Chesapeake Biological Laboratory, Solomons, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CC-78-2.

Holland, A.F., N.K. Mountford, M.H. Hiegel. D. Cargo and J.A. Mihursky. 1979. Results of benthic studies at Calvert Cliffs. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, and the University of Maryland, Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, Solomons, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-MP-28.

Holland, A.F., and M.H. Hiegel. 1981. Results of benthic studies at Chalk Point. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-81-1.

Holland, A.F. and G.F. Johnson. 1982. Analysis of 1980-1981 finfish data collected near the Chalk Point SES. Prepared by Martin Marietta Environmental Center, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-82-1.

Holland, A.F. 1985. Long-term variations of macrobenthos in a mesohaline region of Chesapeake Bay. Estuaries 8:37-45.

Holland, A.F., M.H. Hiegel, A.T. Shaughnessy, C.F. Stroup and E.A. Ross. 1985a. Long-term benthic monitoring programs near the Morgantown and Calvert Cliffs power plants: Third annual report. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CC-85-1.

Holland, A.F., A.T. Shaughnessy, M.H. Hiegel and C.F. Stroup. 1985b. Long-term benthic monitoring near the Morgantown and Calvert Cliffs power plant: Fourth annual report. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CC-85-1.

Holland, A.F., A.T. Shaughnessy, M.H. Hiegel and L.C. Scott. 1986. Long-term benthic monitoring for the Maryland portion of the Chesapeake Bay: July 1984-June 1986. Technical memorandum prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, and Maryland Department of Health and Mental Hygiene, Office of Environmental Programs.

Holland, A.F., A.T. Shaughnessy and M.H. Hiegel. 1988. Long-term variation in mesohaline Chesapeake Bay macrobenthos: Spatial and temporal patterns. Estuaries 10(3):185-203.

Homer, M., P.W. Jones, R. Bradford, Jr., and J.A. Mihursky. 1979a. Fish community studies in the Patuxent estuary, 1978-1979: final report. Prepared by the University of Maryland, Center for Environmental and Estuarine Studies, Solomons, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-80-6.

Homer, M., P.W. Jones, R. Bradford, J.M. Scoville, and J.A. Mihursky. 1979b. Patuxent estuary fish survey: Cooperative PPSP/WRA project. Prepared by the University of Maryland, Center for Environmental and Estuarine Studies, Solomons, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-80-9.

Homer, M., P.W. Jones, R. Bradford, J.M. Scoville, D. Morck, N. Kaumeyer, L. Haddaway, and D. Elam. 1980a. Demersal fish food habitat studies near the Chalk Point power plant, Patuxent estuary, Maryland, 1978-1979. Prepared by the University of Maryland, Center for Environmental and Estuarine Studies, Solomons, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-80-12.

Homer, M., N. Caplin, and J.A. Mihursky. 1980bb. Condition factors and length/weight regressions associated with certain fish species near the Chalk Point power plant, Patuxent estuary, Maryland, 1978-1979. Prepared by the University of Maryland, Center for Environmental and Estuarine Studies,

Solomons, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-80-8.

Jacobs, F., and W. Richkus. 1984. Potential aquatic impacts of various intake/discharge options for the proposed Perryman power plant. Technical memorandum prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD.

Jensen, L.D., ed. 1977. Fourth national workshop on entrainment and impingement. Melville, NY: E.A. Communications.

Johnson, G., J. Foertch, M. Keser and M.B. Johnson. 1983. Thermal backwash as a method of macrofouling control at Millstone nuclear power station, Waterford, Connecticut, U.S.A. In: Symposium on Condenser Macrofouling Control Technologies -- the State-of-the-Art. I.A. Diaz-Tous, M.J. Miller and Y.G. Mussalli, eds. Electric Power Research Institute, Palo Alto, CA.

Jordan, R.A., C.E. Sutton and P.A. Goodwin. 1979. A survey of the late summer benthic community in the vicinity of the C.P. Crane generating station. Prepared by the Virginia Institute of Marine Science, Gloucester Point, VA, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-79-1.

Jordan, R.A., C.E. Sutton and P.A. Goodwin. 1980. Benthic macroinvertebrate population distribution in relation to the C.P. Crane power plant thermal discharge. Prepared by the Virginia Institute of Marine Science, Gloucester Point, VA, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-80-6.

Jordan, R.A., and C.E. Sutton. 1984. Oligohaline benthic invertebrate communities at two Chesapeake Bay power plants. Estuaries 7:192-214.

Koo, T.S.Y., ed. 1975. A biological study of Baltimore Harbor. Prepared by the University of Maryland, Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, Solomons, MD. CEES Special Report No. 6.

Liden, L.H., D.T. Burton, L.H. Bongers and A.F. Holland. 1980. The effects of chlorobrominated and chlorinated cooling waters on estuarine organisms. Journal of Water Pollution Control Federation 52:173-182.

Lippson, A.J., M.S. Haire, A.F. Holland, F. Jacobs, J. Jensen, R.L. Moran-Johnson, T.T. Polgar and W.R. Richkus. 1979. Environmental atlas of the Potomac estuary. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Research Program. Annapolis, MD. Baltimore: The Johns Hopkins Research University Press.

LMS (Lawler, Matusky and Skelly Engineers). 1980. Ecological studies at the H.A. Wagner plant. Prepared for the Baltimore Gas and Electric Company, Baltimore, MD.

Loos, J.J. 1987. Chalk Point station intake liability values computed after deployment of a second barrier net at the mouth of the intake canal and after discontinuation of auxiliary tempering pump usage. Prepared by the Environmental Affairs Group, Water and Land Use Department, Potomac Electric Power Company, Washington, DC.

Magnien, R.E., R.M. Summers, M.S. Haire, W.R. Boynton, D.C. Brownlee, A.F. Holland, F. Jacobs, W.M. Kemp, K.G. Sellner, G.D. Foster and D.A. Wright. 1987. Monitoring for management actions. Prepared by the Maryland Department of Health and Mental Hygiene, Office of Environmental Programs.

Mangum, D.C., and W.F. McIlhenny. 1974. Control of marine fouling in intake stystems: A comparison of ozone and chlorine. In: Aquatic Applications of Ozone, 138-153. Proceedings of International Ozone Institute Workshop Series.

Mansueti, R., and H. Kolb. 1953. A historical review of the shad fisheries of North America. Prepared by the University of Maryland, Chesapeake Biological

Laboratory, for the Maryland Department of Research and Education. Publication No. 97.

Mattice, J.S. 1983. Freshwater macrofouling and control with emphasis on *Corbulica*. In: Symposium on Condenser Macrofouling Control Technologies --the State-of-the-Art. I.A. Diaz-Tous, M.J. Miller and Y.G. Mussalli, eds. Electric Power Research Institute, Palo Alto, CA.

MD-PPRP (Maryland Power Plant Research Program). 1975. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-CEIR-1.

MD-PPRP. 1978. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-CEIR-2.

MD-PPRP. 1982. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-CEIR-3.

MD-PPRP. 1984. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-CEIR-4.

MD-PPRP. 1986. Power plant cumulative environmental impact report. Prepared by Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-CEIR-5.

Mihursky, J.H. 1969. Patuxent thermal studies: Summary and recommendations. Prepared by the University of Maryland, Chesapeake Biological Laboratory, Solomons, MD.

MMEC (Martin Marietta Environmental Center). 1980. Summary of findings: Calvert Cliffs nuclear power plant Aquatic monitoring program. Prepared

for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-CC-80-2.

MMEC. 1981. Impact assessment report: R. Paul Smith steam electric station aquatic monitoring program. Prepared for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. RPS-81-2.

MMEC. 1983. Impact assessment report: C.P. Crane steam electric station aquatic monitoring program. Prepared for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-82-1.

MMES (Martin Marietta Environmental Systems). 1985a. Impact assessment report: Chalk Point steam electric station aquatic monitoring program. Prepared for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-85-1.

MMES. 1985b. Assessment of compliance for the Chalk Point steam electric generating station with mixing zone criteria in COMAR 10.50.01.13E(1). Prepared for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-85-2.

MMES. 1985c. Evaluating the effectiveness of outages Objective I report. Review of statistical estimators for biological parameters of outage assessment measures. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for Consolidated Edison Company of New York.

Moffit, C., and B.E. Kynard. 1981. Connecticut River basin anadromous fish studies, 1 March 1980-28 February 1981. Prepared by Massachusetts Cooperative Fish Research Unit, University of Massachusetts, Amherst, MA. Project No. AFS-4-R-20.

Moore, C.J., and C.M. Frisbie. 1972. A winter sport fishing survey in a warm water discharge of a steam electric station on the Patuxent River, Maryland. Chesapeake Science 13:110-115.

Moore, C.J., G.A. Stevens, A.J. McErlean and H.H. Zion. 1973. A sport fishing survey in the vicinity of a steam electric station on the Patuxent Estuary, Maryland. Chesapeake Science 14:160-170.

Morgan, R.P., III. 1968. Steam electric station effects upon primary productivity in the Patuxent River estuary. Prepared by the University of Maryland, Chesapeake Biological Laboratory, Solomons, MD. NRI Ref. No. 69-27.

Morgan, R.P., III, J.A. Mihursky, S.S. Herman, C.I. Gibson and A.J. McErlean. 1969. Patuxent thermal studies, Supplementary report: Phytoplankton studies. Prepared by the University of Maryland, Chesapeake Biological Laboratory, Solomons, MD. Ref. No. 69-6.

Morgan, R.P., III, and R.G. Stross. 1969. Destruction of phytoplankton in the cooling water supply of a S.E.S. Chesapeake Science 10:165-171.

NA (Normandeau Associates). 1981. Plankton studies conducted at H.A. Wagner generating station, July-September 1980. Technical memorandum prepared for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD.

Nauman, J.W., and R.L. Cory. 1969. Thermal additions and epifaunal organisms at Chalk Point, Maryland. Chesapeake Science 10:218-226.

Newman, E.N., T.P. Meinz and L. Liebenstein. 1981. Evaluation of barrier nets to reduce fish impingement. Prepared for the Workshop on Advanced Intake Technology.

Nichols, B.L., R.R. Anderson, W.C. Banta, E.J. Forman and S.H. Boutwell. 1979. Evaluation of the effects of the thermal discharge on the submerged aquatic vegetation and associated fauna in the vicinity of the C.P. Crane generating station. Prepared by Scientific Applications, Inc., McLean, VA, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-80-1.

Nichols, B.L., and R.R. Anderson. 1980. Evaluation of the effects of thermal discharge on submerged aquatic vegetation growth. Prepared by NTSC Technical Services, Ltd., Vienna, VA, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-80-3.

Otto, R.G., M. VanDeusen and L.S. Kaufman. 1980. Prediction of biological impacts associated with expansion of Vienna steam electric station. Prepared by The Johns Hopkins University, Chesapeake Bay Institute, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSE-9-11.

Otto, R.G., T.I. Hiebert and V.R. Kranz. 1981. The effectiveness of a remote profile-wire screen intake module in reducing the entrainment of fish eggs and larvae. In: Advanced Intake Technology for Power Plant Cooling Water Systems, 47-56. Proceedings of the Workshop of Advanced Intake Technology. P.B. Dorn and J.T. Johnson, eds. San Diego, CA,

Otto, R.G. 1983. Chalk Point Station 316 demonstration summary: An assessment of impacts associated with open-cycle condenser cooling conducted in compliance with COMAR 10.50.01.13. Prepared by R.G. Otto, Assoc., Baltimore, MD, for the Potomac Electric Power Company, Washington, D.C.

Pavol, K.W., and R.M. Davis. 1982. Life history and management of the smallmouth bass in the Susquehanna River below Conowingo Dam. Report F-29-R to the State of Maryland Wildlife Administration.

PEPCO (Potomac Electric Power Company). 1981. Long-term fisheries monitoring in the vicinity of the Dickerson steam electric station. Prepared by the Environmental Affairs Group, Water and Land Use Department, Potomac Electric Power Company, Washington, DC.

PEPCO. 1982. Mortality of impinged blue crabs, *Callinectes sapidus*, Rathbun, after return to the discharge canal at the Morgantown steam electric station.

Prepared by the Environmental Affairs Group, Water and Land Use Department, Potomac Electric Power Company, Washington, DC.

PEPCO. 1983. Estimates of impingement and auxiliary tempering pump entrainment at the Chalk Point station. Prepared by the Environmental Affairs Group, Water and Land Use Department, Potomac Electric Power Company, Washington, DC.

PEPCO. 1984. Long-term fisheries monitoring in the vicinity of the Dickerson station. Prepared by the Environmental Affairs Group Water and Land Use Department, Potomac Electric Power Company, Washington, DC.

PEPCO. 1985. Long-term aquatic monitoring in the vicinity of the Chalk Point generating station. Prepared by the Environmental Affairs Group, Water and Land Use Department, Potomac Electric Power Company, Washington, DC.

PEPCO. 1987. Chalk Point station biofouling control program: 1986 Annual Report. Prepared by the Environmental Affairs Group, Water and Land Use Department, Potomac Electric Power Company, Washington, DC.

Phelps, H. 1979. Copper and zinc concentrations in oysters from selected locations on the Chesapeake Bay, Summary Report 1979-1977. Prepared by the University of the District of Columbia for NASA. Grant NGR 0-050-019.

Polgar, T.T., J.K. Summers and M.S. Haire. 1979. Evaluation of the effects of the Morgantown SES cooling system on spawning and nursery areas of representative species. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-MP-27.

Portner, E.M., and L.C. Kohlenstein. 1979. Prediction of entrainment and impingement impact for striped bass eggs and larvae by the proposed Vienna Unit No. 9. Prepared by The Johns Hopkins University, Applied Physics Laboratory, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-8-1.

Roberts, M.H., Jr., R.J. Diaz, M.E. Bender and R.J. Huggett. 1975. Acute toxicity of chlorine to selected estuarine species. Journal Fisheries Research Board of Canada 32:2525-2528.

Roosenburg, W.H. 1969. Greening and copper accumulation in the American oyster, *Cassostrea virginica*, in the vicinity of steam electric generating station. Chesapeake Science 10:241-252.

Rose, K.A., R.L. Dwyer and M.A. Turner. 1986. Prediction of the effects of nutrient loadings from a power plant at Perryman on the water quality of the Bush River estuary. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSE-2-8.

Rose, K.A. 1987. Personal communication from K.A. Rose, Martin Marietta Environmental Systems, Columbia, MD, to R. Dwyer, Versar, Inc. July 6, 1987.

Schubel, J.R., and V.S. Kennedy. 1984. The Estuary as a Filter. In: The Estuary as a Filter, 1-11. V.S. Kennedy, ed. New York: Academic Press.

Schubel, J.R., and H.H. Carter. 1984. The estuary as a filter for fine-grained suspended sediment. In: The Estuary as a Filter, 81-106. V.S. Kennedy, ed. New York: Academic Press.

Sellner, K.G., L.A. Lyons, R.K. Mahoney, M.M. Olson and E.S. Penny. 1980. Phytoplankton studies and nutrient concentrations in the vicinity of the C.P. Crane generating station, July 1979 through March 1980. Prepared by the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-80-5.

Shaughnessy, A.T. 1983. Population structure and dynamics of the brackishwater clam, *Rangia cuneata*, in upper Chesapeake Bay in the

vicinity of C.P. Crane power plant, Baltimore County, Maryland. Masters thesis, Towson State University, Towson, MD.

Shaughnessy, A.T. 1987. Long-term benthic monitoring studies in the freshwater portion of the Potomac River: 1983 to 1985, cumulative report. (In prep.). Prepared by Versar, Inc., ESM Operations, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD.

Souza, P.A., T.T. Polgar, R.E. Miller and A.F. Holland. 1980. Results of blue crab studies at Chalk Point: Final Report to the Maryland Power Plant Research Program. Prepared by the Martin Marietta Environmental Center, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-80-10.

Sugam, R., and G.R. Helz. 1977. The chemistry of chlorine on estuarine waters. Prepared by the University of Maryland, Chemistry Department, College Park, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPRP-26.

Summers, J.K. 1984. Conowingo reservoir ecosystem simulation model. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. UBLS-82-5.

SWEC (Stone and Webster Engineering Corporation). 1981. Alternate intake designs for reducing fish impingement losses at Morgantown steam electric station. Prepared for Potomac Electric Power Company, Washington, D.C. Ref. No. 13804-W(B)-1.

Tatham, T.R., D.L. Thomas and G.J. Miller. 1977. Survival of fishes and macroinvertebrates impinged at Oyster Creek generating stations. In: Fourth National Workshop on Entrainment and Impingement, 235-244. L.D. Jensen, ed. Mellvile, NY: E.A. Communications.

Taylor, R.J., and L.B. Richardson. 1981. Ultrasonics as an alternative to biocides program report. Prepared by The Johns Hopkins University, Applied Physics Laboratory, Baltimore, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPRP-82.

TI (Texas Instruments). 1981. Evaluation of C.P. Crane generating station thermal discharge effects on the finfish community, Summer 1980. Prepared for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-81-1.

TI. 1980. Evaluation of C.P. Crane generating station thermal discharge effects on the finfish community. Prepared for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-80-7.

Turbak, S.C., D.R. Reichle and C.R. Shriver. 1981. Analysis of environmental issues related to small-scale hydroelectric development IV: Fish mortality resulting from turbine passage. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN. Publication No. 1597.

Vannote, R.L., and B.N. Sweeney. 1985. Long-term benthic monitoring studies in the freshwater portion of the Potomac River. Prepared by Stroud Water Research Center of the Academy of Natural Sciences of Philadelphia, Philadelphia, PA, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-MP-58.

Walburg, C.H., and R.P. Nichols. 1967. Biology and management of the American shad and status of the fisheries, Atlantic Coast of the United States, 1960-1967. Prepared by U.S. Fish and Wildlife Service, Atlanta, GA. Special Scientific Report Fish. No. 550.

Waldock, M.J., and J.E. Thain. 1983. Shell thickening in *Crassostrea gigas*: Organotin antifouling or sediment induced. Marine Pollution Bulletin 14: 411-415.

Waxman, J. 1984. Telephone conversation between J. Waxman, Consolidated Edison Company of New York, and A.F. Holland, Martin Marietta Environmental Systems, Columbus, MD.

Weisberg, S.B., W.H. Burton, E.A. Ross and F. Jacobs. 1984a. The effects of screen slot size, screen diameter, and through-slot velocity on entrainment of estuarine ichthyoplankton through wedge-wire screens. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-84-1.

Weisberg, S.B., C.F. Stroup, A.F. Holland and E.A. Ross. 1984b. Biofouling potential on fine mesh wedge-wire screens and a test of some mechanisms of biofouling control. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CP-84-3.

Weisberg, S.B., and A.J. Janicki. 1985. The effects of an interim minimum flow from the Conowingo Dam on fish feeding and benthos in the Susquehanna River. Prepared by Martin Marietta Environmental Systems, Columbia, MD, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. UBLS-85-4.

Weisberg, S.B., K.A. Rose, B.S. Clevenger and J.O. Smith. 1985. Inventory of Maryland dams and assessment of hydropower resources. Prepared by Martin Marietta Environmental Systems, Columbia, MD, and Dam Safety Division of the Maryland Department of Natural Resources for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. PPSP-85-02.

Wietz, D.H. 1982. Problems associated with the installation of fish barrier nets at the Morgantown generating station. Prepared by Potomac Electric Power Company. Washington, DC.

Zubkoff, P.L. 1980. A preliminary study of community oxygen metabolism in the vicinity of the C.P. Crane electric power generating station. Prepared by the

Virginia Institute of Marine Science, Gloucester Point, VA, for the Maryland Department of Natural Resources, Power Plant Research Program, Annapolis, MD. CPC-81-3.

CHAPTER V

RADIOLOGICAL IMPACT

Three nuclear power plants are regarded as having the potential for producing an environmental impact in Maryland through releases of radioactivity. These plants are the Three Mile Island, Peach Bottom and Calvert Cliffs nuclear power plants. Only Calvert Cliffs is situated in Maryland. Peach Bottom and Three Mile Island are located on the Susquehanna River in Pennsylvania.

In the United States, nuclear power plants are licensed and regulated by the U.S. Nuclear Regulatory Commission (NRC). Conditions imposed in each plant's operating license allow the routine discharge of low levels of radioactivity to the environment. Release quantities are restricted by regulations contained in 10 CFR 50 Appendix I, designed to keep radiation doses "as low as reasonably achievable" (ALARA). Annual total body doses to a hypothetical maximally-exposed individual cannot exceed 3 mrem per reactor for the aqueous pathway and 5 mrem per reactor for the atmospheric pathway (Table V-1). Aqueous pathway doses are received through ingestion of radioactivity in water and seafood, and exposure to contaminated water and sediments. Atmospheric pathway doses result from inhalation of, and direct exposure to, gaseous and airborne particulate radioactivity in a passing plume, or ingestion of radionuclides deposited on or taken up by terrestrial vegetation and animals.

This chapter discusses the radiological impacts of Calvert Cliffs, Peach Bottom and Three Mile Island nuclear power plants. PPRP's assessment is based on results of environmental monitoring and research conducted by PPRP as well as the individual utilities and the Maryland Department of the Environment. Included are discussions of the radioactivity discharged by each plant, the nuclear waste generated, and the actual distribution of radionuclides in the Maryland environment. Doses to man via the atmospheric and aqueous release pathways are calculated. Comparisons are made with natural background doses, operating license restrictions, and environmental radionuclide concentrations present in previous years where appropriate. A brief section describing the impact in Maryland of the accident at the U.S.S.R.'s Chernobyl reactor site is also included.

Table V-1

NRC Guidelines: limiting conditions of operation of light-water cooled nuclear power reactors to keep radioactivity in effluents to unrestricted areas as low as is reasonably achievable

Type of Dose	Design Objectives [a]	Point of Dose Evaluation
Liquid effluents		
Dose to whole body	3 mrem/yr per unit	Location of highest offsite dose [b]
Dose to any organ	10 mrem/yr per unit	Location of highest offsite dose [b]
Gaseous Effluents [c]		
Gamma dose in air	10 mrad/yr per unit	Location of highest offsite dose [d]
Beta dose in air	20 mrad/yr per unit	Location of highest offsite dose [d]
Dose to total body	5 mrem/yr per unit	Location of highest offsite dose [b]
Dose to skin	15 mrem/yr per unit	Location of highest offsite dose [b]
Atmospheric Radioiodines and Particulates [e]		
Dose to any organ	15 mrem/yr per unit	Location of highest offsite dose [f]

Source: 10 CFR 50 Appendix 1

(a) Evaluated for a maximally exposed individual.

(b) Evaluated at a location that is anticipated to be occupied during the plant lifetime, or with respect to such potential land and water usage and food pathways as could actually exist during the term of plant operation.

(c) Calculated for noble gases only.

(d) Evaluated at a location that could be occupied during the term of plant operation.

(e) Doses due to Carbon-14 and tritium intake from terrestrial food chains are included.

(f) Evaluated at a location where an exposure pathway and dose receptor actually exist at the time of licensing. However, if the applicant determines design objectives with respect to radioiodine on the basis of existing conditions and if potential changes in land and water usage and food pathways could result in exposures in excess of the values given above, the applicant must provide reasonable assurance that a monitoring program will be performed to determine: (1) the quantities of radioiodine actually released to the atmosphere and deposited relative to those estimated in the determination of design objectives; (2) whether changes in land and water usage and food pathways which would result in individual exposures greater than originally estimated have occurred; and (3) the content of radioiodine in foods involved in the changes, if they occur.

A. Calvert Cliffs Nuclear Power Plant

The Calvert Cliffs Nuclear Power Plant (CCNPP), owned and operated by the Baltimore Gas and Electric Company (BG&E), is located on the western shoreline of Chesapeake Bay in Calvert County, Maryland. Each of its two units is a pressurized water reactor (PWR) with a maximum dependable capacity of 860 MWe per reactor. Unit 1 was placed into commercial service on May 8, 1975 and produced 64,689,882 MWh gross of electrical energy from 1975-1986. Unit 2 was placed into commercial service on April 1, 1977 and produced 58,837,547 MWh gross of electrical energy from 1975-1986. By the end of 1986, Units 1 and 2 had achieved cumulative unit capacity factors of 73.6% and 79.6%, respectively (US NRC 1987).

The CCNPP releases gaseous and liquid radioactive wastes into the atmosphere and the Chesapeake Bay. While atmospheric releases are chiefly noble gases with little environmental significance, aqueous discharges to Chesapeake Bay contain radionuclides that can be accumulated by Bay biota or become associated with Bay sediments. Through food chain transport these radionuclides may contribute to a radiation dose to man.

Releases of Radioactivity to the Environment

Radionuclides released to the atmosphere and Chesapeake Bay by CCNPP during 1985-1986 are presented in Tables V-2 and V-3. Noble gases accounted for virtually all of the radioactivity released to the atmosphere. Because these nuclides are chemically inert, they are not of significant environmental concern. Of the radioactivity released to the Chesapeake Bay as liquid effluent, Cobalt-58 (Co-58), Cobalt-60 (Co-60), Zinc-65 (Zn-65), and Silver-110m (Ag-110m) are environmentally significant radionuclides because they are readily accumulated by Bay biota (McLean *et al.* 1982). The quantities of these radionuclides released by the Calvert Cliffs plant in 1985 and 1986 and later detected in Chesapeake Bay media were very small, as in prior years (Table V-4).

Table V-2

Total quantities of radionuclides (in curies) released to the atmosphere in 1985 and 1986 by the CCNPP

Radionuclide	1985	1986
Summary		
Tritium	3.28	3.72
Noble Gases [a]	4058.52	7641.65
Iodines	0.15	0.27
Particulates	0.01	<0.01
Total Curies	4061.96	7645.64
Kr-85	12.3090	44.1300
Kr-85m	1.2760	10.0096
Kr-87	0.0044	0.0000
Kr-88	0.0342	4.1500
Xe-131m	17.8500	68.9300
Xe-133	3775.0000	7293.0000
Xe-133m	105.7800	38.9300
Xe-135	146.2100	177.2000
Ar-41	0.0612	1.6040
I-131	0.0520	0.0870
I-132	0.0004	0.0000
I-133	0.0957	0.1818
I-135	0.0029	0.0000
Co-57	<0.0001	0.0000
Co-58	0.0001	0.0000
Sr-89	<0.0001	0.0000
Sr-90	<0.0001	0.0000
Rb-88	0.0089	0.0000
Cs-134	0.0003	0.0000
Cs-137	0.0009	0.0000
Cs-138	0.0002	0.0000

Source: BG&E 1986, 1987.
[a]Includes Ar-41.

Table V-3

Total quantities (in curies) of radionuclides released as liquid effluent in 1985 and 1986 by the CCNPP

Radionuclide	1985	1986
Summary		
Tritium	483.00	734.90
Dissolved Noble Gases	0.23	0.72
Iodines	0.22	0.34
Particulates	2.16	1.52
Total Curies	485.61	737.48
Xe-131m	0.0008	0.0000
Xe-133	0.2096	0.6690
Xe-133m	0.0009	0.0182
Xe-135	0.0109	0.0245
Xe-135m	0.0060	0.0066
I-131	0.1810	0.2480
I-132	0.0008	0.0022
I-133	0.0642	0.0685
I-135	0.0036	0.0169
Na-24	0.0016	0.0017
Cr-51	0.2059	0.0855
Mn-54	0.0245	0.0193
Co-58	0.9060	0.4721
Co-60	0.1029	0.1240
Sr-89	0.0321	0.0026
Sr-90	0.0015	0.0006
Nb-95	0.0796	0.0386
Zr-95	0.0230	0.0153
Nb-97	0.0038	0.0216
Mo-99	0.0004	0.0047
Tc-99m	0.0007	0.0050
Ru-103	0.0019	0.0033
Ag-110m	0.1694	0.0572
Sn-113	0.0028	0.0074
Sb-122	0.0015	0.0002
Sb-124	0.0225	0.0440
Sb-125	0.1810	0.1840
Te-132	0.0013	0.0001
Cs-134	0.1261	0.1165
Cs-136	0.0014	0.0022
Cs-137	0.2575	0.2590
Ba-139	0.0000	0.0705
Ba-140	0.0059	0.0000
La-140	0.0074	0.0000
Ce-139	0.0001	0.0001
Ce-143	0.0000	0.0002
Ce-144	0.0013	0.0006

Source: BG&E 1986, 1987.

Table V-4

Comparison of annual aqueous release quantities from CCNPP (in curies of radionuclides that have been detected in Chesapeake Bay media

	Year							
	1979	1980	1981	1982	1983	1984	1985	1986
Radionuclide	Curies Released							
H-3	514	491	1001	435	756	787	483	735
Co-58	3.81	2.00	1.30	1.50	0.61	0.57	0.91	0.47
CO-60	0.33	0.44	0.21	0.19	0.08	0.10	0.10	0.12
Zn-65	(a)	0.02	(a)	(a)	(a)	(a)	(a)	(b)
Ag-110m	0.10	0.03	0.02	0.22	0.08	0.10	0.17	0.06

Source: MD-PPRP 1982, 1984, 1986.
(a)Below detection limit.
(b) 0.0001

In addition to releases which occur via the primary (cooling water) outfall (001), low levels of radioactivity may be discharged via a stormwater outfall (002) which terminates on a beach to the northwest of the plant site. Low levels of radionuclides are routinely detected in silt samples collected from the outfall pool.

Environmental Monitoring Programs

BG&E, the Maryland Department of the Environment (MDE) and PPRP conduct radiological monitoring programs in the vicinity of CCNPP to assess the environmental impact of radioactivity released. BG&E's program focuses primarily on atmospheric and terrestrial impacts, but also includes aquatic monitoring. The program is structured to conform to NRC operating license requirements. The MDE performs assurance monitoring to provide an independent confirmation of BG&E's program. The PPRP monitoring program focuses on the Chesapeake Bay ecosystem and is designed to assess radiological impact within individual trophic levels and to provide information concerning the behavior and fate of environmentally significant radionuclides. A detailed description of each of these programs may be found elsewhere (BG&E 1986, 1987; MD-PPRP 1984).

Atmospheric and Terrestrial Radionuclide Distributions

- Atmospheric

No plant-related radionuclides were detected in air particulate, air iodine, and precipitation samples collected during 1985-1986. Low levels of Cesium-137 (Cs-137) originating from fallout of past atmospheric weapons tests (most recently the Chinese weapons test of October 15, 1980) were sporadically detected. As in the previous reporting period, concentrations of fallout radionuclides continued to decline since the peak in 1980-1981 (BG&E 1986, 1987).

The Chernobyl reactor accident in the Soviet Union on April 26, 1986 resulted in elevated levels of radioactivity detected in the CCNPP vicinity in atmospheric samples collected from May 5th through June 10th of 1986. Iodine-131 (I-131) was the primary radionuclide detected in air and precipitation samples to a maximum

of 400+-10 fCi/m^3 (baseline I-131 concentrations detected before and after the five week period were < 12 fCi/m^3). Low concentrations of other radionuclides attributable to the accident (Ruthenium-103 (Ru-103), Cs-134, Cs-137, Barium-140 (Ba-140), Lanthanum-140 (La-140), and Ru-106) were also detected during the five-week period. The environmental impact in Maryland of the Chernobyl accident is further discussed in Section D of this chapter.

External radiation as measured by thermoluminescence dosimetry (TLD) indicated that CCNPP's releases of radioactivity to the atmosphere during 1985-1986 did not contribute measurably to offsite radiation levels; nor was any radiation dose increment associated with the Chernobyl reactor accident detectable in TLD monitoring (BG&E 1987).

- Terrestrial

Crop and vegetation samples contained low concentrations of weapons-test fallout and CCNPP-related radionuclides during 1985 and 1986. Low concentrations of Cs-137 were sporadically detected in vegetation samples from onsite and farfield farms, but their distribution and levels indicated that they are attributable to weapons testing. Low concentrations of Co-58 and Co-60 detected in vegetation samples collected from onsite and offsite farms on three occasions during the two-year period are attributable to atmospheric releases by the CCNPP.

Vegetation samples collected during the second quarter of 1986 also contained detectable concentrations of radionuclides attributable to the Chernobyl reactor accident. As for other sampling media (e.g., air particulates) collected during the weeks after the accident, detectable concentrations of Ru-106 and I-131 were observed in several vegetation samples collected from both onsite and farfield farms during May. Cs-137 was also detected during this period, and is attributed to fallout from both the Chernobyl accident and past weapons tests.

CCNPP-related radioactivity was also detected in silt samples collected from a pool into which stormwater outfall 002 terminates. Periodically detectable and fluctuating levels of Co-58, Co-60, Ag-110m, Antimony-125 (Sb-125), Cs-134 and Cs-137 were present in 1985-1986. Radioactivity released via this pathway was first

detected in 1979 (McLean *et al.* 1982). The source was subsequently identified as the diesel oil interceptor, but downwash of stack releases during rainfall may also contribute to the stormwater inventory and provide an increment of radioactivity detected at this outfall, which carries stormwater runoff. The detection of radioactivity in these samples is significant only in that an additional source of radioactivity that may ultimately reach the Bay is identified. The concentrations are sufficiently low that they do not currently represent a potential environmental impact.

Aquatic Radionuclide Distributions

Radionuclides from atmospheric tests of nuclear weapons and discharges from CCNPP were detected in water, biota, and sediment samples collected from the Chesapeake Bay during 1985-1986. Low concentrations of Cs-137 were frequently detected in Bay sediments and in a variety of Bay biota samples (Domotor and McLean 1988). Although CCNPP contributes small quantities of Cs-137, a comparison of concentrations in the nearfield with those from farfield locations indicates that weapons test fallout is the principal source, and that a possible CCNPP-related increment is indiscernible.

The almost daily release of tritium by the Calvert Cliffs plant may occasionally produce concentrations in nearfield Bay water that exceed levels attributable to weapons test fallout. Rapid mixing and dispersion reduce these concentrations to ambient levels in a short time. During the subject period, CCNPP released annual totals of about 500 Ci of tritium to the Bay. Tritium was detected at fallout-attributable levels (<300 pCi/l) in most of the Bay water samples collected during 1985-1986. However, tritium concentrations attributable to releases by CCNPP were also detected on several occasions (maximum of 1100+-800 pCi/l). Because tritium is not bioaccumulated, and release quantities are relatively low, no adverse environmental impact has resulted.

Small quantities of bioaccumulable radionuclides are also released to the Chesapeake Bay. As previously mentioned, upper trophic levels, including man, may ultimately receive dose increments from these radionuclides. Bioaccumulable radionuclides detected in Bay biota and Bay sediments attributable

solely to CCNPP include Co-58, Co-60, Zn-65, and Ag-110m (Domotor and McLean 1988). Maximum concentrations of these radionuclides detected in a variety of sample media collected from the Bay environment during 1985-1986 are presented in Table V-5.

- Sediments

Sediments serve as sinks for both stable and radioactive metals, and are therefore useful indicators of environmental radionuclide concentrations. Results from PPRP's quarterly sediment collections provide an indication of radionuclide concentrations in sediments, and of whether any accumulation or transport of this sediment-associated radioactivity has occurred over time.

Co-60, Co-58, and Ag-110m were the three plant-related radionuclides detected in Bay sediments during 1985-1986. Co-58 and Co-60 were frequently detected in Bay sediments composed primarily of silt and clay material. A slight increase in the ratio of Co-60 to Co-58 within PPRP's sampling grid is apparent, and is explained by the longer half-life of Co-60 (5.3 yrs) relative to Co-58 (71 days). Ag-110m was detected more frequently and at higher concentrations in 1985-1986 than in the previous years. All three radionuclides were detected as far as 3 miles south of Calvert Cliffs, indicating that plant-related radioactivity associated with sediment is transported away from the immediate plant vicinity, generally in a down-Bay direction. Estuarine circulation, sediment scouring, resuspension, and dispersion processes all likely play a role in the transport of radionuclide-labelled sediments.

- Biota

Of the biota harvested for human consumption in the Calvert Cliffs vicinity, oysters are the principal indicators of radiological impact because they are non-mobile and concentrate metals, including radionuclides. Ag-110m was identified as the principal plant-related radionuclide taken up by oysters. Ag-110m was detected in oysters located on natural bars and in oysters immersed quarterly in trays located in the plant discharge vicinity. Low concentrations of Co-58, Co-60, and Zn-65 were also sporadically detected. Natural bar and tray oysters have

Table V-5
Maximum concentrations of Calvert Cliffs-related radionuclides in environmental samples collected from the Chesapeake Bay in 1985-1986

		Radionuclide Concentration (pCi/wet kg) [a]			
Sample Type	Year	Silver-110m	Cobalt-58	Cobalt-60	Zinc-65
Edible Finfish Flesh	1985	<44	<60	<33	<72
	1986	< 8	< 7	< 8	<16
Edible Finfish Gut	1985	<382	<11963	< 96	< 673
	1986	<601	<13052	<152	<1060
Forage Finfish (Whole)	1985	2+-1	79+-7	<12	<24
	1986	<21	<14	<18	<31
Oyster Meat	1985	758+-23	114+-5	3+-2	5+-6
	1986	908+-17	27+-6	5+-11	23+-8
Blue Crab Meat	1985	9+-7	<11	<11	<24
	1986	4+-2	<13	<15	<30
Blue Crab Shell (pCi/dry kg units)	1985	29+-11	<36	<22	< 48
	1986	<65	<52	<54	<102
Grass Shrimp	1985	<157	<119	<122	<247
	1986	18+-4	<122	<127	<222
Epifaunal Organisms (pCi/wet kg units)	1985	1668+-60	2295+-67	491+-31	39+-33
	1986	209+-210	1469+-217	104+-168	<588
Macro-algae	1985	5+-4	31+-5	<155	<330
	1986	<30	<24	< 26	< 53
Bay Sediment (Clay)	1985	153+-13	616+-20	284+-13	6+-3
	1986	46+-7	60+-20	45+-12	<42
Bay Sediment (Sand)	1985	32+-31	99+-30	155+-21	<178
	1986	126+-22	30+-18	94+-12	<143

Source: PPRP monitoring program.

(a) Crab shell and sediment concentrations are pCi/dry kg; epifaunal organisms are in pCi/ash kg.

consistently contained Ag-110m and sporadically contained low concentrations of Co-58 and other plant related radionuclides since first monitored in 1978 (McLean *et al.* 1982). PPRP developed a statistical model to predict radionuclide levels in tray oysters and to determine the role of physical, chemical, and environmental parameters (e.g., plant releases, water temperature, season of exposure) in regulating radionuclide concentrations in oysters. A detailed discussion of the tray oyster study and statistical modelling of tray oyster radionuclide concentrations can be found elsewhere (McLean *et al.* 1987; Rose *et al.* 1987, 1987a).

Plant-related radionuclide concentrations in forage and edible finfish were very low or non-detectable during 1985-1986. Trace concentrations of Co-58 were detected in Atlantic menhaden (forage finfish which serve as prey for edible finfish) collected from the plant site on two occasions. However, no plant-related radionuclides have ever been detected in any edible finfish (Domotor and McLean 1988).

Low concentrations of Ag-110m were sporadically detected in blue crab meat and shell from both plant site and farfield locations. Concentrations detected in meat and shell were similar at both locations, suggesting that the crabs relocated from near the plant to more distant locations after uptake of Ag-110m. Ag-110m was detected in grass shrimp from nearfield and farfield collection locations once, in May 1986 (Domotor and McLean 1988).

Co-58 was consistently detected in several species of macro-algae (which are consumed by blue crabs and grass shrimp) collected from the plant site during spring and summer of 1985. Ag-110m was detected in macro-algae from the plant site on one occasion in the summer of 1985.

Co-58, Co-60, and Ag-110m were detected in nearfield epifauna (fouling organisms) samples collected from wooden panels submerged for 90 days during spring, summer, and fall collection quarters. Radionuclide concentrations were highest in epifauna exposed during the fall quarter (September-December). Co-60 was detected in farfield epifauna on one occasion in the summer of 1986 (Domotor and McLean, 1988).

The Chernobyl event produced detectable concentrations of I-131 in Bay biota collected at nearfield and farfield locations on May 26-27, 1986. I-131 was detected in striped bass flesh (21+-29 pCi/wet kg), grass shrimp (1+-5 pCi/wet kg), and macro-algae (23+-4; 27+-31 pCi/wet kg). I-131 concentrations detected in samples collected from nearfield vs. farfield locations were similar.

Radiation Dose to Humans

Estimates of dose commitments to individuals consuming seafood were calculated using the maximum plant-related radionuclide concentrations (for Co-58, Co-60, Zn-65, and Ag-110m) detected in oysters harvested in the immediate area of CCNPP. Calculated dose commitments to adults, teenagers, and children are given in Table V-6. The estimated maximum dose from seafood consumption would be about 0.3 mrem to an adult's gastrointestinal tract. The estimated maximum total body dose to an adult would be less than 0.002 mrem. These doses are similar to those calculated for previous years. Since the plant began operations, radiation doses to a maximally exposed individual have not exceeded 0.25 mrem to the G.I. tract, and total body doses have been less than 0.01 mrem. These dose estimates are well below 10 CFR Part 50 Appendix I design limits, which restrict offsite total body doses to a maximum exposed individual to 6 mrem per year for the aqueous pathway.

Summary

Radionuclides in atmospheric releases from the Calvert Cliffs Nuclear Power Plant were detected in vegetation samples but not in air or precipitation samples during 1985-1986. Low concentrations of plant-related radionuclides (Co-58 and Co-60) were detected in vegetation samples on three occasions.

Radionuclides in aqueous releases from the plant were detected in the Chesapeake Bay ecosystem during 1985-1986. Co-58, Co-60 and Ag-110m, as in previous years, continue to be the plant-related radionuclides most frequently detected in Bay sediments. These radionuclides were detected 3 miles south of the plant, indicating that plant-related radioactivity associated with sediment is transported down-Bay. Ag-110m was detected in sediments more frequently in 1985 and 1986

Table V-6

Maximum dose commitment (in mrem) for an individual consuming oysters from the Calvert Cliffs vicinity(a)

	ADULT		TEEN		CHILD	
	1985	1986	1985	1986	1985	1986
Total Body:						
Co-58	0.0010	0.0002	0.0010	0.0002	0.0011	0.0003
Co-60	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Zn-65	0.0002	0.0008	0.0002	0.0008	0.0002	0.0009
Ag-110m	0.0003	0.0004	0.0003	0.0004	0.0004	0.0004
TOTAL	0.0016	0.0015	0.0016	0.0015	0.0018	0.0017
Bone:						
Co-58	-	-	-	-	-	-
Co-60	-	-	-	-	-	-
Zn-65	0.0001	0.0006	0.0001	0.0005	0.0001	0.0005
Ag-110m	0.0004	0.0007	0.0006	0.0007	0.0007	0.0008
TOTAL	0.0005	0.0013	0.0007	0.0012	0.0008	0.0013
Liver:						
Co-58	0.0004	0.0001	0.0004	0.0001	0.0003	0.0001
Co-60	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000
Zn-65	0.0004	0.0018	0.0004	0.0017	0.0003	0.0014
Ag-110m	0.0006	0.0007	0.0006	0.0007	0.0005	0.0006
TOTAL	0.0014	0.0027	0.0014	0.0026	0.0011	0.0021
Kidney:						
Co-58	-	-	-	-	-	-
Co-60	-	-	-	-	-	-
Zn-65	0.0003	0.0012	0.0002	0.0011	0.0002	0.0009
Ag-110m	0.0011	0.0014	0.0009	0.0013	0.0009	0.0010
TOTAL	0.0014	0.0026	0.0011	0.0024	0.0011	0.0019
GI Tract:						
Co-58	0.0086	0.0020	0.0058	0.0014	0.0021	0.0005
Co-60	0.0006	0.0010	0.0004	0.0007	0.0001	0.0003
Zn-65	0.0002	0.0011	0.0002	0.0007	0.0001	0.0002
Ag-110m	0.2274	0.2724	0.1570	0.1880	0.0558	0.0669
TOTAL	0.2368	0.2765	0.1634	0.1908	0.0581	0.0679

(a) Based upon Radionuclide Concentrations given in Table V-5. Calculations assume ingestion quantities and dose conversion factors of USNRC Reg. Guide 1.109.

than in previous years. Maximum concentrations of radiocobalt in sediments were also slightly higher than in earlier years. Radionuclides attributable to Calvert Cliffs were detected in forage finfish, oysters, blue crab, algae, and epifauna. With the exception of Ag-110m in oysters, concentrations of all radionuclides in biota were similar to those found in previous years. The maximum Ag-110 concentration of 908 pCi/kg in oysters recorded in 1986 exceeded the highest previously-recorded concentration of 697 pCi/kg (1982). The maximum radionuclide concentrations detected in biota would yield radiation doses to the various organisms that are orders of magnitude lower than those resulting from natural radioactivity present in the environment (Whicker and Schultz 1982).

Atmospheric and aqueous releases of radioactivity by CCNPP are in accordance with technical specifications of the plant's operating license. The very low quantities of radioactivity introduced into the environment by CCNPP are small increments to backgroumd radioactivity from natural sources and weapons test fallout. Ecological and human health impacts are regarded as insignificant.

B. Peach Bottom Atomic Power Station

The Peach Bottom Atomic Power Station (PBAPS), owned jointly by Philadelphia Electric Company (PECO), Public Service Gas & Electric Company, Delmarva Power & Light Company and Atlantic City Electric Company, is operated by PECO. The plant is located in Pennsylvania approximately three miles north of the Pennsylvania-Maryland border on the Susquehanna River. The plant operates two boiling water reactors, each with a maximum dependable capacity of 1,098 MWe (Unit 1, a 40 MWe high-temperature gas-cooled reactor, was decommissioned in 1975).

Unit 2, placed in commercial service in July 1974, had produced 68,371,000 MWh gross of electrical energy as of the end of 1986. Unit 3, placed in commercial service in December 1974, had produced 69,055,872 MWh gross. By the end of 1986, Units 2 and 3 had achieved cumulative unit capacity factors of 56.8% and 60.7%, respectively (USNRC 1987). As of the preparation date of this report, neither unit is in operation. On March 31, 1987, the NRC ordered the plant shut down because of operator negligence. Permission for restart will not be granted until the NRC

approves PECO's management and operational plan and implementation schedule. This plan must provide complete assurance that the facility will operate safely and comply with all regulatory requirements.

Releases to the Environment

Quantities of radionuclides released to the atmosphere and the Susquehanna River by Peach Bottom during 1985 and 1986 are presented in tables V-7 and V-8. Atmospheric releases (Table V-7) are almost exclusively comprised of the relatively short-lived and chemically inert noble gas radionuclides of xenon and krypton.

Quantities of radionuclides released to the Susquehanna River (Conowingo Pond) during the subject period are given in Table V-8. Almost 100% of this release inventory is tritium. Present in the Susquehanna as tritiated water, it is not bioaccumulated and is of no environmental concern. During the subject period, PECO reported that less than 2 curies of radionuclides capable of bioaccumulation were released via the aqueous pathway. Of these, only Co-58, Co-60, Zn-65, I-131 and Cs-134 and Cs-137 were detected in biota and/or sediments of the Susquehanna River and Upper Chesapeake Bay. Release quantities of these radionuclides in 1985 were similar to prior years, and much lower in 1986 (Table V- 9).

In addition to these controlled and monitored releases to the Susquehanna, during the period June 16 through July 18, 1985 unplanned releases occurred as a result of a leak in a Unit 3 heat exchanger. Several unplanned releases also occurred during October and once in December of that year. Release quantities were estimated conservatively, using the highest concentrations measured upon detection, and upper limits of flow rates. In 1986 -- twice in February, during the period March 20-May 14, and on May 21 -- unplanned releases also occurred. As previously, release quantities were conservatively estimated. These estimates (for both 1985 and 1986) indicated that very low levels of radioactivity were actually released. Environmental surveillance by PPRP did not detect any anomalously high radionuclide concentrations in sediments or biota following these events. It

Table V-7

Total quantities (curies) of radionuclides released to the atmosphere by PBAPS via the main stack and roof vents, 1985, 1986

Radionuclide	1985	1986
Summary		
Tritium	38.40	26.30
Noble Gases	127,646.00	27,609.00
Iodines	0.06	0.18
Particulates	0.15	0.68
Total Curies	127,684.61	27,636.16
Kr-85m	0.00	406.90
Kr-87	740.00	383.66
Kr-88	828.00	385.15
Xe-133	113,200.00	19,244.82
Xe-133m	2,938.00	517.24
Xe-135	7,970.00	4,382.00
Xe-135m	994.00	929.38
Xe-138	976.00	1,360.00
I-131	0.05950	0.03899
I-132	0.00000	0.00024
I-133	0.00125	0.07137
I-134	0.00000	0.00019
I-135	0.00000	0.07398
Na-24	0.00005	0.00021
Mn-54	0.00000	0.00002
Mn-56	0.00000	0.00006
Co-57	0.00000	0.00001
Co-58	0.00007	0.00005
Co-60	0.00059	0.00012
Cu-64	0.00130	0.00117
Zn-65	0.00034	0.00089
Rb-88	0.01680	0.00073
Sr-89	0.00448	0.00545
Sr-90	0.00009	0.00017
Sr-91	0.00109	0.01199
Sr-92	0.00000	0.00038
Y-91m	0.00510	0.10933
Mo-99	0.00000	0.00001
Tc-99m	0.00000	0.00001
Cd-109	0.00000	0.00001
Te-132	0.00000	0.00001
Cs-134	0.00182	0.00545
Cs-137	0.00168	0.00040
Cs-138	0.10200	0.38684
Ba-139	0.01200	0.15412
Ba-140	0.00060	0.00723
La-140	0.00085	0.00265

Source: PECO 1986, 1987.

Table V-8

Total quantities (curies) of radionuclides released to the Susquehanna River via the aqueous pathway by PBAPS, 1985 and 1986

Radionuclide	1985	1986
Summary		
Tritium	50.40	44.60
Dissolved Noble Gases	1.03	0.31
Iodines	0.17	0.03
Particulates	1.00	0.43
Total Curies	52.60	45.37
Xe-131m	0.03064	0.00000
Xe-133	0.75130	0.01740
Xe-133m	0.01330	0.00325
Xe-135	0.22130	0.26230
Xe-135m	0.01570	0.02395
I-131	0.12240	0.02145
I-132	0.00133	0.00039
I-133	0.03513	0.00803
I-135	0.01115	0.00365
Na-24	0.02639	0.00845
P-32	0.01757	0.00326
Cr-51	0.00483	0.00852
Mn-54	0.00203	0.00037
Fe-55	0.02257	0.00559
Co-58	0.00250	0.00194
Co-60	0.14270	0.04139
Cu-64	0.00000	0.01756
Zn-65	0.22500	0.13928
Sr-89	0.00234	0.00092
Sr-90	0.00072	0.00042
Sr-91	0.00021	0.00000
Sr-92	0.00049	0.00016
Y-91m	0.00139	0.00010
Nb-95	0.00159	0.00026
Mo-99	0.00242	0.00059
Tc-99m	0.00372	0.00067
Cd-109	0.00185	0.00000
Ag-110m	0.00086	0.00239
Sb-124	0.00041	0.00008
Te-132	0.02546	0.00009
Cs-134	0.21900	0.09129
Cs-136	0.00061	0.00006
Cs-137	0.23300	0.10470
Ba-140	0.00267	0.00000
La-140	0.01002	0.00276
Ce-144	0.00101	0.00279
Np-239	0.04730	0.00034

Source: PECO 1986, 1987.

Table V-9

Comparison of annual release quantities of radionuclides from PBAPS that have been detected in the aqueous environment

	Year							
	1979	1980	1981	1982	1983	1984	1985	1986
Radionuclide	Curies Released							
Co-60	0.16	0.16	0.13	0.65	0.16	0.11	0.14	0.04
Zn-65	0.46	0.31	0.29	1.96	0.79	0.21	0.23	0.14
I-131	0.96	0.06	0.05	0.15	0.13	0.14	0.12	0.02
Cs-134	3.92	0.57	0.10	0.46	0.15	0.16	0.22	0.09
Cs-137	3.26	0.70	0.17	0.65	0.26	0.21	0.23	0.10

Source: MD-PPRP 1986; PECO 1986, 1987.

is, however, noteworthy that with the exception of a leak in the same Unit 3 heat exchanger in 1982, unplanned release events did not reportedly occur prior to 1985.

Environmental Monitoring Programs

PECO, MDE and PPRP conduct radiological monitoring programs in the vicinity of the Peach Bottom Station to assess the environmental impact of radioactivity releases. The PECO program is defined by USNRC operating license requirements. PECO's contractors analyze air, precipitation, vegetation, soil, and milk, and monitor ambient radiation dose levels in addressing atmospheric pathway impact. The MDE monitors air particulate radioactivity and air iodine levels in Harford and Cecil Counties (MD). MDE's Center for Radiological Health also conducts weekly sampling and analysis of river water, and collects and analyzes raw milk from farms in Harford and Cecil Counties near the plant.

Addressing the aqueous pathway impact, PECO's contractors and PPRP analyze aquatic biota and sediments. PECO monitors the Conowingo Pond. PPRP conducts monitoring in Conowingo Pond, the lower Susquehanna River and Upper Chesapeake Bay. Focusing on the aqueous pathway as having the greatest environmental impact, PPRP monitors radionuclide levels monthly in key biological indicators and semi-annually estimates mass balances of radionuclides in the Conowingo Pond.

Atmospheric and Terrestrial Radionuclide Distributions

Other than natural radionuclides and weapons-test fallout levels of Cs-137, a host of fission products attributable to the Chernobyl accident were detected in May and June, 1986. Levels of radioactivity in the PBAPS vicinity were similar to remote locations (see section D, this chapter). No radioactivity attributable to atmospheric releases by PBAPS was detected at any time during 1985 or 1986.