70	1.6	1.9	1.4	0.9	1.4	0.3
MW-63-174	1.5	1.63	0.88	1.8	2.8	2.1	1.1	1.4	0.7

See Page 7 for Notes

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
MW-65-48	28.2	-	-	31.7	-	-	29.9	-	-
MW-65-80	28.5	-	-	32.0	-	-	30.2	-	-
MW-66-21	1.0	1.6	0.3	NA			NA		
MW-66-36	1.4	1.8	0.8	NA			NA		
MW-67-39[9]	2.0	2.7	1.3	NA			NA		
MW-67-105	2.8	3.5	2.1	NA			NA		
MW-67-173	2.3	3.0	1.7	NA			NA		
MW-67-219	2.4	3.0	1.8	NA			NA		
MW-67-276	3.3	3.9	2.7	NA			NA		
MW-67-323	2.2	2.7	1.6	NA			NA		
MW-67-340	2.6	3.1	2.0	NA			NA		
MW-107	116.8	-	-	120.6	-	-	117.4	-	-
MW-108	9.6	-	-	9.8	-	-	7.2	-	-
MW-109	9.5	-	-	9.1	-	-	4.7	-	-
MW-111	9.6	-	-	10.2	-	-	8.2	-	-
U3-1	4.5	4.54	4.20	4.3	4.5	4.1	3.5	3.5	3.5
U3-2	5.4	5.5	5.3	5.4	5.5	5.4	3.8	3.8	3.8
U3-3	8.4	7.5	7.5	8.0	-	-	4.3	4.3	4.3
U3-4D	4.2	4.23	4.25	3.9	3.9	3.9	3.6	3.6	3.6

See Page 7 for Notes

TABLE 6.1
GROUND WATER ELEVATIONS
INDIAN POINT ENERGY CENTER
BUCHANAN, NY

WELL ID	RECENT GW EL. 6/1/2007			WET SEASON GW EL. 3/28/2007			DRY SEASON GW EL. 2/12/2007		
	Avg. of the day[1]	at High Tide[2]	at Low Tide[3]	Avg. of the day	at High Tide[4]	at Low Tide[5]	Avg. of the day	at High Tide[6]	at Low Tide[7]
U3-4S	4.3	4.28	3.91	3.9	4.0	3.7	3.0	3.0	3.0
U3-T1	4.5	4.45	4.51	4.5	4.6	4.3	3.6	3.6	3.6
U3-T2	4.5	4.47	4.33	4.5	4.6	4.3	3.6	3.6	3.6
I-2	50.2	-	-	52.0	-	-	48.7	-	-

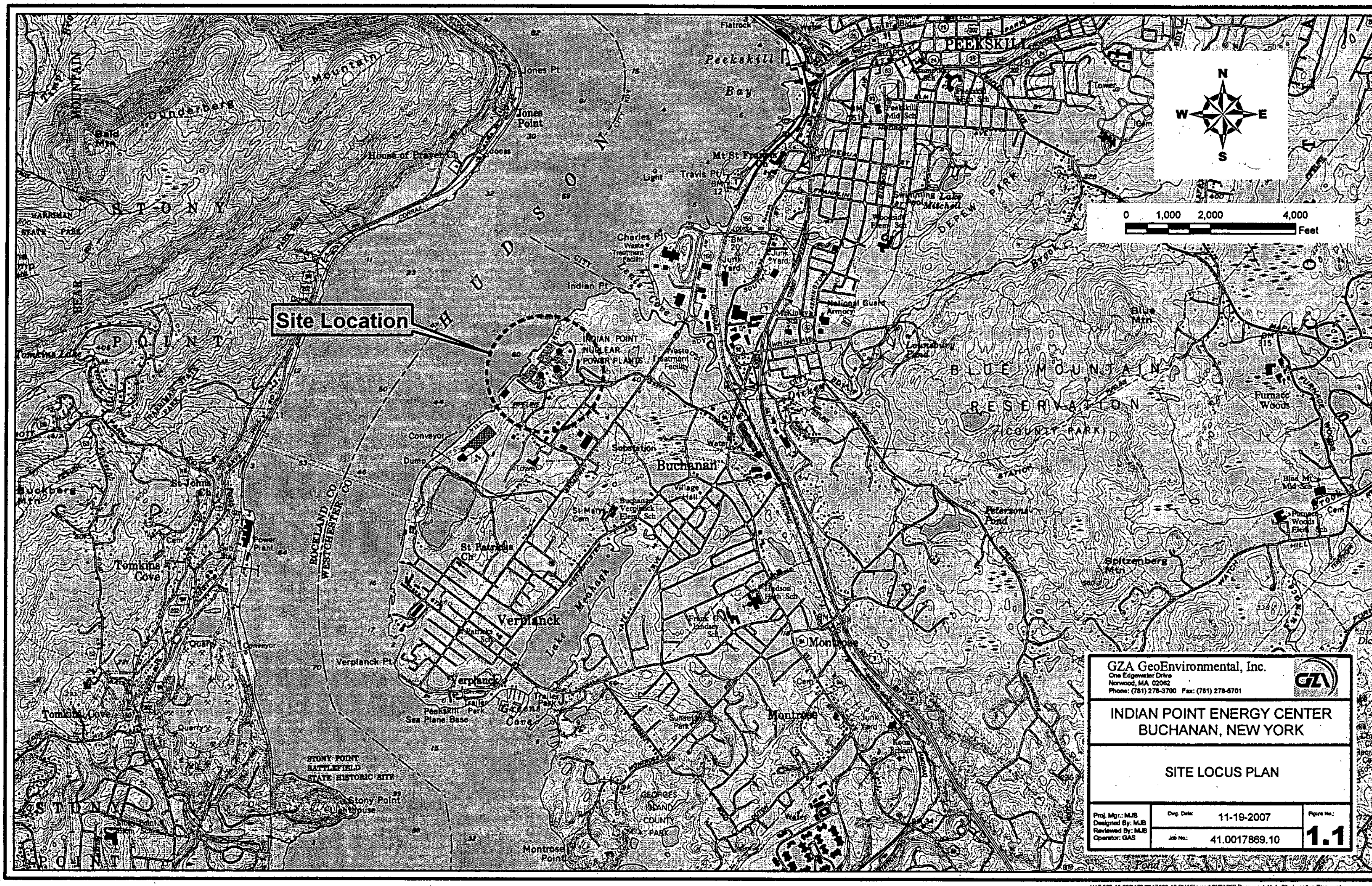
NOTES: Approximated levels from adjacent dates at the same lunar phase are given when data from specified date is unavailable.

[shaded box] well screen in unconsolidated deposit (soil backfill/natural soil)

[blank box] well screen in consolidated rock (bedrock)

All elevations are above NGVD29.

1. Average piezometric heads of the day.
2. Piezometric heads in tidal wells at first high tide of the day in the Hudson river, at 11:44 am.
3. Piezometric heads in tidal wells at first low tide of the day in the Hudson river, at 6:29 am.
4. Piezometric heads in tidal wells at first high tide of the day in the Hudson river, at 5:26 am.
5. Piezometric heads in tidal wells at first low tide of the day in the Hudson river, at 12:21 am.
6. Piezometric heads in tidal wells at first high tideof the day in the Hudson river, at 7:45 am.
7. Piezometric heads in tidal wells at first low tide of the day in the Hudson river, at 1:55 am.
8. Data not available; transducers installed after the specified dates.
9. MW-67 Waterloo system was installed on 8/27/07. The given piezometric heads are responses to the first low tide (at 5:50 am) and the first high tide (at 11:16am) on 8/28/07.



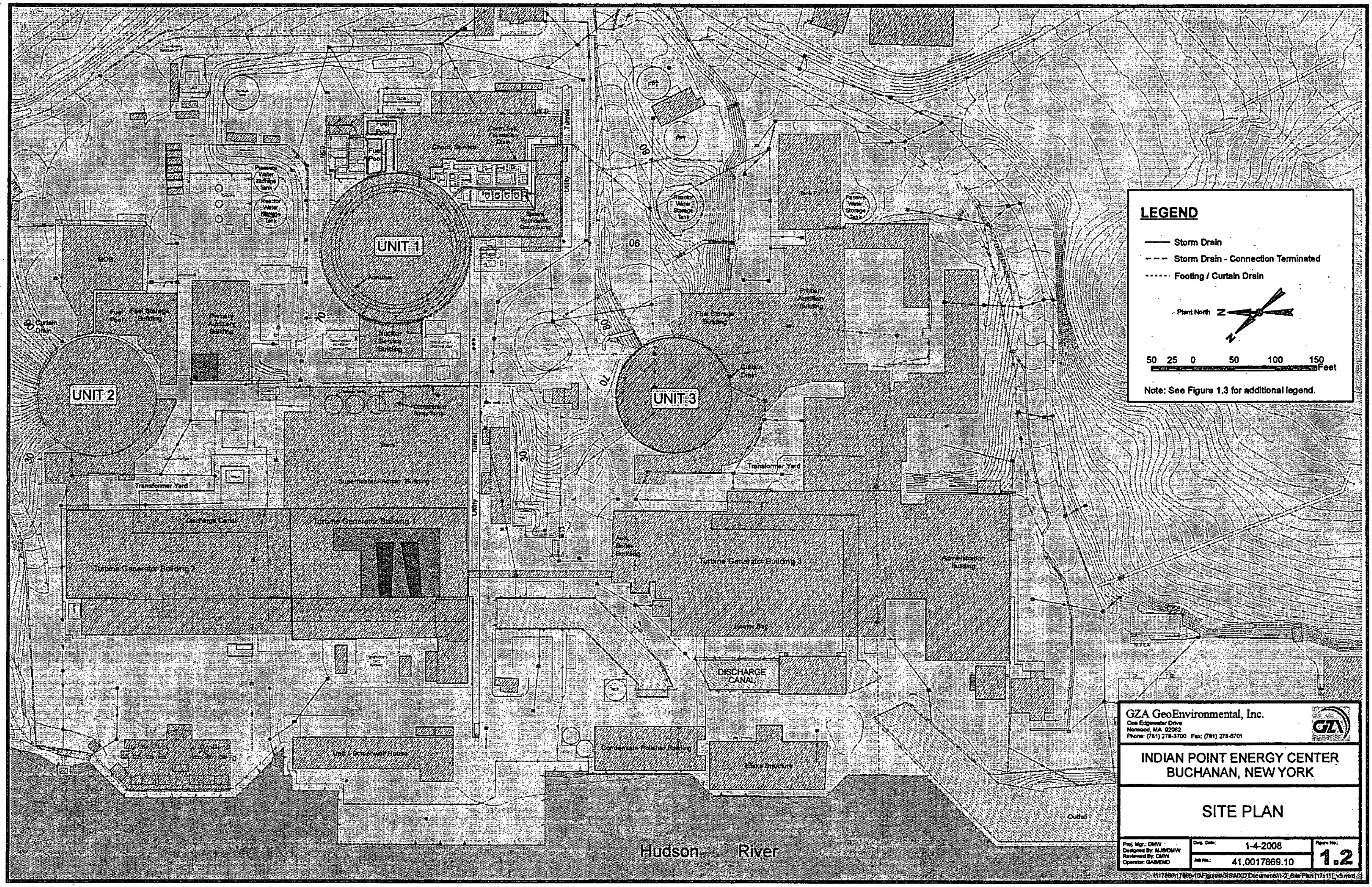
GZA GeoEnvironmental, Inc.
One Edgewater Drive
Norwood, MA 02062
Phone: (781) 278-3700 Fax: (781) 278-5701

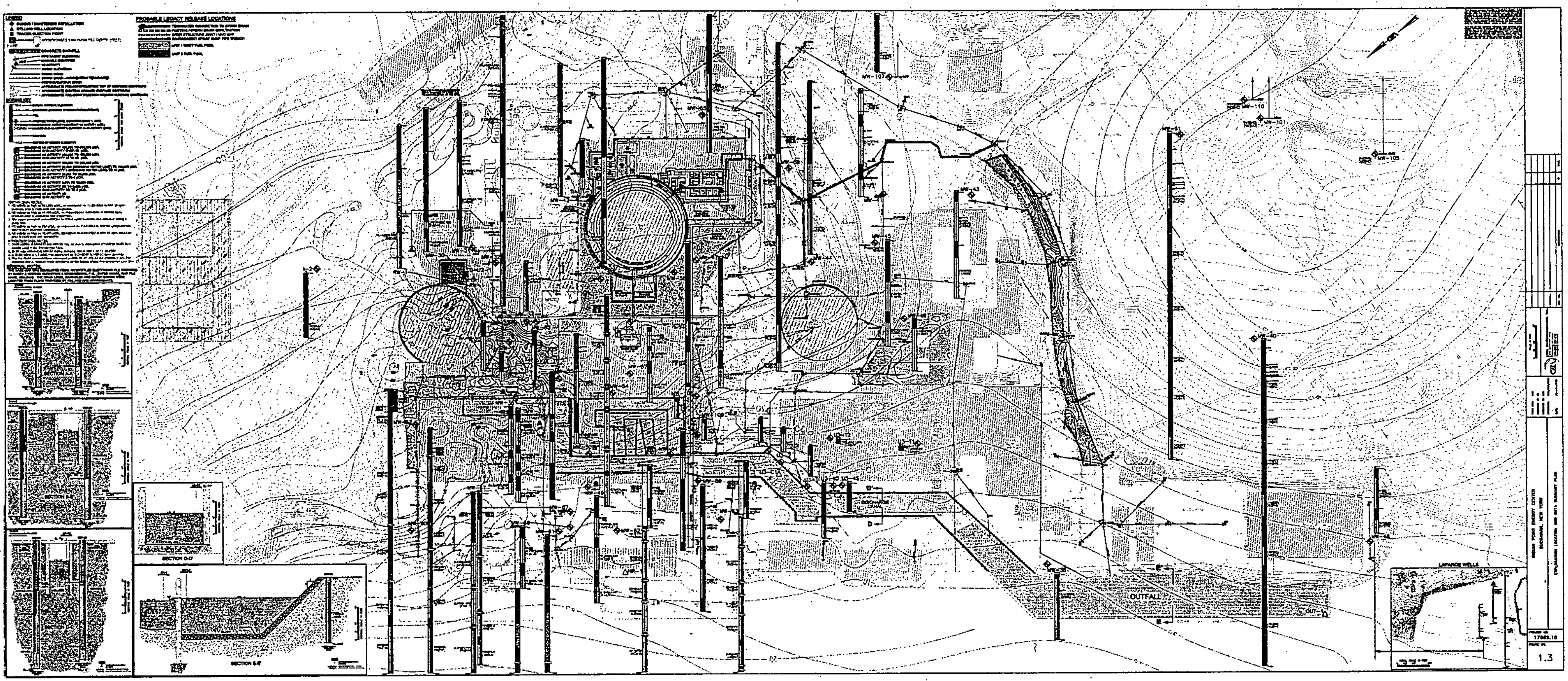
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

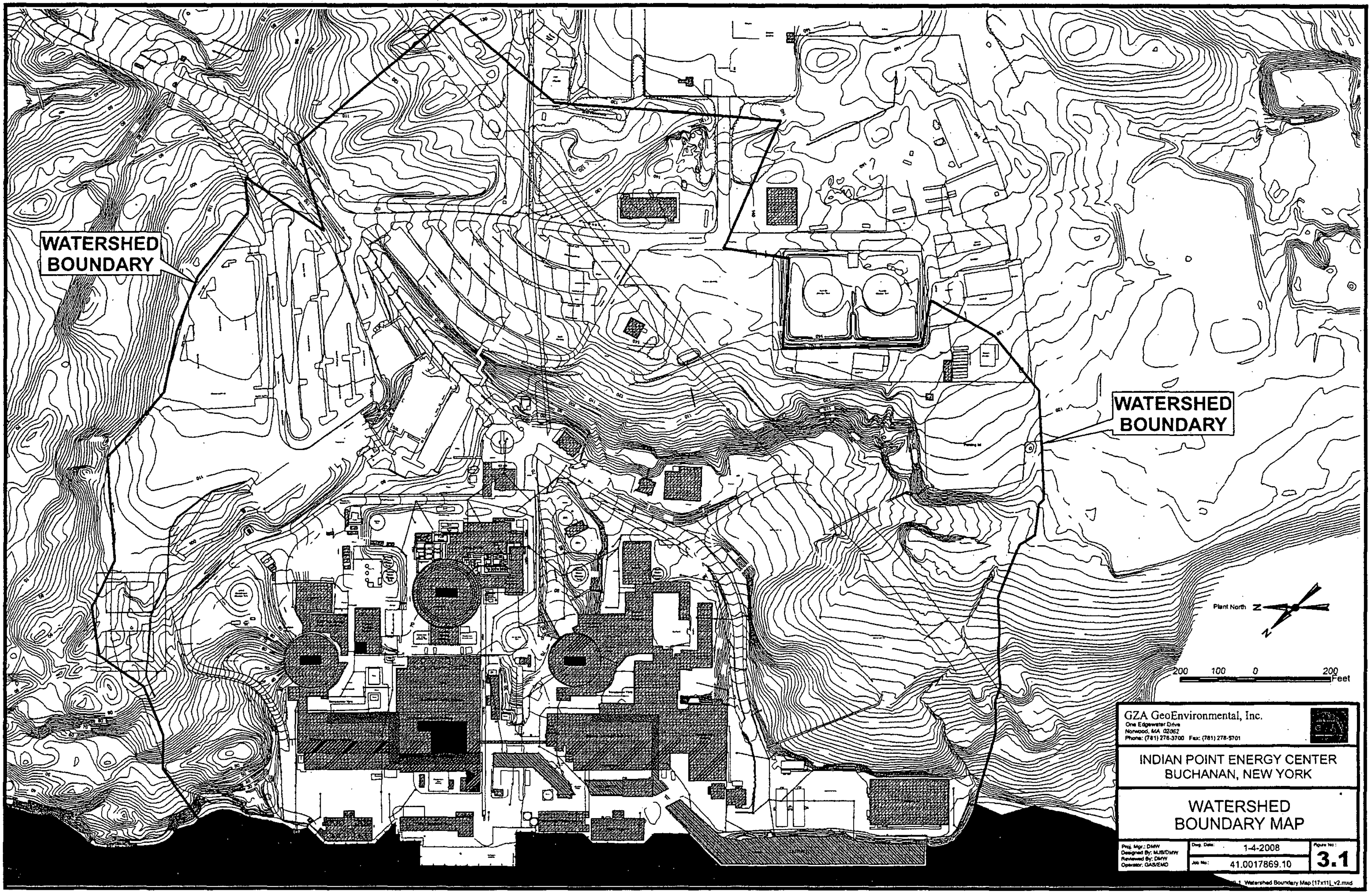
SITE LOCUS PLAN

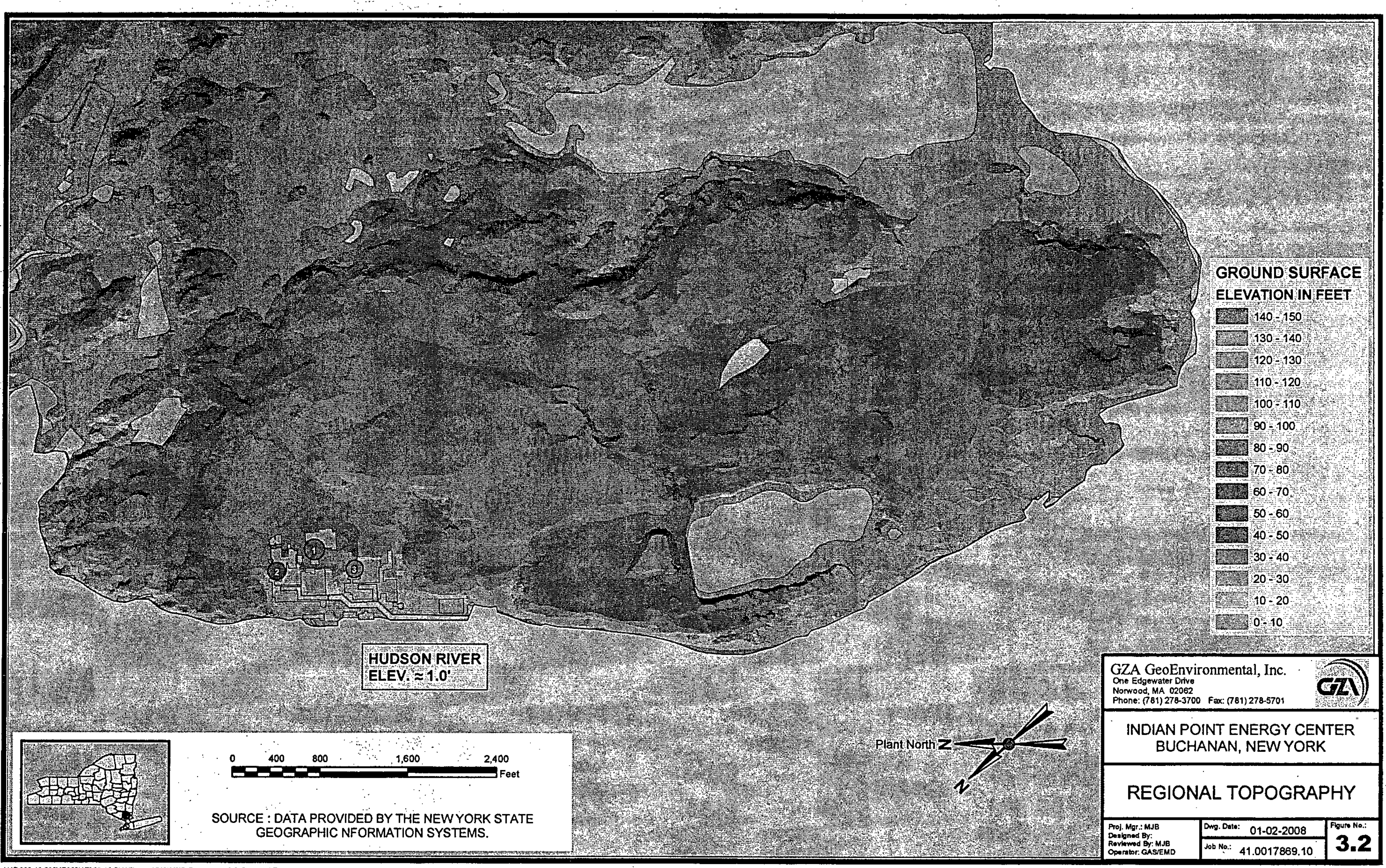
Proj. Mgr.: MJB Designed By: MJB Reviewed By: MJB Operator: GAS	Dwg. Date: 11-19-2007 Job No.: 41.0017869.10	Figure No.: 1.1

J:\17,000-18,999\17869\17869-10.DW\Figures\GIS\MXD Documents\1-1_Site Location Plan.mxd

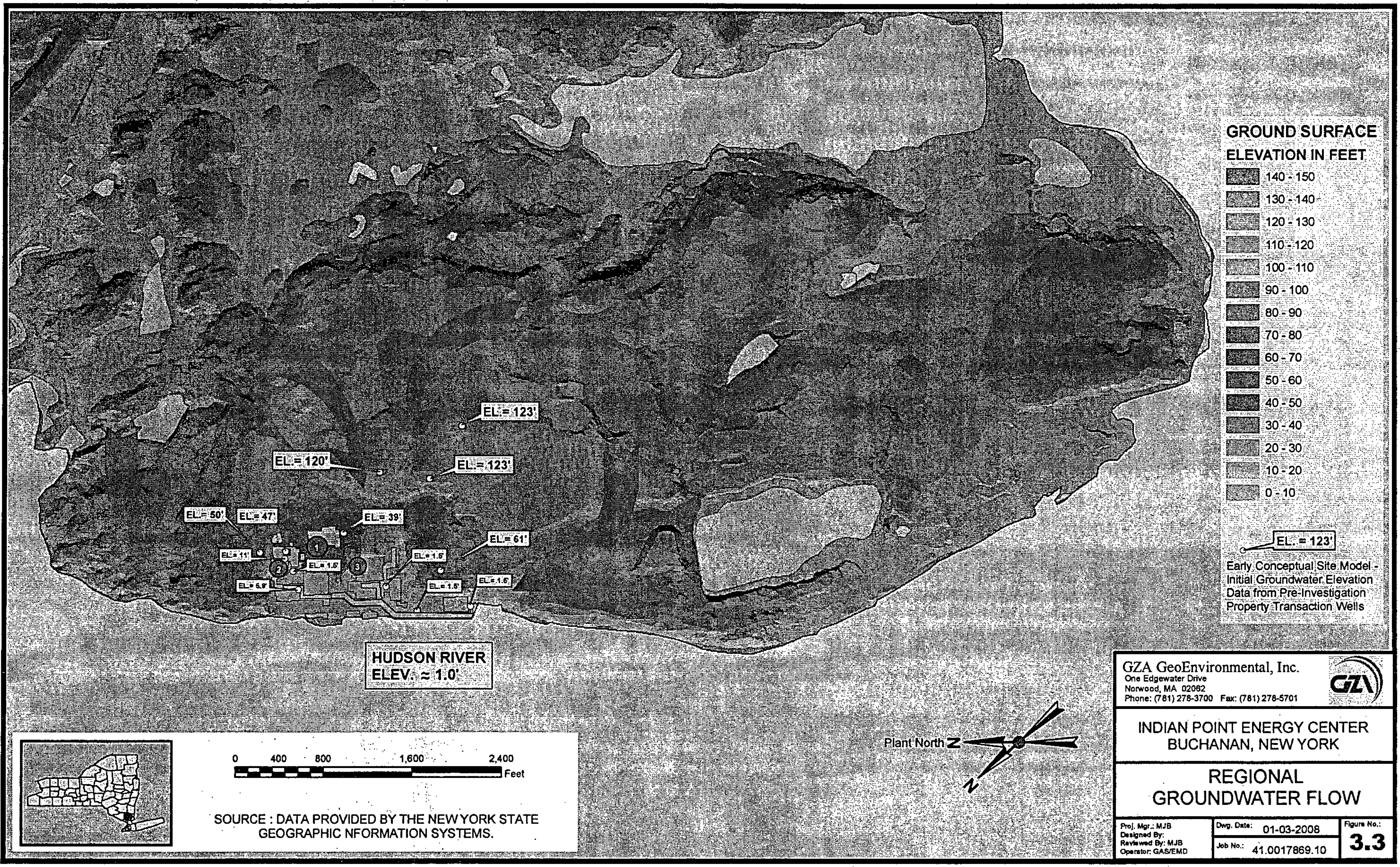

UNIT 1
UNIT 2
UNIT 3
Fuel Pool
Chem. Services
Reactor Water Storage Tank
Primary Water Storage Tank
Primary Auxiliary Building
Fuel Storage Building
Fuel Pool
Transformer Yard
Transformer Yard
Turbine Generator Building 1
Turbine Generator Building 2
Turbine Generator Building 3
Superheater Furnace Building
Discharge Canal
Administration Building
Curtain Drain
DISCHARGE CANAL
Condensate Polisher Building
Intake Structure
Unit 1 Screenwell House
Outfall
Hudson River
LEGEND
Storm Drain
Storm Drain - Connection Terminated
Footing / Curtain Drain
Plant North
50 25 0 50 100 150 Feet
Note: See Figure 1.3 for additional legend.
GZA GeoEnvironmental, Inc.
One Edgewater Drive
Norwood, MA 02062
Phone: (781) 278-3700 Fax: (781) 278-5701
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK
SITE PLAN
Proj. Mgr.: DMW
Designed By: MJB/DMW
Reviewed By: DMW
Operator: GAB/EMD
Dwg. Date: 1-4-2008
Job No.: 41.0017869.10
Figure No.: 1.2


PROBABLE LEGACY RELEASE LOCATIONS
MW-107
MW-110
MW-101
MW-105
OUTFALL
SECTION D-D'
SECTION B-B'
LAFARGE WELLS
1.3

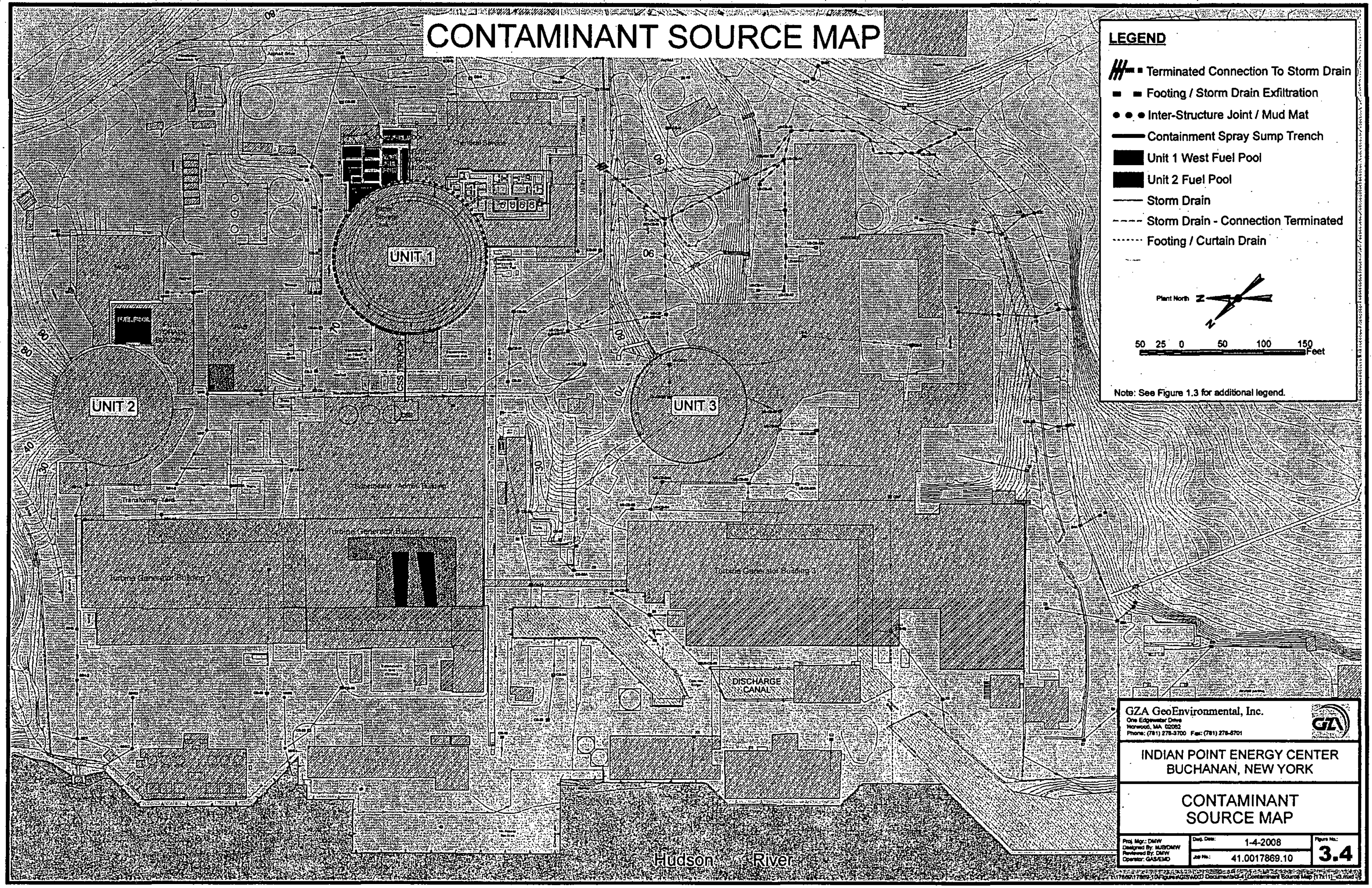

WATERSHED BOUNDARY
WATERSHED BOUNDARY
Plant North
200 100 0 200
Feet
GZA GeoEnvironmental, Inc.
One Edgewater Drive
Norwood, MA 02062
Phone: (781) 278-3700 Fax: (781) 278-5701
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK
WATERSHED
BOUNDARY MAP
Proj. Mgr.: DMW
Designed By: MJB/DMW
Reviewed By: DMW
Operator: GAS/EMO
Dwg. Date: 1-4-2008
Job No.: 41.0017869.10
Figure No.: 3.1
Watershed Boundary Map [17x11]_v2.mxd



J:\17,000-18,999\17869\17869-10.DW\Figures\GIS\MXD Documents\3-2_Regional Topography_v2.mxd



J:\17,000-18,999\17869\17869-10.DW\Figures\GIS\MXD Documents\3-3_Regional Groundwater Flow_v2.mxd


CONTAMINANT SOURCE MAP
LEGEND
Terminated Connection To Storm Drain
Footing / Storm Drain Exfiltration
Inter-Structure Joint / Mud Mat
Containment Spray Sump Trench
Unit 1 West Fuel Pool
Unit 2 Fuel Pool
Storm Drain
Storm Drain - Connection Terminated
Footing / Curtain Drain
Plant North
50 25 0 50 100 150 Feet
Note: See Figure 1.3 for additional legend.
UNIT 1
UNIT 2
UNIT 3
DISCHARGE CANAL
Hudson River
GZA GeoEnvironmental, Inc.
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK
CONTAMINANT SOURCE MAP
1-4-2008
41.0017869.10
3.4

©2007 - GZA GeoEnvironmental, Inc.

GZA-J:\17,000-18,999\17869\17869-10.DW\Figures\CAD\17869-10_Packer Test Schematic_v2.DWG [4.1 Pneumatic Wellhead] December 27, 2007 - 7:35pm Elaine.Donohue

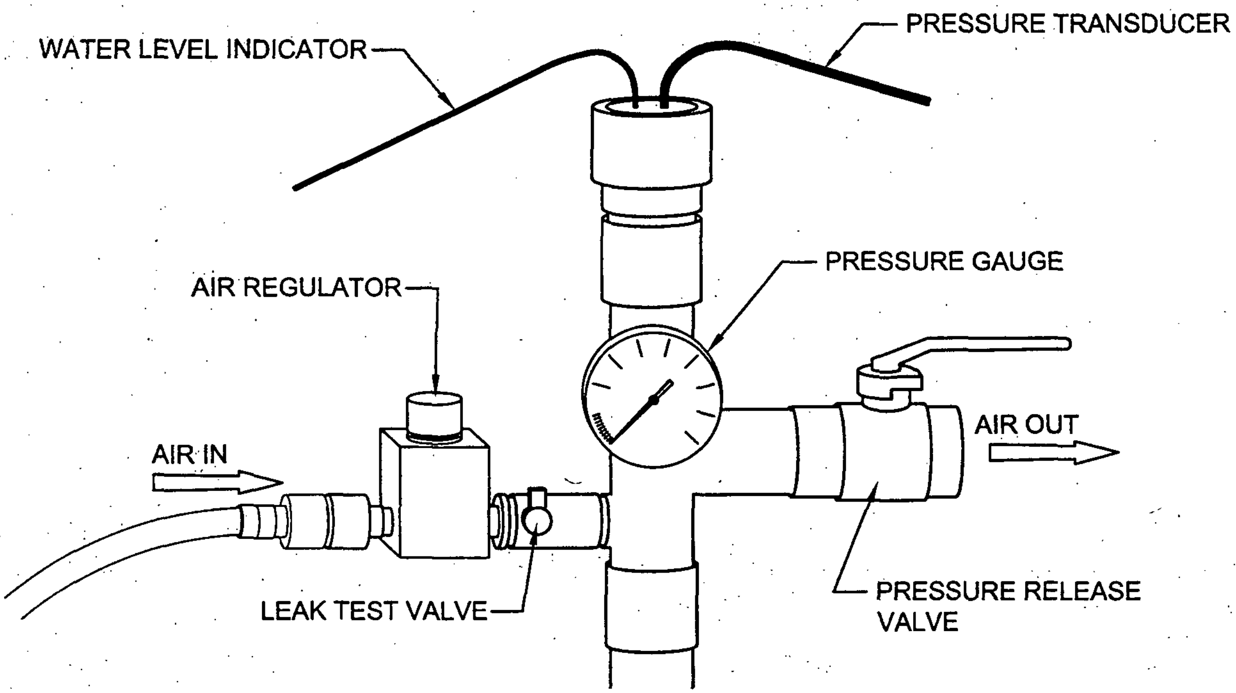


FIGURE NO. 4.1

JOB NO. 17869.10

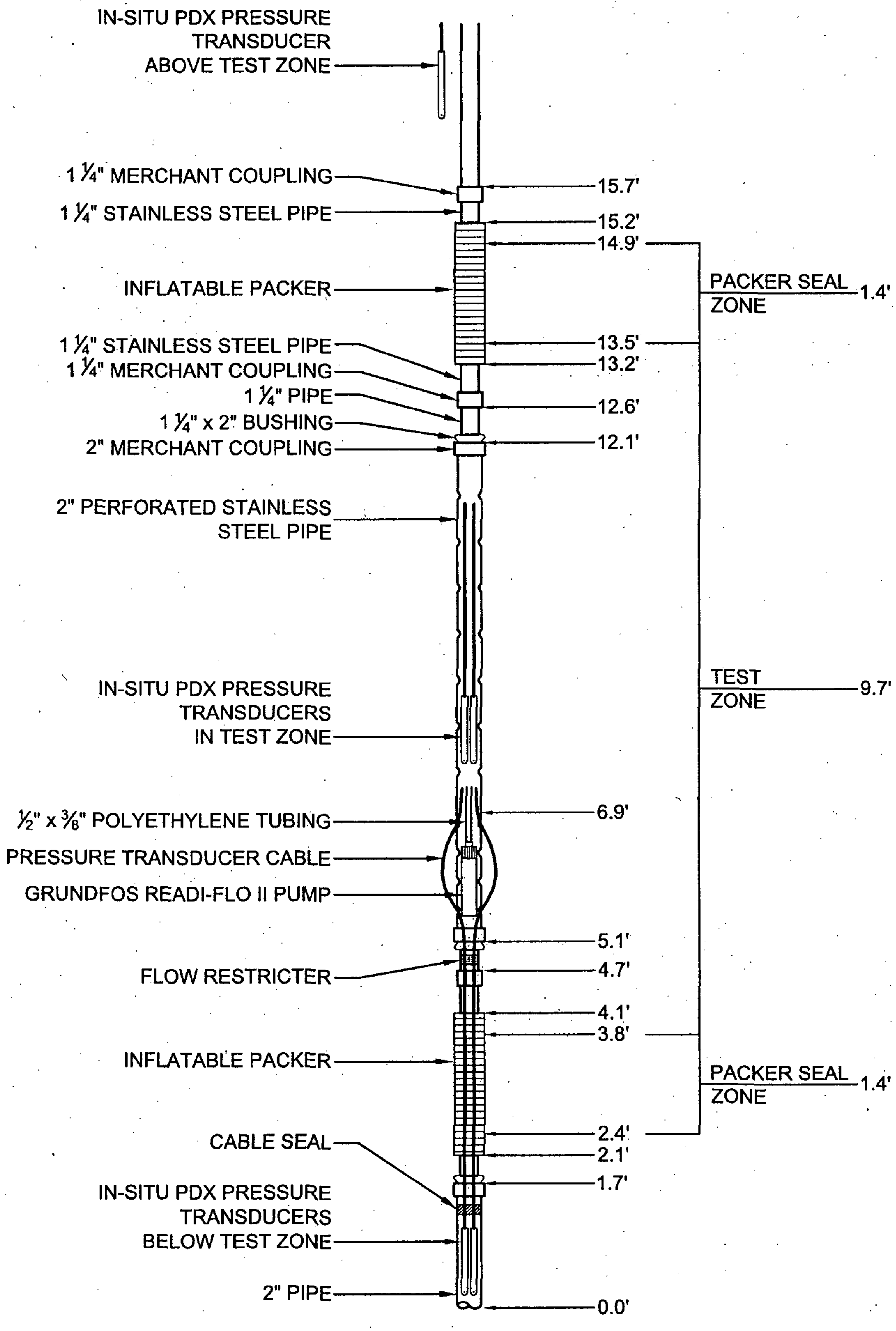
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

PNEUMATIC SLUG TEST
MANIFOLD SCHEMATIC

PROJ MGR: MJB
DESIGNED BY: SC
REVIEWED BY: SC
OPERATOR: GAS/EMD
DATE: 12-27-2007

NOT TO SCALE

GZA GeoEnvironmental, Inc.
ONE EDGEWATER DRIVE
NORWOOD, MA 02062
Ph.: (781) 278-3700
Fax: (781) 278-5701



NOT TO SCALE

GZA GeoEnvironmental, Inc.
ONE EDGEWATER DRIVE
NORWOOD, MA 02062
Ph.: (781) 278-3700
Fax: (781) 278-5701

PROJ MGR: MJB
DESIGNED BY: SC
REVIEWED BY: SC
OPERATOR: GAS/EMD
DATE: 12-27-2007

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

PACKER TEST ASSEMBLAGE SCHEMATIC

JOB NO. 17869.10

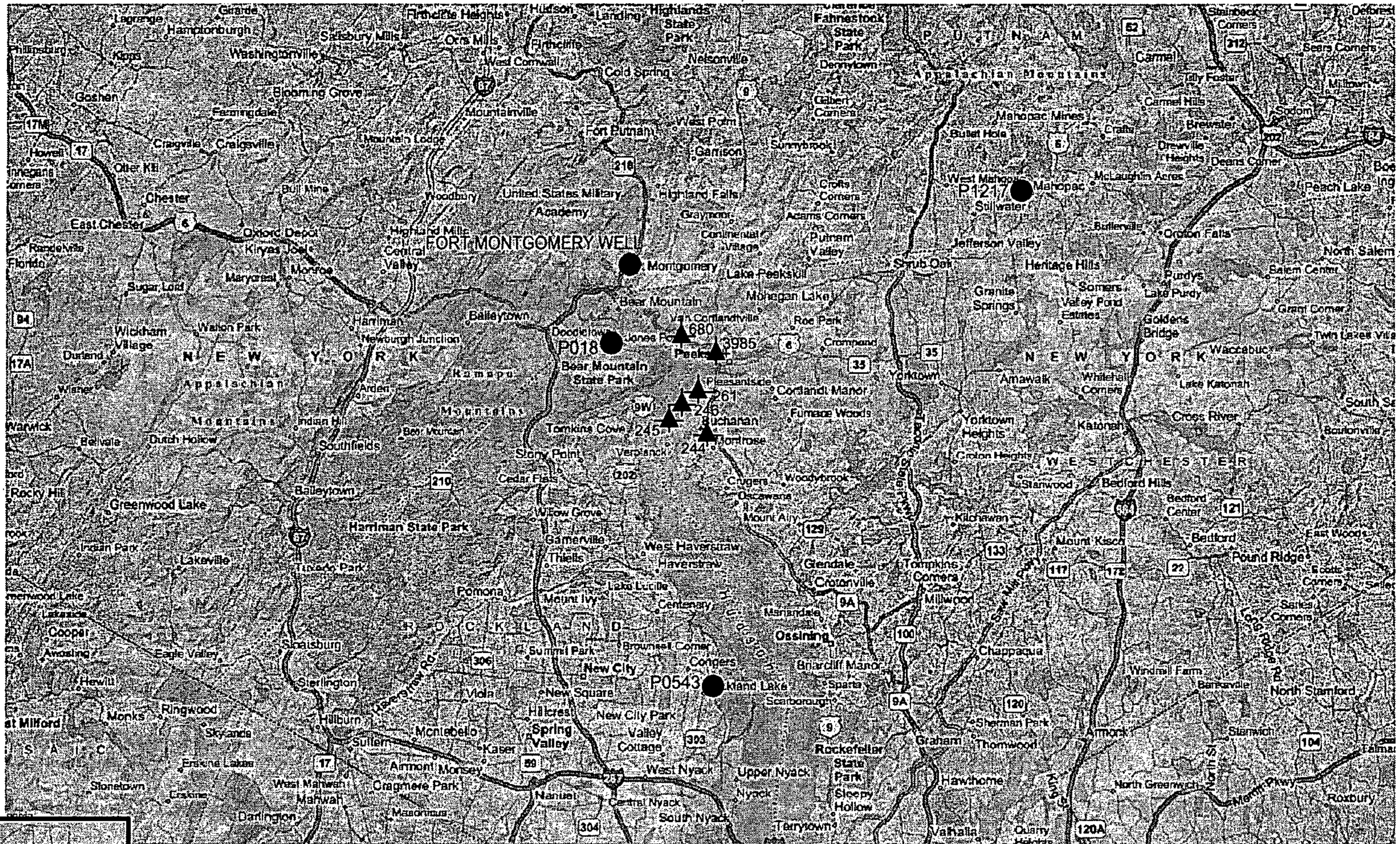
FIGURE NO. 4.2

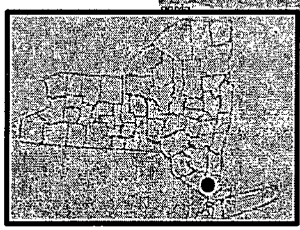
©2007 - GZA GeoEnvironmental, Inc.

GZA-J:\17,000-18,999\17869\17869-10.DW\Figures\CAD\17869-10_Packer Test Schematic_v2.DWG [4-2 Packer Schematic] December 27, 2007 - 7:33pm Elaine.Donohue

©2007 – GZA GeoEnvironmental, Inc.

GZA-J:\17,000-18,999\17869\17869-10.DW\Figures\CAD\4-3_USGS Well Locations_v2.dwg [Layout1] December 27, 2007 - 8:38pm Elaine.Donohue





LEGEND

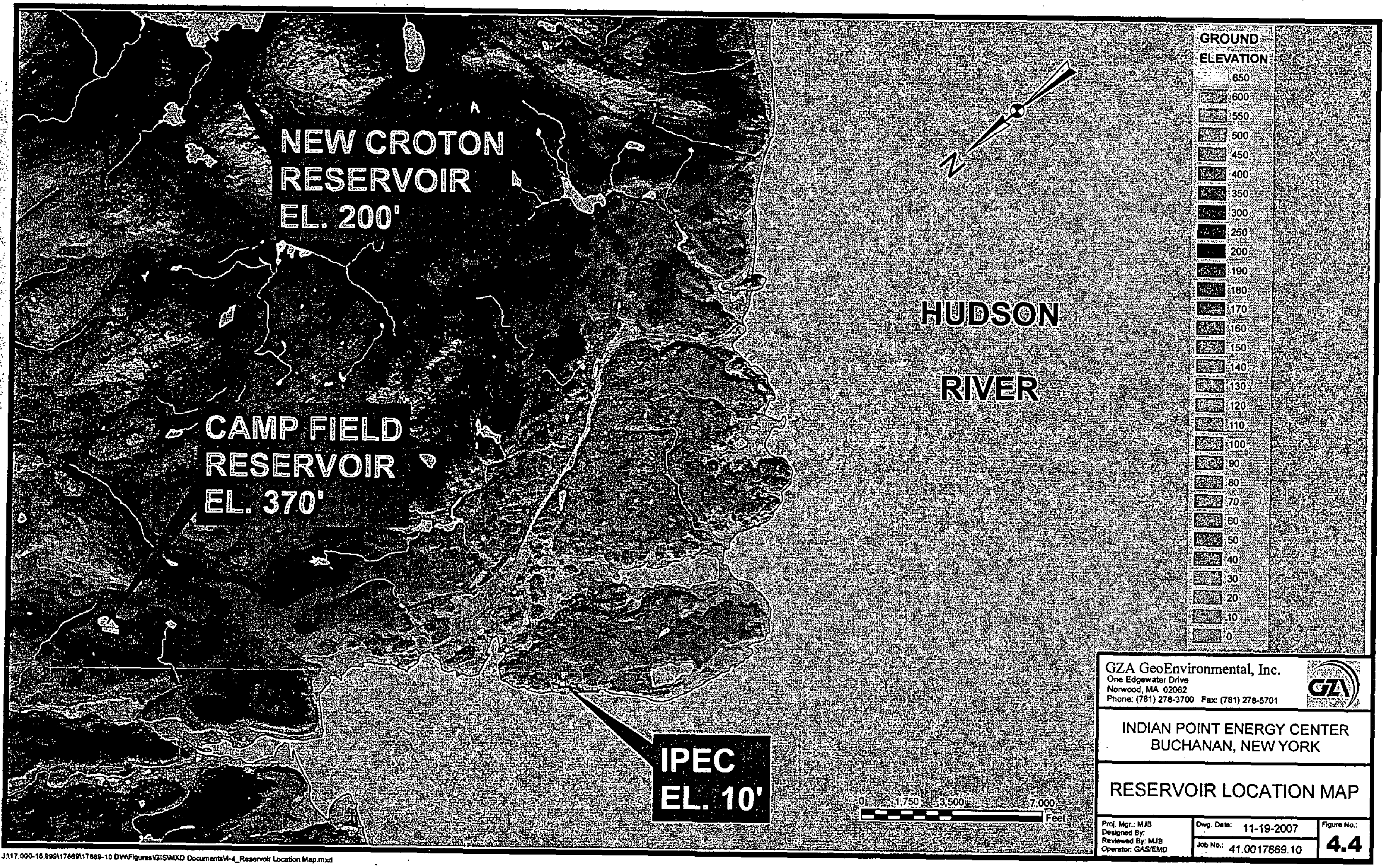
680 ▲ FORMER PUMPING WELL WITH DESIGNATION

P018 ● CURRENT USGS OBSERVATION WELL WITH DESIGNATION

FIGURE NO. 4.3	JOB NO. 17869.10	INDIAN POINT ENERGY CENTER BUCHANAN, NEW YORK USGS WELL LOCATION MAP	PROJ MGR: DMW DESIGNED BY: DMW REVIEWED BY: DMW OPERATOR: GAS/EMD DATE: 12-27-2007

1 INCH = 5 MILES
0 2.5 MI 5 MI 10 MI

GZA GeoEnvironmental, Inc.
ONE EDGEWATER DRIVE
NORWOOD, MA 02062
Ph.: (781) 278-3700
Fax: (781) 278-5701



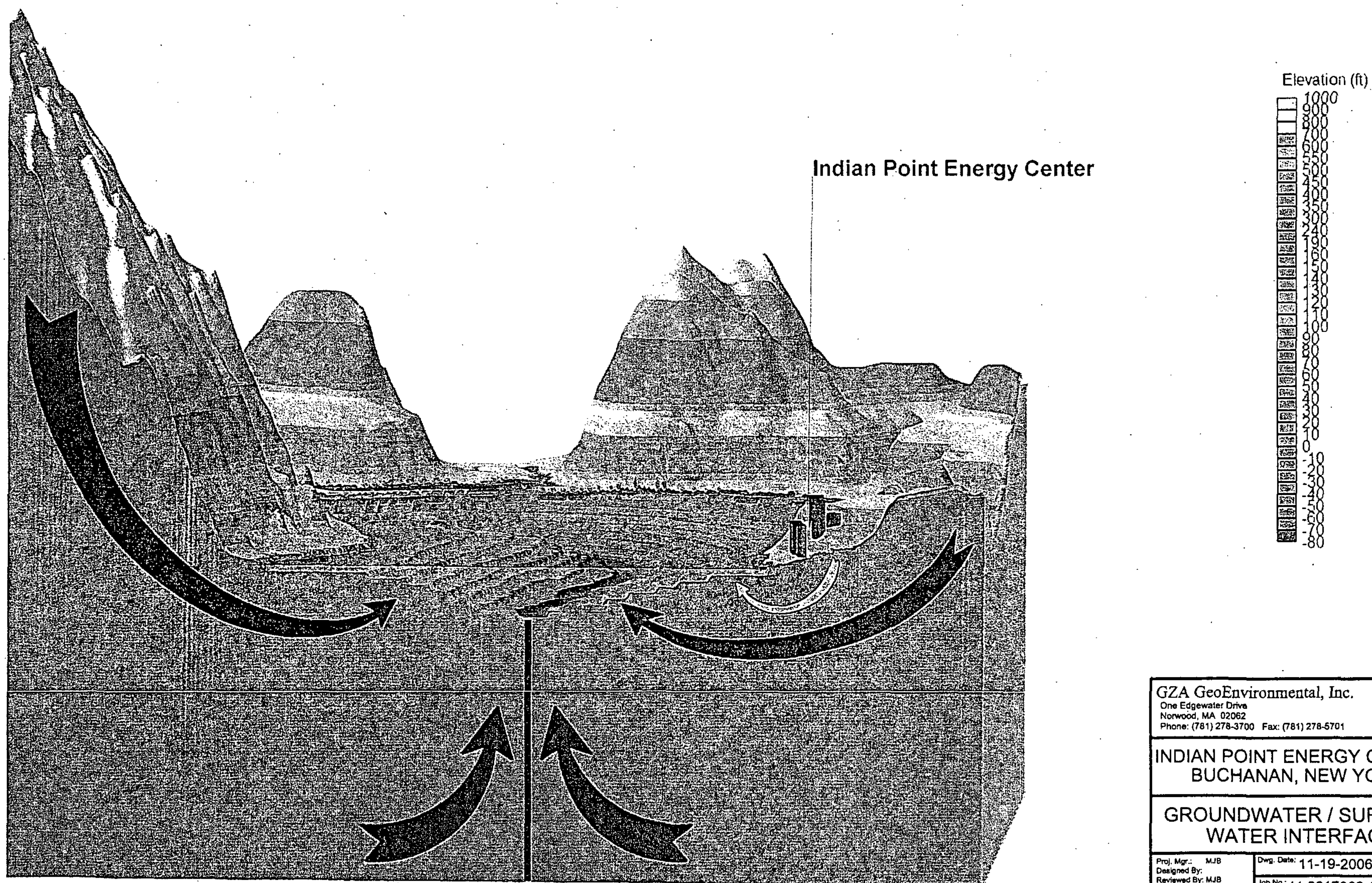
GZA GeoEnvironmental, Inc.
One Edgewater Drive
Norwood, MA 02062
Phone: (781) 278-3700 Fax: (781) 278-5701

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

RESERVOIR LOCATION MAP

Proj. Mgr.: MJB Designed By: Reviewed By: MJB Operator: GAS/EMD	Dwg. Date: 11-19-2007 Job No.: 41.0017869.10	Figure No.: 4.4

J:\17,000-18,999\17869\17869-10.DW\Figures\GIS\MXD Documents\4-4_Reservoir Location Map.mxd



GZA GeoEnvironmental, Inc.
One Edgewater Drive
Norwood, MA 02062
Phone: (781) 278-3700 Fax: (781) 278-5701

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

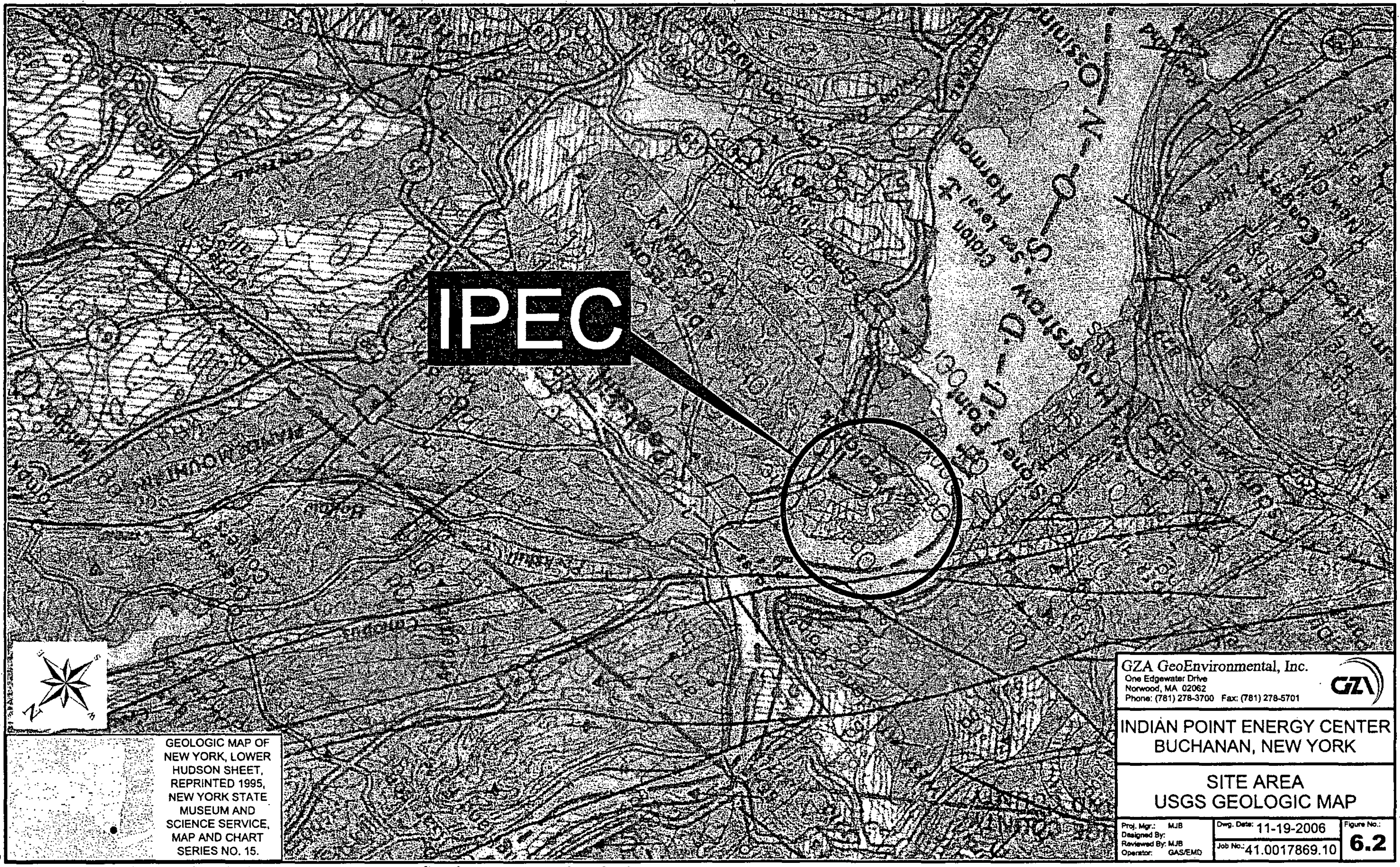
GROUNDWATER / SURFACE WATER INTERFACE

Proj. Mgr.: MJB
Designed By:
Reviewed By: MJB
Operator: GAS/EMD

Dwg. Date: 11-19-2006
Job No.: 41.0017869.10
Figure No.: 6.1

©2006 - GZA GeoEnvironmental, Inc.

GZA-J:\17,000-18,999\17869\17869-10.DW\Figures\CAD\6-1_GW-SW-Interface-v2.dwg [FIG-2.3] January 02, 2008 - 4:45pm Elaine.Donohue



GEOLOGIC MAP OF NEW YORK, LOWER HUDSON SHEET, REPRINTED 1995, NEW YORK STATE MUSEUM AND SCIENCE SERVICE, MAP AND CHART SERIES NO. 15.

GZA GeoEnvironmental, Inc.
One Edgewater Drive
Norwood, MA 02062
Phone: (781) 278-3700 Fax: (781) 278-5701

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

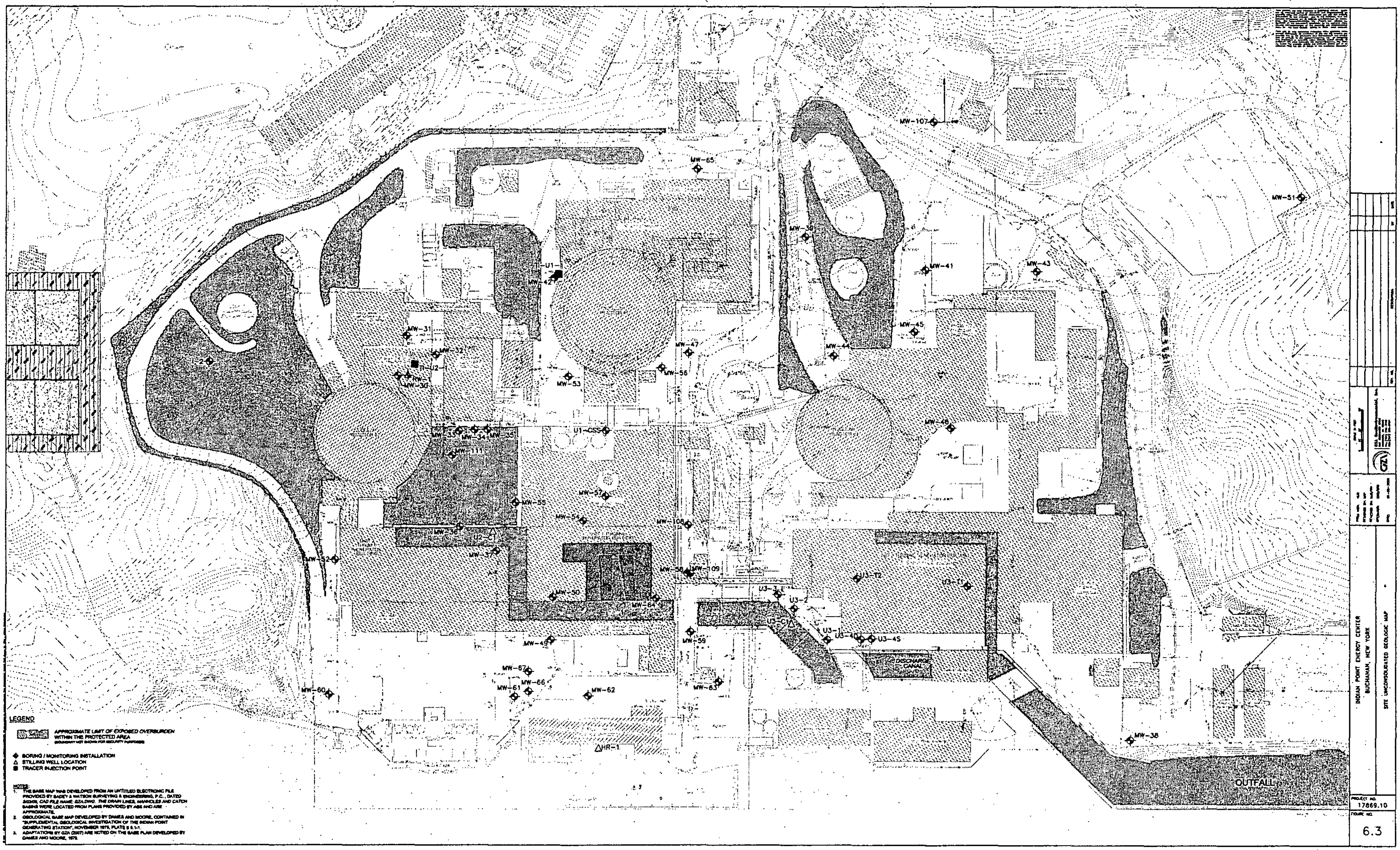
SITE AREA
USGS GEOLOGIC MAP

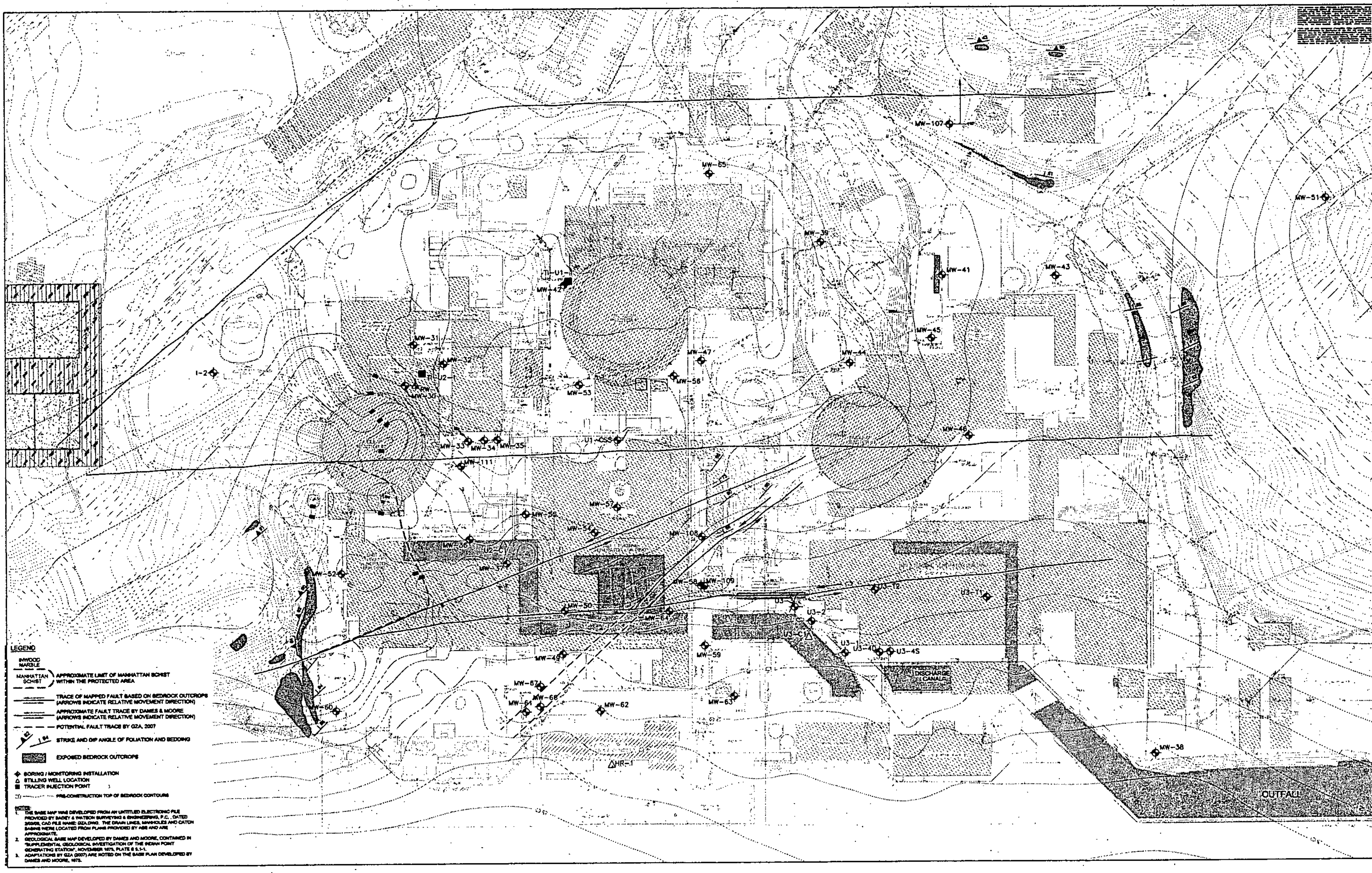
Proj. Mgr.: MJB
Designed By:
Reviewed By: MJB
Operator: GAS/EMD

Dwg. Date: 11-19-2006
Job No.: 41.0017869.10
Figure No.: 6.2

© 2007 - GZA GeoEnvironmental, Inc.

GZA-J:\17,000-18,999\17869\17869-10.DW\Figures\CAD\6-2_Site Area USGS Geologic Map.dwg [Fig 6.2] December 27, 2007 - 8:59pm Elaine.Donohue


MW-107
MW-65
MW-51
MW-41
MW-43
MW-45
MW-44
MW-47
MW-56
MW-53
MW-31
MW-32
MW-30
U1-CSS
MW-33
MW-34
MW-35
MW-111
MW-48
MW-55
MW-57
MW-54
MW-108
MW-36
MW-37
MW-52
MW-58
MW-109
MW-50
MW-64
U3-T2
U3-T1
U3-3
U3-2
U3-1
U3-4D
U3-4S
MW-59
MW-49
MW-67
MW-66
MW-61
MW-62
MW-63
MW-60
HR-1
MW-38
DISCHARGE CANAL
OUTFALL
LEGEND
APPROXIMATE LIMIT OF EXPOSED OVERBURDEN WITHIN THE PROTECTED AREA
BORING / MONITORING INSTALLATION
STILLING WELL LOCATION
TRACER INJECTION POINT
NOTES:
1. THE BASE MAP WAS DEVELOPED FROM AN UNTITLED ELECTRONIC FILE PROVIDED BY BADEY & WATSON SURVEYING & ENGINEERING, P.C., DATED CAD FILE NAME: GZA.DWG. THE DRAIN LINES, MANHOLES AND CATCH BASINS WERE LOCATED FROM PLANS PROVIDED BY ABS AND ARE APPROXIMATE.
2. GEOLOGICAL BASE MAP DEVELOPED BY DAMES AND MOORE, CONTAINED IN "SUPPLEMENTAL GEOLOGICAL INVESTIGATION OF THE INDIAN POINT GENERATING STATION", NOVEMBER 1975, PLATE
3. ADAPTATIONS BY GZA (2007) ARE NOTED ON THE BASE PLAN DEVELOPED BY DAMES AND MOORE, 1975.
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK
SITE UNCONSOLIDATED GEOLOGIC MAP
PROJECT NO.
17869.10
FIGURE NO.
6.3



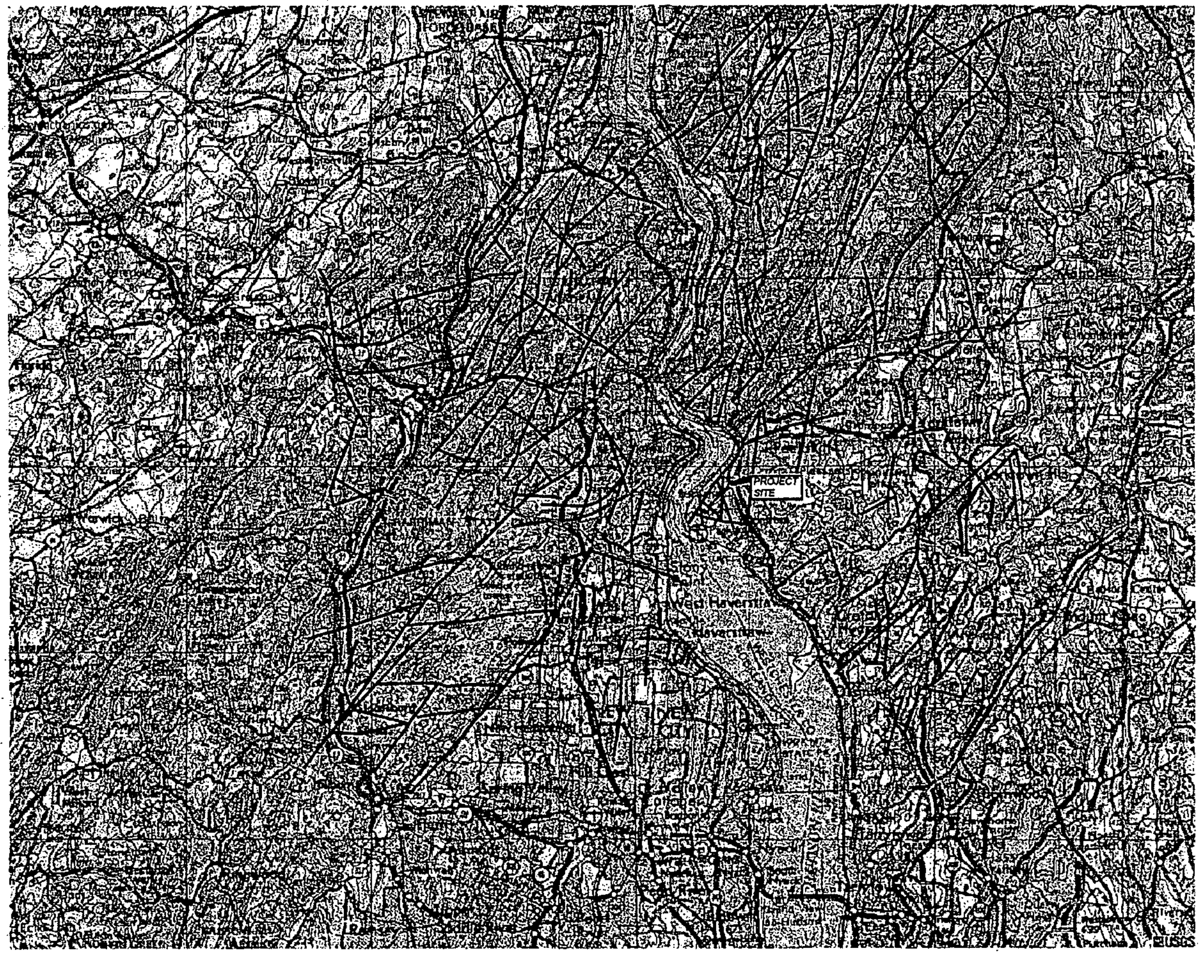
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

SITE GEOLOGICAL MAP

GZA GeoEnvironmental, Inc.

PROJECT NO.
17869.10

FIGURE NO.
6.4



LEGEND

LINEAMENTS

TRIBUTARY STREAMS

NOTE:
BASE MAP ADAPTED FROM U.S.G.S. TOPOGRAPHIC MAPS DOWNLOADED FROM TERRASERVER.MICROSOFT.COM. LINEAMENTS ADAPTED FROM "PHOTO LINEAMENT AND FAULT MAP" REPORTED BY DAMES & MOORE, DATED APRIL ,1965

"THIS DRAWING HAS BEEN PREPARED IN ELECTRONIC FORMAT. CLIENT MAY BE PROVIDED COPIES OF DRAWINGS AND SPECIFICATIONS ON MAGNETIC MEDIA FOR HIS/HER INFORMATION AND USE FOR SPECIFIC APPLICATION TO THIS PROJECT. DUE TO THE POTENTIAL THAT THE MAGNETIC INFORMATION MAY BE MODIFIED UNINTENTIONALLY OR OTHERWISE, GZA GEOENVIRONMENTAL, INC. ("GZA") MAY REMOVE ALL INDICATION OF THE DOCUMENT'S AUTHORSHIP ON THE MAGNETIC MEDIA. PRINTED REPRESENTATIONS OF THE DRAWINGS AND SPECIFICATIONS SHALL BE THE ONLY RECORD COPIES OF GZA'S WORK PRODUCT.

"ANY USE OF THIS DOCUMENT PRODUCED FROM MAGNETIC MEDIA WITHOUT VERIFICATION OR ADAPTATION BY GZA FOR THE SPECIFIC USE INTENDED WILL BE THE RECIPIENT'S SOLE RESPONSIBILITY AND WITHOUT RISK OR LIABILITY TO GZA GEOENVIRONMENTAL, INC. BY ACCEPTING THIS DOCUMENT IN MAGNETIC MEDIA FORMAT, CLIENT AGREES TO INDEMNIFY AND HOLD HARMLESS GZA GEOENVIRONMENTAL, INC. FROM ALL CLAIMS FOR DAMAGES, LOSSES AND EXPENSES ARISING OUT OF OR RESULTING FROM THE USE OR MISUSE OF THIS ELECTRONIC DOCUMENT."

ONE INCH = 12,000 FEET
0 6,000' 12,000' 24,000'

PROJ MGR: DMW
DESIGNED BY: DEW
REVIEWED BY: DMW
OPERATOR: DEW/GAS
DATE : 11-19-2007

GZA GeoEnvironmental, Inc.
ONE EDGEWATER DRIVE
NORWOOD, MA 02062
Ph.: (781) 278-3700
Fax: (781) 278-5701

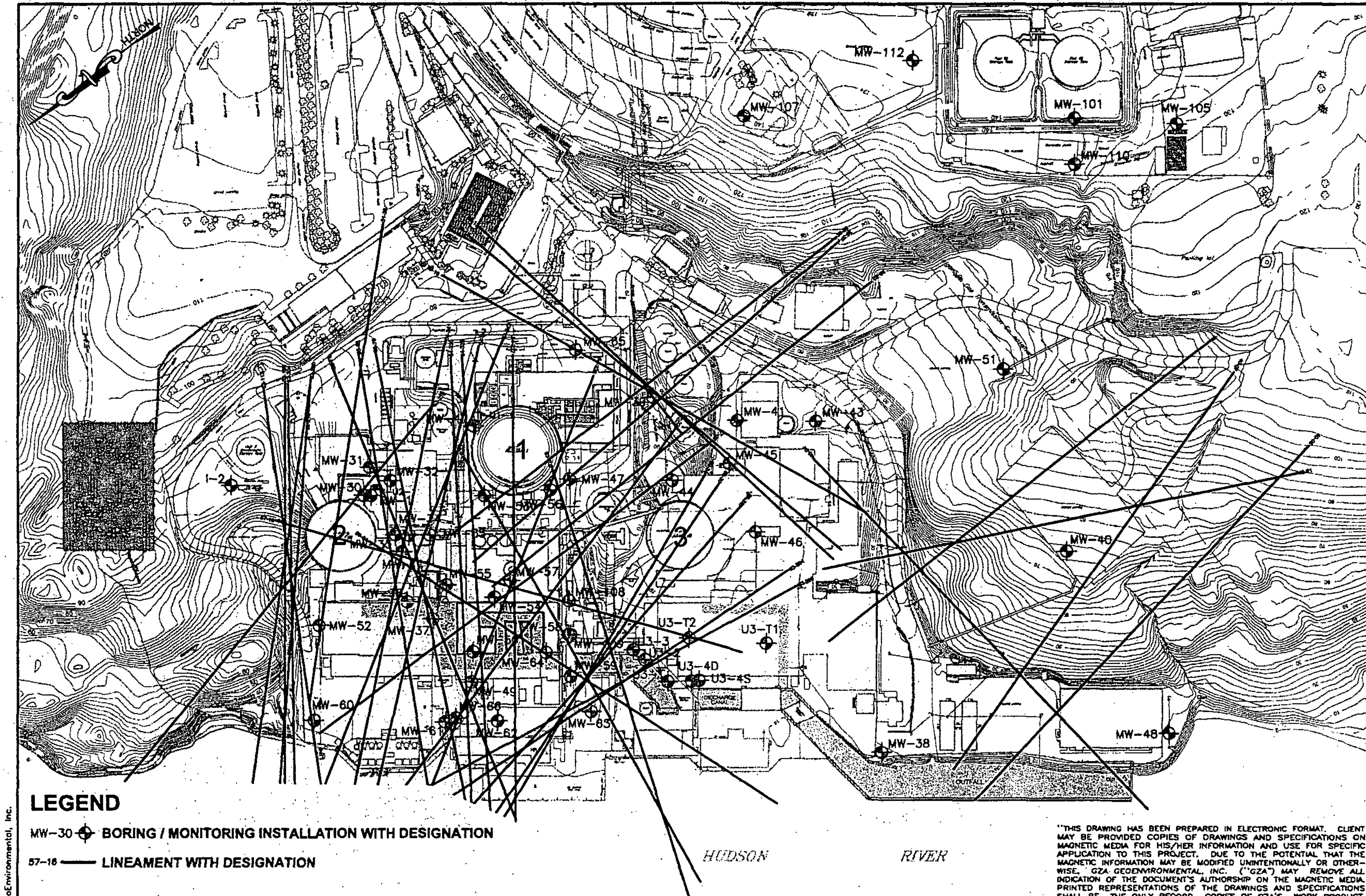
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

REGIONAL LINEAMENT MAP

PROJECT NO. 17869.10

FIGURE NO. 6.5

© 2007 - GZA GeoEnvironmental, Inc.



LEGEND

MW-30 ⊕ **BORING / MONITORING INSTALLATION WITH DESIGNATION**

57-16 —— **LINEAMENT WITH DESIGNATION**

NOTE: All lineament data obtained from Supplemental Geological Investigation of the Indian Point Generating Station for Consolidated Edison Company of New York, Inc. dated December, 1975.

"THIS DRAWING HAS BEEN PREPARED IN ELECTRONIC FORMAT. CLIENT MAY BE PROVIDED COPIES OF DRAWINGS AND SPECIFICATIONS ON MAGNETIC MEDIA FOR HIS/HER INFORMATION AND USE FOR SPECIFIC APPLICATION TO THIS PROJECT. DUE TO THE POTENTIAL THAT THE MAGNETIC INFORMATION MAY BE MODIFIED UNINTENTIONALLY OR OTHERWISE, GZA GEOENVIRONMENTAL, INC. ("GZA") MAY REMOVE ALL INDICATION OF THE DOCUMENT'S AUTHORSHIP ON THE MAGNETIC MEDIA. PRINTED REPRESENTATIONS OF THE DRAWINGS AND SPECIFICATIONS SHALL BE THE ONLY RECORD COPIES OF GZA'S WORK PRODUCT.

"ANY USE OF THIS DOCUMENT PRODUCED FROM MAGNETIC MEDIA WITHOUT VERIFICATION OR ADAPTATION BY GZA FOR THE SPECIFIC USE INTENDED WILL BE THE RECIPIENT'S SOLE RESPONSIBILITY AND WITHOUT RISK OR LIABILITY TO GZA GEOENVIRONMENTAL, INC. BY ACCEPTING THIS DOCUMENT IN MAGNETIC MEDIA FORMAT, CLIENT AGREES TO INDEMNIFY AND HOLD HARMLESS GZA GEOENVIRONMENTAL, INC. FROM ALL CLAIMS FOR DAMAGES, LOSSES AND EXPENSES ARISING OUT OF OR RESULTING FROM THE USE OR MISUSE OF THIS ELECTRONIC DOCUMENT."

SCALE IN FEET
0 100' 200' 400'

PROJ MGR: DMW
DESIGNED BY: MDK
REVIEWED BY: DMW
OPERATOR: MDK
DATE: 01-04-2008

GZA GeoEnvironmental, Inc.
ONE EDGEWATER DRIVE
NORWOOD, MA 02062
Ph.: (781) 278-3700
Fax: (781) 278-3701

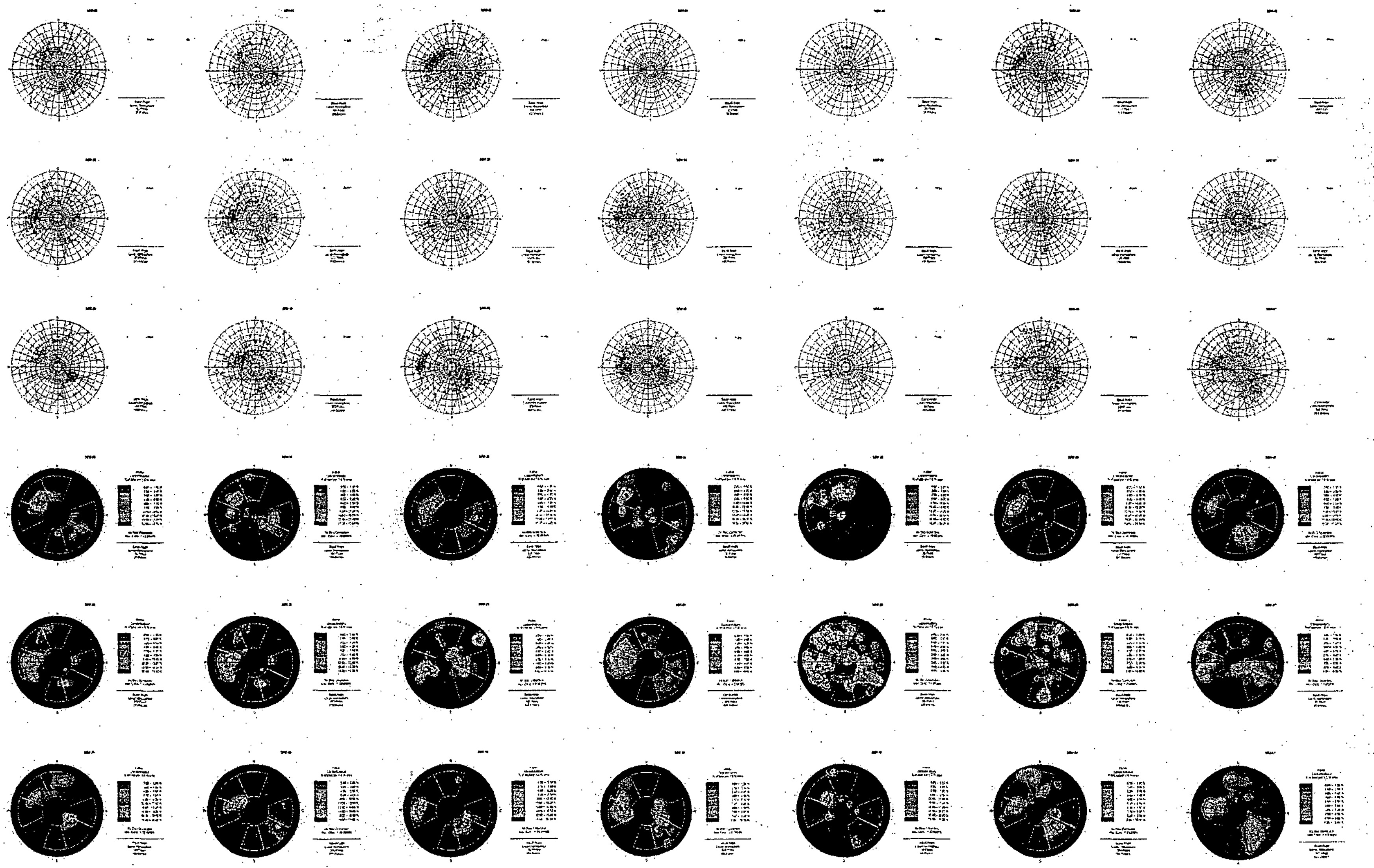
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

SITE LINEAMENT MAP

PROJECT NO. 17869.10

FIGURE NO. 6.6

© 2008 - GZA GeoEnvironmental, Inc.



Notes:

1. This plot is based on geophysics data provided by Geophysical Applications, Inc. For details, refer to Appendices C and Q.
2. Site sets represent large scale interpretations of significant joint/fracture sets based on geophysical analysis. They correspond to dip direction angle ranges as follows with a dip angle range between 34° and 81°.

Set No.	1	2	3	4	5	6
Dip direction	SE	NW	E	W	S	N
Azimuth range	116-165	291-335	70-115	245-290	166-200	336-21

3. Pole plots use the equal-angle net (Wulff net) with the site set ranges represented as green windows. The average plane for the poles within each set is represented in red lines.
4. Contour plots represent statistical pole concentrations (in percentages of the total surface area of the lower hemisphere) calculated using the Fisher distribution method.

REV. NO.	DESCRIPTION	BY	DATE

NOT TO SCALE

GZA GeoEnvironmental, Inc.
ONE EDGEWATER DRIVE
NORWOOD, MA 02062
PH: (781) 278-3700
FAX: (781) 278-5701

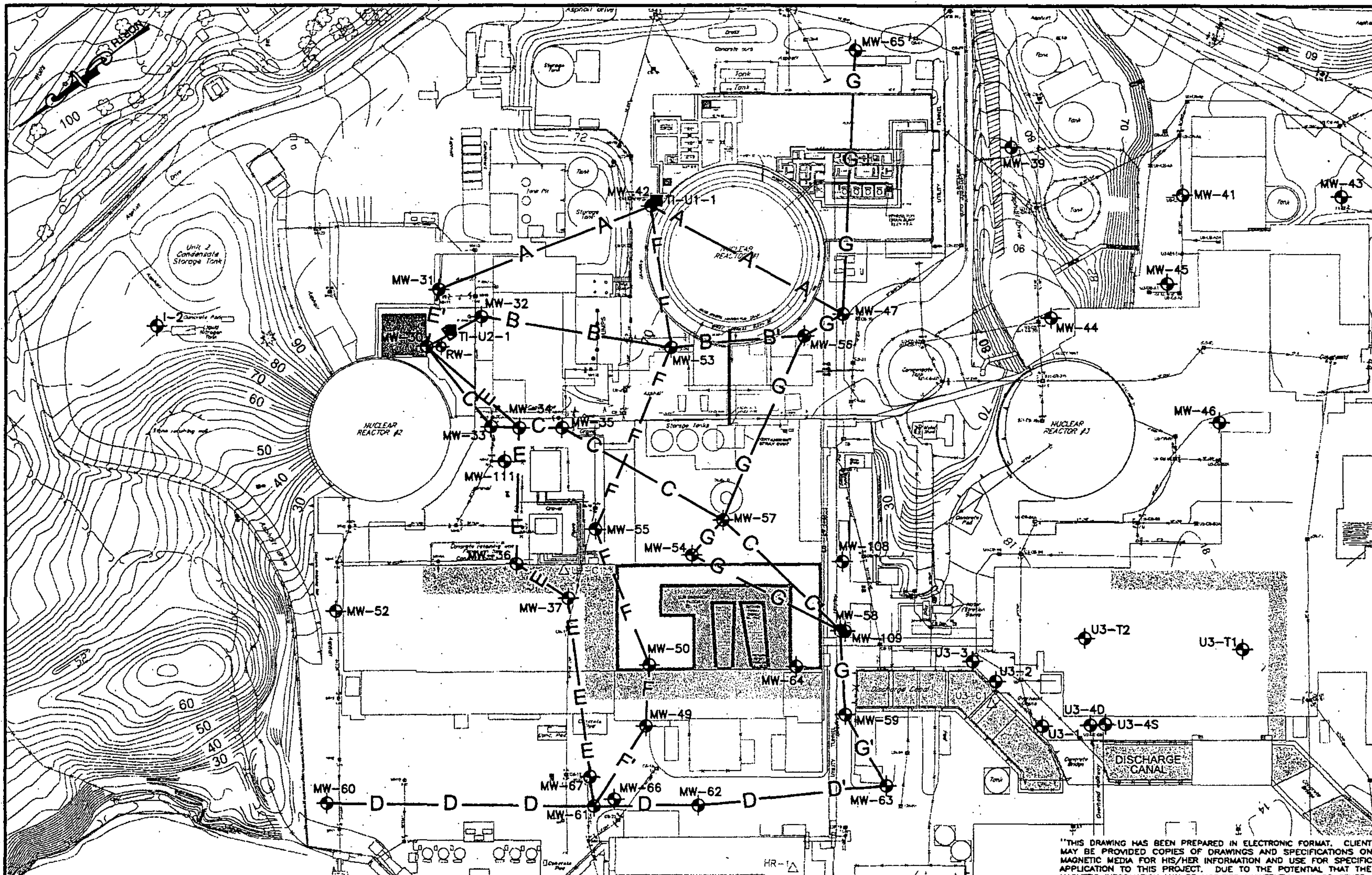
PROJ MGR: DMW
DESIGNED BY: DMW
REVIEWED BY: DMW
OPERATOR: GAS/EMD
DATE: 01-04-2008

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

POLAR PROJECTIONS

PROJECT NO. 17869.10

FIGURE NO. 6.7



LEGEND

MW-30 BORING / MONITORING INSTALLATION AND DESIGNATION

A—— A —— A' —— PROFILE LINE

"THIS DRAWING HAS BEEN PREPARED IN ELECTRONIC FORMAT. CLIENT MAY BE PROVIDED COPIES OF DRAWINGS AND SPECIFICATIONS ON MAGNETIC MEDIA FOR HIS/HER INFORMATION AND USE FOR SPECIFIC APPLICATION TO THIS PROJECT. DUE TO THE POTENTIAL THAT THE MAGNETIC INFORMATION MAY BE MODIFIED UNINTENTIONALLY OR OTHERWISE, GZA GEOENVIRONMENTAL, INC. ("GZA") MAY REMOVE ALL INDICATION OF THE DOCUMENT'S AUTHORSHIP ON THE MAGNETIC MEDIA. PRINTED REPRESENTATIONS OF THE DRAWINGS AND SPECIFICATIONS SHALL BE THE ONLY RECORD COPIES OF GZA'S WORK PRODUCT.

"ANY USE OF THIS DOCUMENT PRODUCED FROM MAGNETIC MEDIA WITHOUT VERIFICATION OR ADAPTATION BY GZA FOR THE SPECIFIC USE INTENDED WILL BE THE RECIPIENT'S SOLE RESPONSIBILITY AND WITHOUT RISK OR LIABILITY TO GZA GEOENVIRONMENTAL, INC. BY ACCEPTING THIS DOCUMENT IN MAGNETIC MEDIA FORMAT, CLIENT AGREES TO INDEMNIFY AND HOLD HARMLESS GZA GEOENVIRONMENTAL, INC. FROM ALL CLAIMS FOR DAMAGES, LOSSES AND EXPENSES ARISING OUT OF OR RESULTING FROM THE USE OR MISUSE OF THIS ELECTRONIC DOCUMENT."

SCALE IN FEET
0 50' 100' 200'

PROJ MGR: DMW
DESIGNED BY: MDK
REVIEWED BY: DMW
OPERATOR: MDK/EMD
DATE : 01-04-2008

GZA GeoEnvironmental, Inc.
ONE EDGEWATER DRIVE
NORWOOD, MA 02062
Ph.: (781) 278-3700
Fax: (781) 278-5701

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

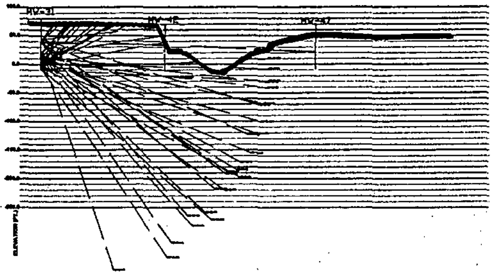
PROFILE LOCATIONS

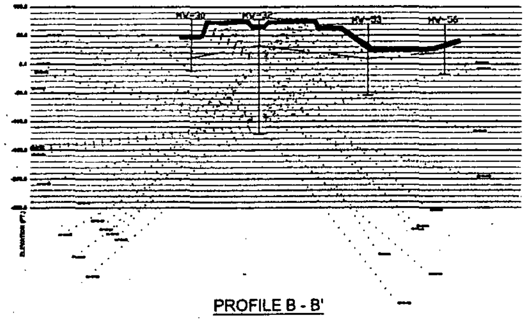
PROJECT NO. 17869.10

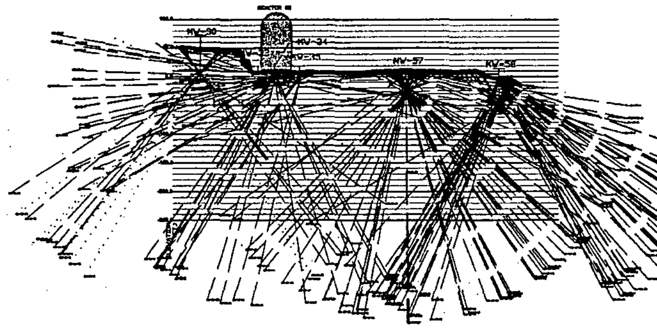
FIGURE NO. 6.8

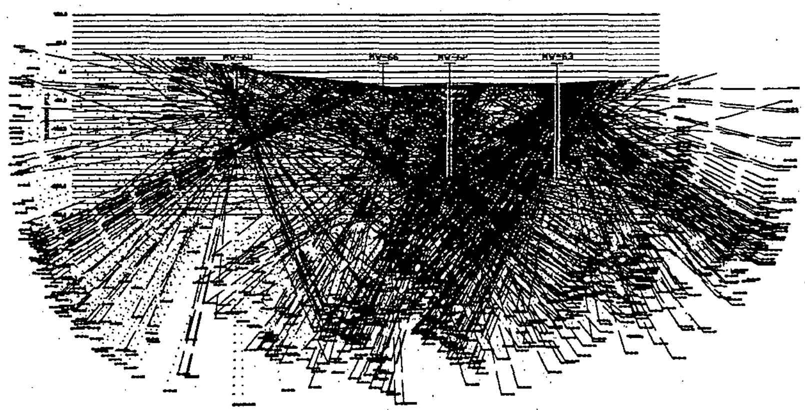
© 2008 - GZA GeoEnvironmental, Inc.

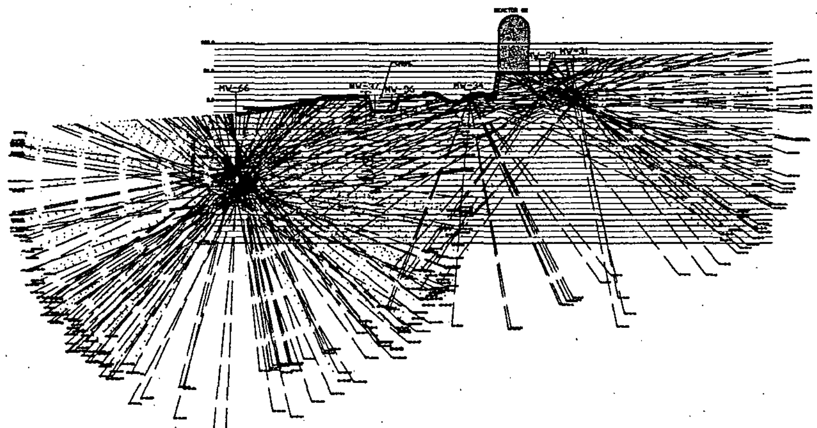
GZA-J:\17,000-18,999\17869\17869-10.DW\Figures\CAD\6-6_Site Lineament Map_v2.dwg [Profiles] January 06, 2008 - 3:56am Elaine.Donahue

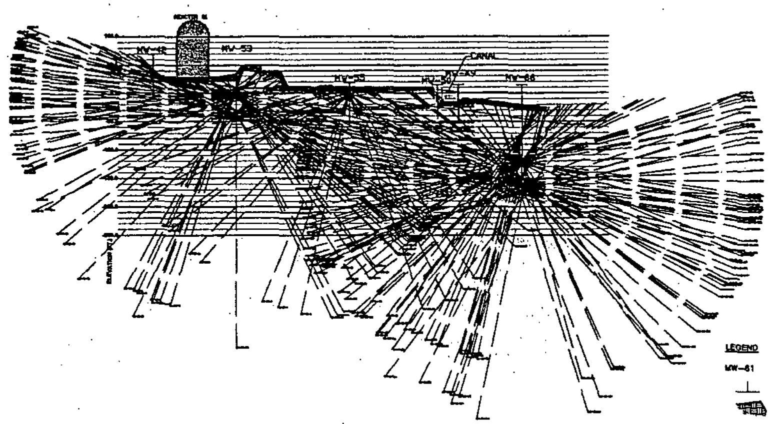

PROFILE A - A'

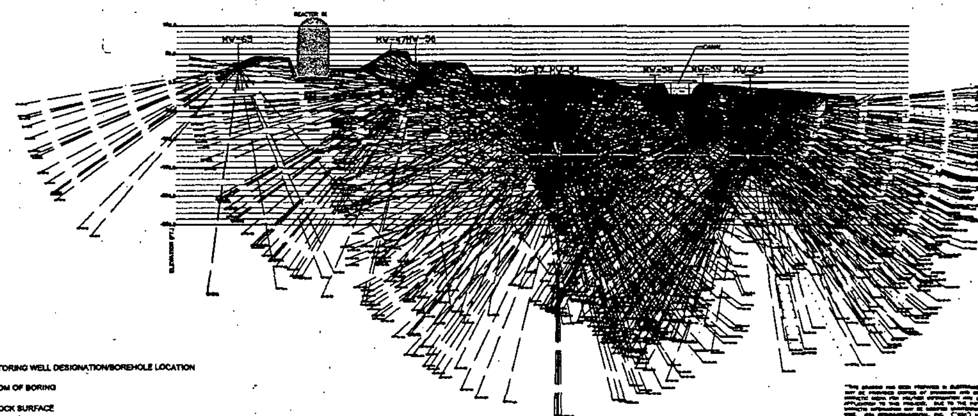

PROFILE B - B'


PROFILE C - C'


PROFILE D - D'


PROFILE E - E'


PROFILE F - F'


PROFILE G - G'

LEGEND

MW-61 MONITORING WELL DESIGNATION/BOREHOLE LOCATION

BOTTOM OF BORING

BEDROCK SURFACE

REPRESENTS ATV BOREHOLE-MEASURED PLANES EXTENDED ON EITHER SIDE OF THE BOREHOLE. THE JOINT/FRACTURE LINES REPRESENT THE TRACE OF THE PLANE PROJECTED ONTO A VERTICAL PROFILE. HYDRAULIC CONDUCTIVITY OF JOINT/FRACTURE IS GREATER THAN 5 x 10-6 cm/sec.

REPRESENTS ATV BOREHOLE-MEASURED PLANES EXTENDED ON EITHER SIDE OF THE BOREHOLE. THE JOINT/FRACTURE LINES REPRESENT THE TRACE OF THE PLANE PROJECTED ONTO A VERTICAL PROFILE. HYDRAULIC CONDUCTIVITY OF JOINT/FRACTURE IS LESS THAN 5 x 10-6 cm/sec.

NOTE: REFER TO FIGURE NO. 6.8 FOR PROFILE LOCATIONS.

REV. NO.	DESCRIPTION	BY	DATE

SCALE IN FEET: 0 50' 100' 200'

GZA GeoEnvironmental, Inc.
ONE EDGEWATER DRIVE
NORWOOD, MA 02062
PH: (781) 278-3700
FAX: (781) 278-5701

PROJ MGR: DMW
DESIGNED BY: DMW
REVIEWED BY: DMW
OPERATOR: GAS/EMD
DATE: 01-04-2008

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

FRACTURE PROFILE PROJECTIONS

PROJECT NO. 17869.10

FIGURE NO. 6.9

©2007 – GZA GeoEnvironmental, Inc.

GZA-J:\17,000-18,999\17869\17869-10.DW\Figures\November-2007-Report\17869-10_lowT_fractures.dwg [FIG_6-10] January 04, 2008 - 4:23am Elaine.Donohue

FIGURE NO. 6.10

JOB NO. 17869.10

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

TRANSMISSIVE FRACTURE LOCATIONS
LOW TRANSMISSIVITY

PROJ MGR: MJB
DESIGNED BY: JDR
REVIEWED BY: MJB
OPERATOR: JDR
DATE: 08-06-2007

GZA GeoEnvironmental, Inc.
ONE EDGEWATER DRIVE
NORWOOD, MA 02062
Ph.: (781) 278-3700
Fax: (781) 278-5701

©2007 – GZA GeoEnvironmental, Inc.

GZA–J:\17,000–18,999\17869\17869–10.DW\Figures\November–2007–Report\17869–10_midT_fractures.dwg [FIG_6–11] January 04, 2008 – 4:21am Elaine.Donohue

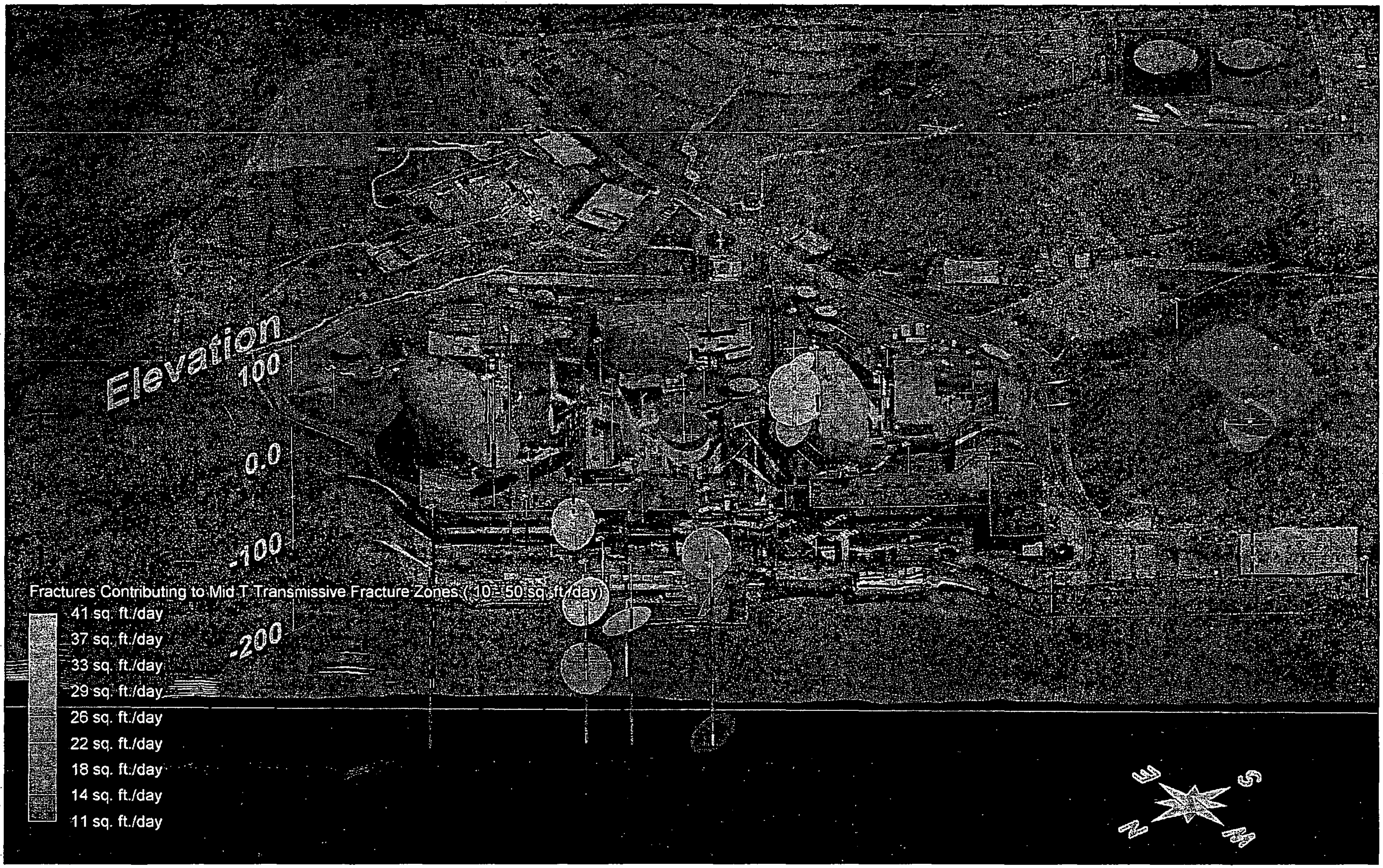


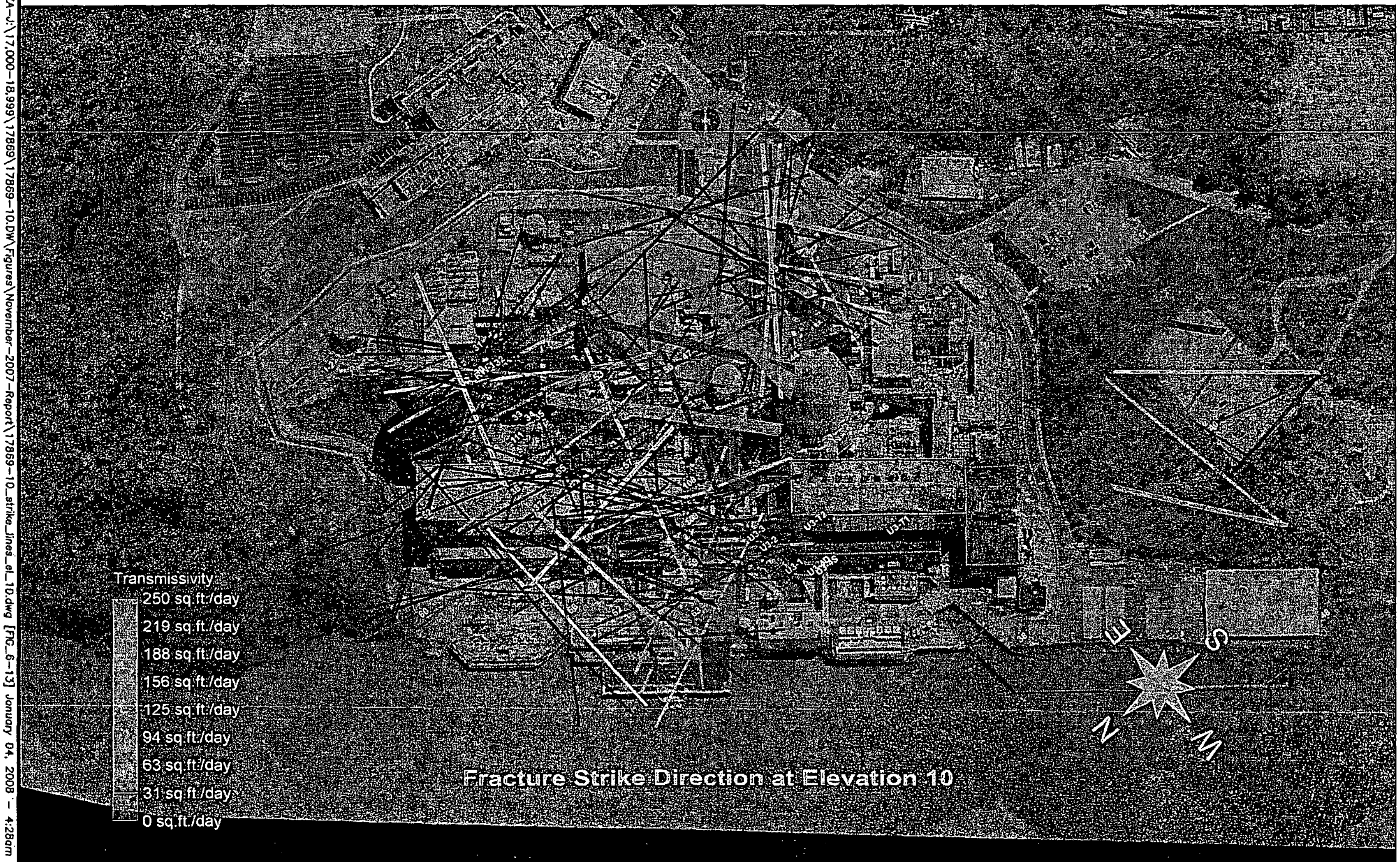
FIGURE NO.	JOB NO.			
6.11	17869.10	INDIAN POINT ENERGY CENTER BUCHANAN, NEW YORK TRANSMISSIVE FRACTURE LOCATIONS MODERATE TRANSMISSIVITY	PROJ MGR: MJB DESIGNED BY: JDR REVIEWED BY: MJB OPERATOR: JDR DATE: 08–06–2007	GZA GeoEnvironmental, Inc. ONE EDGEWATER DRIVE NORWOOD, MA 02062 Ph.: (781) 278–3700 Fax: (781) 278–5701

©2007 – GZA GeoEnvironmental, Inc.

GZA-J:\17,000-18,999\17869\17869-10.DW\Figures\November-2007-Report\17869-10_hiT_fractures.dwg [FIG_6-12] January 04, 2008 - 4:24am Elaine.Donohue

FIGURE NO. 6.12	JOB NO. 17869.10	INDIAN POINT ENERGY CENTER BUCHANAN, NEW YORK TRANSMISSIVE FRACTURE LOCATIONS HIGH TRANSMISSIVITY	PROJ MGR: MJB DESIGNED BY: JDR REVIEWED BY: MJB OPERATOR: JDR DATE: 08-06-2007	GZA GeoEnvironmental, Inc. ONE EDGEWATER DRIVE NORWOOD, MA 02062 Ph.: (781) 278-3700 Fax: (781) 278-5701

©2007 – GZA GeoEnvironmental, Inc.

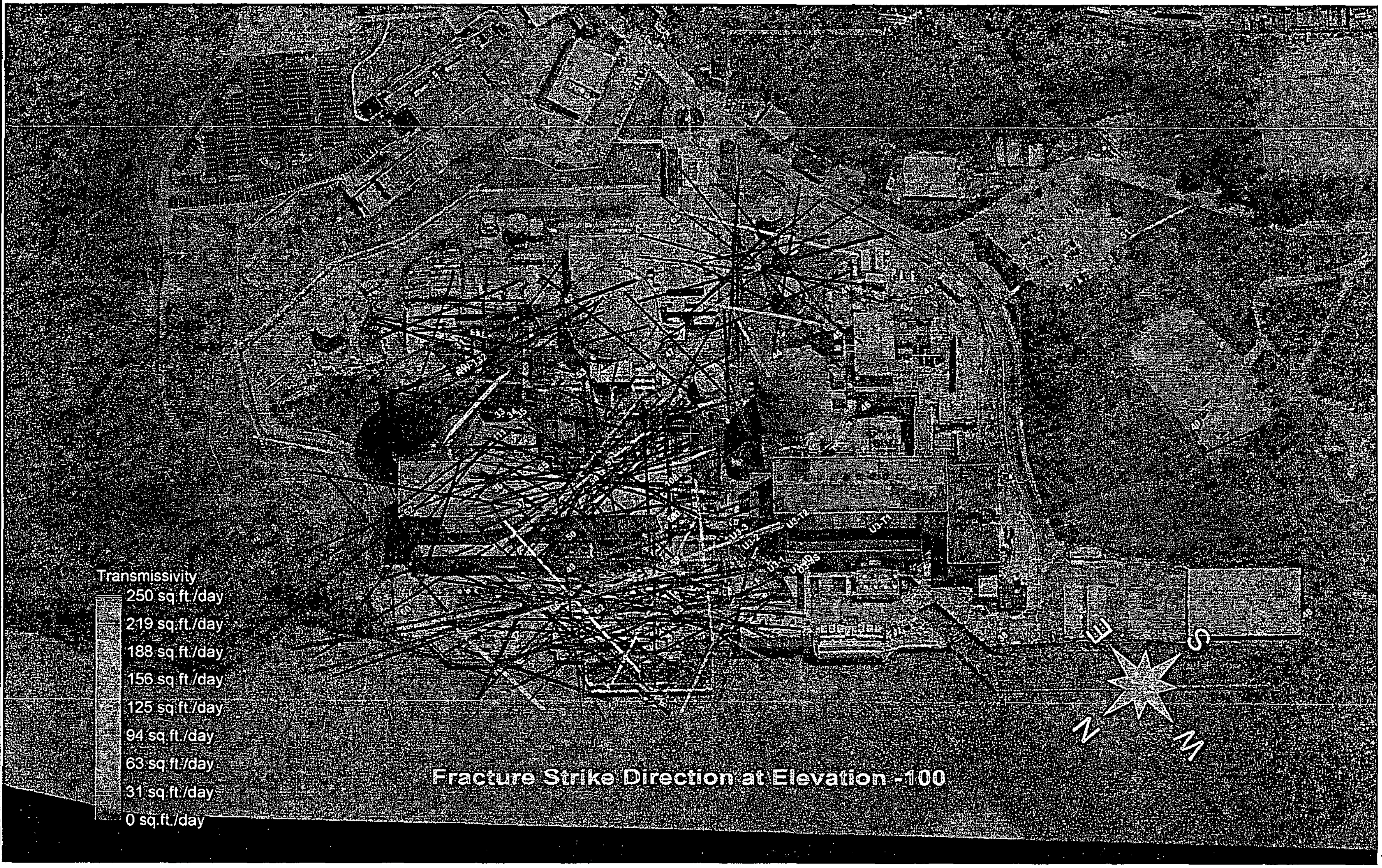


GZA–J:\17,000–18,999\17869\17869–10.DW\Figures\November–2007–Report\17869–10_strike_lines_el_10.dwg [FIG_6–13] January 04, 2008 – 4:28am Elaine.Donohue

JOB NO. 17869.10	INDIAN POINT ENERGY CENTER BUCHANAN, NEW YORK	PROJ MGR: MJB DESIGNED BY: JDR REVIEWED BY: MJB OPERATOR: JDR	GZA GeoEnvironmental, Inc. ONE EDGEWATER DRIVE NORWOOD, MA 02062 Ph.: (781) 278–3700 Fax: (781) 278–5701
FIGURE NO. 6.13	FRACTURE STRIKE ORIENTATION AT ELEVATION 10	DATE: 08–06–2007	

©2007 – GZA GeoEnvironmental, Inc.

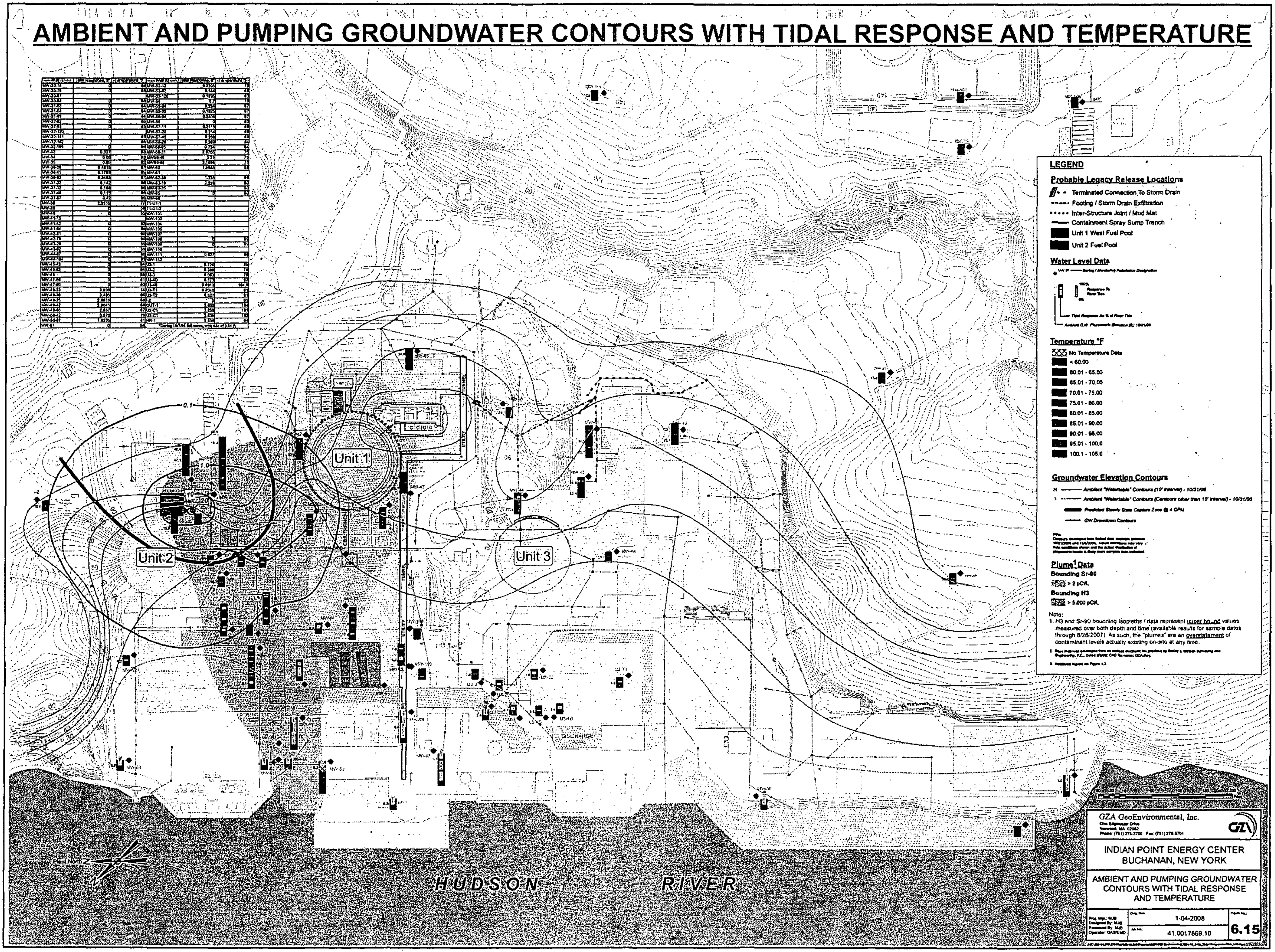
GZA–J:\17,000–18,999\17869\17869–10.DW\Figures\November–2007–Report\17869–10_strike_lines_el_–100.dwg [FIG_6–14] January 04, 2008 – 4:26am Elaine.Donohue



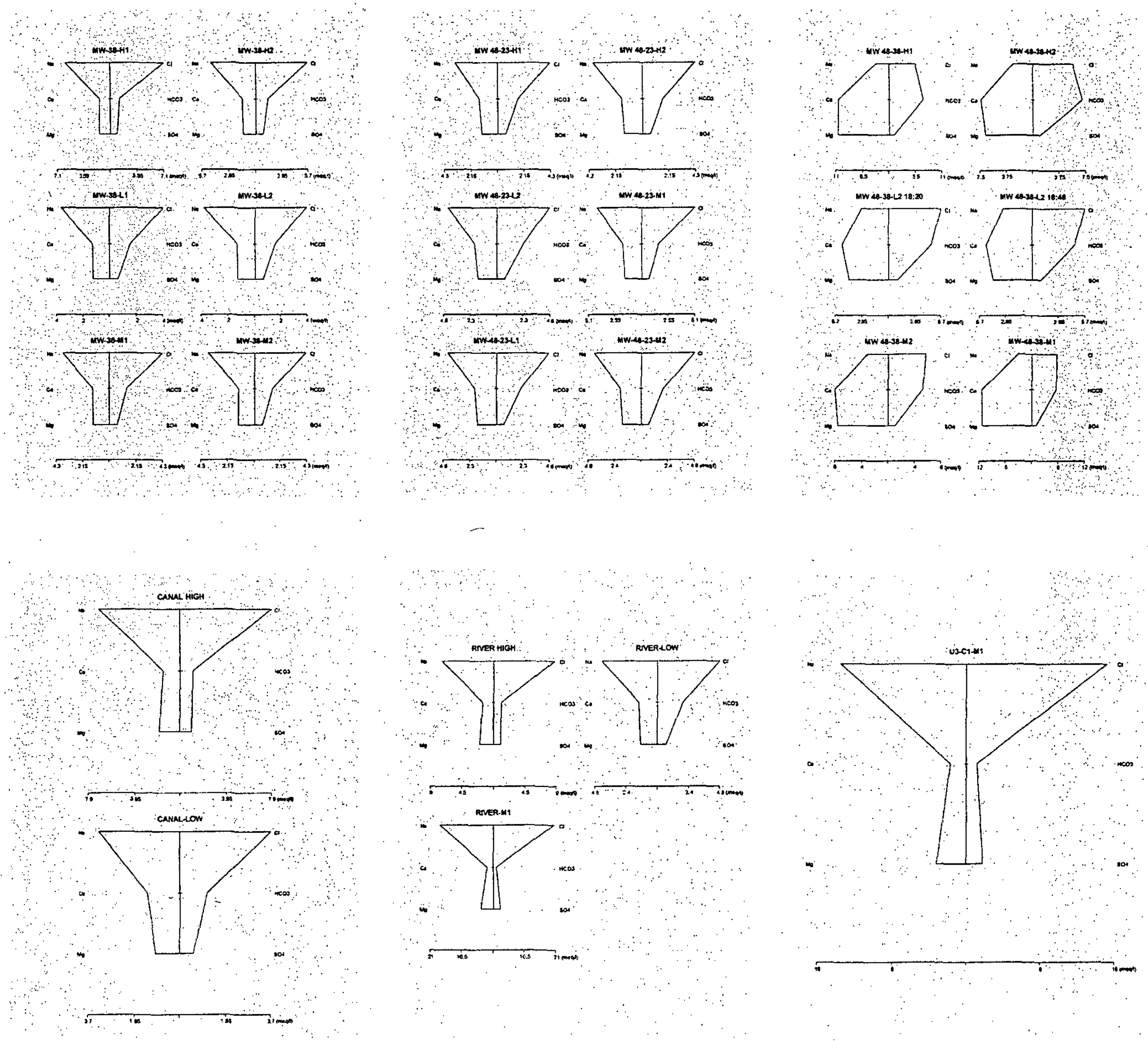
INDIAN POINT ENERGY CENTER BUCHANAN, NEW YORK	PROJ MGR: MJB DESIGNED BY: JDR REVIEWED BY: MJB OPERATOR: JDR	
FRACTURE STRIKE ORIENTATION AT ELEVATION –100	DATE: 08–06–2007	GZA GeoEnvironmental, Inc. ONE EDGEWATER DRIVE NORWOOD, MA 02062 Ph.: (781) 278–3700 Fax: (781) 278–5701

JOB NO. 17869.10

FIGURE NO. 6.14



AMBIENT AND PUMPING GROUNDWATER CONTOURS WITH TIDAL RESPONSE AND TEMPERATURE
Unit 1
Unit 2
Unit 3
HUDSON RIVER
LEGEND
Probable Legacy Release Locations
Terminated Connection To Storm Drain
Footing / Storm Drain Exfiltration
Inter-Structure Joint / Mud Mat
Containment Spray Sump Trench
Unit 1 West Fuel Pool
Unit 2 Fuel Pool
Water Level Data
Temperature °F
No Temperature Data
< 60.00
60.01 - 65.00
65.01 - 70.00
70.01 - 75.00
75.01 - 80.00
80.01 - 85.00
85.01 - 90.00
90.01 - 95.00
95.01 - 100.0
100.1 - 105.0
Groundwater Elevation Contours
Plume[1] Data
Bounding Sr-90
> 2 pCi/L
Bounding H3
> 5,000 pCi/L
Note:
1. H3 and Sr-90 bounding isopleths / data represent upper bound values measured over both depth and time (available results for sample dates through 8/28/2007). As such, the "plumes" are an overstatement of contaminant levels actually existing on-site at any time.
GZA GeoEnvironmental, Inc.
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK
AMBIENT AND PUMPING GROUNDWATER CONTOURS WITH TIDAL RESPONSE AND TEMPERATURE
1-04-2008
41.0017869.10
6.15



NOT TO SCALE

GZA GeoEnvironmental, Inc.

PROJ MGR: DMW
DESIGNED BY: DMW
REVIEWED BY: DMW
OPERATOR: GAS
DATE: 12-12-2007

REV. NO. | DESCRIPTION | BY | DATE

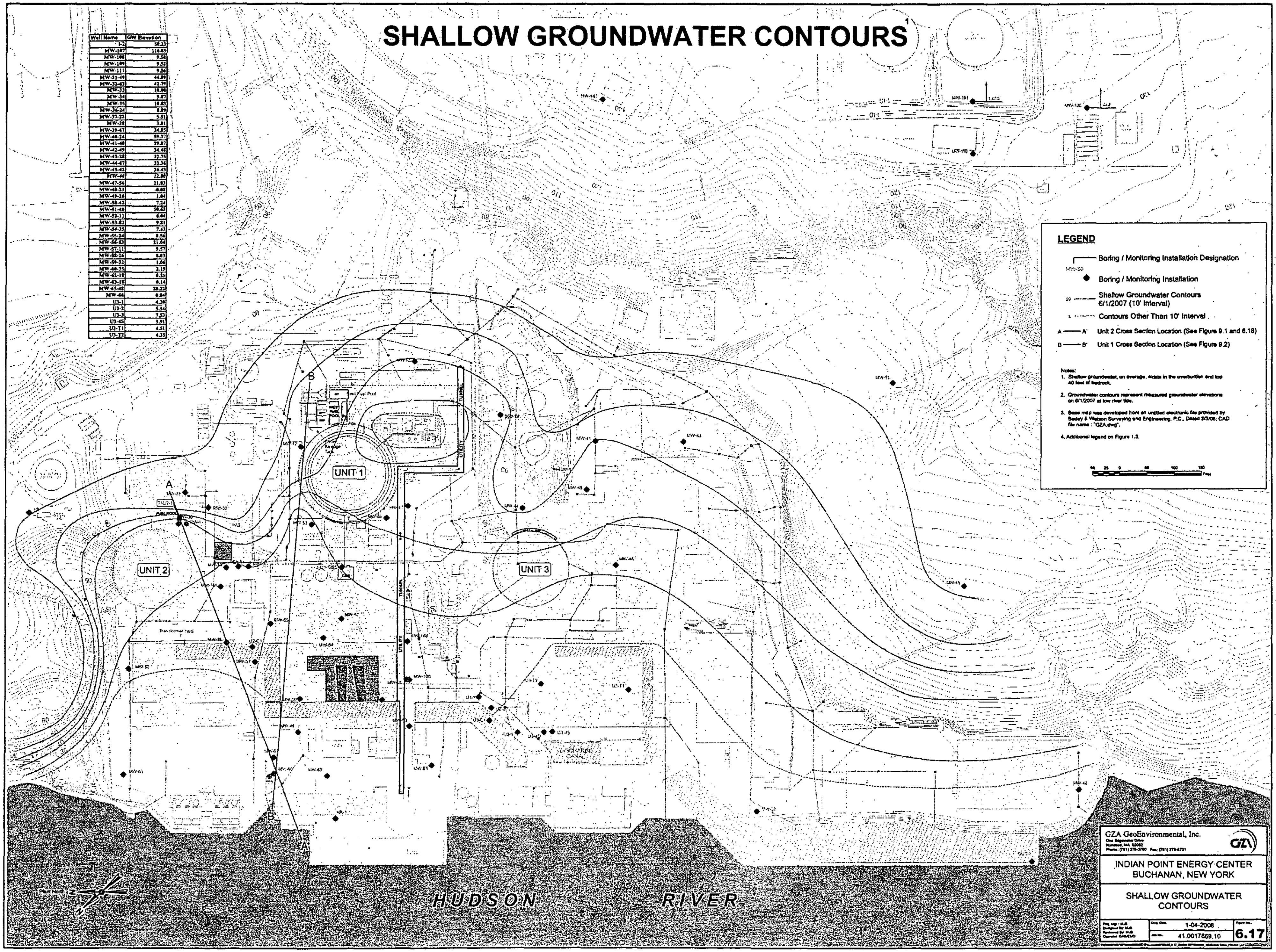
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

STIFF DIAGRAMS OF MW-38, MW-48, HUDSON RIVER, AND DISCHARGE CANAL

PROJECT NO. 17869.10

FIGURE NO. 6.16

SHALLOW GROUNDWATER CONTOURS[1]



Well Name	GW Elevation
I-2	58.23
MW-107	116.85
MW-108	9.58
MW-109	9.52
MW-111	9.56
MW-31-49	44.89
MW-32-62	42.79
MW-33	10.06
MW-34	9.87
MW-35	10.83
MW-36-24	8.89
MW-37-22	5.51
MW-38	3.81
MW-39-47	24.85
MW-40-24	59.37
MW-41-40	29.87
MW-42-49	34.48
MW-43-28	32.75
MW-44-67	33.36
MW-45-42	26.43
MW-46	12.80
MW-47-56	21.83
MW-48-23	-0.08
MW-49-26	1.84
MW-50-42	7.24
MW-51-40	50.63
MW-52-11	6.84
MW-53-82	9.81
MW-54-35	7.43
MW-55-24	8.56
MW-56-53	21.84
MW-57-11	9.57
MW-58-26	8.03
MW-59-32	1.06
MW-60-35	2.19
MW-62-18	8.25
MW-63-18	8.14
MW-65-48	28.22
MW-66	0.84
U3-1	4.28
U3-2	5.34
U3-3	7.53
U3-45	3.91
U3-T1	4.51
U3-T2	4.33

LEGEND

- Boring / Monitoring Installation Designation
- Boring / Monitoring Installation
- Shallow Groundwater Contours 6/1/2007 (10' Interval)
- Contours Other Than 10' Interval
- A —— A' Unit 2 Cross Section Location (See Figure 9.1 and 6.18)
- B —— B' Unit 1 Cross Section Location (See Figure 9.2)

Notes:

1. Shallow groundwater, on average, exists in the overburden and top 40 feet of bedrock.
2. Groundwater contours represent measured groundwater elevations on 6/1/2007 at low river tide.
3. Base map was developed from an untitled electronic file provided by Badey & Watson Surveying and Engineering, P.C., Dated 2/3/06; CAD file name : "GZA.dwg".
4. Additional legend on Figure 1.3.

50 25 0 50 100 150 Feet

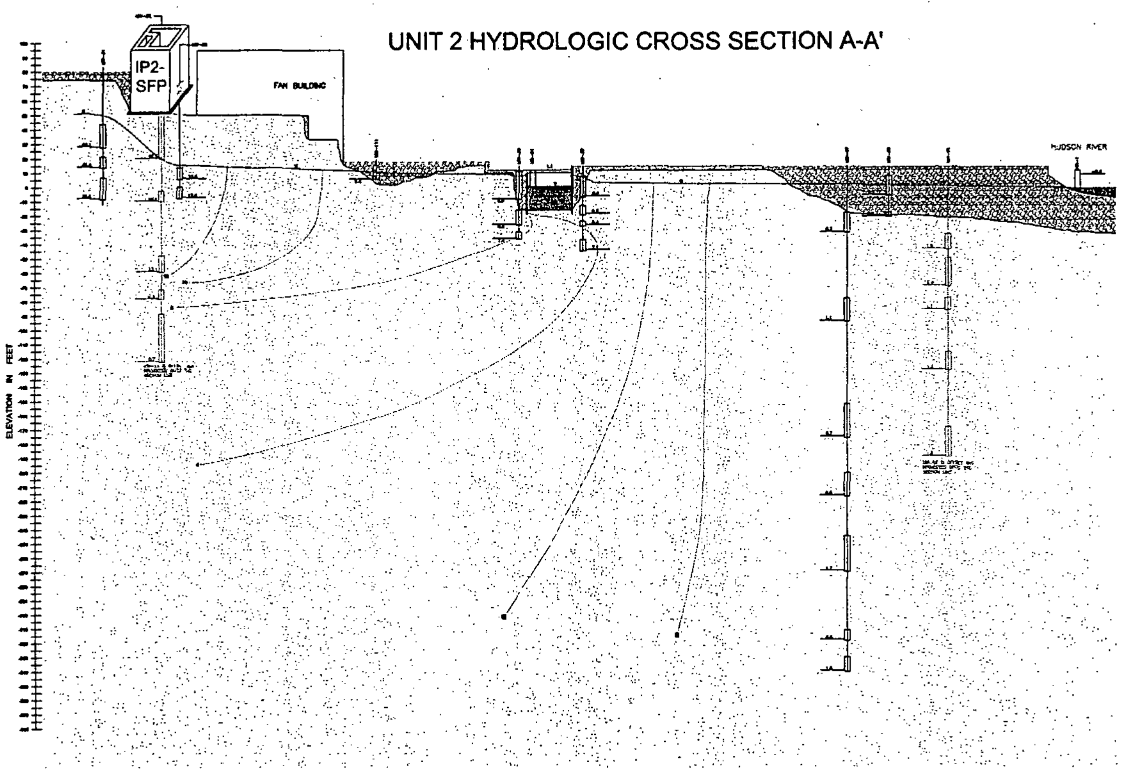
GZA GeoEnvironmental, Inc.
One Edgewater Drive
Norwood, MA 02062
Phone: (781) 278-3700 Fax: (781) 278-5701

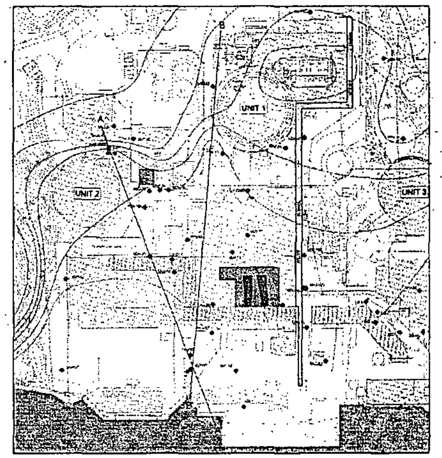
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

SHALLOW GROUNDWATER CONTOURS

Dwg. Date: 1-04-2008
Job No.: 41.0017869.10
Figure No.: 6.17

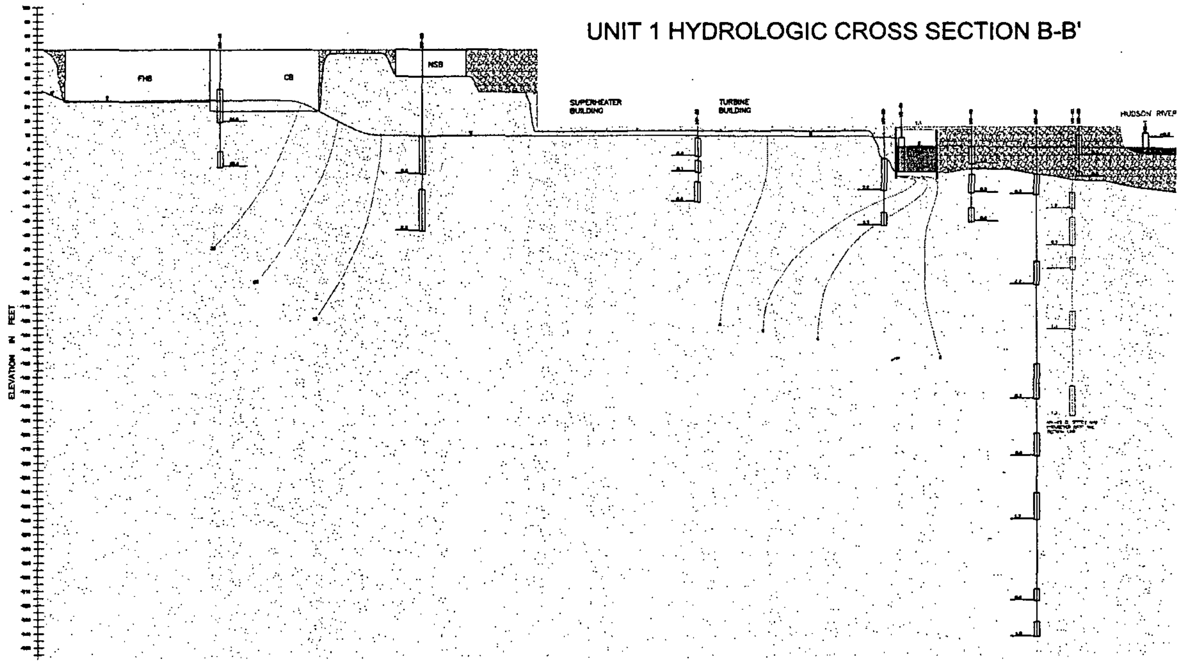
UNIT 2 HYDROLOGIC CROSS SECTION A-A'





CROSS SECTION LOCATION - FROM FIGURE 6.17

UNIT 1 HYDROLOGIC CROSS SECTION B-B'



LEGEND:

- CONCRETE
- OVERBURDEN
- BEDROCK
- GROUNDWATER PIEZOMETRIC HEAD CONTOUR
- GROUNDWATER TABLE
- MUD MAT
- MONITORING WELL
- SCREENED INTERVAL
- 6.2 MEASURED GROUNDWATER ELEVATION 6/1/07 LOW RIVER TIDE

NOTES:

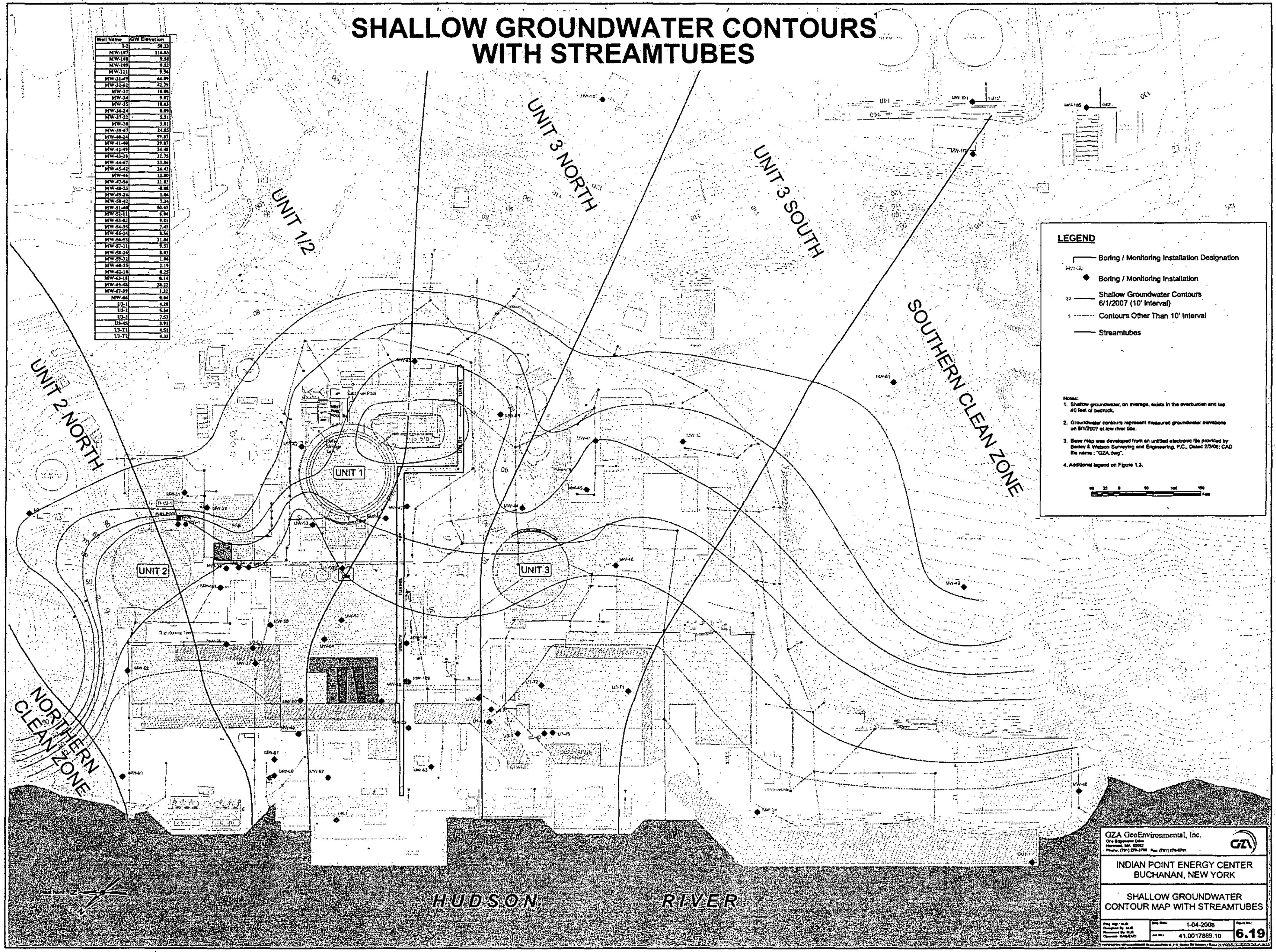
1. BASE MAP DEVELOPED FROM ELECTRONIC FILES, PREPARED BY BADEY AND WATSON SURVEYING & ENGINEERING PC, COLD SPRING, NY 10516. EXACT LOCATIONS AND ORIENTATIONS OF STRUCTURES ABOVE THE WATER TABLE ARE APPROXIMATE AND/OR HAVE BEEN MODIFIED ON THESE SECTIONS TO BETTER ILLUSTRATE CONTAMINANT SOURCE MECHANISMS AND/OR MIGRATION PATHWAYS.
2. WATER LEVEL READINGS HAVE BEEN MADE IN THE MONITORING WELLS AT THE TIMES AND UNDER THE CONDITIONS STATED. THESE DATA HAVE BEEN REVIEWED AND INTERPRETATIONS MADE IN THE TEXT OF THIS REPORT. HOWEVER, IT MUST BE STATED THAT FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO VARIATIONS IN RAINFALL, TIDES, TEMPERATURE AND OTHER FACTORS.
3. THE STRATIFICATION LINES ARE BASED UPON INTERPOLATIONS BETWEEN WIDELY SPACED BORINGS, AND MONITORING WELLS AND THUS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES. ACTUAL TRANSITIONS MAY VARY FROM THOSE SHOWN.
4. MW-67 NOT INSTALLED PRIOR TO 6/1/07 GROUND WATER ELEVATION MONITORING. MW-67 GROUNDWATER ELEVATIONS SHOWN WERE MEASURED ON 6-28-07.
5. MW-32 AND MW-62 ARE OFFSET AND PROJECTED ONTO THE SECTION LINE.
6. SEE FIGURE 6.17 FOR CROSS SECTION LOCATION.

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

UNITS 1 AND 2
HYDROLOGIC CROSS SECTIONS A-A' AND B-B'

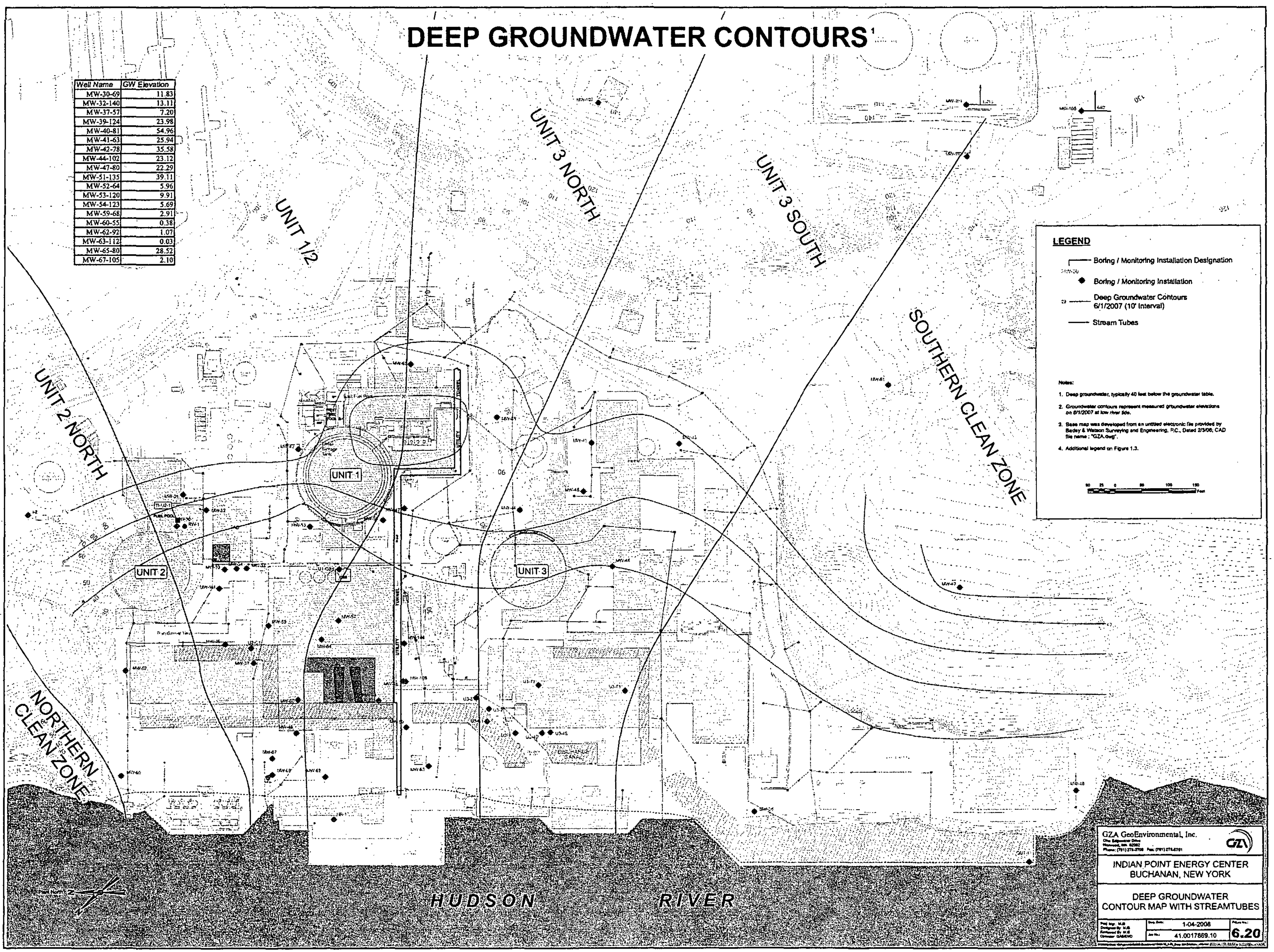
PROJECT NO. 17869.10

FIGURE NO. 6.18

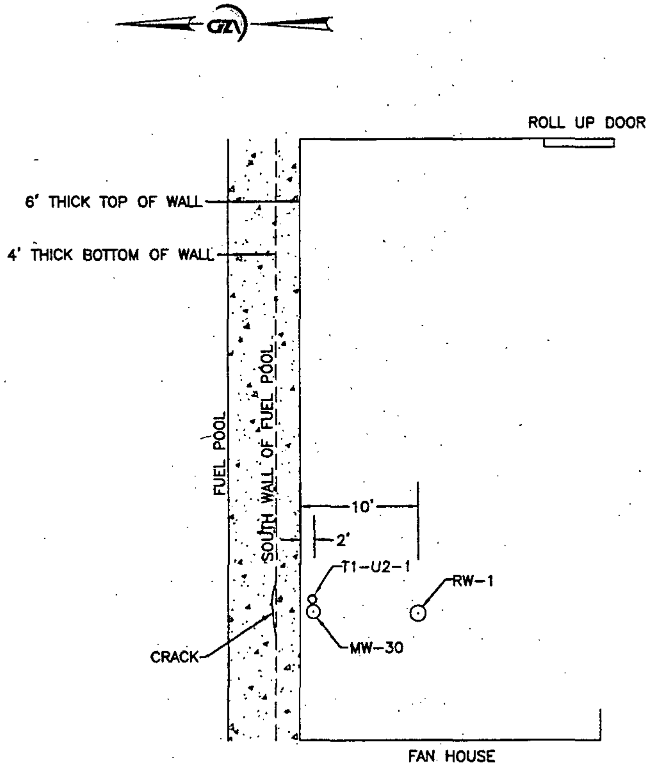


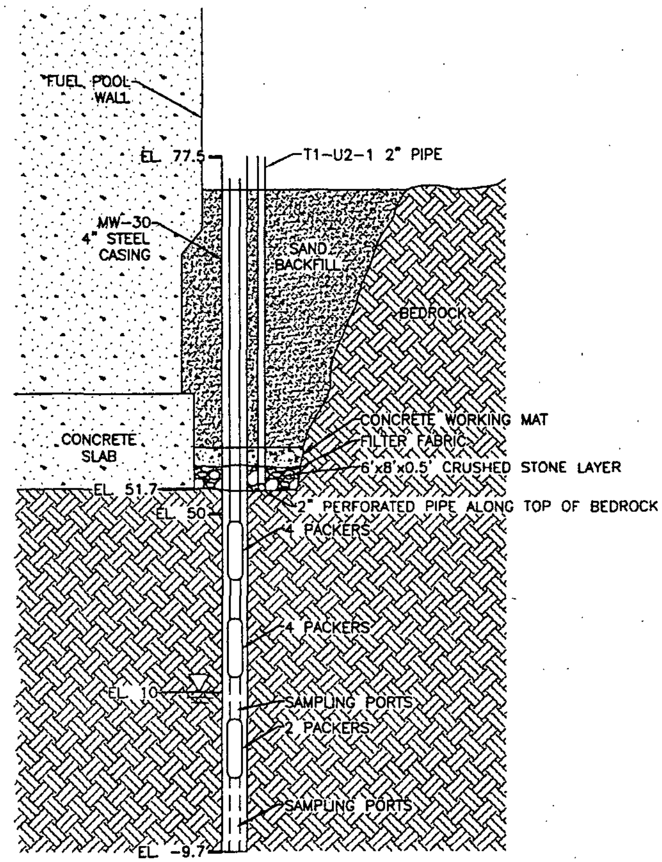
Well Name	GW Elevation
I-2	50.23
MW-107	116.85
MW-108	9.58
MW-109	9.52
MW-111	9.56
MW-31-49	44.09
MW-32-62	42.79
MW-33	10.08
MW-34	9.87
MW-35	10.83
MW-36-24	8.89
MW-37-22	5.51
MW-38	3.81
MW-39-67	24.85
MW-40-24	59.37
MW-41-40	29.87
MW-42-49	34.48
MW-43-28	32.75
MW-44-67	33.36
MW-45-42	26.43
MW-46	12.80
MW-47-56	21.83
MW-48-23	-8.88
MW-49-26	1.84
MW-50-42	7.34
MW-51-40	50.63
MW-52-11	6.84
MW-53-82	9.81
MW-54-35	7.43
MW-55-24	8.56
MW-56-53	21.84
MW-57-11	9.57
MW-58-26	8.83
MW-59-32	1.86
MW-60-35	2.19
MW-62-18	8.25
MW-63-18	8.14
MW-65-48	28.22
MW-67-39	1.32
MW-66	8.84
U3-1	4.20
U3-2	5.34
U3-3	7.53
U3-4S	3.91
U3-T1	4.51
U3-T2	4.33

DEEP GROUNDWATER CONTOURS[1]



Well Name	GW Elevation
MW-30-69	11.83
MW-32-140	13.11
MW-37-57	7.20
MW-39-124	23.98
MW-40-81	54.96
MW-41-63	25.94
MW-42-78	35.58
MW-44-102	23.12
MW-47-80	22.29
MW-51-135	39.11
MW-52-64	5.96
MW-53-120	9.91
MW-54-123	5.69
MW-59-68	2.91
MW-60-55	0.38
MW-62-92	1.07
MW-63-112	0.03
MW-65-80	28.52
MW-67-105	2.10





REV. NO.	DESCRIPTION	BY	DATE

DESIGNED BY: DW
CHECKED BY: DW
REVIEWED BY: DW

DRAWN BY: EM/EMD/OCO
DATE: 01-04-2008

GZA GeoEnvironmental, Inc.
Engineers and Scientists
ONE EDGEWATER DRIVE
NORWOOD, MA 02062
(781) 278-3700
(781) 278-5701

NOT TO SCALE

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

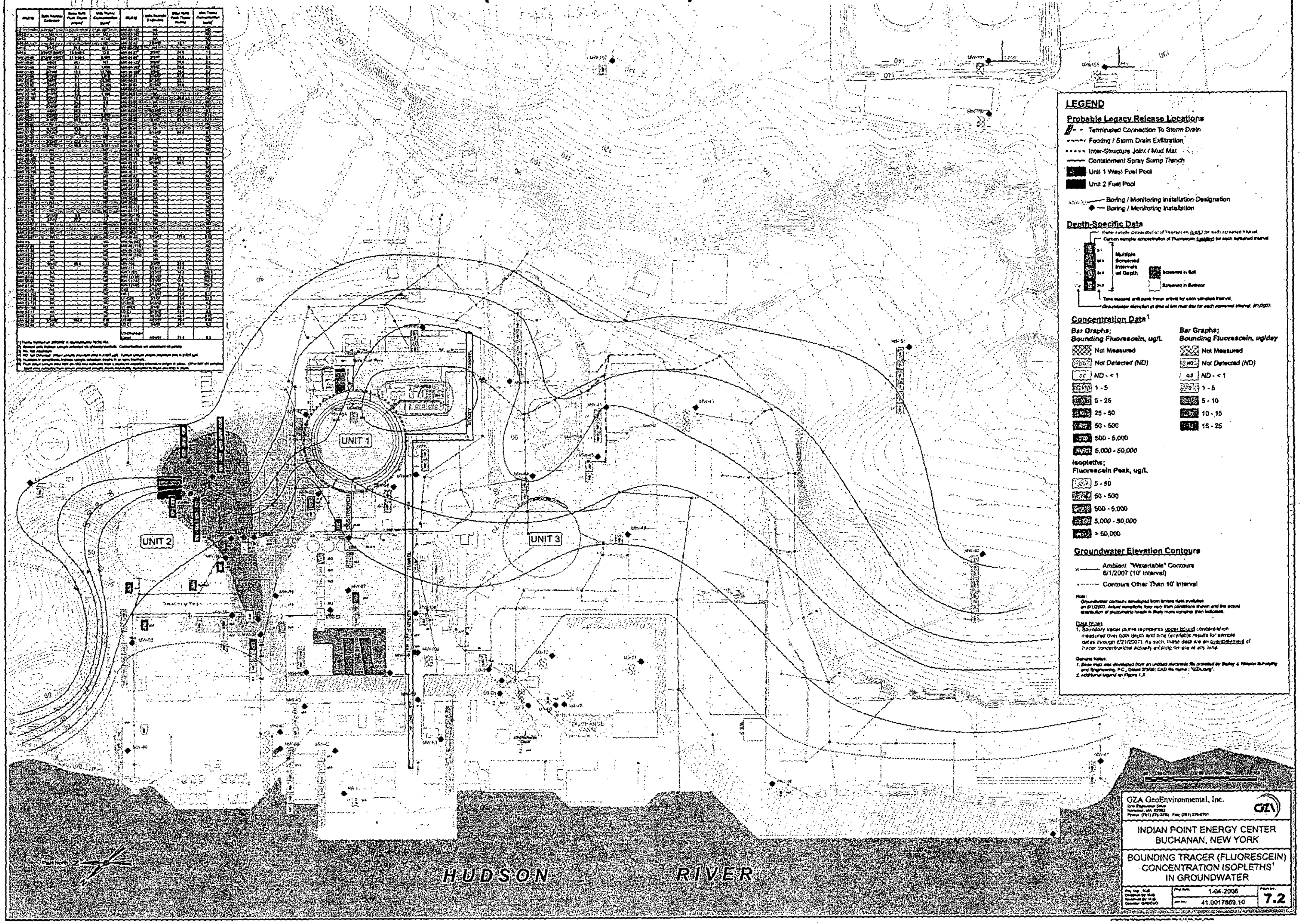
SCHEMATIC OF INJECTION WELL LOCATION AND DESIGN

JOB NO. 41.0017869.10

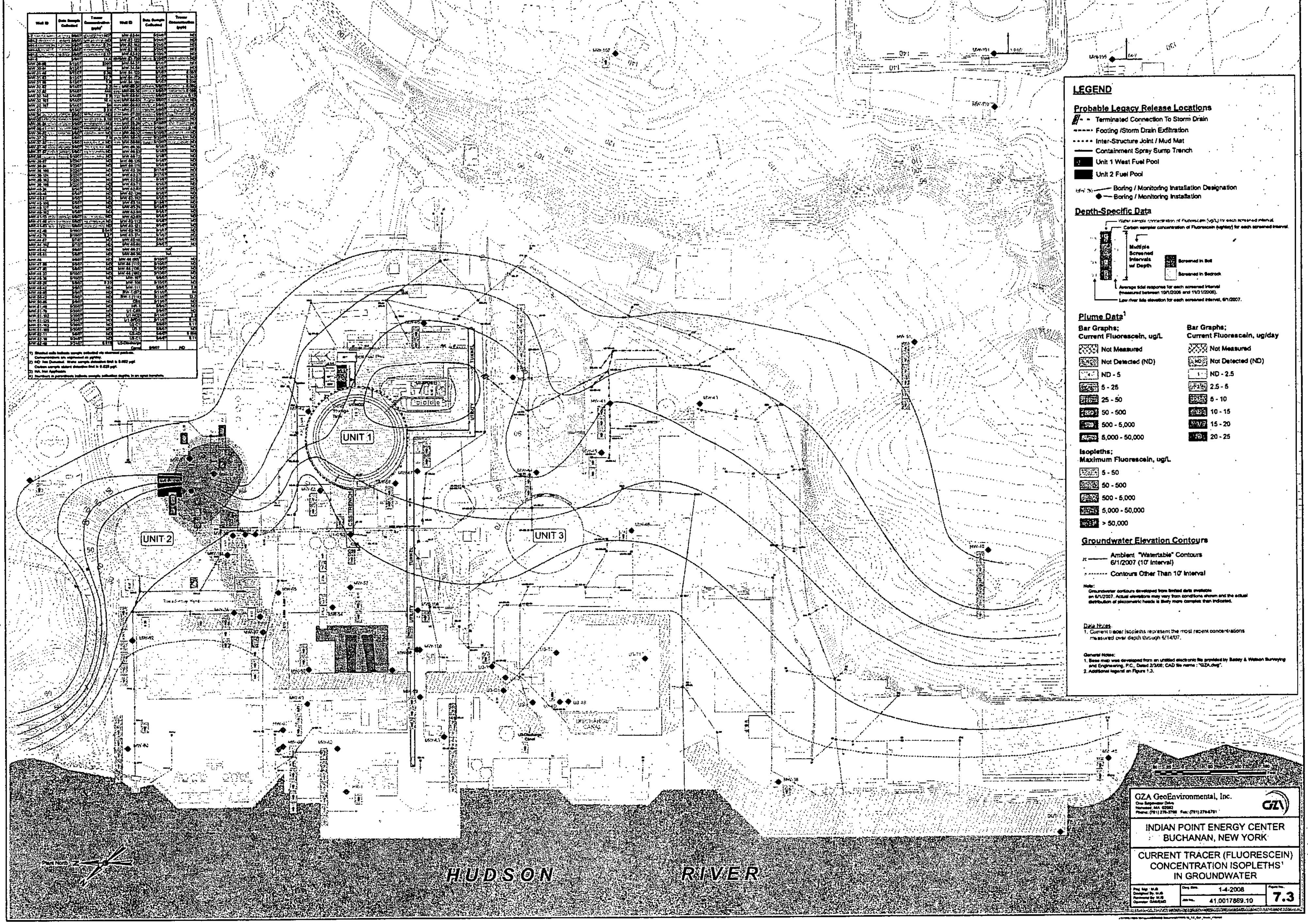
SHEET NO. 7.1

©2008 - GZA GeoEnvironmental, Inc. J:\17,000-18,999\17869\17869-10.DW\Figures\CAD\7-1_Injection Well Detail_v2.dwg

BOUNDING TRACER (FLUORESCEIN) CONCENTRATION ISOPLETHS[1]

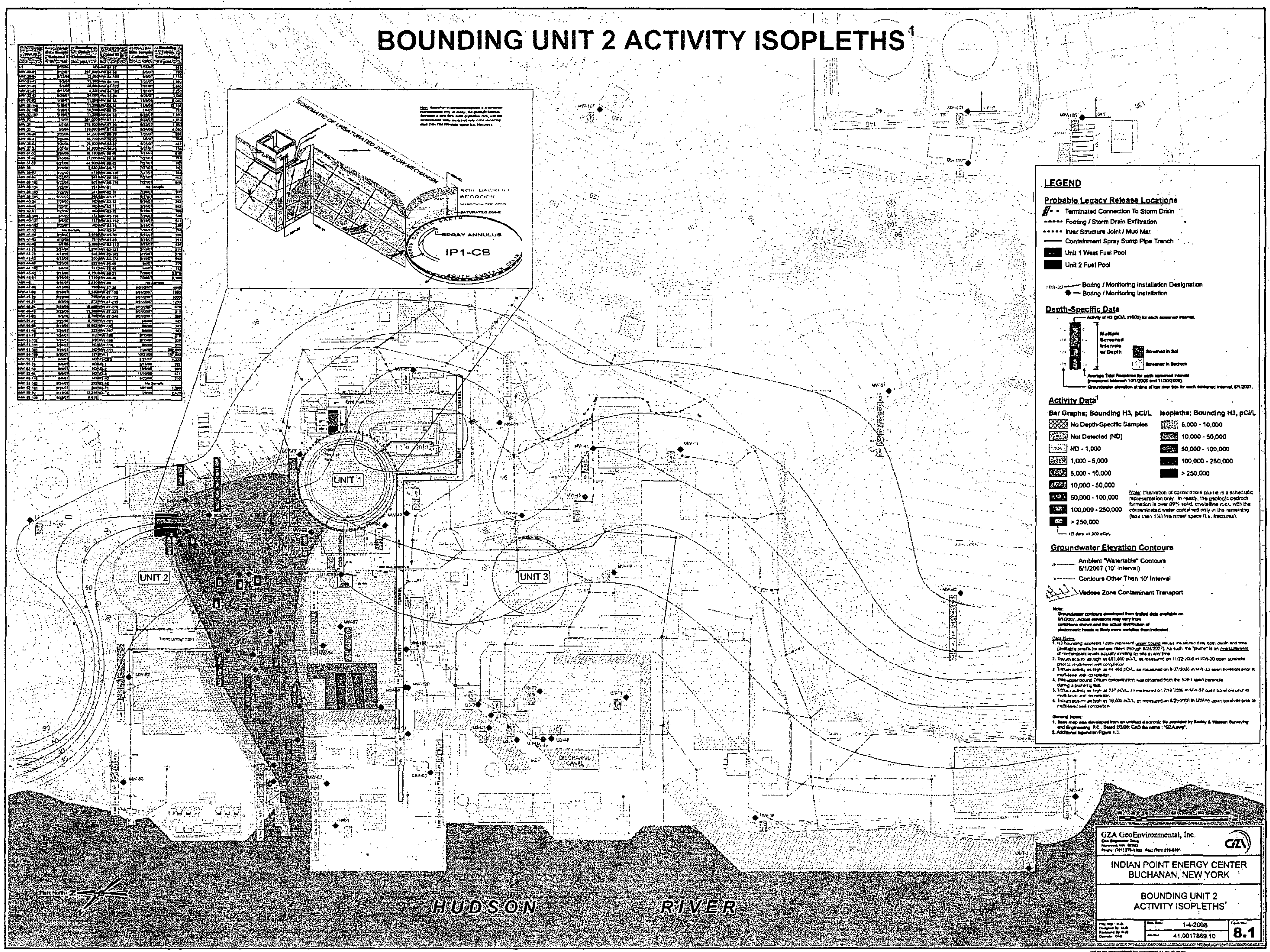


CURRENT TRACER (FLUORESCEIN) CONCENTRATION ISOPLETHS[1] IN GROUNDWATER

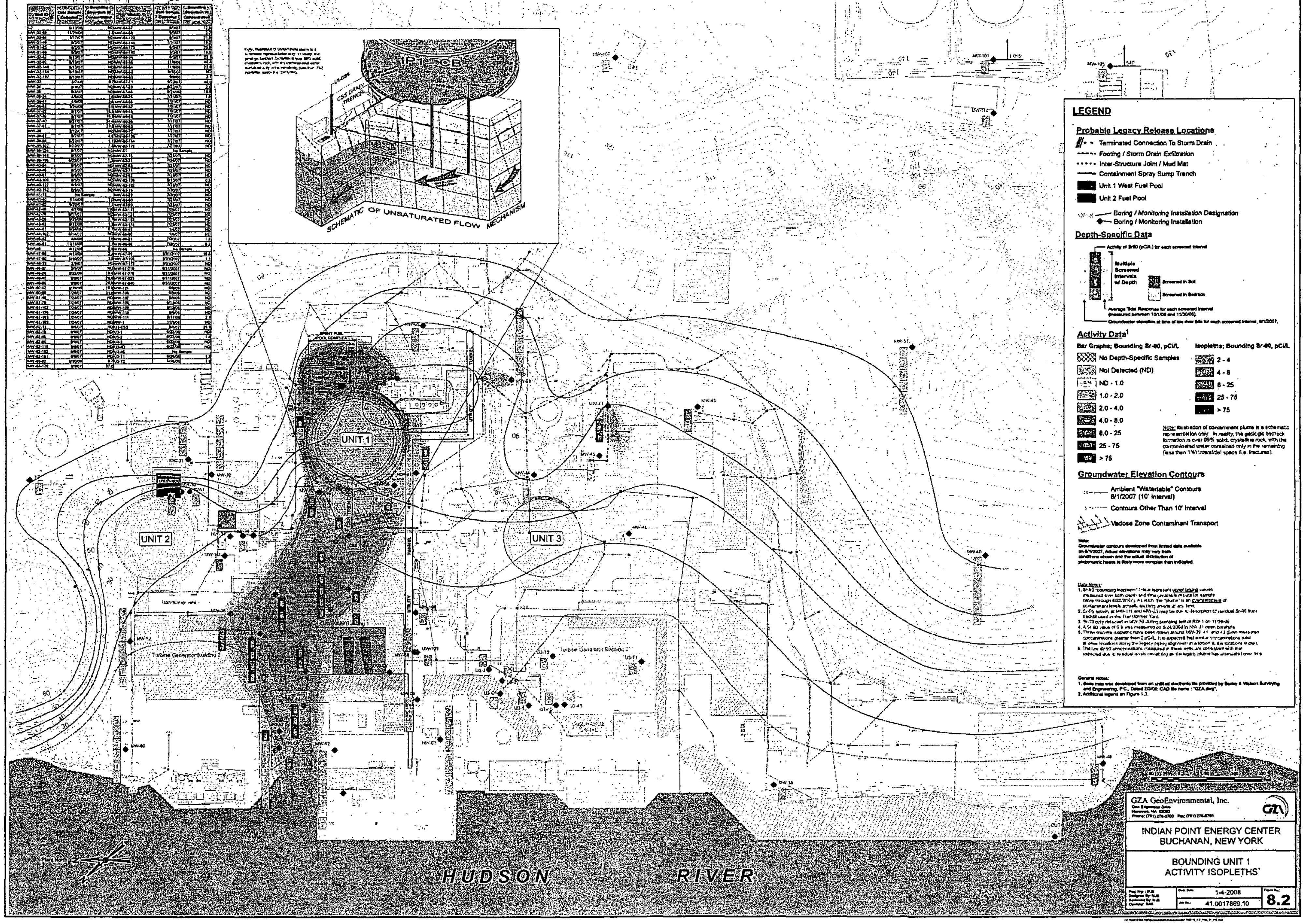


BOUNDING UNIT 2 ACTIVITY ISOPLETHS[1]

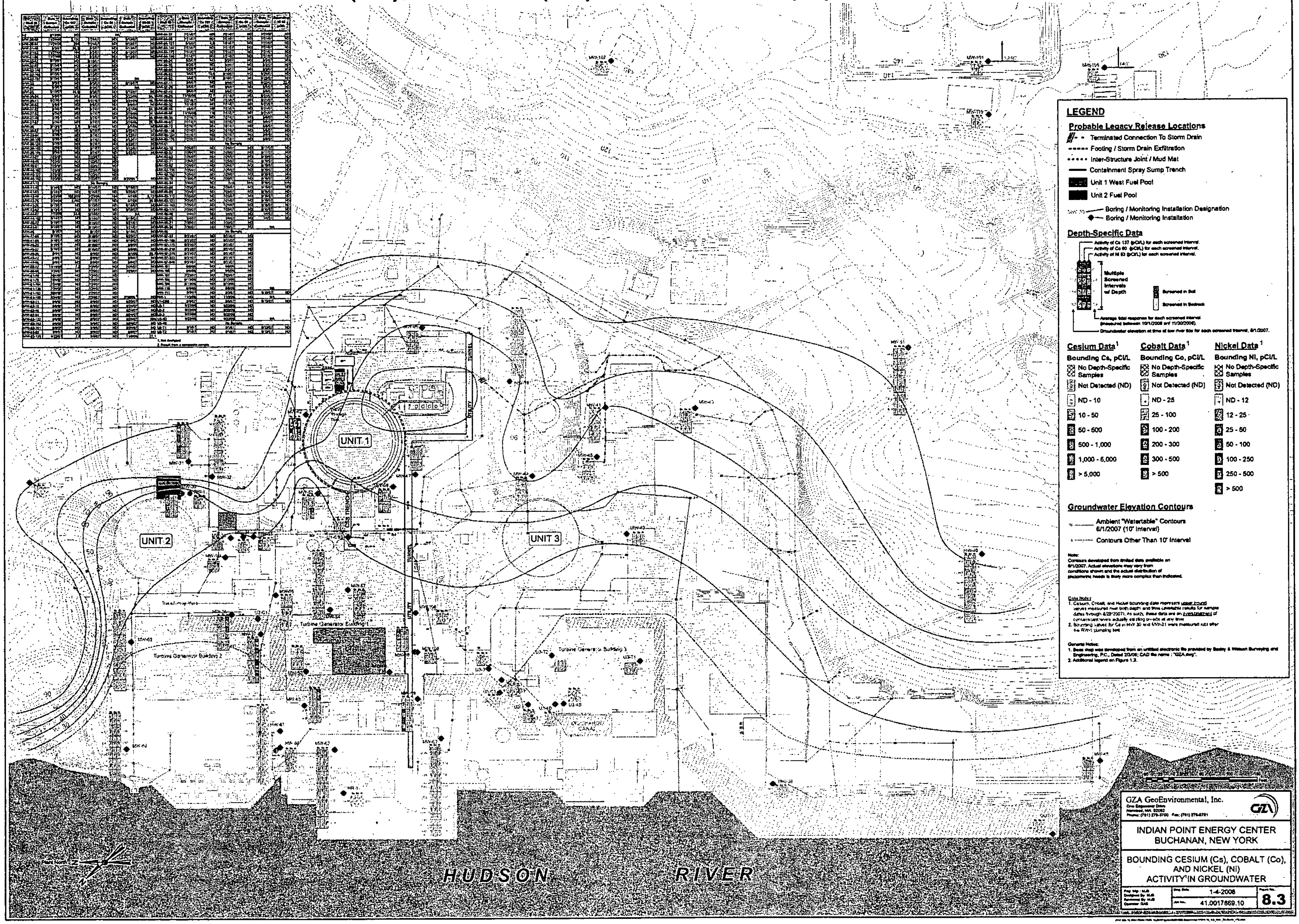
Well ID	Date Sample Collected	Bounding Tritium Concentration pCi/L	Well ID	Date Sample Collected	Bounding Tritium Concentration pCi/L
I-2	9/13/06	ND	MW-53-37	7/31/07	568
MW-30-69	8/13/07	287,000	MW-54-58	8/3/07	760
MW-30-84	5/23/06	12,500	MW-54-123	8/3/07	1,110
MW-31-49	8/3/07	11,900	MW-54-144	7/31/07	1,880
MW-31-63	8/3/07	48,600	MW-54-173	7/31/07	2,980
MW-31-85	8/1/07	4,320	MW-54-190	7/31/07	2,250
MW-32-62	8/24/07	26,000	MW-55-24	8/24/07	3,080
MW-32-85	1/18/07	11,200	MW-55-35	11/9/06	8,040
MW-32-149	1/18/07	11,300	MW-55-54	11/9/06	13,100
MW-32-173	1/18/07	10,500	MW-56-53	1/4/07	780
MW-32-190	1/18/07	11,300	MW-56-83	8/22/07	1,850
MW-33	7/3/06	284,000	MW-57-11	8/22/07	4,610
MW-34	4/7/06	278,000	MW-57-20	8/22/07	1,050
MW-35	3/3/06	110,000	MW-57-45	8/24/06	4,080
MW-36-24	3/23/06	34,200	MW-58-26	7/31/07	856
MW-36-41	3/24/06	35,200	MW-58-65	1/5/07	550
MW-36-52	3/24/06	26,800	MW-59-32	8/21/07	467
MW-37-22	3/27/06	34,800	MW-59-45	8/21/07	754
MW-37-32	3/24/06	38,100	MW-59-68	7/31/07	619
MW-37-40	3/10/06	17,000	MW-60-35	7/27/07	761
MW-37-57	6/27/06	44,900	MW-60-53	7/27/07	ND
MW-38	3/23/06	1,630	MW-60-72	7/27/07	ND
MW-39-67	5/22/07	473	MW-60-135	7/27/07	312
MW-39-84	5/22/07	591	MW-60-154	7/27/07	467
MW-39-102	5/22/07	605	MW-60-176	7/27/07	949
MW-39-124	5/22/07	261	MW-61	No Sample	
MW-39-183	5/22/07	247	MW-62-18	7/26/07	308
MW-39-195	5/22/07	255	MW-62-37	8/17/07	297
MW-40-26	7/23/07	ND	MW-62-53	8/10/07	343
MW-40-46	7/23/07	ND	MW-62-71	8/10/07	507
MW-40-81	7/23/07	ND	MW-62-92	8/10/07	700
MW-40-100	9/5/07	174	MW-62-138	7/26/07	530
MW-40-127	9/5/07	157	MW-62-182	8/10/07	541
MW-40-162	7/23/07	ND	MW-63-18	8/10/07	238
MW-41-13	No Sample		MW-63-34	7/30/07	280
MW-41-40	8/15/07	3,910	MW-63-50	8/15/07	326
MW-41-63	4/12/06	781	MW-63-93	8/15/07	261
MW-42-49	4/7/06	3,880	MW-63-112	8/15/07	434
MW-42-78	3/24/06	1,780	MW-63-121	8/15/07	311
MW-43-28	4/12/06	348	MW-63-163	8/15/07	578
MW-43-62	4/12/06	700	MW-63-174	8/15/07	590
MW-44-67	7/20/06	887	MW-65-48	1/4/07	208
MW-44-102	8/4/06	761	MW-65-80	1/4/07	183
MW-45-42	9/13/06	4,150	MW-66-21	7/30/07	3,570
MW-45-61	9/25/06	1,710	MW-66-36	7/30/07	8,100
MW-46	8/14/07	3,430	MW-66	No Sample	
MW-47-56	4/13/06	780	MW-67-39	8/31/2007	4080
MW-47-80	8/18/07	3,510	MW-67-105	8/31/2007	1960
MW-48-23	5/23/06	735	MW-67-173	8/31/2007	1050
MW-48-37	6/3/06	573	MW-67-219	8/31/2007	1730
MW-49-26	3/22/06	15,400	MW-67-276	8/31/2007	679
MW-49-42	3/22/06	11,300	MW-67-323	8/31/2007	317
MW-49-65	9/7/06	8,780	MW-67-340	8/31/2007	282
MW-50-42	3/22/06	8,750	MW-101	6/6/06	ND
MW-50-66	3/19/06	10,902	MW-105	6/6/06	ND
MW-51-40	7/24/07	223	MW-107	6/6/06	ND
MW-51-79	7/24/07	ND	MW-108	9/13/06	278
MW-51-104	7/24/07	ND	MW-109	9/13/06	339
MW-51-135	7/24/07	ND	MW-110	6/6/06	225
MW-51-163	7/24/07	ND	MW-111	11/4/05	302,000
MW-51-189	9/20/07	187	RW-1	10/31/06	107,000
MW-52-11	8/6/07	ND	U1-CSS	2/27/07	4,320
MW-52-18	8/6/07	ND	U3-1	2/16/06	763
MW-52-49	8/6/07	ND	U3-2	10/6/05	990
MW-52-84	8/6/07	ND	U3-3	11/10/05	471
MW-52-118	8/6/07	ND	U3-4D	6/23/06	710
MW-52-162	8/24/07	282	U3-4S	No Sample	
MW-52-181	9/24/07	348	U3-T1	10/1/05	1,580
MW-53-82	9/23/06	13,200	U3-T2	1/6/06	2,420
MW-53-120	9/23/07	8,810			



BOUNDING UNIT 1 ACTIVITY ISOPLETHS[1]



BOUNDING CESIUM (Cs), COBALT (Co), AND NICKEL (Ni) ACTIVITY[1] IN GROUNDWATER



GZA GeoEnvironmental, Inc.

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

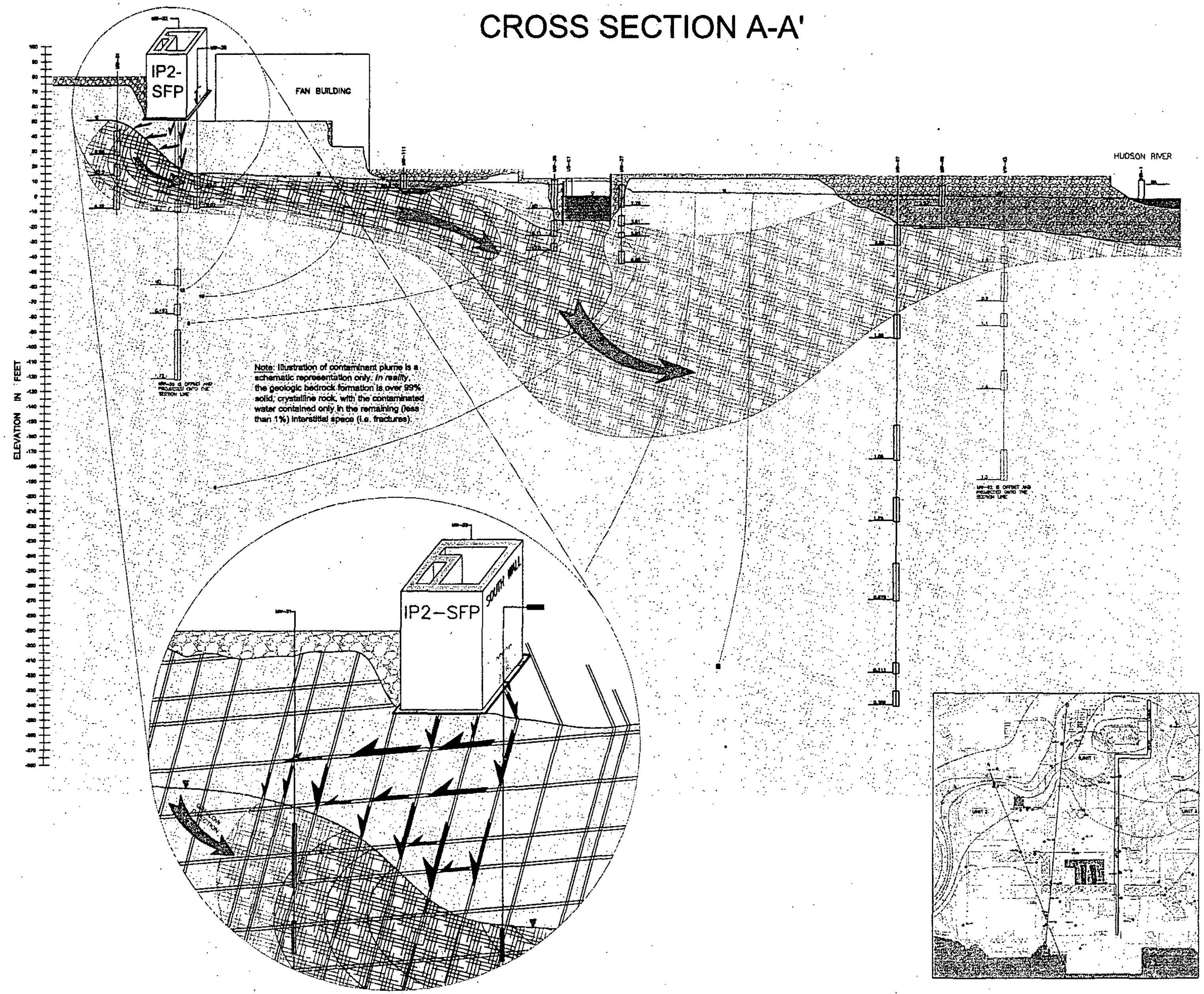
BOUNDING CESIUM (Cs), COBALT (Co), AND NICKEL (Ni) ACTIVITY[1] IN GROUNDWATER

1-4-2008

41.0017669.10

8.3

CROSS SECTION A-A'



UNSATURATED ZONE FLOW MECHANISM

CROSS SECTION LOCATION - FROM FIGURE 6.17

LEGEND:

- CONCRETE
- OVERBURDEN
- BEDROCK
- GROUNDWATER PIEZOMETRIC *HEAD CONTOUR*
- GROUNDWATER TABLE
- GROUNDWATER FLOW
- UNSATURATED ZONE FLOW DIRECTION
- MUD MAT
- MONITORING WELL
- SCREENED INTERVAL
- 1.25 MEASURED ACTIVITY OF H3 (pCi/L X 1,000) FOR EACH SCREENED INTERVAL AUG./SEPT. 2007.

CONTOUR INTERVAL

SOIL ROCK

- 5,000 – 10,000
- 10,000 – 50,000
- 50,000 – 100,000
- > 100,000

MOST RECENT MEASURED ACTIVITIES IN pCi/L THROUGH AUGUST 2007 DATA

NOTES:

1. BASE MAP DEVELOPED FROM ELECTRONIC FILES, PREPARED BY BADEY AND WATSON SURVEYING & ENGINEERING PC, COLD SPRING, NY 10516. EXACT LOCATIONS AND ORIENTATIONS OF STRUCTURES ABOVE THE WATER TABLE ARE APPROXIMATE AND/OR HAVE BEEN MODIFIED ON THESE SECTIONS TO BETTER ILLUSTRATE CONTAMINANT SOURCE MECHANISMS AND/OR MIGRATION PATHWAYS.
2. WATER LEVEL READINGS HAVE BEEN MADE IN THE MONITORING WELLS AT THE TIMES AND UNDER THE CONDITIONS STATED. THESE DATA HAVE BEEN REVIEWED AND INTERPRETATIONS MADE IN THE TEXT OF THIS REPORT. HOWEVER, IT MUST BE STATED THAT FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO VARIATIONS IN RAINFALL, TIDES, TEMPERATURE AND OTHER FACTORS.
3. THE STRATIFICATION LINES ARE BASED UPON INTERPOLATIONS BETWEEN WIDELY SPACED BORINGS, AND MONITORING WELLS AND THUS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES. ACTUAL TRANSITIONS MAY VARY FROM THOSE SHOWN.
4. MW–32 AND MW–62 ARE OFFSET AND PROJECTED ONTO THE SECTION LINE.
5. SEE FIGURE 6.17 FOR CROSS SECTION LOCATION.

REV. NO.	DESCRIPTION	BY	DATE

SCALE: 1" = 30 FEET (0, 15', 30', 60')

GZA GeoEnvironmental, Inc.
440 NINTH AVENUE
NEW YORK, NY 10001
PH: (212) 594–8140
FAX: (212) 279–8180

PROJ MGR: DMW
DESIGNED BY: MJG
REVIEWED BY: DMW/MJB
OPERATOR: CJF/DAS/CRB
DATE: 01–04–2008

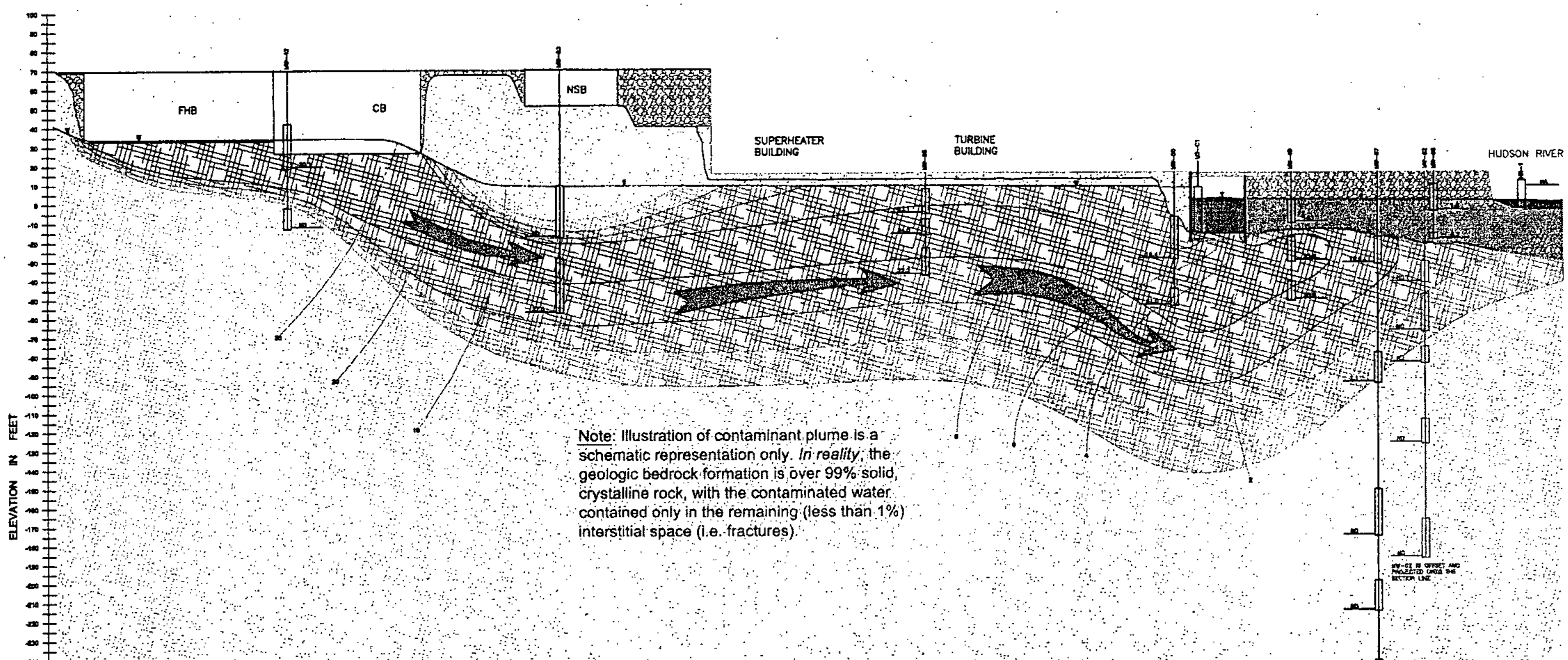
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

UNIT 2 TRITIUM PLUME
CROSS SECTION A–A'

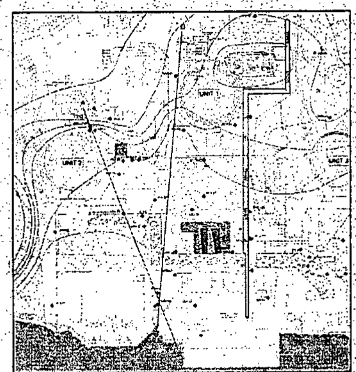
PROJECT NO. 17869.10

FIGURE NO. 9.1

CROSS SECTION B-B'



Note: Illustration of contaminant plume is a schematic representation only. *In reality*, the geologic bedrock formation is over 99% solid, crystalline rock, with the contaminated water contained only in the remaining (less than 1%) interstitial space (i.e. fractures).



CROSS SECTION LOCATION - FROM FIGURE 6.17

LEGEND:

- CONCRETE
- OVERBURDEN
- BEDROCK
- GROUNDWATER PIEZOMETRIC HEAD CONTOUR
- GROUNDWATER TABLE
- GROUNDWATER FLOW DIRECTION
- MONITORING WELL
- SCREENED INTERVAL
- 8.6 MEASURED ACTIVITY OF SR-90 (pCi/L) FOR EACH SCREENED INTERVAL

CONTOUR INTERVAL

SOIL ROCK

- 2-4 pCi/L
- 4-8 pCi/L
- 8-25 pCi/L
- >25 pCi/L

MOST RECENT MEASURED ACTIVITIES IN pCi/L THROUGH AUGUST 2007 DATA.

NOTES:

1. BASE MAP DEVELOPED FROM ELECTRONIC FILES. PREPARED BY BADEY AND WATSON SURVEYING & ENGINEERING PC, COLD SPRING, NY 10516. EXACT LOCATIONS AND ORIENTATIONS OF STRUCTURES ABOVE THE WATER TABLE ARE APPROXIMATE AND/OR HAVE BEEN MODIFIED ON THESE SECTIONS TO BETTER ILLUSTRATE CONTAMINANT SOURCE MECHANISMS AND/OR MIGRATION PATHWAYS.
2. WATER LEVEL READINGS HAVE BEEN MADE IN THE MONITORING WELLS,AT THE TIMES AND UNDER THE CONDITIONS STATED. THESE DATA HAVE BEEN REVIEWED AND INTERPRETATIONS MADE IN THE TEXT OF THIS REPORT. HOWEVER, IT MUST BE STATED THAT FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO VARIATIONS IN RAINFALL, TIDES, TEMPERATURE AND OTHER FACTORS.
3. THE STRATIFICATION LINES ARE BASED UPON INTERPOLATIONS BETWEEN WIDELY SPACED BORINGS, AND MONITORING WELLS AND THUS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN SOIL TYPES. ACTUAL TRANSITIONS MAY VARY FROM THOSE SHOWN.
4. MW-62 IS OFFSET AND PROJECTED ONTO THE SECTION LINE.
5. SEE FIGURE 6.17 FOR CROSS SECTION LOCATION

REV. NO.	DESCRIPTION	BY	DATE

SCALE: 1" = 30 FEET

GZA GeoEnvironmental, Inc.
440 NINTH AVENUE
NEW YORK, NY 10001
PH: (212) 594-8140
FAX: (212) 279-8180

PROJ MGR: DMW
DESIGNED BY: MJC
REVIEWED BY: DMW/MJB
OPERATOR: CJF/CAS/CRB
DATE: 01-04-2008

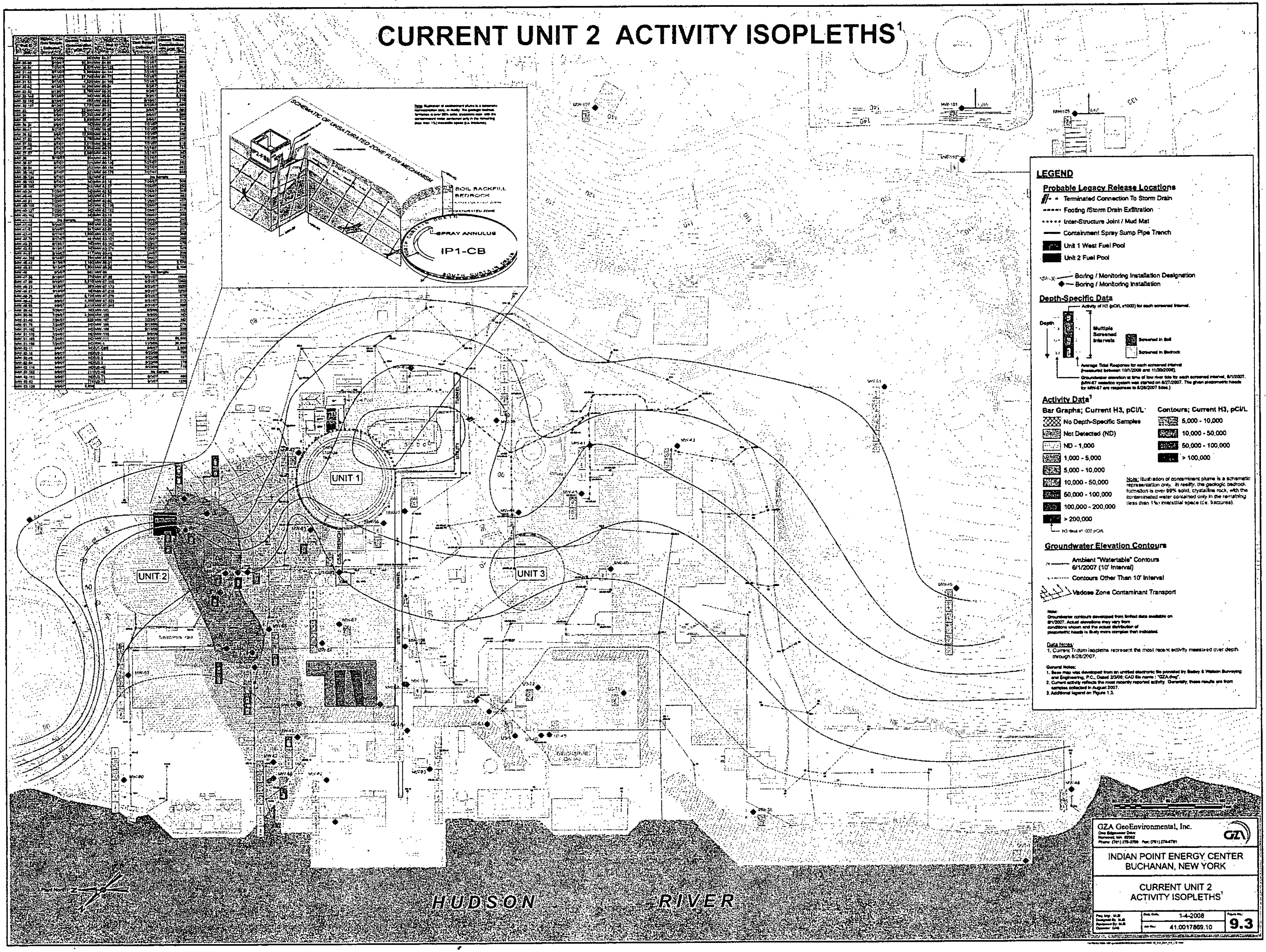
INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

UNIT 1 STRONTIUM PLUME
CROSS SECTION B-B'

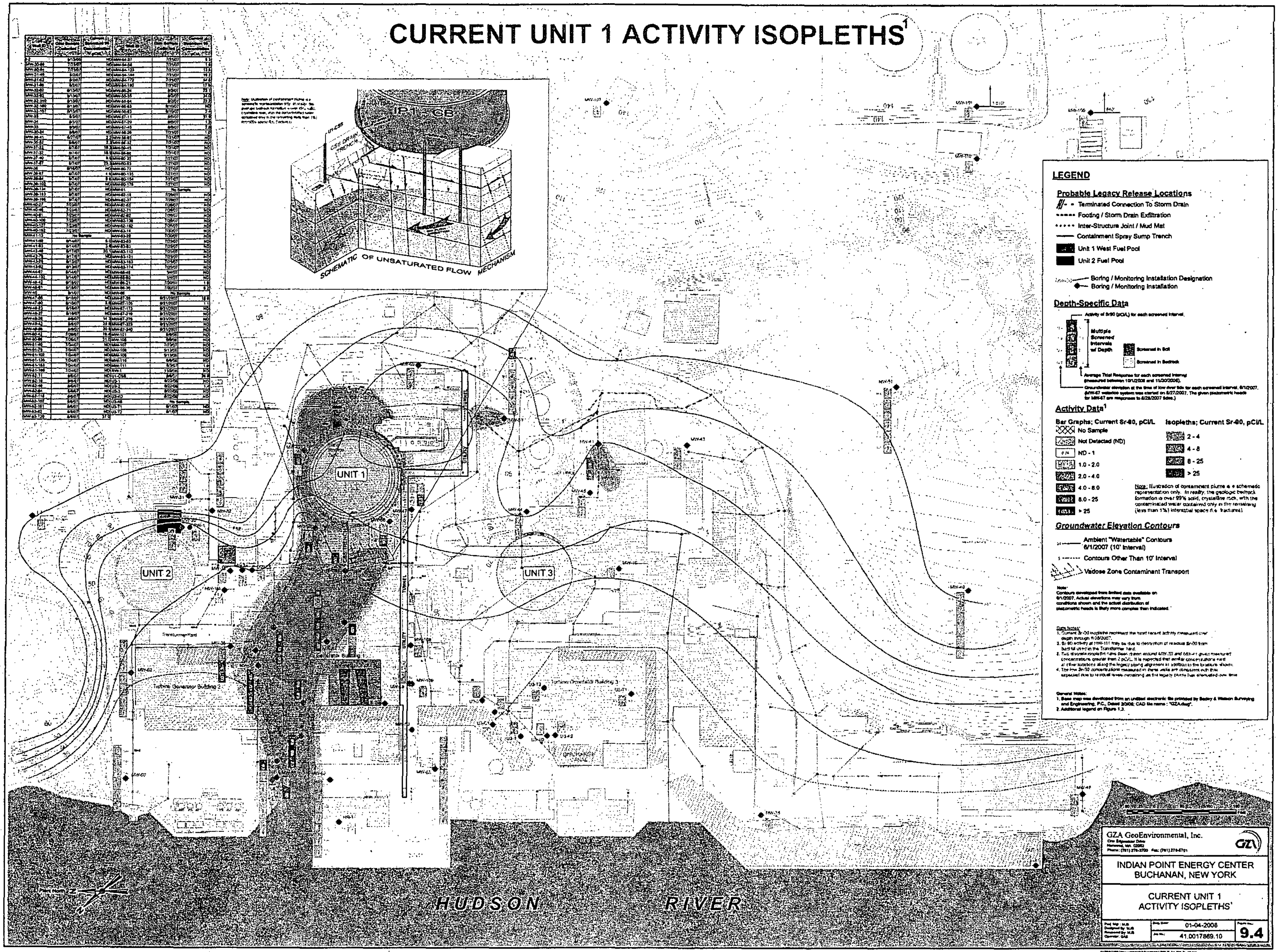
PROJECT NO.
17869.10

FIGURE NO.
9.2

CURRENT UNIT 2 ACTIVITY ISOPLETHS[1]



CURRENT UNIT 1 ACTIVITY ISOPLETHS[1]



Well ID	Date Sample Collected	Current Strontium 90 Concentration (pCi/L)	Well ID	Date Sample Collected	Current Strontium 90 Concentration (pCi/L)
I-2	8/13/06	ND	MW-54-37	7/31/07	8.3
MW-30-69	7/23/07	ND	MW-54-58	7/31/07	1.8
MW-30-84	7/23/07	ND	MW-54-123	7/31/07	13.5
MW-31-49	8/2/07	ND	MW-54-144	7/31/07	16.2
MW-31-63	8/2/07	ND	MW-54-173	7/31/07	14.6
MW-31-85	8/2/07	ND	MW-54-190	7/31/07	17.9
MW-32-62	8/13/07	ND	MW-55-24	8/2/07	23.1
MW-32-85	8/13/07	ND	MW-55-35	8/2/07	34.0
MW-32-149	8/13/07	ND	MW-55-54	8/2/07	22.3
MW-32-190	8/13/07	ND	MW-56-53	8/10/07	ND
MW-32-197	8/13/07	ND	MW-56-83	8/10/07	2.4
MW-33	8/3/07	ND	MW-57-11	8/6/07	17.9
MW-34	8/3/07	ND	MW-57-20	8/6/07	1.2
MW-35	8/3/07	ND	MW-57-45	8/6/07	2.8
MW-36-24	8/8/07	ND	MW-58-26	7/31/07	1.0
MW-36-41	6/27/07	2.2	MW-58-65	7/31/07	ND
MW-36-52	8/8/07	2.3	MW-59-32	7/31/07	ND
MW-37-22	8/7/07	10.3	MW-59-45	7/31/07	ND
MW-37-32	8/7/07	10.9	MW-59-68	7/31/07	ND
MW-37-40	8/7/07	8.9	MW-60-35	7/27/07	ND
MW-37-57	8/7/07	23.3	MW-60-53	7/27/07	ND
MW-38	8/16/07	ND	MW-60-72	7/27/07	ND
MW-39-67	8/7/07	4.9	MW-60-135	7/27/07	ND
MW-39-84	8/7/07	8.9	MW-60-154	7/27/07	ND
MW-39-102	8/7/07	ND	MW-60-176	7/27/07	ND
MW-39-124	8/7/07	ND	MW-61	No Sample	
MW-39-183	8/7/07	ND	MW-62-18	7/26/07	ND
MW-39-195	8/7/07	ND	MW-62-37	7/26/07	ND
MW-40-27	7/23/07	ND	MW-62-53	7/26/07	ND
MW-40-46	7/23/07	ND	MW-62-71	7/26/07	ND
MW-40-81	7/23/07	ND	MW-62-92	7/26/07	ND
MW-40-100	7/23/07	ND	MW-62-138	7/26/07	ND
MW-40-127	7/23/07	ND	MW-62-182	7/26/07	ND
MW-40-162	7/23/07	ND	MW-63-18	7/30/07	ND
MW-41-13	No Sample		MW-63-28	7/30/07	ND
MW-41-40	8/14/07	5.0	MW-63-50	7/25/07	ND
MW-41-63	8/14/07	3.8	MW-63-81	7/25/07	ND
MW-42-49	8/17/07	20.1	MW-63-112	7/25/07	ND
MW-42-78	8/17/07	ND	MW-63-121	7/25/07	ND
MW-43-28	8/13/07	ND	MW-63-163	7/25/07	ND
MW-43-62	8/13/07	ND	MW-63-174	7/25/07	ND
MW-44-67	8/14/07	ND	MW-65-48	9/4/07	ND
MW-44-102	8/14/07	ND	MW-65-80	9/4/07	ND
MW-45-42	8/16/07	ND	MW-66-21	7/30/07	1.8
MW-45-61	8/16/07	ND	MW-66-36	7/30/07	6.2
MW-46	8/1/07	ND	MW-66	No Sample	
MW-47-56	8/10/07	ND	MW-67-39	8/31/2007	18.8
MW-47-80	8/10/07	3.6	MW-67-105	8/31/2007	1.1
MW-48-23	8/16/07	ND	MW-67-173	8/31/2007	ND
MW-48-37	8/16/07	ND	MW-67-219	8/31/2007	ND
MW-49-26	8/6/07	14.3	MW-67-276	8/31/2007	ND
MW-49-42	8/6/07	23.8	MW-67-323	8/31/2007	ND
MW-49-65	8/6/07	20.8	MW-67-340	8/31/2007	ND
MW-50-42	7/26/07	19.4	MW-101	6/6/06	ND
MW-50-66	7/26/07	31.0	MW-105	6/6/06	ND
MW-51-40	7/24/07	ND	MW-107	7/23/07	ND
MW-51-79	7/24/07	ND	MW-108	9/13/06	ND
MW-51-102	7/24/07	ND	MW-109	9/13/06	ND
MW-51-135	7/24/07	ND	MW-110	6/6/06	ND
MW-51-163	7/24/07	ND	MW-111	8/3/07	1.6
MW-51-189	7/24/07	ND	RW-1	11/2/06	ND
MW-52-11	8/6/07	ND	U1-CSS	8/8/07	36.8
MW-52-18	8/6/07	ND	U3-1	8/22/06	ND
MW-52-40	8/6/07	ND	U3-2	8/22/06	1.4
MW-52-84	8/6/07	ND	U3-3	8/22/06	ND
MW-52-118	8/6/07	ND	U3-4D	8/22/06	ND
MW-52-162	8/6/07	ND	U3-4S	No Sample	
MW-52-181	8/6/07	ND	U3-T1	8/1/07	ND
MW-53-82	8/8/07	ND	U3-T2	8/1/07	ND
MW-53-120	8/8/07	37.0			

GZA GeoEnvironmental, Inc.

INDIAN POINT ENERGY CENTER
BUCHANAN, NEW YORK

CURRENT UNIT 1 ACTIVITY ISOPLETHS[1]

01-04-2008

41.0017869.10

9.4

Entergy's Objections to Declaration of Roy A. Jacobson, Jr.
(hereinafter "Jacobson Declaration")

Source: Jacobson Declaration, at ¶ 4

Statement: Thus, the total amount of water used each day for both units under these conditions is approximately 2.5 *billion* gallons. This volume of water is by far the greatest single industrial use of water in New York State and is more than the combined water use of two other major Hudson River power plants (Roseton Generating Station and Bowline Generating Station). Put another way, Indian Point uses all the water in a 450-acre lake (15 foot deep) *each day.*

Objection(s):

- Relevance: The question of whether the Indian Point facility uses a significant amount of water is an irrelevant contention for this NRC proceeding. Entergy has submitted a valid SPDES permit (which explicitly states that it meets all state criteria by incorporating the HRSA) and the HRSA, which is an effective variance from the state criteria. The NRC may not, therefore, consider the water usage of Entergy's cooling water intake systems in determining whether to approve Entergy's application. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

Source: Jacobson Declaration, at ¶ 9

Statement: However, research conducted on the Hudson River and elsewhere has shown that aquatic organisms suffer substantial mortality due to impingement and entrainment in the cooling water systems of power plants.

Objection(s):

- Speculation: Mr. Jacobson sets forth no facts or data showing with any degree of certainty why generalizations about other power plants are applicable to Indian Point. Specifically, Mr. Jacobson does not account for abatement measures such as installation of Ristroph screens or the high survival rate of entrained fish eggs and larvae. *See In re S. Nuclear Operating Co.* (Vogel ESP Site), 52-011-ESP, 65 N.R.C. 237, 254 (2007) (observing that "neither mere speculation nor bare or conclusory assertions, even by an expert, alleging that a matter should be considered will suffice to allow the admission of a proffered contention"); *In re Duke Cogema Stone & Webster* (Savannah River Mixed Oxide Fuel Fabrication Facility), 070-03098-ML, 61 N.R.C. 71, 80 (2005) (noting that "[w]hile the expert's method for forming his opinion need not be generally recognized in the scientific community, the opinion must be based on the 'methods and procedures of science' rather than on 'subjective belief or unsupported speculation'"); *see also Pelletier v. Main Street Textiles*, 470 F.3d 48, 52 (1st Cir. 2006) (concluding plaintiff's expert's opinion was speculative and was based on insufficient facts and data because he had never visited the site of the accident and apparently based his opinions on deposition testimony and preliminary expert reports about the accident); *Bouchard v. N.Y. Archdiocese*, No. 04 Civ. 9978 (CSH), 2006 WL 3025883, at *7 (S.D.N.Y. Oct. 24, 2006) (concluding expert's opinions were "argumentative and conclusory" because they were speculative and not based on sufficient facts and data); *Colt Defense LLC v. Bushmaster Firearms, Inc.*, No. Civ. 4-240-P-S, 2005 WL 2293909, at *4

(D. Me. Sept. 20, 2005) (concluding plaintiff failed to demonstrate the qualifications of its expert, because the expert, who grounded his opinion in an inadequate review of secondary sources, failed to base his expert opinion on sufficient facts or data); *see also* FED. PROC. § 80:225 (June 2006) ("In keeping with the judicially expressed notion that experts' opinions are worthless without data and reasons, FRE 702, as amended in 2000, requires as one of the conditions of the admissibility of expert testimony that the testimony be based upon sufficient facts or data, as opposed to hypotheses and "guesstimations" which have little grounding in actual physical realities. Thus, evidence is subject to exclusion where it is not founded on objective data, studies, or sampling techniques.") (internal citations omitted); *Clough v. Szymanski*, 809 N.Y.S.2d 707, 709 (N.Y. Supr. Ct. 2006) ("[m]ere speculation, including that set forth in an expert's affidavit, is insufficient to raise an issue of fact"). • Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See In re Duke Energy Corporation*, (Catawba Nuclear Station), CLI-04-21, 60 N.R.C. 21, 27 (2004) (a "witness may qualify as an expert by 'knowledge, skill, experience, training, or education' to testify '[i]f scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue'"); *In re Duke Power Co.* (McGuire Nuclear Station), 50-369-OL, 15 N.R.C. 453, 474-75 (1982) (affirming decision finding expert to be unqualified where "his claimed expertise on the subjects at issue rest[ed] mainly on his asserted ability to 'understand and evaluate' matters of a technical nature due to his background of 'academic and practical training' and 'years of reading AEC and NRC documents'").
Source: Jacobson Declaration, at ¶ 10 **Statement:** Impingement occurs when large aquatic organisms, such as fish, are trapped against intake screens that are used to keep debris from clogging the mechanisms of the plant. Screens at most electrical generating stations are constructed of 3/8 inch square wire mesh mounted in frames that are attached to chains and sprockets. Screens of this type are commonly referred to as "traveling screens" and can be rotated continuously or at regular intervals to wash off debris and aquatic organisms. Fish larger than about two inches long are trapped against the screens while smaller organisms pass through the screens. **Objection(s):** • Relevance: Mr. Jacobson's background discussion of impingement is irrelevant – Indian Point uses Ristroph modified screens as opposed to traveling screens. Furthermore, Mr. Jacobson's generalizations about power plants without specifically discussing measures taken at Indian Point are not admissible without further foundation. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted"). • Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 11 **Statement:** Fish trapped on the screens can be killed or otherwise harmed from contacting both the screens and the debris that accumulates on the screens. In addition, as the screens are rotated for cleaning, fish may be trapped out of water for extended periods and deprived of oxygen, which causes them to suffocate. Substantial mortality can occur for some species, such as bay anchovy, even with continuously rotated traveling screens and a functioning system to return fish back to the waterbody. Between 1974 and 1990, when the impingement sampling was conducted at Indian Point, tens of thousands, and even millions, of Bay anchovy were impinged at IP2 and IP3 annually. (Citations omitted). **Objection(s):** • Relevance: Mr. Jacobson's background discussion of impingement is irrelevant – Indian Point uses Ristroph modified screens as opposed to traveling screens. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted"). • Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.
Source: Jacobson Declaration, at ¶ 13 **Statement:** In addition to impingement, aquatic organisms can also become entrained. Entrainment occurs when small aquatic organisms are drawn into and pass through the intake traveling screens with the cooling water. These organisms, including early life stages of fishes, are smaller and generally very delicate. As these tiny life forms move through a facility's cooling system, they are subjected to injury from contacting screens, pump mechanisms, and piping. In addition, they are exposed to significant and sudden changes in water temperature and pressure. The additive effects of these stressors result in the mortality of most entrained fish. In other words, most entrained fish die. **Objection(s):** • Misleading and mischaracterizes evidence: Ample evidence demonstrates that survival rates from both impingement and entrainment are high. Furthermore, the Petitioner's evidence shows only that millions of fish *eggs and larvae* are entrained, not actual fish. Moreover, nothing in the AG's filings justifies equating fish eggs and larvae to grown fish. The Petitioner's argument that large numbers of eggs and larvae entrained equate to large impacts on fish populations is not scientifically valid, as explained in Section 2.2 of the AEI Report. Fish that spawn in estuaries produce a very large numbers of eggs to ensure that sufficient offspring will survive to sustain the populations, even in an environment characterized by the presence of multiple stressors. Declaration of Douglas G. Heimbuch, Ph.D. in Opposition to Riverkeeper Proposed Contention EC-1 and New York Attorney General Contention 31 ¶ 16 (hereinafter "Heimbuch Declaration"). For example, more than 99.99% of striped bass eggs

die from natural causes within 60 days following spawning. Less than one striped bass egg in 100,000 is likely to survive to become a one-year-old fish. Because nearly all of the eggs and larvae entrained at IP2 and IP3 would have died in any case, counts of total numbers entrained reveal nothing meaningful about the potential impact of IP2 and IP3 on fish populations. Riverkeeper's attempt to mislead the NRC with entrainment figures lacking both factual support and explanation is misleading and should be rejected.

- Relevance: Mr. Jacobson's background discussion of impingement is irrelevant – Indian Point uses Ristroph modified screens as opposed to traveling screens. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 15

Statement: The millions of fish that are killed each year from operations at Indian Point represent a significant mortality and a stress on the River's fish community.

Objection(s):

- Misleading and mischaracterizes evidence: Ample evidence demonstrates that survival rates from both impingement and entrainment are high. Furthermore, the Petitioner's evidence shows only that millions of fish *eggs and larvae* are entrained, not actual fish. Moreover, nothing in the Petitioner's filings justifies equating fish eggs and larvae to grown fish. The Petitioner's argument that large numbers of eggs and larvae entrained equate to large impacts on fish populations is not scientifically valid, as explained in Section 2.2 of the AEI Report. Fish that spawn in estuaries produce a very large numbers of eggs to ensure that sufficient offspring will survive to sustain the populations, even in an environment characterized by the presence of multiple stressors. Heimbuch Declaration at 16. For example, more than 99.99% of striped bass eggs die from natural causes within 60 days following spawning. Less than one striped bass egg in 100,000 is likely to survive to become a one-year-old fish. Because nearly all of the eggs and larvae entrained at IP2 and IP3 would have died in any case, counts of total numbers entrained reveal nothing meaningful about the potential impact of IP2 and IP3 on fish populations. Riverkeeper's attempt to mislead the NRC with entrainment figures lacking both factual support and explanation is misleading and should be rejected.

- Relevance: Mr. Jacobson's background discussion of impingement is irrelevant – Indian Point uses Ristroph modified screens as opposed to traveling screens. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 17

Statement: Annual in-plant impingement sampling was conducted at IP2 and IP3 between 1976 and 1990, and the data demonstrate that impingement figures are significant. During that time, impingement ranged between 850,000 to almost 6.5 million fish per year, with an average of 1.18 million fish impinged per year over the last five years of sampling (1986-1990). (citations omitted). Since impingement sampling was conducted more than 10 years ago, the Department asked Entergy, as part of the SPDES permit review process, for more recent estimates of impingement at IP2 and IP3. Consultants working for Entergy (ASA Analysis and Communication) developed an algorithm to adjust the 1986-1990 data to account for estimated changes in fish abundance since that time. This algorithm uses data from annual sampling of the Hudson River (Fall Juvenile Survey) and is based on the ratio of fish abundance when in-plant sampling was conducted (1986-1990) to more recent sampling (1997-2001). Using this algorithm, Entergy estimated that current baseline impingement at IP2 and IP3 is about 350,000 fish/year. (citations omitted). This estimate is one third the number estimated from in-plant sampling in the late 1980s. The decrease presumably is a reflection of declines in the numbers of juvenile and older fish in the waters near Indian Point.

Objection(s):

- Relevance: Mr. Jacobson's background discussion of impingement is irrelevant – Indian Point uses Ristroph modified screens as opposed to traveling screens. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 18

Statement: I have reviewed Entergy's Environmental Report submitted with its license renewal application, and I note that it does not provide any estimate of the actual numbers of fish impinged at either IP2 or IP3. Nowhere in the six pages of analysis regarding impingement are the actual numbers of fish impinged provided. In my view, that is a major omission because it fails to acknowledge a significant and obvious environmental impact of once-through cooling

Objection(s):

- Relevance: Mr. Jacobson's subjective belief that Entergy's lack of quantitative analysis is a "major omission" is irrelevant since such an analysis is not required in this NRC proceeding. *See* 10 C.F.R. 51.53(c)(3)(ii) et. seq.; *see also* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 20

Statement: The number of fish entrained by the two Indian Point plants is astounding, with over 1.2 billion fish eggs and larvae entrained each year. (citations omitted). This estimate was generated based on inplant entrainment sampling conducted by the previous owners of IP2 and IP3 between 1981 and 1987, and only included estimates of entrainment for bay anchovy, striped bass, river herring (*Alosa spp.*), American shad, and white perch. More recently, Entergy's consultants created an algorithm to account for changes in fish populations since in-plant data were collected and estimated that over 1.3 billion fish eggs and larvae were entrained each year. See ASA 2003 Response, p. 16, Exhibit G. This estimate included all the species of the earlier estimate and an additional species, Atlantic tomcod.

Objection(s):

- Misleading and mischaracterizes evidence: Ample evidence demonstrates that survival rates from both impingement and entrainment are high. Furthermore, the Petitioner's evidence shows only that millions of fish *eggs and larvae* are entrained, not actual fish. Moreover, nothing in the AG's filings justifies equating fish eggs and larvae to grown fish. The Petitioner's argument that large numbers of eggs and larvae entrained equate to large impacts on fish populations is not scientifically valid, as explained in Section 2.2 of the AEI Report. Fish that spawn in estuaries produce a very large numbers of eggs to ensure that sufficient offspring will survive to sustain the populations, even in an environment characterized by the presence of multiple stressors. Heimbuch Declaration at 16. For example, more than 99.99% of striped bass eggs die from natural causes within 60 days following spawning. Less than one striped bass egg in 100,000 is likely to survive to become a one-year-old fish. Because nearly all of the eggs and larvae entrained at IP2 and IP3 would have died in any case, counts of total numbers entrained reveal nothing meaningful about the potential impact of IP2 and IP3 on fish populations. Riverkeeper's attempt to mislead the NRC with entrainment figures lacking both factual support and explanation is misleading and should be rejected.

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 21

Statement: Just as Entergy's Environmental Report does not provide any estimate of the numbers of fish impinged at either IP2 or IP3, it also does not provide any estimate of the actual numbers of fish entrained at both plants. Nowhere in the five plus pages of analysis regarding entrainment are the actual numbers of fish eggs and larvae entrained provided. In my opinion, that, too, is a major omission of a significant and obvious environmental impact of once-through cooling.

Objection(s):

- Relevance: Mr. Jacobson's subjective belief that Entergy's lack of quantitative analysis is a "major omission" is irrelevant since such an analysis is not required in this NRC proceeding. *See* 10 C.F.R. 51.53(c)(3)(ii) *et. seq.*; *see also* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 22

Statement: In 1991, Ristroph screens with fish return systems were installed at Indian Point and survival of impinged fish was estimated to be about 70%. While 70% survival is consistent with other estimates of fish protective screens (See Jinks 2003, Exhibit D), this estimate is based on simulation studies conducted off site using a prototype Ristroph system and not the actual systems at use at IP2 or IP3. The actual benefit to fish impinged on the Ristroph screens currently in use at Indian Point has never been measured and could vary from this estimate.

Objection(s):

- Speculation: Mr. Jacobson sets forth no facts or data showing with any degree of certainty why estimates of survival rates due to impingement after installation of Ristroph screens "could vary" from estimates in scientific literature. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 23

Statement: While reductions in the mortality of impinged fish have been achieved at IP2 and IP3, few reductions in entrainment have been realized. In the past several years, Indian Point has taken refueling outages during March when only a small fraction of the total fish eggs and larvae are in the water column. In addition, IP2 and IP3 have reduced cooling water flow between October and early June when river water temperatures are relatively low. However, most of these flow reductions occur when relatively few fish eggs and larvae are in the water column. Consequently, all of these operational measures combined result in only a 30% reduction in entrainment.

Objection(s):

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 24

Statement: Other than closed-cycle cooling, few options are available to substantially reduce entrainment and impingement mortality at Indian Point. Those that have been developed have had varying degrees of success, but few could substantially reduce entrainment and impingement mortality beyond current conditions. For example, behavioral devices that deter fishes from entering the cooling water intake – such as angled screens, intakes with escape passageways, and sonic deterrent systems (none of which are used at Indian Point) – have been effective to varying degrees. However, these systems can only reduce impingement since they are only effective on fish with a well-developed ability to swim (juvenile and adult fish). In addition, angled screens and escape passageways would not likely reduce impingement mortality much beyond the Ristroph screens currently in use at IP2 and IP3, and sonic deterrent systems would provide limited additional benefit for reducing impingement since they are only effective on alewife and herring.

Objection(s):

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 25

Statement: The only technology for substantially reducing entrainment at IP2 and IP3 is closed-cycle cooling. Use of closed-cycle cooling systems at IP2 and IP3 would result in substantial reductions in cooling water use compared to the current once-through cooling system because cooling water would be recirculated and waste heat would be dissipated using cooling towers. Reductions in entrainment and impingement would be substantial using closed-cycle cooling. Entergy's consultants estimated that use of closed-cycle cooling systems at IP2 and IP3 would reduce both impingement and entrainment by about 98%. *See* ASA 2003 Response, pp. 16-17, Exhibit G.

Objection(s):

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Jacobson Declaration, at ¶ 28

Statement: Since in-plant impingement sampling has not been conducted in well over ten years, no accurate estimates exist of the numbers of shortnose sturgeon currently being impinged. However, twenty-eight shortnose sturgeon were collected in impingement samples between 1977 and 1990. Since impingement collections were only conducted during a small fraction of that period, the number of sturgeon that were actually impinged at IP2 and IP3 is likely much greater. Indeed, the NMFS estimated the number of shortnose sturgeon impinged at IP2 and IP3 to be 63 from 1972-1998.

Objection(s):

- Speculation: Mr. Jacobson sets forth no facts or data showing with any degree of certainty why "the number of sturgeon that were actually impinged at IP2 and IP3 is likely much greater" than estimates. *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Mr. Jacobson is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Entergy's Objections to Declaration of David W. Dilks
(hereinafter "Dilks Declaration")

Source: Dilks Declaration, at ¶ 2 **Statement:** I reviewed numerous documents to determine whether the substantial thermal discharges from the Indian Point Nuclear Generating Facility meet New York State regulatory requirements for those discharges. **Objection(s):** • Relevance: Dr. Dilks's investigation of "the substantial thermal discharges from the Indian Point Nuclear Generating Facility meet New York State regulatory requirements" is irrelevant because a thermal analysis is unnecessary pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B); *see also* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted"). • Entergy operates under a current NYSDEC-issued SPDES permit, in which the NYSDEC explicitly states that Indian Point meets the New York State Criteria Governing Thermal Discharges (1987 SPDES Permit, at 11).
Source: Dilks Declaration, at ¶ 3 **Statement:** All of the technical analyses conducted related to the thermal discharges from the two Indian Point nuclear power plants clearly indicate that the discharges do not meet New York State water quality criteria. The operator of the Indian Point Nuclear Generating Facility has failed to demonstrate that it meets the New York State water quality standard for thermal discharges because the analyses that the operator uses in its demonstration that the discharges "will assure the presence of a balanced and indigenous population of aquatic organisms" are laced with significant uncertainties, which relate to both the modeling conducted to estimate the temperature increases in the Hudson River and the biological assessment of the impacts of those temperature increases. The operator of Indian Point is using outmoded technology with its once-through cooling system, and closed-cycle cooling water intake structures would mitigate substantially the impacts from the thermal discharges at Indian Point. **Objection(s):** • Entergy operates under a current NYSDEC-issued SPDES permit, which explicitly states that it meets the New York State Criteria Governing Thermal Discharges (1987 SPDES Permit, at 11). • Whether Indian Point meets New York State water quality criteria is irrelevant because a thermal analysis is unnecessary pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B). Compliance with 10 C.F.R. §51.53(c)(3)(ii)(B) renders contentions regarding cooling towers moot and, therefore, immaterial. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable

evidence which is not unduly repetitious will be admitted").

- Dr. Dilks is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See In re Duke Energy Corporation*, (Catawba Nuclear Station), CLI-04-21, 60 N.R.C. 21, 27 (2004) (a "witness may qualify as an expert by 'knowledge, skill, experience, training, or education' to testify '[i]f scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue'"); *In re Duke Power Co.* (McGuire Nuclear Station), 50-369-OL, 15 N.R.C. 453, 474-75 (1982) (affirming decision finding expert to be unqualified where "his claimed expertise on the subjects at issue rest[ed] mainly on his asserted ability to 'understand and evaluate' matters of a technical nature due to his background of 'academic and practical training' and 'years of reading AEC and NRC documents'").

Source: Dilks Declaration, at ¶ 6

Statement: IP2 and IP3 draw enormous amounts of water – 2.5 *billion* gallons each day. Nearly all of this water is eventually discharged into the Hudson River, but at a much higher temperature because it has been used to cool the plants' operations. Collectively, the maximum permitted thermal discharge for IP2 and IP3 is for trillions of BTUs of total heat per year. Based on my review of the EPA Permit Compliance System, these BTU limits are hundreds of times larger than most power facilities.

Objection(s):

- Speculation: Dr. Dilks sets forth insufficient facts and data to support his statement that Indian Point's "BTU limits are hundreds of times larger than most power facilities." *See In re S. Nuclear Operating Co.* (Vogel ESP Site), 52-011-ESP, 65 N.R.C. 237, 254 (2007) (observing that "neither mere speculation nor bare or conclusory assertions, even by an expert, alleging that a matter should be considered will suffice to allow the admission of a proffered contention"); *In re Duke Cogema Stone & Webster* (Savannah River Mixed Oxide Fuel Fabrication Facility), 070-03098-ML, 61 N.R.C. 71, 80 (2005) (noting that "[w]hile the expert's method for forming his opinion need not be generally recognized in the scientific community, the opinion must be based on the 'methods and procedures of science' rather than on 'subjective belief or unsupported speculation'"); *see also Pelletier v. Main Street Textiles*, 470 F.3d 48, 52 (1st Cir. 2006) (concluding plaintiff's expert's opinion was speculative and was based on insufficient facts and data because he had never visited the site of the accident and apparently based his opinions on deposition testimony and preliminary expert reports about the accident); *Bouchard v. N.Y. Archdiocese*, No. 04 Civ. 9978 (CSH), 2006 WL 3025883, at *7 (S.D.N.Y. Oct. 24, 2006) (concluding expert's opinions were "argumentative and conclusory" because they were speculative and not based on sufficient facts and data); *Colt Defense LLC v. Bushmaster Firearms, Inc.*, No. Civ. 4-240-P-S, 2005 WL 2293909, at *4 (D. Me. Sept. 20, 2005) (concluding plaintiff failed to demonstrate the qualifications of its expert, because the expert, who grounded his opinion in an inadequate review of secondary sources, failed to base his expert opinion on sufficient facts or data); *see also* FED. PROC. § 80:225 (June 2006) ("In keeping with the judicially expressed notion that experts' opinions are worthless without data and reasons, FRE 702, as amended in 2000, requires as one of the conditions of the admissibility of expert testimony that the testimony be based upon sufficient facts or data, as opposed to hypotheses and "guesstimations" which have little grounding in actual physical realities. Thus, evidence is subject to exclusion where it is not founded on objective data, studies, or sampling techniques.") (internal citations omitted); *Clough v. Szymanski*, 809 N.Y.S.2d 707, 709 (N.Y. Supr. Ct. 2006) ("[m]ere speculation, including that set forth in an expert's affidavit, is insufficient to raise an issue of fact").

Source: Dilks Declaration, at ¶ 7

Statement: The discharge of this large amount of waste heat can have drastic physical and biological consequences.

Objection(s):

- Speculation: Dr. Dilks sets forth no facts or data showing with particularity that the Indian Point thermal discharges "can have drastic physical and biological consequences" or that the thermal discharges from Indian Point are a "large amount of waste heat." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Dilks Declaration, at ¶ 7

Statement: The heated water, when initially discharged, is poorly diluted and is contained in what is called a thermal plume.

Objection(s):

- Speculation: Dr. Dilks provides no facts or data to support his assertion that the discharge is "poorly diluted." *See In re Southern Nuclear Operating Co.*, No. 52-011-ESP, 65 N.R.C. at 253; *In re Duke Cogema Stone & Webster*, 61 N.R.C. at 80; *see also See, e.g., Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Dilks Declaration, at ¶ 7

Statement: Furthermore, for large discharges such as IP2 and IP3, temperatures are noticeably raised outside of the discharge plume, because the quantity of heat released is greater than the capacity of the river to fully dilute it.

Objection(s):

- Speculation: Dr. Dilks provides no facts or data to support his assertion that the discharge is "temperatures are noticeably raised outside of the discharge plume, because the quantity of heat released is greater than the capacity of the river to fully dilute it." *See In re Southern Nuclear Operating Co.*, No. 52-011-ESP, 65 N.R.C. at 253; *In re Duke Cogema Stone & Webster*, 61 N.R.C. at 80; *see also See, e.g., Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Dilks Declaration, at ¶ 8 **Statement:** Increases in water temperatures have been shown to have numerous biological consequences. These consequences can be divided into the following categories: • Lethal effects: High or low temperatures, which kill an organism within a finite time. Low temperature lethality can happen when plant operations shut down temporarily during cold water periods, exposing warm water acclimated fish to cod water. • Controlling effects: Non-lethal temperatures which affect biological processes such as growth or reproduction. • Directive effects: Changes in behavioral responses or migrations. • Indirect effects: Changes in some other factor (e.g., oxygen), which in turn affect aquatic life. **Objection(s):** • Dr. Dilks is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.
Source: Dilks Declaration, at ¶ 9 **Statement:** The final outcome of the HRSA studies has now demonstrated non-compliance with thermal criteria. **Objection(s):** • Misleading and mischaracterizes the significance of the results of the HRSA studies: Dr. Dilks neglects to mention that the hydrothermal modeling performed for the 1999 DEIS was undertaken at the direction of NYSDEC, which set the extreme case conditions to be modeled. Declaration of Charles V. Beckers, Ph.D. in Opposition to Riverkeeper Proposed Contention EC-1 and New York Attorney General Contention 30, Ex. 2 at 1-2 (hereinafter "Beckers Declaration"). The conditions modeled were wholly unrealistic and the results represent conditions that can never occur in the River, because the tidal and current conditions specified never occur. *Id.* at 2. NYSDEC intended the hydrothermal modeling results presented in the 1999 DEIS to overstate the effects of the discharges modeled on the Hudson River, to be protective of the resource. *Id.* at 3.
Source: Dilks Declaration, at ¶ 10 **Statement:** As explained more fully in the Declaration of William G. Little, in November 2003, the Department issued a draft SPDES permit for IP2 and IP3 that included provisions for the eventual construction of closed-cycle cooling. The Department also provided that Entergy could provide a comparable alternative to closed-cycle cooling (Condition 28 c). **Objection(s):** • Entergy objects to Dr. Dilks' characterization of the draft SPDES permit, which speaks for

LIBA/1860558.1

itself.

Source: Dilks Declaration, at ¶ 16

Statement: As demonstrated below, based on my review of the record documents in the SPDES renewal proceeding and the Environmental Report submitted by Entergy in the Nuclear Regulatory Commission (NRC) license renewal proceeding, I conclude that the thermal discharges from IP2 and IP3 do not meet the special water quality criteria for estuaries in 6 NYCRR sections 704.2(5)(ii), (iii), and (iv).

Objection(s):

- Relevance: The question of whether the thermal discharges from IP2 and IP3 meet the New York State Criteria for Thermal Discharges is an irrelevant contention for this NRC Proceeding. Pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B), Entergy has submitted a valid SPDES permit (which explicitly states that it meets all state criteria by incorporating the HRSA) and the HRSA, which is an effective variance from the state criteria. The NRC may not, therefore, conduct a thermal analysis to determine Entergy's compliance with 6 NYCRR Part 704. *See* 10 C.F.R. 51.53(c)(3)(ii) *et. seq.*; *see also* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Entergy operates under a current NYSDEC-issued SPDES permit, which explicitly states that it meets the New York State Criteria Governing Thermal Discharges (1987 SPDES Permit, at 11).

Source: Dilks Declaration, at ¶ 17

Statement: The Environmental Report that Entergy filed with its license renewal application to the NRC does not adequately, or even accurately, address the impacts from the thermal discharges from IP2 and IP3. Entergy relies on the 1999 DEIS that it submitted in the NYS SPDES permit proceeding. In the DEIS, Entergy claimed that "[t]he surface orientation of the plume allows a zone of passage in the lower portions of the water column, the preferred habitat for many of the indigenous species." DEIS, p. VI-29. As discussed in detail below, this claim focuses only on the plume itself and does not adequately consider the temperature impacts on bottom waters that occur outside of the plume.

Objection(s):

- Irrelevant because a thermal analysis is unnecessary pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B). *See* 10 C.F.R. 51.53(c)(3)(ii) *et. seq.*; *see also* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Compliance with 10 C.F.R. §51.53(c)(3)(ii)(B) renders contentions regarding Entergy's hydrothermal modeling and Environmental Report content moot and, therefore, immaterial. *See* 10 C.F.R. 51.53(c)(3)(ii) et. seq.; *see also* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

Source: Dilks Declaration, at ¶ 18

Statement: The modeling conducted for the environmental review attendant to the SPDES permit renewal – i.e., the 1999 DEIS, which was cited by the DEC in the 2003 Final Environmental Impact Statement (FEIS) - clearly indicates that the discharge violates these thermal criteria under certain river flow conditions. This is true both for Indian Point discharges alone, and when considered along with all thermal discharges in the region.

Objection(s):

- Compliance with 10 C.F.R. §51.53(c)(3)(ii)(B) renders contentions regarding Entergy's hydrothermal modeling moot and, therefore, immaterial. *See* 10 C.F.R. 51.53(c)(3)(ii) *et. seq.*; *see also* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Misleading and mischaracterizes the significance of the results of the HRSA studies: Dr. Dilks neglects to mention that the hydrothermal modeling performed for the 1999 DEIS was undertaken at the direction of DEC, which set the extreme case conditions to be modeled. Beckers Declaration, Ex. 2 at 1-2. The conditions modeled were wholly unrealistic and the results represent conditions that can never occur in the River, because the tidal and current conditions specified never occur. *Id.* at 2. NYSDEC intended the hydrothermal modeling results presented in the 1999 DEIS to overstate the effects of the discharges modeled on the Hudson River, to be protective of the resource. *Id.* at 3.

- Dr. Dilks is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Dilks Declaration, at ¶ 19

Statement: Specifically, operation of the Indian Point facilities alone is predicted to violate 6 NYCRR section 704.2(5)(ii). Where the criteria require that a minimum of one-third of the surface shall not be raised more than four Fahrenheit degrees, model results indicate that 100% of the surface width will be raised by more than four degrees (i.e., 0% of the surface width will not be raised) during certain tidal conditions.

Objection(s):

- Relevance: The question of whether the thermal discharges from IP2 and IP3 meet the New York State Criteria for Thermal Discharges is an irrelevant contention for this NRC Proceeding. Pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B), Entergy has submitted a valid SPDES permit (which explicitly states that it meets all state criteria by incorporating the HRSA) and the HRSA, which is an effective variance from the state criteria. The NRC may not, therefore, conduct a thermal analysis to determine Entergy's compliance with 6 NYCRR Part 704. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Entergy operates under a current NYSDEC-issued SPDES permit, which explicitly states that it meets the New York State Criteria Governing Thermal Discharges (1987 SPDES Permit, at 11).

- Misleading and mischaracterizes the significance of the results of the HRSA studies: Dr. Dilks neglects to mention that the hydrothermal modeling performed for the 1999 DEIS was undertaken at the direction of DEC, which set the extreme case conditions to be modeled. Beckers Declaration, Ex. 2 at 1-2. The conditions modeled were wholly unrealistic and the results represent conditions that can never occur in the River, because the tidal and current conditions specified never occur. *Id.* at 2. NYSDEC intended the hydrothermal modeling results presented in the 1999 DEIS to overstate the effects of the discharges modeled on the Hudson River, to be protective of the resource. *Id.* at 3.

Source: Dilks Declaration, at ¶ 20

Statement: When operation of the Indian Point plant is considered in conjunction with other thermal discharges, the extent of criteria violation increases substantially. In this multiple discharger case, the "cross-sectional area" component of the criteria is also violated (6 NYCRR, § 704.2(5)(iv)), and the number of months that the "surface" component of the criteria is violated increases as well (6 NYCRR § 704.2(5)(iii)).

Objection(s):

- Relevance: The question of whether the thermal discharges from IP2 and IP3 meet the New York State Criteria for Thermal Discharges is an irrelevant contention for this NRC Proceeding. Pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B), Entergy has submitted a valid SPDES permit (which explicitly states that it meets all state criteria by incorporating the HRSA) and the HRSA, which is an effective variance from the state criteria. The NRC may not, therefore, conduct a thermal analysis to determine Entergy's compliance with 6 NYCRR Part 704. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Entergy operates under a current NYSDEC-issued SPDES permit, which explicitly states that it meets the New York State Criteria Governing Thermal Discharges (1987 SPDES Permit, at 11).

- Misleading and mischaracterizes the significance of the results of the HRSA studies: Dr. Dilks neglects to mention that the hydrothermal modeling performed for the 1999 DEIS was undertaken at the direction of DEC, which set the extreme case conditions to be modeled. Beckers Declaration, Ex. 2 at 1-2. The conditions modeled were wholly unrealistic and the results represent conditions that can never occur in the River, because the tidal and current conditions specified never occur. *Id.* at 2. NYSDEC intended the hydrothermal modeling results presented in the 1999 DEIS to overstate the effects of the discharges modeled on the Hudson River, to be protective of the resource. *Id.* at 3.

Source: Dilks Declaration, at ¶ 21

Statement: I have also concluded that while the water quality criteria are being violated by the Indian Point thermal discharges, either alone or in conjunction with other thermal discharges, the applicant's modeling contains many uncertainties and flaws. This means that the extent of the thermal impacts from Indian Point could be much greater than predicted in the DEIS.

Objection(s):

- Speculation: Dr. Dilks sets forth no facts or data showing with particularity that "the extent of the thermal impacts from Indian Point could be much greater than predicted in the DEIS." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Misleading and mischaracterizes the significance of the results of the HRSA studies: Dr. Dilks neglects to mention that the hydrothermal modeling performed for the 1999 DEIS was undertaken at the direction of DEC, which set the extreme case conditions to be modeled. Beckers Declaration, Ex. 2 at 1-2. The conditions modeled were wholly unrealistic and the results represent conditions that can never occur in the River, because the tidal and current conditions specified never occur. *Id.* at 2. NYSDEC intended the hydrothermal modeling results presented in the 1999 DEIS to overstate the effects of the discharges modeled on the Hudson River, to be protective of the resource. *Id.* at 3.

- Relevance: The question of whether the thermal discharges from IP2 and IP3 meet the New York State Criteria for Thermal Discharges is an irrelevant contention for this NRC Proceeding. Pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B), Entergy has submitted a valid SPDES permit (which explicitly states that it meets all state criteria by incorporating the HRSA) and the HRSA, which is an effective variance from the state criteria. The NRC may not, therefore, conduct a thermal analysis to determine Entergy's compliance with 6 NYCRR Part 704. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Entergy operates under a current NYSDEC-issued SPDES permit, which explicitly states that it meets the New York State Criteria Governing Thermal Discharges (1987 SPDES Permit, at 11).

Source: Dilks Declaration, at ¶ 21

Statement: To the extent that real world conditions differ from these idealized conditions, CORMIX results may be accurate or may be completely inaccurate.

Objection(s):

- Speculation: Dr. Dilks sets forth no facts or data showing with particularity that the "CORMIX results may be accurate or may be completely inaccurate." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Misleading and mischaracterizes the significance of the results of the DEIS hydrothermal modeling: Dr. Dilks neglects to mention that the hydrothermal modeling performed for the 1999 DEIS was undertaken at the direction of DEC, which set the extreme case conditions to be modeled. Beckers Declaration, Ex. 2 at 1-2. The conditions modeled were wholly unrealistic and the results represent conditions that can never occur in the River, because the tidal and current conditions specified never occur. *Id.* at 2. NYSDEC intended the hydrothermal modeling results presented in the 1999 DEIS to overstate the effects of the discharges modeled on the Hudson River, to be protective of the resource. *Id.* at. 3. In addition, the CORMIX near-field model remains today the preferred model for analysis of discharge plumes, as recognized by the United States Environmental Protection Agency. CORMIX is unique in that it does not require calibration. *Id.*
- Compliance with 10 C.F.R. §51.53(c)(3)(ii)(B) renders contentions regarding Entergy's hydrothermal modeling moot and, therefore, immaterial. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

Source: Dilks Declaration, at ¶ 28

Statement: The "temperature balance model" used to merge the results of CORMIX and FFTM models is very simplistic and is based on assumptions that are violated for this application.

Objection(s):
- Entergy objects to Dr. Dilks' characterizations of the assumptions of the CORMIX and FFTM models, which speak for themselves.
- The CORMIX near-field model remains today the preferred model for analysis of discharge plumes, as recognized by the United States Environmental Protection Agency. CORMIX is unique in that it does not require calibration. Beckers Declaration, Ex. 2 at 3.

Source: Dilks Declaration, at ¶ 30

Statement: In this regard, comments on the DEIS, which were incorporated in the FEIS, indicated that temperatures in the river may have increased since the time of the DEIS analysis. If this is true, the expected maximum temperatures in the river (although not the extent of the 4T plume) may be greater than predicted in the DEIS. As stated above, the use of steady state conditions in the model does not necessarily provide upper bound predictions for plume extent, counter to the supporting argument in the DEIS.

Objection(s):
- Speculation: Dr. Dilks sets forth insufficient facts and data to support his statement that the "temperatures in the river may have increased since the time of the DEIS analysis." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

Source: Dilks Declaration, at ¶ 31

Statement: Many of the limitations inherent to the DEIS modeling were driven by computational and data limitations that existed at the time of the analysis. Three-dimensional far field models now exist that would minimize many of the limitations of the models that were discussed above. Remote sensing provides the capability to collect large amounts of surface temperature data, and could be used to determine validity of the existing models or any other models applied in the future. **Objection(s):** • Compliance with 10 C.F.R. §51.53(c)(3)(ii)(B) renders contentions regarding Entergy's hydrothermal modeling moot and, therefore, immaterial. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").
Source: Dilks Declaration, at ¶ 32 **Statement:** Given that the Indian Point thermal discharges exceed the 6 NYCRR Part 704 thermal criteria, it is next necessary to determine whether the Indian Point discharge meets the thermal discharge requirements of Section 316(a) of the Clean Water Act. **Objection(s):** • Relevance: The question of whether the thermal discharges from IP2 and IP3 meet the New York State Criteria for Thermal Discharges is an irrelevant contention for this NRC Proceeding. Pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B), Entergy has submitted a valid SPDES permit (which explicitly states that it meets all state criteria by incorporating the HRSA) and the HRSA, which is an effective variance from the state criteria. The NRC may not, therefore, conduct a thermal analysis to determine Entergy's compliance with 6 NYCRR Part 704. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted"). • Entergy operates under a current NYSDEC-issued SPDES permit, which explicitly states that it meets the New York State Criteria Governing Thermal Discharges (1987 SPDES Permit, at 11).
Source: Dilks Declaration, at ¶ ¶ 33-38 **Statement:** Based on my critical review of the biological analysis, I can point out specific weaknesses or oversights in the analysis that was used to support the applicant's original assessment[.] **Objection(s):** • Irrelevant because a biological analysis is unnecessary pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B). *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted"). • Dr. Dilks is not qualified to discuss the environmental effects of once-through cooling since he lacks the educational background and technical experience necessary to opine on such

matters. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Dilks Declaration, at ¶ 39

Statement: The discharges have not and do not currently meet New York State's water quality criteria.

Objection(s):

- Relevance: The question of whether the thermal discharges from IP2 and IP3 meet the New York State Criteria for Thermal Discharges is an irrelevant contention for this NRC Proceeding. Pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B), Entergy has submitted a valid SPDES permit (which explicitly states that it meets all state criteria by incorporating the HRSA) and the HRSA, which is an effective variance from the state criteria. The NRC may not, therefore, conduct a thermal analysis to determine Entergy's compliance with 6 NYCRR Part 704. *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").

- Entergy operates under a current NYSDEC-issued SPDES permit, which explicitly states that it meets the New York State Criteria Governing Thermal Discharges (1987 SPDES Permit, at 11).

Entergy's Objections to Declaration of William Little (hereinafter "Little Declaration")

Source: Little Declaration, at ¶ 2 **Statement**: I submit this declaration to provide the history of NPDES and SPDES permitting of Indian Point and of the significant adverse impacts that arise from the technologically outmoded once-through cooling system that Indian Point uses. **Objection(s):** • Mr. Little's statement is irrelevant because an analysis of adverse impacts arising from Entergy's use of a once-through cooling system is unnecessary pursuant to 10 C.F.R. §51.53(c)(3)(ii)(B). *See* 10 C.F.R. § 2.337(a) ("only relevant, material, and reliable evidence which is not unduly repetitious will be admitted").
Source: Little Declaration, at ¶ 7 **Statement:** Furthermore, it was understood that construction of a closed-cycle cooling system would eliminate the environmental injuries to aquatic biota associated with thermal discharges and impingement and entrainment. **Objection(s):** • Speculation: Mr. Little sets forth insufficient facts and data to support his statement that the NRC "understood that construction of a closed-cycle cooling system would eliminate the environmental injuries to aquatic biota associated with thermal discharges and impingement and entrainment." *See In re S. Nuclear Operating Co.* (Vogel ESP Site), 52-011-ESP, 65 N.R.C. 237, 254 (2007) (observing that "neither mere speculation nor bare or conclusory assertions, even by an expert, alleging that a matter should be considered will suffice to allow the admission of a proffered contention"); *In re Duke Cogema Stone & Webster* (Savannah River Mixed Oxide Fuel Fabrication Facility), 070-03098-ML, 61 N.R.C. 71, 80 (2005) (noting that "[w]hile the expert's method for forming his opinion need not be generally recognized in the scientific community, the opinion must be based on the 'methods and procedures of science' rather than on 'subjective belief or unsupported speculation'"); *see also Pelletier v. Main Street Textiles*, 470 F.3d 48, 52 (1st Cir. 2006) (concluding plaintiff's expert's opinion was speculative and was based on insufficient facts and data because he had never visited the site of the accident and apparently based his opinions on deposition testimony and preliminary expert reports about the accident); *Bouchard v. N.Y. Archdiocese*, No. 04 Civ. 9978 (CSH), 2006 WL 3025883, at *7 (S.D.N.Y. Oct. 24, 2006) (concluding expert's opinions were "argumentative and conclusory" because they were speculative and not based on sufficient facts and data); *Colt Defense LLC v. Bushmaster Firearms, Inc.*, No. Civ. 4-240-P-S, 2005 WL 2293909, at *4 (D. Me. Sept. 20, 2005) (concluding plaintiff failed to demonstrate the qualifications of its expert, because the expert, who grounded his opinion in an inadequate review of secondary sources, failed to base his expert opinion on sufficient facts or data); *see also* FED. PROC. § 80:225 (June 2006) ("In keeping with the judicially expressed notion that experts' opinions are worthless without data and reasons, FRE 702, as amended in 2000, requires as one of the conditions of the admissibility of expert testimony

that the testimony be based upon sufficient facts or data, as opposed to hypotheses and "guesstimations" which have little grounding in actual physical realities. Thus, evidence is subject to exclusion where it is not founded on objective data, studies, or sampling techniques.") (internal citations omitted); *Clough v. Szymanski*, 809 N.Y.S.2d 707, 709 (N.Y. Supr. Ct. 2006) ("[m]ere speculation, including that set forth in an expert's affidavit, is insufficient to raise an issue of fact").

Source: Little Declaration, at ¶ 11

Statement: The Indian Point plants have always operated with once-through cooling technology, and that technology has always posed a problem for the Hudson River environment. Once-through cooling technology withdraws water directly from the Hudson River to cool the secondary cooling system and then discharges that heated water into the Hudson Diver. Once-through cooling poses three main environmental issues: impingement, entrainment, and thermal discharges. These issues are explained more fully in the accompanying Declarations of Roy Jacobson and David Dilks, which accompany the State's Petition.

Objection(s):

- Speculation: Mr. Little sets forth insufficient facts and data to support his statement that once-through cooling "has always posed a problem for the Hudson River environment." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- As an attorney with no apparent training in fisheries biology or hydrothermal modeling, Mr. Little lacks the requisite qualifications to testify to the environmental issues potentially caused by the different types of cooling systems employed by facilities. *See In re Duke Energy Corporation*, (Catawba Nuclear Station), CLI-04-21, 60 N.R.C. 21, 27 (2004) (a "witness may qualify as an expert by 'knowledge, skill, experience, training, or education' to testify '[i]f scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue'"); *In re Duke Power Co.* (McGuire Nuclear Station), 50-369-OL, 15 N.R.C. 453, 474-75 (1982) (affirming decision finding expert to be unqualified where "his claimed expertise on the subjects at issue rest[ed] mainly on his asserted ability to 'understand and evaluate' matters of a technical nature due to his background of 'academic and practical training' and 'years of reading AEC and NRC documents'").

- Since he is unqualified to opine on environmental issues, Mr. Little similarly cannot rely on the declarations of Dr. Dilks and Mr. Jacobson without running afoul of expert witness qualification requirements. *Plourde v. Gladstone*, 190 F.Supp.2d 708, 720-21 (D. Vt. 2002) (expert's lack of qualifications in requisite subject area invalidated attempts to rely on opinions of properly qualified experts); *see also Polythane Sys., Inc. v. Marina Ventures Int'l, Ltd.*, 993 F.2d 1201, 1201-08 (5th Cir. 1993) (one expert may not put in evidence the opinion of a nontestifying expert without running afoul of the hearsay rule unless used to demonstrate the basis for the testifying expert's opinion, not to establish the truth of the nontestifying expert's opinion). It is also "unduly repetitious," *see* 10 C.F.R. § 2.337 (a), for

Mr. Little to adopt the testimony of Mr. Jacobson and Dr. Dilks, who filed their own declarations.

Source: Little Declaration, at ¶ 12

Statement: Briefly stated, impingement occurs when the massive flow of intake water "impinges" or traps larger aquatic organisms, such as fish, against grills or screen. Entrainment occurs when the microscopic aquatic organisms pass through the grills and screens and are sucked into the plant operations. In addition, "thermal discharges" refers to the hated water that is discharged into the Hudson River after cooling the super-heated water generated by plant operations. These thermal discharges also pose problems for aquatic life in the Hudson River ecosystem.

Objection(s):

- As an attorney with no apparent training in fisheries biology or hydrothermal modeling, Mr. Little lacks the requisite qualifications to testify to the environmental issues potentially caused by the different types of cooling systems employed by facilities. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Little Declaration, at ¶ 30

Statement: Entergy's Environmental Report thus errs by placing any reliance on and directing the NRC's attention toward the analyses contained in the DEIS (to the exclusion of the FEIS). The FEIS superseded the DEIS entirely and is the appropriate final record of environmental analyses and findings.

Objection(s):

- Mr. Little mischaracterizes the FEIS, which expressly states that "[t]he fundamental underlying data and studies are contained in the 1999 DEIS, which is incorporated as part of this FEIS." FEIS, at ii. The NRC may not, therefore, completely ignore the DEIS, as the Petitioner would suggest.

- The Supreme Court of the State of New York (Albany), has determined that the FEIS is not a final order. *In re Entergy Nuclear Indian Point 2 & 3, LLC et al.*, No. 6747/03, at 6-7 (Mar. 11, 2004) ("FEIS on its face indicates that considerably more environmental review is necessary and is specifically contemplated.").

- In 2004, Mr. Little filed an affirmation in the SPDES proceeding stating that "[p]iecemeal review of components of the DEC permit application review process, such as the FEIS, does not present . . . a fully-formed record . . . . This creates uncertainty for the Department, the applicant, and those who would oppose a particular project." This suggests that taken alone, the FEIS is not, by Mr. Little's own admission, "the appropriate final record of environmental analyses and findings." Little Affirmation, No. 6747/03, at ¶ 6 (N.Y. Supr. Ct. Jan. 20, 2004).

Source: Little Declaration, at ¶ 31

Statement: In other words, the 1999 DEIS would only have preserved the operational *status quo* at the three Hudson River power plants, allowing continued significant levels of fish mortalities in the River, whereas the Department's FEIS determined that impacts to fish through entrainment and impingement were continuous significant adverse impacts warranting the installation of closed-cycle cooling.

Objection(s):

- Speculation: Mr. Little provides no facts or data to support his assertion that the "operational *status quo* at the three Hudson River power plants" "allow[ed] continued significant levels of fish mortalities in the River." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709.

- Mr. Little mischaracterizes the FEIS, which expressly states that "[t]he fundamental underlying data and studies are contained in the 1999 DEIS, which is incorporated as part of this FEIS." FEIS, at ii. The NRC may not, therefore, completely ignore the DEIS, as the Petitioner would suggest.

- As an attorney with no apparent training in fisheries biology or hydrothermal modeling, Mr. Little lacks the requisite qualifications to testify to the environmental issues potentially caused by the different types of cooling systems employed by facilities. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.

Source: Little Declaration, at ¶ 37

Statement: However, the generators' own statements in the 1999 DEIS pointed out that IP2 and IP3 did not meet the State's §704.2 water quality criteria as to all requirements. The DEIS states that lateral (across the River) and cross-sectional top-to-bottom of the water column) thermal criteria would be exceeded in the vicinity of Indian Point during some months and during full load operating conditions. The effect is that aquatic species could be blocked from migrating through this part of the Hudson River during certain time periods or seasons.

Objection(s):

- Misleading and mischaracterizes the significance of the results of the hydrothermal modeling results presented in the 1999 DEIS. Mr. Little neglects to mention that the hydrothermal modeling performed for the 1999 DEIS was undertaken at the direction of DEC, which set the extreme case conditions to be modeled. Declaration of Charles V. Beckers, Ph.D. in Opposition to Riverkeeper Proposed Contention EC-1 and New York Attorney General Contention 30, Ex. 2 at 1-2 (hereinafter "Beckers Declaration"). The conditions modeled were wholly unrealistic and the results represent conditions that can never occur in the River, because the tidal and current conditions specified never occur. *Id.* at 2. NYSDEC intended the hydrothermal modeling results presented in the 1999 DEIS to overstate the effects of the discharges modeled on the Hudson River, to be protective of the resource. *Id.* at 3.

- Speculation: Mr. Little sets forth no facts or data showing with particularity that "aquatic

species could be blocked from migrating through this part of the Hudson River during certain time periods or seasons." *See* Vogel, 52-011-ESP, 65 N.R.C. at 253; Savannah River, 070-03098-ML, 61 N.R.C. at 80; *see also Pelletier*, 470 F.3d at 52; *Bouchard*, 2006 WL 3025883, at *7; *Colt Defense LLC*, 2005 WL 2293909, at *4; *Clough*, 809 N.Y.S.2d at 709. • As an attorney with no apparent training in fisheries biology or hydrothermal modeling, Mr. Little lacks the requisite qualifications to testify to the environmental issues potentially caused by the different types of cooling systems employed by facilities. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.
Source: Little Declaration, at ¶ 38 **Statement:** Closed-cycle cooling would drastically reduce thermal discharges from IP2 and IP3, thereby removing nearly all of the concern with thermal impacts to fish in the Hudson River. **Objection(s):** • As an attorney with no apparent training in fisheries biology or hydrothermal modeling, Mr. Little lacks the requisite qualifications to testify to the environmental issues potentially caused by the different types of cooling systems employed by facilities. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.
Source: Little Declaration, at ¶ 39 **Statement:** A closed-cycle system consumes approximately 95% less River water for the secondary reactor cooling system and, concomittantly, reduces impact to fish through entrainment and impingement by approximately 95%. At the same time, closed-cycle cooling would reduce or eliminate thermal impacts to the Hudson River fishery because it eliminates approximately 95% of the thermal discharge. **Objection(s):** • As an attorney with no apparent training in fisheries biology or hydrothermal modeling, Mr. Little lacks the requisite qualifications to testify to the environmental issues potentially caused by the different types of cooling systems employed by facilities. *See* Catawba, CLI-04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.
Source: Little Declaration, at ¶ 42 **Statement:** They were originally required to install closed-cycle cooling and the years of subsequent data and known significant adverse effects on the Hudson River fishery demonstrate that closed-cycle cooling water intake structures are the only solution to those environmental impacts. **Objection(s):** • As an attorney with no apparent training in fisheries biology or hydrothermal modeling, Mr. Little lacks the requisite qualifications to testify to the environmental issues potentially caused by the different types of cooling systems employed by facilities. *See* Catawba, CLI-

04-21, 60 N.R.C. at 27; McGuire, 50-369-OL, 15 N.R.C. at 474-75.