United States General Accounting Office

GAO

Report to Congressional Committees

June 1987

NUCLEAR REGULATION

A Perspective on Liability Protection for a Nuclear Plant Accident

GAO/RCED-87-124

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-223582

June 2, 1987

Congressional Committees

The Price-Anderson Act, which sets the basic insurance framework for the nuclear industry, expires on August 1, 1987. The 99th Congress considered bills to extend the act and increase the limit of financial protection it provides. This report provides information on the potential consequences of various nuclear power plant accidents, the likelihood of accident occurrence, the impact of inflation on the protection originally provided by the act, and other issues related to the act. It should be helpful to the committees listed at the end of this letter in their deliberations on the need for the act and appropriate protection to be provided by it.

We are sending copies of this report to the Director, Office of Management and Budget; the Chairman, Nuclear Regulatory Commission; the Secretary of Energy; and other interested parties.

This work was performed under the direction of Keith O. Fultz, Associate Director, Resources, Community, and Economic Development Division. Other major contributors are listed in appendix III.

J. Dexter Peach

J. Dexter Peach
Assistant Comptroller General

B-223582

The Honorable John C. Stennis, Chairman
Committee on Appropriations
United States Senate

The Honorable J. Bennett Johnston, Chairman
Subcommittee on Energy and Water Development
Committee on Appropriations
United States Senate

The Honorable Sam Nunn, Chairman
Committee on Armed Services
United States Senate

The Honorable Lawton Chiles, Chairman
Committee on Budget
United States Senate

The Honorable J. Bennett Johnston, Chairman
Committee on Energy and Natural Resources
United States Senate

The Honorable Howard M. Metzenbaum, Chairman
Subcommittee on Energy Regulation and Conservation
Committee on Energy and Natural Resources
United States Senate

The Honorable Wendell H. Ford, Chairman
Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources
United States Senate

The Honorable Quentin N. Burdick, Chairman
Committee on Environment and Public Works
United States Senate

The Honorable John B. Breaux, Chairman
Subcommittee on Nuclear Regulation
Committee on Environment and Public Works
United States Senate

The Honorable John Glenn, Chairman
Committee on Governmental Affairs
United States Senate

The Honorable Jamie L. Whitten, Chairman
Committee on Appropriations
House of Representatives

B-223582

The Honorable Tom Bevill, Chairman
Subcommittee on Energy and Water Development
Committee on Appropriations
House of Representatives

The Honorable Les Aspin, Chairman
Committee on Armed Services
House of Representatives

The Honorable William H. Gray III, Chairman
Committee on Budget
House of Representatives

The Honorable John D. Dingell, Chairman
Committee on Energy and Commerce
House of Representatives

The Honorable Philip R. Sharp, Chairman
Subcommittee on Energy and Power
Committee on Energy and Commerce
House of Representatives

The Honorable Jack Brooks, Chairman
Committee on Government Operations
House of Representatives

The Honorable Mike Synar, Chairman
Subcommittee on Environment, Energy, and Natural Resources
Committee on Government Operations
House of Representatives

The Honorable Morris K. Udall, Chairman
Committee on Interior and Insular Affairs
House of Representatives

The Honorable Morris K. Udall, Chairman
Subcommittee on Energy and the Environment
Committee on Interior and Insular Affairs
House of Representatives

The Honorable Robert A. Roe, Chairman
Committee on Science, Space, and Technology
House of Representatives

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Development
Committee on Science, Space, and Technology
House of Representatives

Executive Summary

Purpose

The April 1986 Chernobyl accident in the Soviet Union showed that a major nuclear power plant accident could cause significant personal injury and property damage. The potential financial consequences of such an accident in this country are not known. At the request of Senator George Mitchell, GAO estimated what these consequences might be and examined the need for financial protection against a nuclear accident in this country. This report is being addressed to the congressional committees because of the broad implications of these issues. The report provides information to assist these committees in reassessing liability protection provided by the Price-Anderson Act, the indemnity provisions of which expire on August 1, 1987.

Background

In 1957 the Congress passed the Price-Anderson Act to encourage private industry development of nuclear energy. The act establishes a source of funds to compensate personal injury and property damage from a nuclear accident and limits the liability of private industry for such accidents. As prescribed by the act, claims are to be paid through a combination of private insurance, industry contributions, and Nuclear Regulatory Commission (NRC) and Department of Energy (DOE) indemnity up to a designated limit. Congress will review public liability exceeding the limit to determine whether additional compensation will be made.

Both the limit and the system of payment differ for NRC licensees and DOE contractors. Initially, the limit for commercial plants was $560 million; now it is $695 million—$160 million of mandatory private insurance and $535 million of contributions payable by plant operators ($5 million per 107 operating plants). By the early 1990s, when NRC expects to license 13 additional plants, the limit would increase to $760 million. The act also set a $500 million liability ceiling for DOE's contractors. Since DOE does not require its contractors to obtain private insurance, the entire $500 million would be paid by the government.

The indemnity provisions of the act, which allow NRC and DOE to enter into new indemnity agreements and set the liability limits, expire on August 1, 1987; the Congress has been reexamining the act's objectives and the amount of liability to be provided. Last year both House and Senate committees reported on proposals to extend the act and increase the liability limit between $2.6 billion and $7.7 billion, but no legislation was passed. (See ch. 1.)

Results in Brief

GAO believes that the act's indemnity authority should be extended because many of the same issues exist as when the Congress originally passed the act. For example, private insurance would not fully cover the expected consequences of a major accident. In addition, indemnity agreements under the act cover the life of NRC licenses (40 years) and DOE contracts (5 years). As a result, expiration of the act's indemnity authority could have an immediate impact on the people that live near, and the contractors that operate, DOE's nuclear facilities. Three contracts for four facilities expire in September 1987.

Further, the liability protection provided by the act is too low to provide reasonable compensation for the worst nuclear plant accident (catastrophic) —inflation has eroded the financial protection originally provided by the act. On the basis of GAO's analysis, the financial consequences of a catastrophic accident at 115 of 119 plants could far exceed the liability limit. Further, because the liability limit for DOE nuclear activities is lower than that for commercial plants, the public is not afforded the same level of protection at DOE facilities.

The act covers all off-site accident damages resulting from the release of radioactive material. However, it does not clearly state whether the costs for a precautionary evacuation are covered when a release appears imminent but does not actually occur.

GAO's Analysis

Need for the Act

NRC's indemnity authority is needed because the potential for a major commercial nuclear accident still exists, private insurance would not fully cover the expected consequences of a major nuclear accident, industry is not willing to assume the risks of an accident without adequate financial protection, and the public's ability to obtain accident compensation could be hindered. Although all plants operating or under construction would continue to be afforded $695 million of liability protection under the act, extending NRC's indemnity provisions would provide the Congress an opportunity to reassess and modify the liability limit.

More importantly, GAO believes that DOE's indemnity authority should be extended. Without it, DOE would not be able to extend the act's protection to its activities beyond the life of its contracts. DOE contractors rely

solely on government indemnity for liability protection—DOE pays all contractor costs and does not require them to obtain private insurance. According to DOE officials, without the act's indemnity, contractors may be reluctant to operate DOE's nuclear defense facilities, and states may not agree to the transportation and storage of high-level nuclear waste.

Commercial Liability Limit

Inflation has decreased the level of financial protection originally established by the act; the $560 million limit for commercial activities would have to be raised to $2.2 billion today. Further, on the basis of GAO's assessment, the off-site financial consequences of a catastrophic accident for 119 commercial plants could range from $67 million to $15.5 billion; the consequences for 71 plants would be less than $2 billion. The consequences of the next worst accident (severe) would be less than $225 million for all 119 plants and would be covered by the act's liability limit. Although these two accidents result in the greatest consequences, they are rare events. According to NRC, the general probability of a catastrophic accident occurring is 1 in 100,000 and of a severe accident occurring, 2 in 100,000.

Although GAO believes the liability limit should reflect estimated accident consequences and probabilities, GAO also recognizes the uncertainties in consequence estimates. This country has never had an accident of the magnitude that could validate the assumptions supporting these and other consequence estimates. Further, the assumptions on which the estimates are based are changing as NRC and the industry acquire more information on the causes and consequences of accidents. (See ch. 2.)

DOE Contractor Liability Limit

To keep pace with inflation, the $500 million DOE contractor liability limit would have to increase to almost $2 billion. The liability protection for DOE activities is $195 million lower than for commercial plants under the existing act. By the early 1990s, this gap could widen by $260 million. GAO believes the public should be provided the same level of financial protection regardless of where an accident occurs. (See ch. 3.)

Precautionary Evacuation Costs

The act defines a nuclear incident as an occurrence that causes damage as a result of the radioactive properties of nuclear materials. Confusion exists over whether the public could seek compensation where the release of radioactive material appears imminent, such that a precautionary evacuation is ordered, but no release occurs. Although NRC's licensees carry insurance to cover precautionary evacuation costs, DOE's

contractors do not. Therefore, costs arising from a precautionary evacuation at a DOE facility may not be covered. In 1981 GAO recommended that the Congress amend the definition of nuclear "incident" to clearly include Price-Anderson coverage for precautionary evacuation costs. (See ch. 3.)

Matters for Congressional Consideration

Unless the Congress extends the act's indemnity authority, it will expire on August 1, 1987. In previous reports and testimony, GAO recommended that the Congress extend the indemnity provisions of Price-Anderson, and set the limit for DOE contractors at the same level as for commercial licensees. NCR and DOE also support these positions

Ultimately, the decision on where to set the liability limit for nuclear plant accidents is one of national policy. The Congress will have to weigh national policy interests against commercial and defense needs and the interests of the public. This report provides the Congress with information on the estimated financial consequences of nuclear accidents, the likelihood of accident occurrence, and the impact of inflation on the protection originally provided by the act to assist it in its Price-Anderson deliberations. GAO believes the Congress should

- reassess the commercial liability limit on the basis of inflation, estimates of accident consequences and probabilities, and the uncertainties in the estimates and
- set the liability limit for DOE at the same level as for commercial licensees.

In addition, the act is ambiguous concerning coverage of precautionary evacuation costs. Although NRC's licensees obtain private insurance to cover these costs, DOE does not require its contractors to carry such insurance. Since the impact of a precautionary evacuation would be the same on the people that live around DOE facilities as those that live near commercial plants, GAO believes that the Congress should clarify the act to provide equal protection for the public in the event of a precautionary evacuation.

Agency Comments

GAO provided NRC and DOE officials with pertinent sections of the report and incorporated their clarifications where appropriate. As requested, GAO did not ask NRC and DOE to review and comment officially on this report.

Contents

Abbreviations

DOE	Department of Energy
EMD	Energy and Minerals Division
NRC	Nuclear Regulatory Commission
PRA	probabilistic risk assessment

Introduction

The Atomic Energy Act of 1954 (42 U.S.C. 2011) permitted—and encouraged—private industry to develop and apply atomic energy for peaceful uses, such as generating electricity from privately owned nuclear power plants. Until then, the government had conducted atomic energy activities such as research, development, and production of nuclear weapons. Soon thereafter, government and industry experts identified a major impediment to accomplishing the act's objective of stimulating private industry participation in nuclear energy development. The impediment centered on the payment of damages resulting from a nuclear accident.

Although government and industry experts considered the chances of an accident with catastrophic off-site property damages and health effects exceedingly remote, they also recognized that if such an accident occurred, the resulting financial damages could be large. Unwilling to risk huge financial liability, private companies viewed even the remote spector of a serious accident as a roadblock to their participation in the development and use of nuclear power. In addition, since contractors performed much of the government's nuclear weapons development and production activities, they were concerned about accident liability.

At the same time, congressional concern developed over a second facet of the liability issue—ensuring adequate financial protection to the public. If private industry had moved forward with nuclear power development despite the liability risks, the public had no assurance that it would receive compensation for personal injury or property damages from the liable party in the event of a serious accident. Any compensation the public could receive would have depended on whether the liable party had sufficient insurance to pay for the damages or could pay them "out of pocket."

Faced with these concerns, and convinced that they constituted a major hurdle to encouraging private industry participation in nuclear energy development, the Congress enacted the Price-Anderson Act (42 U.S.C. 2210) in September 1957, which added section 170 to the Atomic Energy Act. The major provisions of the Price-Anderson Act are discussed in the following section.

Principal Features of the Act

The Price-Anderson Act has two underlying objectives: (1) to establish a mechanism for compensating the public for personal injury or property damage in the event of a nuclear accident and (2) to remove the roadblock to the private development of nuclear power. The act provides

"umbrella" coverage and limits the liability for anyone (contractors, subcontractors, vendors, suppliers, architect-engineers, and transporters) who performs work in connection with commercial or government nuclear activities. In addition, the act prescribes a system of private insurance and government indemnity (reimbursement of liability) to cover the off-site consequences of a nuclear accident at commercial and government facilities.

For commercial plants, the Congress initially limited liability to $560 million per accident and established a two-step process to pay claims: (1) liability claims would first be paid from private insurance that each nuclear power plant licensee is required to carry—$60 million in 1957— and (2) amounts exceeding the insurance limit would be paid by the government up to $500 million.

In 1975 the Congress enacted a major change in liability for commercial activities by creating a third source of funds to pay accident damages—a retrospective premium or secondary insurance plan. This amendment authorized NRC to require each commercial licensee to pay a retrospective premium of up to $5 million per operating plant if public liability exceeds the amount of private insurance available (private insurance had increased to $160 million). NRC, by regulation, has established a maximum amount of $10 million per year, per plant (two accidents). The amendment also provided for increasing the liability limit, and established a new limit of $560 million or the amount of financial protection required of licensees, whichever is greater.

The effect of these changes has been that (1) the government's indemnity was essentially phased out when the Nuclear Regulatory Commission (NRC) licensed the 80th plant ($160 million of private insurance + 80 plants x $5 million = $560 million), and (2) the liability limit has increased as the number of operating plants increased. Further, the 1975 amendment authorized NRC to establish requirements it deems necessary to ensure the availability of funds to meet any assessment of the retrospective premium. In this regard, NRC, by regulation, requires that each utility carry a secondary insurance policy on each reactor that provides up to $30 million per accident if the utility cannot make or is required to make more than its $5 million contribution per plant.

Because the funds available to pay damages resulting from any single nuclear power plant accident now total $695 million ($160 million of private insurance + 107 plants x $5 million), the government would pay liability claims only if a utility cannot meet its retrospective premium

obligation and the aggregate premium for all of the utility's reactors exceeds the $30 million of secondary insurance. By the early 1990s, when NRC expects to license 13 other plants, the limit will increase to $760 million.

Should damages exceed that limit, the 1975 amendment specified that the Congress will thoroughly review the accident and take whatever action it considers necessary and appropriate to protect the public. However, this provision does not obligate the Congress to authorize or appropriate additional funds.

In addition to the ceiling for commercial nuclear activities, the act limits liability for government contractor activities to $500 million in government indemnity plus private insurance. Since the Department of Energy (DOE) has generally reimbursed contractors for all costs of doing business with the government, DOE has not required its contractors to obtain private insurance. In addition, the Congress has not changed the liability limit for DOE's nuclear activities—the limit remains at $500 million, set in 1957.

Further, because the Congress wanted to review periodically the effectiveness and continued need for liability protection, the act limits NRC and DOE indemnity authority to 10 years. However, the act stipulated that any agreements negotiated with commercial plant operators and government contractors during that time were to remain in effect over the life of the licenses and/or contracts. The Congress has amended the act three times and extended the agencies' authority to indemnify licensees and contractors through August 1, 1987.

If the Congress does not act by that date, expiration of NRC's indemnification authority would have no direct effect on commercial nuclear power plants that have NRC construction or operating licenses as of that date. These plants would continue to be covered until their licenses expire. However, NRC would lose its authority to indemnify nuclear power plants licensed after August 1, 1987.

In addition, all DOE contracts that include indemnity arrangements that are in effect on that date would continue to be covered until the contracts expire. Similar to NRC, DOE would lose its authority to indemnify new contractor activities after that date. However, expiration of the act's indemnity authority could have a more direct and immediate impact on DOE's nuclear activities since DOE renegotiates its contracts every 5 years. Without the indemnity authority of Price-Anderson, DOE

could not extend the act's financial protection to either existing facilities when their contracts expire or to future facilities, such as a nuclear waste repository or interim storage facility, after August 1, 1987. DOE told us that although it could indemnify its contractors under its authority in the War Powers Act,[1] DOE may have to enter into separate contracts with each party operating or supplying its nuclear facilities absent the "umbrella," no-fault coverage of Price-Anderson. However, this authority would not extend to DOE's nondefense-related activities.

Proposals Introduced in the Congress

Since both NRC's and DOE's authority to indemnify licensees and contractors expire on August 1, 1987, the Congress has been considering whether to extend the indemnification authority and make other changes to the act, such as increasing the liability limit. During the 99th Congress, two bills were reported out of five House and Senate Committees. The legislation reported by the House Committees on Interior and Insular Affairs, Energy and Commerce, and Science and Technology (H.R. 3653) would have increased the retrospective premium paid by the commercial sector from $5 million to $63 million per licensed plant. In the Senate, the Committees on Environment and Public Works and Energy and Natural Resources reported two versions of one bill (S. 1225)—one recommended a maximum retrospective premium of $60 million per plant and the other, $20 million per plant. The 100th Congress has also proposed similar Price-Anderson legislation; these bills are still with the committees and therefore are not discussed in this report.

The bills before the Congress did not go unnoticed. Both advocates and opponents of the act raised concerns about the need for, and amount of, the liability limit. Opponents argued that (1) the current liability limit is much lower than estimates of the possible off-site financial consequences of a nuclear power plant accident and (2) the act is a disincentive to nuclear power plant safety because the industry is not held fully liable for the consequences of an accident. On the other hand, advocates purport that (1) a reasonable liability limit is essential to continued private industry participation in commercial and government nuclear activities, (2) the act provides the public with a source of funds to pay for damages up to the liability limit regardless of who is at fault for an accident, and (3) without the act, public compensation would be limited

[1]Public Law 85-804 authorizes any department or agency of the government to provide government indemnification against claims or losses of contractors involved in national defense activities.

to the amount of private insurance available and/or the liable parties' ability to pay damages "out of pocket."

Objectives, Scope, and Methodology

On January 27, 1986, Senator George Mitchell requested that we determine (1) the potential off-site personal injury and property damage consequences resulting from a catastrophic accident at a commercial nuclear power plant and (2) the liability limit, if any, that should be set out in the act. On the basis of subsequent discussions with the Senator's office, we agreed to conduct our work in two parts: (1) a preliminary report by July 1986 to coincide with hearings on legislation to amend the act and (2) a broader assessment of liability, accident consequences, and other issues related to the act. On July 16, 1986, we issued a report on the results of our preliminary analysis—Nuclear Regulation: Financial Consequences of a Nuclear Power Plant Accident (GAO/RCED-86-193BR). This report presents our final assessment of accident consequences, a comparison of these consequences to the liability limits proposed, and general observations on the act.

To determine the potential off-site financial consequences of a nuclear power plant accident, we assessed two NRC studies: Technical Guidance for Siting Criteria Development (NUREG/CR-2239, Dec. 1982) and Estimates of the Financial Consequences of Nuclear Power Reactor Accidents (NUREG/CR-2723, Sept. 1982). We discussed the results of these studies with NRC staff in the Office of Nuclear Regulatory Research and Sandia National Laboratory staff who prepared the studies for NRC and conducted research to refine consequence projections. We relied on these studies because, according to NRC and Sandia staff, they represent the most current, complete, and authoritative estimates of off-site personal injury and property damage that might result from a nuclear power plant accident. However, we tested the reasonableness of some of the key assumptions in the studies, such as the criteria NRC used to determine whether property is too contaminated for continued use. We also escalated the costs to 1986 dollars. Appendix I describes the evolution of NRC's methodology to estimate accident consequences.

Although NRC's studies analyze five different accident releases, we limited our analysis to two: a catastrophic accident involving extensive core damage, the joint or sequential failure of all safety features, and a massive, early rupture of the containment and a severe accident involving the same circumstances with the exception that some safety systems operate and the rupture is not immediate. We selected these accidents

because they result in the most significant off-site consequences. We calculated the off-site financial consequences for both property damages and health effects for 119 of 120 nuclear plants now operating, applying for operating licenses, or under active construction. NRC's studies omitted one operating plant—Hope Creek—therefore, we were not able to obtain data for it. Although some of the plants are not operating, we were able to estimate potential accident consequences on the basis of generic accident scenarios and plant-specific information concerning operating levels and population density around the plants.

Our estimates of the off-site property damages and health effects for the 119 plants include the following considerations. With respect to the dollar value of off-site property damages, we accepted NRC's calculation of lost wages, relocation expenses for the evacuated population, decontamination costs, lost public and private property costs, and land and farm crop values. With respect to dollar estimates for health effects, we included early fatalities, early injuries, latent cancers, and thyroid effects--the most probable health effects of a nuclear power plant accident, according to a National Academy of Sciences report, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation (the 1980 Beir Report).

To derive an appropriate estimate of health effects, we first compared the reasonableness of the costs suggested in the NRC studies with the average compensation levels awarded in radiation-and asbestos-related litigation. Specifically, we looked at the awards made in Irene Allen v. the United States for leukemia deaths and latent cancers resulting from atmospheric nuclear weapons tests during the 1950s in Nevada. We also reviewed the average compensation paid for asbestos-induced injuries and cancer claims against asbestos manufacturers, as reported in a 1984 Rand Corporation study, Variation in Asbestos Litigation Compensation and Expenses. These cases covered the period January 1980 through August 1982. Finally, we contracted with Jury Verdict Research, Inc., to analyze jury verdicts and judgments in product liability cases to determine the average awards for cancer- and radiation-related deaths and injuries. Since NRC's estimates of $100,000 for early injuries and latent cancers and $1 million for early fatalities generally equalled or exceeded those awarded by the courts, we used NRC's estimates to ensure that our analysis is sufficiently conservative and did not understate the potential financial consequences. We then calculated for all 119 plants the financial health consequences by multiplying the NRC-suggested costs by the number of early injuries, early fatalities, thyroid effects, and latent cancers reported in the two studies.

Our results are shown for the mean, or average, values of possible accident costs. We recognize that actual property damages and public health effects could be less or more severe depending on factors such as weather conditions at the time of the accident. However, we believe it is more appropriate to rely on the mean values because (1) they represent the consequences that would most likely occur during typical weather and (2) good data does not exist to calculate maximum consequences. Appendix II shows the results of our financial consequence analysis for each of the 119 plants.

To determine whether the consequences we estimated would change significantly on the basis of recent developments in the methodology for estimating accident consequences, we monitored ongoing projects sponsored by NRC. We reviewed NRC's Reassessment of the Technical Bases for Estimating Source Terms (NUREG-0956, July 1986), which describes a major advancement in the technology for calculating the amount and timing of radioactive material that could be released from postulated accidents at U.S. nuclear power plants. We also assessed information on a new computer model that NRC developed to estimate accident consequences—we wanted to determine the improvements it offered over the model used in NRC's 1982 studies. Finally, we monitored NRC's research project to develop accident sequences and plant-specific estimates of radiation releases and consequences for five plants using both the new radiation release and accident consequence models. We assessed the potential implications of the draft report on this research, Reactor Risk Reference Document (NUREG-1150, Feb. 1987), on our financial consequence estimates. We discussed the findings in NUREG-1150 with NRC Office of Reactor Research and Sandia National Laboratory staff. We also discussed with NRC officials the ramifications of the Soviet Union's Chernobyl nuclear plant accident on catastrophic and severe accident consequence analyses.

In addition, we compared our estimates of off-site financial consequences for the 119 plants resulting from a catastrophic and severe accident with the current Price-Anderson Act liability limit and the liability limits proposed by the 99th Congress in H.R. 3653 and S. 1225. Finally, we reviewed the treatment of claims arising from the March 1979 Three Mile Island accident to determine how the Price-Anderson insurance system performed for this accident.

We provided NRC and DOE headquarters and Sandia staffs with pertinent sections of the draft report, discussed the concerns raised, and incorporated their clarifications where appropriate. Both NRC and DOE support

extending their indemnification authority under the act. As requested, we did not ask these agencies to review and comment officially on this report. Our work was performed between April 1986 and February 1987 and in accordance with generally accepted government auditing standards.

Potential Off-Site Consequences Could Exceed the Liability Limit

We found that the estimated average financial consequences for the worst (catastrophic) nuclear power plant accident could range from $67 million to $15.5 billion at any one of the 119 plants; the consequences for 71 plants would be less than $2 billion. However, the probability that this accident could occur is 1 in 100,000 per plant, per year. On the other hand, the average consequences of the next worst (severe) accident at any plant would be less than $225 million. Although the severe accident has a higher probability of occurrence (2 in 100,000), the catastrophic accident poses the greatest threat to public health and safety.[1]

In addition, the estimated financial consequences for 114 of the 119 commercial plants that are operating or under active construction would exceed the current liability limit if a catastrophic accident occurred. However, the estimated consequences for 78 to 115 of the 119 plants would be within the limits of the various proposals reported on by committees of the 99th Congress. On the other hand, the current liability limit would be sufficient to cover the average consequences of a severe accident at all 119 plants. Since the off-site consequences are only approximations of what a nuclear accident could cost, these estimates should be considered in conjunction with the uncertainties in the estimates, probability of accident occurrence, and the only significant power plant accident in this country— Three Mile Island. Although no direct off-site health effects or property contamination resulted from the accident, as of January 1987 private insurance had paid $41 million for public liability claims.

The Financial Impact of Catastrophic and Severe Accidents

According to NRC staff, only accidents involving melting of the fuel in the reactor core could cause substantial off-site radiological damage. Although NRC and Sandia assessed the probability and projected consequences of five types of core-melt accident scenarios, only two pose a major threat to public health and safety: catastrophic and severe. The catastrophic accident would result in extensive core damage, the joint or sequential failure of all safety features, and a massive rupture within 1 hour of core melt of the concrete and steel containment building that surrounds the reactor and attendant equipment. The severe accident involves the same accident sequence as the catastrophic, except that

[1]NRC's probability estimates were derived from risk assessments available at the time of the 1982 studies. These probabilities were intended to represent the accident likelihood for all plants. According to NRC's February 1987 report, Reactor Risk Reference Document (NUREG-1150), the actual probability at any individual plant could be up to 100 times greater or 1,000 times less than the probabilities represented here.

some safety systems continue to operate and the containment rupture occurs 2 to 3 hours later. Since the other three accident scenarios NRC assessed would not result in extensive off-site contamination (i.e., safety systems operate as designed), we limited our analysis to the catastrophic and severe accidents.

Because a catastrophic or severe accident has never occurred in this country's commercial nuclear power program, NRC and industry experts can only approximate the off-site costs that might result from such accidents. In addition, the estimates derived are very sensitive to key assumptions used in the analysis, such as the criteria used to determine whether land is too contaminated for continued use and weather conditions when the accident occurs. The methodology most widely accepted and used by NRC and the industry to estimate accident probabilities and consequences is called probabilistic risk assessment (PRA).

This methodology provides for a systematic examination of the components of a nuclear reactor to identify accident sequences and measures the likely public health, environmental, and economic impacts. In addition to estimating the potential consequences of an accident, the PRA methodology calculates the probability of an accident's occurrence so that both consequences and probabilities can be viewed in combination to assess the risk posed by nuclear power plant accidents. As a result, NRC and the nuclear industry recognize the value of PRA to analyze reactor safety and assess potential accident consequences. In our opinion, PRA is the best tool today for determining the likelihood, causes, and potential consequences of nuclear power plant accidents.

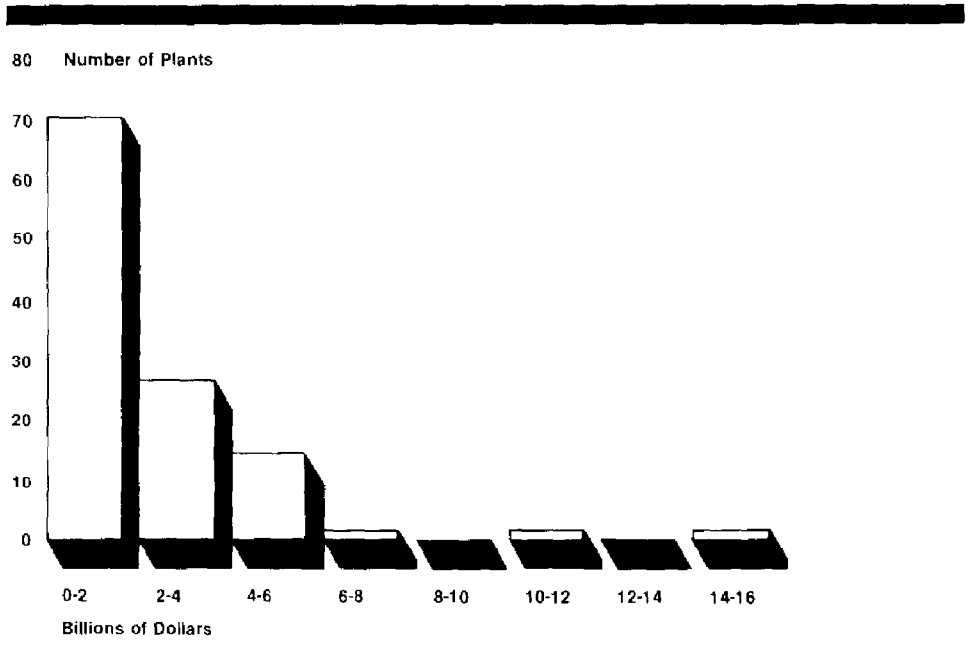
Nevertheless, PRA is only an approximation tool, and many uncertainties exist in the methodology and the results derived from it. These uncertainties stem from NRC's and the industry's incomplete knowledge about events that initiate accidents, plant systems, human behavior, and the physical and chemical processes that could take place during an accident. NRC staff told us that even if additional information on the Chernobyl accident becomes available, these uncertainties will persist because design differences exist between the Soviet reactor and those built in this country that will limit the usefulness of such information. A more detailed description of the methodology used to quantify consequences can be found in Probabilistic Risk Assessment: An Emerging Aid to Nuclear Power Plant Safety Regulation (GAO/RCED-85-11, June 19, 1985) and in appendix I of this report.

The expected financial consequences of catastrophic and severe accidents differ significantly. On the basis of two NRC studies that used the PRA methodology, we found that the average off-site personal injury and property losses for a catastrophic accident at any of the 119 plants in this country could range from $67 million at the Big Rock Point plant to $15.5 billion at the Indian Point 3 plant.[2] Generally, 90 percent of these costs are for economic or property damages, such as lost wages, relocation expenses for the evacuated population, decontamination costs, and land and farm crop values. Since NRC does not have information concerning the utility's costs to investigate, defend, and settle liability claims, or the economic losses indirectly associated with the accident, such as lost production, jobs, or wages for vendors or suppliers located outside the area directly affected by the accident, we could not estimate these costs. Appendix II shows the estimated personal injury and property costs for each of the 119 plants.

Although the estimated catastrophic consequences range from $67 million to $15.5 billion, the financial consequences for 113 plants are less than $6 billion. The remaining six plants with consequences in excess of $6 billion are located near densely populated areas—Indian Point 2 and 3 (New York), Limerick 1 and 2 (Philadelphia), and Zion 1 and 2 (Chicago). In addition, catastrophic accident consequences at 98 of the 119 plants (82 percent) would be less than $4 billion and at 71 of the 119 plants (60 percent), less than $2 billion. Figure 2.1 presents the range of average estimated financial consequences for a catastrophic accident at the 119 nuclear power plants operating or under active construction in this country. In contrast, the average off-site financial consequences for a severe accident would not exceed $225 million at any plant.

[2]According to NRC, 120 plants are operating or under active construction, but NRC did not have information for one—the Hope Creek plant. As a result, our consequence analysis addresses 119 plants.

Figure 2.1: Range of Average Accident Consequences for 119 Plants



Source: GAO

The estimates we derived for catastrophic and severe accident consequences include the costs of early injuries, early fatalities, latent cancers, and the types of property damages discussed earlier. They represent average consequences resulting from a wide range of weather conditions. According to NRC staff, more extreme weather conditions could produce greater health effects and property damages and higher off-site financial consequences. However, NRC's weather sampling techniques, consequence model assumptions, and limited available weather data preclude NRC from reliably estimating maximum consequences. In addition, NRC staff told us that PRAs performed for each plant—a long and expensive process that takes into account plant-specific data—would provide more precise estimates of accident consequences. However, the NRC studies supporting our estimates use a "standard" model plant and a "standard" set of accidents at each plant to calculate accident consequences. These studies assume, for example, a 1,120-megawatt pressurized water reactor for all plants (regardless of the actual design and size of the plants) and use generic source terms (measures of the amount and timing of radioactive material released during an accident) for all types of accidents.

Although the consequences of a catastrophic and severe accident could be significant, such accidents have never occurred in this country. NRC estimates that at any particular plant the probability that a catastrophic accident can occur is about 1 in 100,000 in a single year. On the other hand, NRC estimates that the severe accident, the accident with potentially less financial consequences, is more likely to occur; the probability is 2 in 100,000. Because these are generic probabilities based on a standard plant and accident assumption, the probability for an individual plant may be up to 100 times greater or 1,000 times less than NRC projects, as demonstrated by the NRC study, NUREG-1150.

Although the probability of the accident scenario occurring that produces the catastrophic or severe accident—fuel melt, safety system failure, and early containment failure—is low, the probability of a core melt starting the sequence is higher. NRC estimates that the probability of an accident involving the melting of the fuel in the reactor core at any of the approximately 100 operating plants is about 12 percent in the next 20 years, or one chance in eight. However, NRC staff told us that this industrywide likelihood of severe core damage is only an estimate since PRA studies have not been performed on all plants. Plant-specific PRAs would, according to NRC staff, account for specific plant features that could cause the core damage frequency to depart significantly from the average stated above.

Consequence Estimates Contain Large Uncertainties

Since this country has never had an accident of the magnitude needed to validate the assumptions supporting the consequence and probability estimates presented above, no actuarial basis exists for them. As a result, NRC and the industry continue to conduct research to obtain a better understanding about plant systems, human behavior, and the chemical and physical changes that take place during an accident.

NRC has recently completed a draft reassessment of accident consequences on the basis of two recent changes in the PRA methodology.[3] One change allows NRC to better estimate the uncertainty in the source term. The other change allows NRC, in part, to (1) estimate consequences that previously were not in the PRA methodology, such as population relocation costs during the decontamination process and costs of personal injuries sustained by workers performing decontamination activities, and

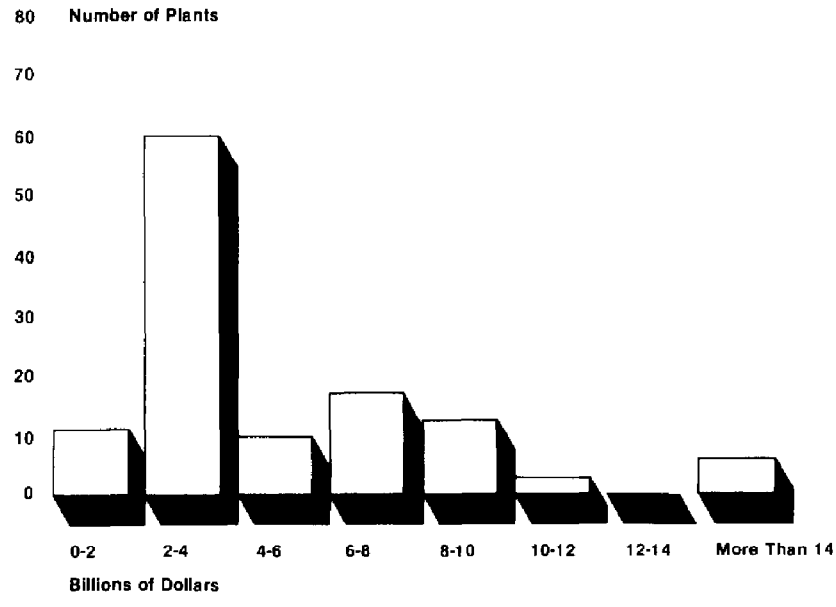
[3]Reactor Risk Reference Document (NUREG-1150, Feb. 1987).

(2) improve upon assumptions that contribute to the magnitude of consequences, such as the criteria to determine whether land in urban and farm areas is too contaminated for continued use.

In NUREG-1150, a draft report of NRC's findings for five plants, NRC found that property costs associated with the worst accidents are generally twice as large as the estimates we derived. However, for four of the five plants, estimates of personal injury and early death are generally lower than previous NRC estimates. Since NUREG-1150 indicates that the source term—the major contributor to the magnitude of consequences—for an accident at any particular plant could be as high as the largest release calculated in the two 1982 NRC studies, or several orders of magnitude lower, NRC staff told us they have no better indication of what actual consequences would be. Further, since NRC assessed only a limited number of plants, the staff told us that generic conclusions about NUREG-1150 results cannot be made until a sensitivity study of these results to plant-specific design factors and operating procedures can be made. For these reasons, we believe the estimates we derived using the two 1982 NRC studies are still reasonable.

However, since 90 percent of the estimated off-site consequences represent property damages, and NUREG-1150 property costs are at least two times greater than previously projected, we doubled our consequence estimates to illustrate one possible impact of NRC's PRA improvements. Figure 2.2 shows the distribution of the 119 plants when the estimated consequences of a catastrophic accident are doubled.

Figure 2.2: Range of Doubled Catastrophic Accident Consequences



Source: GAO.

As shown in figure 2.2, when the estimated financial consequences of a catastrophic accident are doubled, 81 plants would still fall below $6 billion, and the financial consequences for 71 plants would be less than $4 billion. In addition, estimated consequences of a severe accident, when doubled, would not exceed $500 million. However, NRC officials pointed out that even doubling the estimates may not adequately account for all uncertainties in the PRA methodology. Since PRA contains many uncertainties and NRC's NUREG-1150 study indicates a large uncertainty in actual source terms, we believe that consequence estimates should be only one of several factors considered in setting a liability limit. These factors are discussed in chapter 3.

Comparison of Consequences With the Act's Liability Limit

In the event of a catastrophic accident, total estimated off-site damages at 114 of the 119 plants would exceed the act's existing liability limit. However, estimated off-site damages resulting from a severe accident at any plant would not exceed the liability limit. If the Congress does not extend NRC's indemnification authority beyond August 1, 1987, all commercial power plants with construction or operating licenses would continue to be provided financial protection under the act. As of March

1987, NRC had issued operating licenses to 107 plants,[4] and it expects to make licensing decisions on 13 other plants by the early 1990s.[5] At that time, assuming that all 13 plants are licensed to operate, the liability limit under the current act would total $760 million.

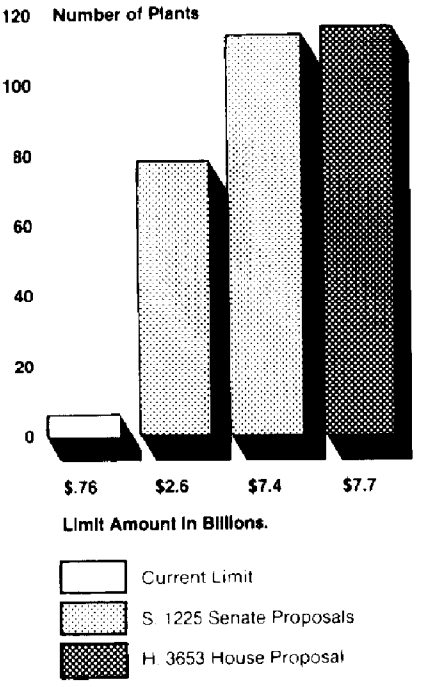
During the 99th Congress, five House and Senate committees considered legislation to extend the act and increase the liability limit. One bill (H.R. 3653) reported by the House Committees on Interior and Insular Affairs, Energy and Commerce, and Science and Technology would have increased the industry contribution to $63 million per operating nuclear plant plus the $160 million of private insurance available. For the 120 plants operating or under active construction, this proposal would have effectively resulted in a $7.7 billion liability limit. On the other hand, the Senate Committees on Environment and Public Works and Energy and Natural Resources reported two variations of one bill (S. 1225). One recommended a limit of $7.4 billion on the basis of private insurance and an industry contribution of $60 million per plant. The other recommended a limit of $2.6 billion, including private insurance and a maximum industry contribution of $20 million per plant.

If enacted, these legislative proposals would have covered the estimated damages resulting from a catastrophic accident at many more plants than under the existing act. Figure 2.3 compares the number of plants whose catastrophic consequences would fall within the suggested limits of the two legislative proposals with those that fall within the existing limit.

[4]Three Mile Island unit 2 has an operating license but is not included here as it was shut down at the time of NRC's analysis.

[5]Utilities have received construction licenses for five other plants but have halted construction of these plants.

Figure 2.3: Liability Limit Coverage of a Catastrophic Accident



Source: GAO.

As shown in figure 2.3, a limit of $2.6 billion would have covered the estimated consequences for 66 percent (78 of 119) of the plants; a limit of $7.4 billion would have covered 95 percent (113 of 119); and $7.7 billion, 97 percent (115 of 119) of the plants. If the Congress used the severe accident as its basis for setting a liability limit, $760 million would cover the potential personal injuries and property damages for all 119 plants.

Three Mile Island Accident Costs Should Be Considered

In setting a liability limit, projected accident consequences and probabilities should be considered in conjunction with the Three Mile Island accident in Pennsylvania. The March 1979 accident represents the first—and only—test of the adequacy of the act's financial protection for the public and the nuclear industry in this country. Prior to that, the public had never filed for damages arising from an accident at an operating commercial nuclear power plant, and the largest claim for damages related to a government nuclear facility was about $271,000. Since the Three Mile Island accident produced very low levels of radiation releases compared with those expected to result from a catastrophic

or severe accident, the public experienced no short-term radiation illnesses, deaths, or off-site property contamination.

Despite the lack of detectable off-site health effects or property contamination, private insurance has paid claims totaling about $41 million as of January 1987. The payments consisted of $14 million for anticipated health effects that may occur as much as 20 to 40 years after the accident; $5 million to monitor the health of residents within 15 miles of the plant; and $22 million for alleged reduction of property values around the plant and economic losses incurred when, as a precaution, pregnant women and children were evacuated from the area. As of January 1987 an additional 2,000 personal injury claims are still pending. According to an insurance representative, these claims will be resolved by the courts on the basis of whether claimants can establish a relationship between alleged damages and the Three Mile Island accident. Nevertheless, the damages agreed to so far are well within the act's existing liability limit.

Observations on Price-Anderson Issues

We believe the act's indemnification authority should be extended since many of the same issues exist today as when the Congress initially passed the act. For example, private insurance would not fully cover the expected consequences of a major accident. If the Congress does not extend the indemnity authority, NRC's licensees and DOE's contractors would continue to be protected until the licenses or contracts expire, but NRC and DOE could not indemnify new plants or contractors. However, removing this protection could have an immediate impact on the people that live near, and the contractors that operate, some of DOE's facilities. Three contracts for four facilities expire in September 1987. If DOE does not complete contract negotiations and sign new contracts before August 1, 1987, the contractors would lose the act's government indemnity protection and the public's ability to receive accident compensation could be hindered.

If the Congress extends the indemnity provisions, we believe it should also reassess the liability limit because the public is not afforded the same level of protection for an accident at a DOE and commercial facility, and inflation has eroded the financial protection originally provided by the act. Once the Congress determines that a need exists to limit liability, it should also consider the amount in light of the act's objectives and who should bear the financial burden.

The Act Should Be Retained

In previous reports and testimony, we concluded that the act's indemnity authority should be extended since many of the original premises for the act still exist.[1] We continue to believe this today because (1) the potential for an accident that causes significant off-site personal injury and property damage exists, (2) private insurance to cover fully the expected consequences of a catastrophic accident is not available, (3) industry is not willing to assume the risks of an accident without adequate financial protection, and (4) the public would not be assured of personal injury and property damage compensation if an accident bankrupted the party responsible for the accident.

If the Congress does not extend NRC's indemnification authority by August 1, 1987, the people that live near, and the utilities that operate, the 107 commercial nuclear power plants would continue to be provided

[1] Analysis of the Price-Anderson Act (EMD-80-80, Aug. 18, 1980), Congress Should Increase Financial Protection to the Public From Accidents at DOE Nuclear Operations (EMD-81-111, Sept. 14, 1981), and November 8, 1985, hearings before the Subcommittee on Energy Research and Production, House Committee on Science and Technology.

protection under the act. In addition, 13 other nuclear plants with construction licenses would be covered. When all plants are operating, the liability coverage provided would total $760 million. However, NRC could not indemnify new plants if the Congress does not extend NRC's indemnification authority. NRC has repeatedly supported extending its indemnification authority, most recently at April 30, 1987, hearings before the Subcommittee on Nuclear Regulation, Senate Committee on Environment and Public Works.

However, expiration of the indemnity provisions could have an immediate impact on DOE's nuclear defense programs and nondefense activities; its plans to transport and dispose of nuclear waste; and the people that live near, and the contractors that operate, its nuclear facilities. Because DOE indemnification continues through the 5-year life of its contracts, the financial protection provided by the act would not apply to any contract that DOE awards after August 1, 1987.

As of June 1985 DOE reportedly had indemnity agreements with 45 prime contractors to operate and manage its nuclear facilities; the agreements also covered an estimated 60,000 subcontractors and vendors. As of September 30, 1987, three contracts for the operation of four DOE facilities will expire: Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Lawrence Berkeley National Laboratory, and the Hanford facility. Unless the Congress extends DOE's indemnification authority beyond August 1, 1987, the contractors selected to operate and manage, and the public living near, these facilities would not be afforded the financial protection provided by the act. In addition, contracts awarded in subsequent years would not be covered. In September 1988 the operation and maintenance contracts at DOE's Fernald, Argonne, and Mound facilities expire, and in September 1989 the one at Oak Ridge expires. DOE officials in March 1987 supported extending the agency's indemnification authority because without it industry may be reluctant to enter into contracts with DOE.

DOE has at least two options to ensure that the public is provided some form of financial protection if an accident occurs at one of its facilities. First, DOE could require its contractors to obtain the maximum amount of private insurance available. However, the amount of insurance may not be sufficient to cover all claims arising from an accident, which was one of the principal reasons for passing the original act. Second, DOE might be able to indemnify contractors under the War Powers Act authority. Using this authority, DOE may have to enter into an indemnity agreement with each contractor, subcontractor, and supplier, whereas

Price-Anderson provides "umbrella" coverage for all attendant parties under a single agreement. In addition, the War Powers Act applies only to national defense activities. Expiration of the act's indemnification provisions would not only affect existing DOE facilities but could also impede DOE's ability to enter into contracts for the design, construction, and operation of high-level waste repositories or interim storage facilities. State officials are concerned that public compensation would not be available for damages resulting from a nuclear waste accident without statutory liability coverage.

We believe the Congress should extend the act's indemnity authority because many of the same issues exist today as when Congress initially passed the act. Further, the act provides a source of funds to pay claims that are determined valid by the courts and limits the liability of plant operators. Without Price-Anderson, the public has no assurance that it could receive compensation if a catastrophic accident bankrupted the utility, or if a supplier of a defective part held liable for the accident lacked the resources to pay damages.

The Liability Limit for Commercial Activities Should Be Reassessed

If the Congress extends the indemnity authority under the act, it should also reassess the level of financial protection to be provided. In 1957 when the Congress established the original $560 million liability limit, only one study existed on potential accident consequences. This study, completed in 1957, estimated that consequences could range from $500 million to $7 billion on the basis of the subjective judgment of the study's authors rather than a systematic examination of causes and consequences of accidents. Despite this information, the Congress set the limit on the basis of what it believed the federal budget and private insurance could bear. Today inflation has eroded the level of financial protection initially guaranteed by the act. To keep pace with inflation alone, the limit for NRC's licensees would have to be raised from the 1957 figure of $560 million to $2.2 billion (1986 dollars).

In reassessing the act's liability limit, the Congress should consider not only inflation but also a number of other factors, such as the estimated consequences of various accidents, the probability that accidents could occur, and the Three Mile Island accident. The Congress should also consider the Chernobyl accident, which resulted in the deaths of 26 individuals and extensive damage to Russian crop land. Although the exact costs of this catastrophic accident are unknown, they are presumed to be significant.

We believe our analysis provides a starting point for this reassessment (see ch. 2). We identified the two types of accidents—catastrophic and severe—that would result in significant off-site financial consequences. For the catastrophic accident, we found that the potential off-site financial consequences for 119 plants could range from $67 million to $15.5 billion; the consequences for 60 percent of the plants would be less than $2 billion. For a severe accident, the consequences would be less than $225 million for all 119 plants.

Although we obtained our estimates from studies that employed the best available methodology, the estimates derived should be viewed only as a guideline to determine the appropriate liability limit. First, the actual financial consequences could be higher or lower than projected by our analysis because a large number of uncertainties exist in the estimates and the methods used to develop them. Second, this country has never had a catastrophic or severe accident to determine the actual off-site consequences and assess the validity of the assumptions used to derive them. Third, the methodology is changing as NRC and industry develop more information on the possible causes and consequences of an accident.

In addition, the estimated consequences should be balanced against the probability of accident occurrence. Although a catastrophic accident could result in as much as $15.5 billion in off-site consequences, the probability of this type of accident occurring at any one plant in a single year is small—1 in 100,000. For the less severe accident, the consequences could be less than $225 million, and the probability is only slightly higher—2 in 100,000. According to NRC, these probabilities could be 100 times greater or 1,000 times less for any individual plant.

Further, Three Mile Island—the worst nuclear power plant accident in this country—released very low levels of radiation and resulted in no off-site property contamination or detectable personal injuries. The property damage claims filed involved compensation of economic losses during the precautionary evacuation and alleged reductions in property values. The health claims filed related to the potential for latent cancer development (20 to 40 years later) rather than actual illness. As of January 1987 private insurance has paid approximately $41 million for Three Mile Island claims; the outcome of 2,000 additional claims will be decided by the courts.

In deciding where to set the liability limit, the Congress should weigh and balance the act's objectives: industry participation in commercial

activities and financial protection for the public. The industry wants a limit on liability; the public wants unlimited liability regardless of who pays. However, the higher the limit (or if liability was unlimited), the greater the disincentive for industry participation in commercial nuclear activities. The lower the limit, the less equitable the protection for the public. However, by a 1975 amendment to the act, the Congress specified that should damages exceed the limit, it would thoroughly review the accident and take whatever action it considered necessary and appropriate to protect the public from the financial consequences of such a disaster. This provision does not obligate the Congress to authorize or appropriate additional funds.

Ultimately, the decision on where to set the liability limit for nuclear plant accidents is one of national policy. The Congress will have to weigh national policy interests against commercial and national defense needs and the interests of the public.

Coverage for DOE Contractors Should Be Comparable to Commercial Activities

The public is not afforded the same level of financial protection for an accident at a DOE facility as an accident at a commercial nuclear power plant. The liability limit for DOE's contractors remains at $500 million per accident as set out in 1957, although inflation alone has eroded the level of financial protection provided. To keep pace with inflation, the indemnity for DOE contractors would have to be raised from $500 million to $2 billion (1986 dollars).

In addition, DOE does not require its contractors to obtain private insurance. Therefore, DOE's contractors are covered by only one layer of protection—the government. This coverage is currently $195 million lower than that for NRC's licensees (on the basis of 107 operating plants). By the early 1990s, when NRC expects to issue operating licenses to 13 other plants, this gap will increase to $260 million. DOE supported the same liability limit for its contractors as that available to commercial licensees in an August 1983 report, The Price Anderson Act—Report to the Congress as Required by Section 170 p. of the Atomic Energy Act of 1954, as Amended, and most recently at April 30, 1987, hearings before the Subcommittee on Nuclear Regulation, Senate Committee on Environment and Public Works.

As early as 1981, we noted that some DOE nuclear facilities could experience accidents comparable to those projected for commercial nuclear power plants, and DOE needed to assess the potential consequences of such accidents. In June 1985 DOE told the Subcommittee on Energy

Research and Development, Senate Committee on Energy and Natural Resources, that it would have to develop a complex model for each of its facilities to determine the potential financial consequences of a major accident. DOE stated that the risk assessment would require "hundreds of scenarios" to analyze a range of consequences for each facility and that the wide range of values derived from the assessments would be of "very little value" in establishing a liability limit for DOE's contractors. Nevertheless, DOE concluded that a limit of between $1 billion and $2.5 billion may be sufficient to satisfy claims arising from an accident at its facilities.

In addition, in a 1986 report concerning DOE's safety analysis review process, we noted that DOE analyzed potential accidents; however, it did not assess catastrophic and severe accident consequences at all of its facilities.[2] Further, for the facilities for which a safety analysis review had been conducted, DOE used different methods to estimate consequences.

Several reasons exist for the Congress to reassess the liability limit for DOE contractors. First, inflation has eroded the level of protection established by the act. The $500 million in 1957 dollars would have to be increased to $2 billion (1986 dollars) to provide equivalent coverage. Second, because the act treats DOE contractors differently than NRC licensees, the public is not afforded the same financial protection at DOE facilities. For example, in October 1988 DOE expects to transport one type of nuclear waste from six locations around the country to a repository located near Carlsbad, New Mexico. If an accident occurs while DOE's contractors are transporting this waste, funds available to pay public claims would be limited to $500 million. In contrast, transportation of nuclear waste from a commercial nuclear plant to an interim storage facility would be covered by the act's commercial power plant provisions—up to $695 million would now be available to pay claims stemming from a transportation accident.

We believe that the public should be afforded the same level of protection regardless of where a nuclear accident occurs. We noted that the legislative proposals of the 99th Congress included the same liability limit for DOE contractors as for commercial nuclear activities.

[2]Nuclear Safety: Safety Analysis Reviews for DOE's Defense Facilities Can Be Improved (GAO/RCED-86-175, June 1986).

Precautionary Evacuation Costs Should Be Covered

The Price-Anderson Act may not cover the costs of a precautionary evacuation at either an NRC licensee or DOE facility. The act covers liability for a nuclear incident that causes off-site damages as a result of the radioactive properties of nuclear materials. Neither the act nor its legislative history discuss whether this includes the cost of a precautionary evacuation—where a radiation release appears imminent, such that a precautionary evacuation is ordered, but in fact, no release occurs. NRC officials told us that the private insurance commercial licensees carry covers precautionary evacuation costs. However, DOE does not require its contractors to obtain private insurance; therefore, it is uncertain whether costs arising from a precautionary evacuation at a DOE facility would be covered.

In 1981 we recommended that the Congress amend the definition of a "nuclear incident" to clearly include any occurrence in which NRC or DOE determines that a release of radiation may be imminent.[3] Although both DOE and NRC initially agreed with this recommendation, in an August 1983 report to the Congress, DOE changed its position. DOE concluded that public protection should be dealt with in the same manner as any potentially hazardous activity, whether nuclear, toxic, or explosive, and that priority treatment for DOE's nuclear activities was not necessary. In the 1983 report, DOE recommended that the act not be amended to cover precautionary evacuation costs. DOE reiterated its position in June 1985 and stated that since the decision to order a precautionary evacuation would be made by state or local government officials, the resulting costs should not be covered under the act.

However, the Price-Anderson Act, in effect, distinguishes— and treats—nuclear activities differently from other types of industrial accidents. In addition, the public incurs costs regardless of whether radioactive material is released or not; that is, lives are disrupted and the potential exists for economic damage, such as lost wages and relocation costs. For example, about $22 million of the $41 million paid for Three Mile Island claims represented compensation for economic losses suffered by the public, including precautionary evacuation costs. In addition, inequities exist for public compensation of precautionary evacuation costs. NRC licensees carry insurance to cover these costs, but DOE does not require its contractors to do so. However, the impact of a precautionary evacuation on people that live near DOE facilities would be the same as on people that live around commercial plants.

[3]Congress Should Increase Financial Protection to the Public From Accidents at DOE Nuclear Operations (EMD-81-111, Sept. 14, 1981).

We noted that the two legislative proposals of the 99th Congress included provisions to redefine a nuclear incident such that precautionary evacuation costs for both NRC and DOE activities would be covered by the act. We support this effort.

Matters for Congressional Consideration

Unless the Congress extends the act's indemnity authority, it will expire on August 1, 1987. In previous reports and testimony, we recommended that the Congress extend the indemnity provisions of the act and set the liability limit for DOE contractors at the same level as for commercial licensees. NRC and DOE also support these positions.

Ultimately, the decision on where to set the liability limit for nuclear power plant accidents is one of national policy. The Congress will have to weigh national policy interests against commercial and defense needs and the interests of the public. This report provides information to assist in congressional deliberations, such as the estimated financial consequences of nuclear accidents, likelihood of accident occurrence, and the impact of inflation on the protection originally provided by the act. Therefore, we believe that the Congress should

- reassess the commercial liability limit on the basis of inflation, estimates of accident consequences and probabilities, and the uncertainties in these estimates and
- set the liability limit for DOE at the same level as for commercial licensees.

In addition, the Price-Anderson Act is ambiguous concerning coverage of precautionary evacuation costs. Although NRC's licensees obtain private insurance to cover these costs, DOE does not require its contractors to carry such insurance. Since the impact of a precautionary evacuation would be the same on the people that live around DOE facilities as on those that live near commercial plants, we believe that the Congress should clarify the act to provide equal protection for the public in the event of a precautionary evacuation.

Methodology for Estimating Accident Consequences

Historical Perspective

In 1957 the Atomic Energy Commission, predecessor to NRC, completed the first major study of the potential radioactive releases arising from major power plant accidents. In this study, entitled Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants (WASH-740), the Commission estimated the number of personal injuries, property damages, and relocation expenses of a major accident on the basis of subjective judgments of the most knowledgeable experts in reactor technology. The study results showed that personal injuries could range from no off-site injuries or deaths to 3,400 deaths and 43,000 injuries, and that property damages could range from $500,000 to $7 billion.

The authors of WASH-740 recognized that they lacked the data and methods to systematically examine accident probabilities and consequences. Nevertheless, they attempted to describe the progress of such accidents by defining "hazard states" for the reactor that focused on the large inventory of radioactive material in the core and the potential for containment failure. When the authors lacked information in the analysis, they made conservative or pessimistic assumptions. In the judgment of the experts conducting the study, the likelihood of a major reactor accident occurring was low; however, they were reluctant to quantify the probability of occurrence.

In 1975 the Commission began to use a systematic method to assess the impacts of nuclear accidents. The methodology, called probabilistic risk assessment (PRA), was first used in the Reactor Safety Study (formerly WASH-1400, now NUREG-75-014), which estimated both the probabilities and consequences of accidents in large nuclear reactors. However, NRC did not use PRA routinely as an aid to evaluate and regulate nuclear power plant safety until after the March 1979 Three Mile Island accident. For example, NRC has used PRA to assess the risk of various types of accidents in environmental impact statements for new plants and to analyze and improve the safety of operating plants. NRC and nuclear industry experts recognize that the 1975 PRA approach is the best tool for quantifying the potential risk of various types of accidents.

Overview of PRA Methodology

PRA quantifies the probabilities of potential accidents and their consequences. In the nuclear power plant safety field, PRAs focus on core-damage and core-melt accidents, since they are expected to pose the greatest risk to public health and safety. This technique addresses three basic questions about nuclear plant accidents:

- What could go wrong?
- How likely is it that this will happen?
- If it happens, what are the consequences?

PRAs can be performed at three general levels: level one—plant systems analysis; level two—plant systems and containment analysis; and level three—plant systems, containment, and consequence analysis.

A level-one PRA analyzes nuclear power plant design and operation at the plant system and component levels. It examines normal plant operations, component test and maintenance data, and the effect of human errors and external events to identify how, when, and why accidents could occur in a plant and the probability of accident occurrences. A level-one PRA systematically searches for the sequence of events that could cause an accident, determines how failures in safety systems may occur, and estimates the probability of a core melt.

A level-two PRA examines the physical processes of an accident and the effects on the reactor vessel, which is the immediate reactor container, and on the concrete and steel containment building that surrounds the reactor vessel, steam generator, and much of the reactor cooling system. A level-two analysis predicts how and when containment can fail and the amount of radiation that could be released if such failures occur. For example, a release could occur as a steam explosion or a slow leak into the atmosphere, or the core could melt into the ground beneath the containment building. Since the PRA may identify hundreds of accident sequences, it may not be practical to perform release analyses for every sequence individually; therefore, the sequences may be grouped into release categories that share similar characteristics. The grouping simplifies the analysis by assuming that the radiation release for all sequences within each category will be the same, and it allows accidents to be organized by severity of release. The release categories, which are the product of a level-two PRA, are referred to as source terms.

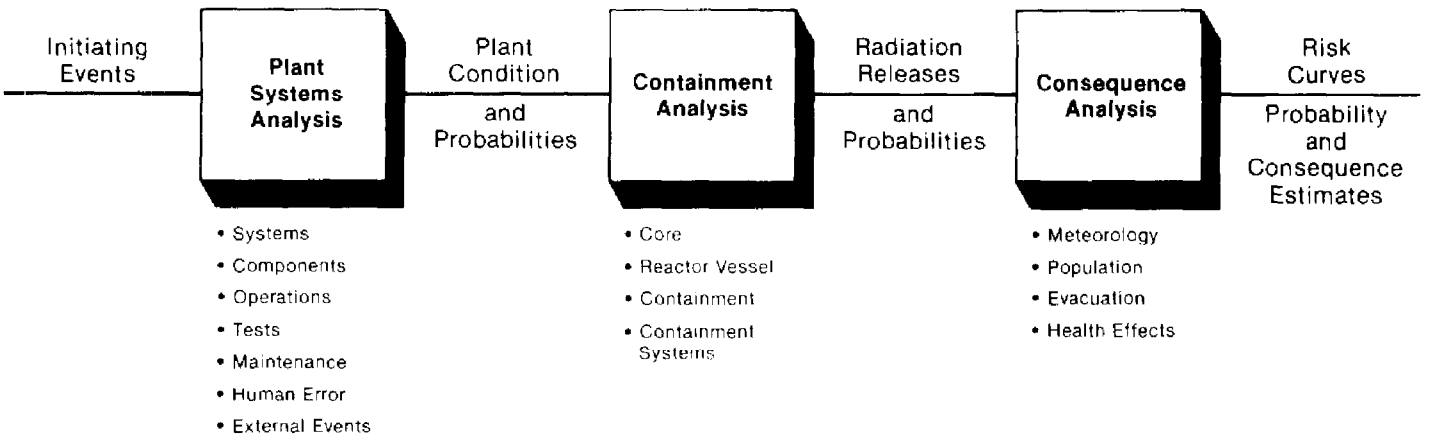
A level-three PRA analyzes the movement and deposition of radiation throughout the environment after it has been released (i.e., after containment failure) and estimates the public health and economic effects of the release. To do this, the methodology includes many variables, such as

- weather conditions, wind direction, and land usage of the surrounding area;
- the location and density of nearby populations;

- the amount of radiation and the method by which the population could be exposed to it; and
- other factors that could affect the nearby population, such as the speed at which the public could be evacuated or the availability of shelter.

Figure I.1 shows the interrelationship of the three levels of a PRA.

Figure I.1: Probabilistic Risk Assessment Flow Chart



Source: NRC

As shown in figure I.1, the results of a level-three PRA integrate the findings of the plant systems analysis, the containment analysis, and the consequence analysis. The results can be presented in tables that list major scenarios and identify their release categories, contribution to core melt, likelihood of causing damage to public health, and estimates of health effects and property damage.

NRC's Efforts to Improve PRA Methodology

Over the last 12 years, NRC has attempted to make the PRA methodology more realistic by incorporating into it the substantial amount of nuclear power plant operating experience that has been acquired. NRC has concentrated its efforts on the areas having large uncertainties and where improvements are possible in light of scientific knowledge and available resources, such as the release and behavior of radioactive materials. As of February 1987, NRC had changed two major aspects of the PRA methodology (source terms and consequence modeling) and demonstrated the

impact of both changes in a draft report on accident consequences, Reactor Risk Reference Document (NUREG-1150, Feb. 1987).

In one case, NRC reevaluated the technical bases used in PRA to estimate the uncertainty in the quantity and timing of radioactive materials released during an accident (the source term). NRC has developed a new package of computer models and a supporting data base that officials believe should more realistically estimate the amount of radiation released during an accident. This package contains 10 separate computer models that integrate the interactions between the release and transport of radioactive material in the reactor containment. NRC has also eliminated from the computer models the conservative biases that were intentionally built into the source terms estimated in the Reactor Safety Study and used in NRC's two 1982 studies.

As a result of this change, the nuclear industry expects that calculated radiation releases would be reduced by several orders of magnitude from those developed in the Reactor Safety Study and that the estimated consequences would be lower. Industry representatives would not speculate how much lower.

However, NRC officials do not believe it is appropriate to generalize about the possible reductions in consequences that could occur from its research efforts on source terms. Although NRC's research was directed at making source terms more realistic, the final report on this project, Reassessment of the Technical Bases for Estimating Source Terms (NUREG-0956, July 1986), indicates that not all of the accident sequences studied exhibited lower radiation releases. NUREG-0956 also states that since source terms are determined by plant characteristics, the results for one plant are not likely to describe the results from another. Therefore, PRAs would have to be done for each plant to determine the potential amount of radiation that could be released during a major accident at any one plant.

In NUREG-1150 NRC attempted to determine the scope of the uncertainties in source term estimates. For the five plants studied (Grand Gulf, Peach Bottom, Sequoyah, Surry, and Zion), NRC found that the source terms could be as high as those estimated in the two 1982 studies (i.e., Reactor Safety Study source terms), but could also be orders of magnitude lower. As a result, NUREG-1150 does not provide a better indication of what the actual source term may be, but instead demonstrates that the potential source term can fall anywhere within a large range of possibilities. NRC staff stated that any comparison between the Reactor

Safety Study source terms and the revised estimates in NUREG-1150 may be difficult since the revised estimates are for single accident sequences, while the Reactor Safety Study's source terms represented groups of accident sequences.

NRC's second PRA research effort produced a new computer model to estimate the costs of post-accident population protection measures and public health impacts. NRC officials believe that the model, using the expected radiation releases of the new source term models, will provide more realistic estimates of the economic costs to evacuate and temporarily relocate the population, dispose of agricultural products, decontaminate land and property, and compensate the public for property that is too contaminated for continued use. Specifically, the new model allows NRC to estimate certain consequences that were not in the earlier models, such as population relocation costs during the decontamination process and costs of personal injuries sustained by workers performing decontamination activities. The new model also allows NRC to analyze a wider range of assumptions that contribute to the magnitude of consequences, such as the criteria to determine whether land in urban and farm areas is too contaminated for continued use.

Since this consequence model contains more comprehensive assumptions and employs better estimating techniques, NRC officials believe that the estimates derived would be more realistic than those used in the two 1982 NRC studies that support our analysis. In NUREG-1150 NRC tested the new model and derived revised consequence estimates for five plants. For four of these plants, NRC found that property damages would be twice as much as those calculated in 1982, solely on the basis of the modeling improvements made.

As a result of NRC's source term and consequence modeling improvements, off-site consequence estimates of catastrophic and severe accidents could change. NRC officials pointed out, however, that additional sensitivity analyses for design-specific factors would have to be made to determine whether generic conclusions could be drawn from the NUREG-1150 results. In addition, since source terms could be as large as previously estimated, and because the actual source terms remain a large uncertainty in PRA methodology, our consequence estimates are still reasonable.

Uncertainties in Consequence Estimates

Although NRC continues to improve the PRA methodology, officials told us that uncertainties will remain in consequence estimates until actual accident data is available to assess the validity of the assumptions made. These uncertainties are not caused by, or unique to, PRA but reflect NRC's and the industry's lack of knowledge about plant systems, human behavior, accident processes (the physical and chemical changes that take place during an accident), the off-site consequences of accidents, and the impact of external events, such as earthquakes, fires, and floods, on accidents. Therefore, NRC cannot ensure that the PRA methodology has

- identified all events that could start or direct an accident,
- accurately modeled and quantified the behavior of plant systems and accident processes, or
- used the best assumptions in areas where data are lacking.

Although some of these uncertainties may be resolved through continued research and increased plant operating experience, some uncertainties may remain open indefinitely because they are inherent to the science of risk assessment. These include identifying all potential causes of accidents because they have not occurred or may never occur, or identifying the precise physical and chemical changes that occur in a reactor core during a core-melt accident.

The Chernobyl accident—the only catastrophic nuclear plant accident to occur in the world—might provide NRC and the industry with some useful information to better understand how radioactive materials disperse after they are released into the environment (e.g., how heavy the particles are and how fast they fall) and to determine where the larger population doses will occur. However, NRC officials told us that information gained from the Chernobyl accident may be of limited use for improving the PRA methodology in this country. For example, Chernobyl's design is not similar to the designs of commercial reactors in this country; therefore, data on accident progression may have little relevance to our reactors. In addition, the Soviets may not make all of the data available to the rest of the world.

Maximum Off-Site Consequences Caused by Adverse Weather

In addition to estimating average consequences, PRA also calculates maximum values of off-site fatalities, injuries, and economic costs. These values represent consequences for the largest amount of radioactive material released, densest population distribution, and worst weather sequence. To calculate maximum values, NRC's consequence model

requires data on expected weather patterns, including wind velocity and a year of hourly observations of wind speed, atmospheric stability, and accumulated rainfall. Since this type of historical data is not available for individual nuclear plant sites, NRC obtains general information from 29 regional National Weather Service stations that now have 25 years' worth of data.

From this data, NRC constructs a typical meterological year for each of the 29 National Weather Service regions that represent the long-term average behavior of the weather at each station. NRC selects the "most typical" month of the 25-year period and repeats this procedure for each of the 12 calendar months to obtain one full year of data, or 8,760 weather sequences. NRC then sorts the 8,760 weather sequences into representative groups defined by windspeed, atmospheric stability, and rain. NRC examines only a representative subset of these sequences (typically about 100 weather sequences) and a representative set of population exposure areas downwind from the plant (usually 16) in its consequence calculations. NRC's sampling methodology and consequence model generates about 1,600 consequence estimates based on 1,600 particular weather combinations (100 weather sequences x 16 population distributions).

The 1,600 consequence values are then averaged to produce the most reasonably expected consequences under typical weather. NRC believes this procedure allows it to look at a broad spectrum of accident conditions (rather than a single set of conditions) and what can reasonably be expected to occur for an accident. In contrast, a maximum value represents the single worst observed consequence out of 1,600 possible consequences. Therefore, maximum values are extremely unstable and almost always will vary on the basis of the sampling technique and the size of the sample. According to NRC officials, the maximum values can be two or four times greater or less depending on the size of the universe of weather data sampled.

NRC also believes that maximum values are unrealistic because many of the assumptions built into the consequence model are directed at calculating average values; therefore, they are inappropriate for calculating maximum values. For example, the model assumes that 20 percent of the population will be outside during the accident. However, during adverse weather such as rain, a larger percentage of the population will most likely be indoors. As a result, NRC officials told us that the model may significantly overestimate the maximum values of early fatalities.

NRC officials also contend that maximum consequences are very conservative (higher than are likely to occur from a real accident) because of assumptions employed for source term and emergency response. For example, maximum consequences are calculated on the basis of slow emergency response (a 3-hour delay before notifying people living within 10 miles of the plant to evacuate, the evacuation does not take place as rapidly as might be expected, and no sheltering or evacuation occurs beyond 10 miles).

Further, the values derived do not represent true maximum consequences for each reactor site. Because of the sampling technique, NRC has no assurance that the computer selected (1) the worst weather pattern from each of the six weather groups, (2) a typical meterological year, or (3) the most extreme weather. In addition, it has no assurance that the 25 years of National Weather Service data reflect the worst weather patterns (the sampling base would have to be very broad to capture the worst weather sequence). According to NRC staff, a less than 1-percent chance exists that the true maximum value would be selected on the basis of the limited number of trials the model now runs.

Average Estimated Off-Site Financial Consequences of a Catastrophic Accident

Dollars in millions

Plant	Escalated property costs	Total personal injury costs	Total dollars consequences
Big Rock Point	$62	$5	$67
La Crosse	67	6	73
Maine Yankee	291	64	355
Yankee Rowe	314	46	359
Fort St. Vrain	564	39	603
Crystal River 3	721	68	789
Farley 1	748	71	819
Farley 2	748	71	819
Robinson	795	76	871
Hatch 1	812	65	877
Hatch 2	812	65	877
Saint Lucie 1	888	129	1,017
Saint Lucie 2	888	129	1,017
Nine Mile Point 1	955	81	1,036
Brunswick 1	993	83	1,076
Brunswick 2	993	83	1,076
Fort Calhoun	1,001	87	1,088
Kewaunee	1,024	68	1,092
Point Beach 1	1,041	74	1,115
Point Beach 2	1,041	74	1,115
Arkansas 1	1,020	100	1,119
Turkey Point 3	1,036	95	1,131
Turkey Point 4	1,036	95	1,131
Riverbend	1,057	114	1,172
Monticello	1,103	73	1,176
Palo Verde 1	1,112	68	1,180
Palo Verde 2	1,112	68	1,180
Palo Verde 3[a]	1,112	68	1,180
Vermont Yankee	1,040	164	1,204
Arkansas 2	1,114	109	1,223
Ginna	1,131	112	1,243
Pilgrim	1,099	158	1,257
Cooper	1,191	73	1,265
Summer	1,163	107	1,270
Grand Gulf	1,164	107	1,271
Prairie Island 1	1,201	113	1,313
Prairie Island 2	1,201	113	1,313
Oconee 1	1,234	125	1,359

Plant	Escalated property costs	Total personal injury costs	Total dollars consequences
Oconee 2	$1,234	$125	$1,359
Oconee 3	1,234	125	1,359
North Anna 1	1,201	168	1,369
North Anna 2	1,201	168	1,369
Fitzpatrick	1,268	106	1,374
South Texas 1[a]	1,296	82	1,378
South Texas 2[a]	1,296	82	1,378
Vogtle 1	1,313	104	1,417
Vogtle 2[a]	1,313	104	1,417
Washington Public Power Supply System 2	1,394	93	1,486
Rancho Seco	1,407	101	1,508
Palisades	1,367	168	1,535
San Onofre 1	1,447	92	1,539
Browns Ferry 1	1,434	147	1,580
Browns Ferry 2	1,434	147	1,580
Duane Arnold	1,461	121	1,582
Browns Ferry 3	1,447	149	1,596
Surry 1	1,434	202	1,636
Surry 2	1,434	202	1,636
Wolf Creek	1,581	89	1,670
Commanche Peak 1[a]	1,635	77	1,712
Commanche Peak 2[a]	1,635	77	1,712
Callaway	1,595	155	1,749
Shearon Harris	1,621	164	1,785
Bellefonte 1[a]	1,608	201	1,809
Bellefonte 2[a]	1,608	201	1,809
Nine Mile Point 2	1,688	143	1,831
Watts Bar 1[a]	1,688	144	1,833
Watts Bar 2[a]	1,688	144	1,833
Diablo Canyon 1	1,715	135	1,850
Diablo Canyon 2	1,742	138	1,880
Calvert Cliffs 1	1,755	223	1,978
Calvert Cliffs 2	1,755	223	1,978
Haddam Neck	1,863	229	2,091
Seabrook	1,943	155	2,098
Trojan	2,010	213	2,223
Quad Cities 1	2,090	178	2,268
Quad Cities 2	2,090	178	2,268
Waterford 3	2,023	355	2,378
Millstone 1	2,171	411	2,582

Plant	Escalated property costs	Total personal injury costs	Total dollars consequences
Sequoyah 1	$2,345	$343	$2,688
Sequoyah 2	2,345	343	2,688
Clinton	2,533	232	2,765
Catawba 1	2,707	352	3,059
Catawba 2	2,707	352	3,059
McGuire 1	2,841	401	3,242
McGuire 2	2,841	401	3,242
Davis Besse 1	3,028	281	3,309
Donald Cook 1	2,975	365	3,340
Oyster Creek	3,015	347	3,362
Millstone 2	2,868	542	3,410
Three Mile Island 1	2,894	539	3,433
Donald Cook 2	3,095	379	3,474
Peach Bottom 2	3,283	409	3,692
Peach Bottom 3	3,283	409	3,692
Susquehanna 1	3,203	580	3,782
Susquehanna 2	3,203	580	3,782
San Onofre 2	3,658	230	3,888
San Onofre 3	3,658	230	3,888
Perry 1	3,538	452	3,990
Byron 1	3,685	365	4,050
Byron 2	3,685	365	4,050
Salem 1	3,578	485	4,063
Shoreham	3,658	444	4,102
Salem 2	3,658	497	4,155
Beaver Valley 1	3,725	490	4,216
Beaver Valley 2[a]	3,725	490	4,216
LaSalle 1	3,993	336	4,329
LaSalle 2	3,993	336	4,329
Dresden 2	4,033	332	4,366
Dresden 3	4,033	332	4,366
Millstone 3	3,779	718	4,496
Fermi 2	4,703	592	5,296
Braidwood 1	5,159	561	5,720
Braidwood 2[a]	5,159	561	5,720
Zion 1	6,432	1,122	7,554
Zion 2	6,432	1,122	7,554
Limerick 1	8,348	1,782	10,131
Limerick 2[a]	8,348	1,782	10,131

Plant	Escalated property costs	Total personal injury costs	Total dollars consequences
Indian Point 2	$12,328	$1,690	$14,018
Indian Point 3	13,668	1,868	15,536

[a]Under active construction.

Source: GAO

Major Contributors to This Report

Resources, Community, and Economic Development Division, Washington, D.C.

Keith O. Fultz, Associate Director, 275-1441
Mary Ann Kruslicky, Group Director
Debra S. Ritt, Evaluator-in-Charge
Karen R. Roelkey, Typist

Requests for copies of GAO reports should be sent to:

U.S. General Accounting Office
Post Office Box 6015
Gaithersburg, Maryland 20877

Telephone 202-275-6241

The first five copies of each report are free. Additional copies are $2.00 each.

There is a 25% discount on orders for 100 or more copies mailed to a single address.

Orders must be prepaid by cash or by check or money order made out to the Superintendent of Documents.