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ENVIRONMENTAL IMPACT ASSESSMENT OF ABNORMAL EVENTS: A FOLLOW-UP STUDY

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ABSTRACT

In the United States, environmental assessment is performed in response to the National Environmental Policy Act (NEPA), which describes a federal environmental policy and requires consideration of environmental impacts in federal decisionmaking. Assessing the significant adverse environmental impacts of abnormal (i.e., low probability) events associated with a project must be done even if information essential to assessing these impacts is missing. In these cases, current NEPA regulations require assessing the worst-case impacts of the events and stating the probability of the worst-case impact occurring. Proposed changes to the regulations eliminate the concept of wost-case analysis and require the analysis of only those consequences that are based on credible science. For projects where operational accidents have occurred, the actual impacts are an effective means of evaluating the credibility of impact analyses of abnormal events presented in environmental assessment documents. Impact analyses included in environmental assessments for a selected nuclear power plant, petroleum storage facility, crude oil pipeline, and geopressure well that have experienced operational, abnormal events are compared with the data quantifying the environmental impacts of the events. Comparisons of predicted vs actual impacts suggests that prediction of the types of events and associated impacts could be improved; in some instances, impacts have been underestimated. Analysis of abnormal events is especially important in environmental assessment documents addressing a technology that is novel or unique to a particular area. Incorporation of abnormal event impact analysis into project environmental monitoring and emergency response plans can help improve these plans and can help reduce the magnitude of environmental impacts resulting from said events.

ENVIRONMENTAL IMPACT ASSESSMENT OF ABNORMAL EVENTS: A FOLLOW-UP STUDY

1.0 Introduction

Assessing the environmental impacts of abnormal (i.e., low probability) events in Environmental Impact Assessment (EIA) documents is a topic of much discussion in the United States. In recent years, federal agencies and courts have attempted to clarify the need for and content of said analyses in EIA documents. None of these efforts, however, have attempted to shed light on this subject by conducting a follow-up study that compares actual impacts from abnormal operational events at facilities with those postulated in impact analyses contained in EIA documents for the facilities.

In the United States, the National Environmental Policy Act [(NEPA), Pub. L. 91-190, 1970], is the principal body of federal legislation governing the preparation of EIA documents. In general, NEPA requires federal agencies to consider environmental factors in their decision making process. In November 1978 the President's Council on Environmental Quality (CEQ) promulgated regulations that are binding on federal agencies for the implementation of NEPA (40 CFR 1500-1508).

In 40 CFR 1502.22, the CEQ outlines procedures by which federal agencies must deal with the required discussion of significant adverse impacts in an Environmental Impact Statement (EIS) when essential information relevant to adverse impacts is missing or when analytical tools are not developed. In such situations, the potential adverse impacts in the "worst-case" must be discussed and analyzed. If an agency proceeds with the action of interest, then it must, under current regulations, include a worst-case analysis and an estimate of the probability of the worst-case occurring.[1] CEQ has issued and withdrawn guidance to federal agencies regarding worst-case analysis;[2,3] recently, the Council proposed changes to the regulations for worst-case analysis.[4] In its recent proposed changes to 40 CFR 1502.22, the CEQ eliminates the concept of worst-case analysis in situations where information essential to an understanding of significant adverse environmental impacts is missing or incomplete. Instead, the Council proposes to require analyses of low probability, high consequence impacts when the postulated occurrence of said impacts is based on credible science rather than speculation.[4]

Low probability, high consequence impacts can result from normal operations of a facility during a perturbation in the sensitivity of the existing environment to impacts, or from abnormal operations that produce environmental releases or discharges of exceptionally high magnitude. Given the recent increase in public interest in the impacts of abnormal events in the wake of the Bhopal incident, this paper is concerned with the latter situation. In the past, and under current CEQ regulations, worst-case analyses of impacts from abnormal events have been triggered by a lack of key information. This in turn has lead to speculation in some EIA documents on the type of event and associated environmental releases that could occur for a facility of interest. NEPA and the CEQ regulations do not specify the types of abnormal events (i.e., specific probabilities of occurrence) that must be considered in EIA documents. Rather they outline procedures for assessing the direct, indirect and cumulative impacts of reasonable alternatives. The criterion of reasonableness influences the selection of the types of events to be considered.

Worst-case analysis has been addressed by several recent appellate court decisions; a number of cases dealt with worst-case accident analysis. Ramifications of three of the key decisions are as follows: 1) an agency may not exclude a worst-case analysis from a NEPA document simply because the analysis deals with an event that has a low probability of occurrence;[5] 2) the worst-case analysis requirements in 40 CFR 1502.22 apply to an Environmental Assessments (EA), even though the pertinent regulation refers only to an EIS;[6] and 3) an agency may issue a Finding of No Significant Impact based on an EA that identified a significant impact from a remote event.[7]

In light of changes in guidance, proposed changes in regulations, and recent court decisions, it is of interest to conduct a follow-up study that compares predicted vs actual environmental impacts of abnormal events at selected facilities, and that provides information relevant to the following questions in this general area: (1) Were reasonable events analyzed? (2) Were impacts based on conjecture or credible science? (3) Were catastrophic impacts identified in EIA documents? (4) Did catastrophic impacts, not identified, actually occur? Answers to these questions will help determine the usefulness of analyzing low probability, high consequence impacts in EIA documents, and will help determine whether or not proposed regulatory changes are appropriate.

2.0 Data and Analysis

2.1 Approach

Two principal criteria were used in selecting projects for this paper: project diversity and data availability. In terms of the former, it was felt that a broader perspective could be obtained by examining a range of technologies and projects. The second criterion, data availability, was by far the more important of the two and actually was the limiting factor in selecting projects for review. In terms of data availability, a project was required to meet three conditions: existence of EIA documentation, occurrence of one or more abnormal events, and performance and reporting of post-event impact monitoring. It was also of interest to examine EIA documents prepared at various times throughout the history of NEPA.

2.2 Description of Case Studies

Four case studies were identified for follow-up evaluation using the criteria identified in the previous section. These case studies represent a broad range of energy technologies and all have environmental documentation associated with the project development. Each case study is associated with an operational abnormal event and subsequent studies that evaluated the effects of the event.

2.2.1 West Hackberry Strategic Petroleum Reserve Site

The West Hackberry Strategic Petroleum Reserve (SPR) site is a crude oil storage facility with a capacity of 60 million barrels located in Cameron Parish, Louisiana. The purpose of the facility is to store crude oil to mitigate the economic impacts of any future disruption of petroleum imports.

EIA documentation for the project consists of an Environmental Impact Statement[8] prepared prior to construction and a Supplemental Environmental Impact Statement that was subsequently prepared to reflect changes in the oil distribution system and the resulting changes in the anticipated impacts.[9] The issue of abnormal events from facility operation was addressed in both Environmental Impacts Statements. Specific events that were considered included pipeline accidents, oil spills during marine transportation, fires, explosions, accidental injury to personnel, cavity collapse, and natural diasters. The analysis of fires and explosions is of interest to this study. In the original EIS, the possibility of major fires or explosions was associated with high pressure operations or blowouts. The principal impact was postulated to be a temporary release of smoke to the atmosphere.[8] In the Supplemental EIS, it was estimated that vapors from spills of unweathered crude oil could be ignited if ignition sources were nearby, but that the offsite ignition of vapors would probably not occur for spills of 1000 barrels (bbl) or less. Based on experience at oil handling facilities, only localized fires were expected to occur. The impacts associated with a crude oil fire were assessed to be generally a localized destruction of vegetation and the release of smoke and other combustion products to the atmosphere.

On September 21, 1978 an oil workover rig was in the process of removing brine piping from a well when a packer slipped up the piping and allowed oil to flow to the surface. Vapors from the oil ignited, resulting in the death of a worker, serious injury to another worker, equipment destruction, and the release of 72,000 bbl of crude oil. The fire burned for six days before the well could be sealed and the fire extinguished. About 52,000 bbl of oil were eventually recovered, including 32,000 bbl recovered from Black Lake, which is adjacent to the site. The remaining 20,000 bbl were either burned or irrecoverably attached to the soil and debris. The recovered oil was reinjected into the salt cavern. The contaminated soil and debris were removed for treatment and disposal. The explosion, fire and spill were declared a major pollution incident. Cleanup of the spilled oil lasted for two weeks with an associated cost of approximately $20 million.

Monitoring was conducted in detail for one year after the event. The oil spilled remained in the marsh sediments west of the site throughout the monitoring period and was expected to persist for several years. No adverse impacts on animals in the marsh were detected. Adverse impacts to marsh vegetation were detected and were associated with the accelerated deterioration of the marsh habitat. Since the site area had been extensively impacted by previous oil production activities, some of the impacts may have been difficult to detect. Based on monitoring results, products of combustion distributed by the fire plume were found to consist largely of chemically stable compounds, rather than more physiologically dangerous compounds such as benzopyrene. Remote sensing of stress in vegetation indicated that stress was evident immediately after the fire, but had disappeared by the end of the one year survey.[10]

2.2.2 Three Mile Island

The Three Mile Island Nuclear Station Unit 2 is an 880 Mw pressurized water reactor located 10 miles southeast of Harrisburg, Pennsylvania. The plant was announced on February 3, 1967, granted a construction permit on November 4, 1969, granted an operating license on February 8, 1978, went critical for the first time on March 27, 1978, and went into commercial operation shortly thereafter. Commercial operation was suspended after a serious accident occurred on March 28, 1979. The plant is located on a 200 acre tract of land on the 427 acre Three Mile Island in the Susquehanna River. The nearest towns are Middleton, located three miles to the north, and Goldsboro, located 1.25 miles to the west. During operation the plant provided power to the southeastern Pennsylvania and New Jersey sevice areas.

A variety of EIA documents were prepared for TMI, ranging from the initial "Environmental Report, Operating License Stage" submitted by the project sponsors (Metropolitan Edison Company, Pennsylvania Electric Company, and Jersey Central Power and Light Company) in October 1970 to the U.S. Atomic Energy Commission (AEC), to the "Final Supplement to the Final EIS" issued in December 1976 by the U.S. Nuclear Regulation Commission (NRC) prior to issuing the operating license for Unit 2. Impacts from plant operation were considered throughout the environmental review process and were updated as new information became available.[11] The analysis contained in the Final Supplement to the Final Environmental Statement considered impacts resulting from abnormal plant operations and from transportation of nuclear materials. Potential radiological doses to the nearby population from a large break, loss-of-coolant accident were estimated by the NRC to be about 1100 man-rem (within a 50 mile radius). These estimates were considered to be realistic assessments of possible events. More conservative evaluations were incorporated in the safety analysis of the project.[12]

The principal abnormal event that occurred at TMI was a loss of coolant with attendant failures. About 4 a.m. on March 28, 1979, a loss of feedwater to the steam generators resulted in a shutdown of plant operations, and subsequently reduced the removal of heat from the reactor coolant system. Initially, the reactor protection systems performed as designed. Forty seconds afterwards, water levels in the steam generators had dropped to the point that an emergency feedwater injection was necessary. Erroneously closed valves prevented this injection from occurring, resulting in the opening of the pilot operated relief valve (PORV) to reduce internal pressure. This valve inadvertently remained open resulting in the further loss of reactor coolant. High pressure injection pumps were automatically turned on to provide cooling water but were turned off by the operators resulting in continued loss of coolant. After 2 hours and 20 minutes the PORV was closed. High pressure injection of cooling water was resumed after 3 hours and 40 minutes. Within 100 minutes these pumps were turned off by the operators because of high vibration and fear of damage to the pumps. Subsequent hydrogen generation resulted in loss of control of cooling system circulation. The low pressure decay heat removal system and the PORV were then used to relieve excess pressure and vent hydrogen to the containment building. Another high pressure injection was made which allowed circulation within one steam generator to be established. A hydrogen explosion occurred within the containment building at 9 hours and 50 minutes. High levels of hydrogen persisted in the reactor over the next seven days as efforts continued to establish coolant circulation within the reactor. With the venting of hydrogen to containment, coolant circulation was restored and the decay heat removal system allowed for cold shutdown of the plant on April 27, 1979.

During the accident, coolant was piped to the reactor coolant drain tank. This tank developed a ruptured pressure disk which allowed the coolant to drain to the reactor building sump. Some of this coolant was pumped to the auxiliary building where it spilled onto the floor from a tank with a previously ruptured pressure disk. After core damage occurred, radioactive coolant was pumped out of the reactor by the letdown line of the makeup system. This coolant was highly radioactive and resulted in spills within the auxiliary building and fuel handling building that contaminated the previously spilled coolant. The spills of coolant within the fuel handling building and the auxiliary building resulted in the release of large quantities of gases through the plant vent system with a total radioactivity content of 2.5 million curies.

Prior to the accident at Three Mile Island, extensive monitoring equipment was already in place as part of the conditions on the operating license for the plant.[12] Both a radiological environmental and occupational monitoring program were being performed. Onsite monitoring determined that releases through the liquid treatment system were nominal and were well within operating criteria. Offsite monitoring was directed towards detecting releases, build up of radionuclides, and any changes in gamma radiation levels. Fish and sediment samples were taken semi-annually; air particulates, milk, and precipitation were sampled monthly; green leafy vegetables were sampled annually; gaseous iodine was sampled weekly. Direct radiation monitors [Thermoluminescent Detectors (TLDs)] were placed quarterly at 20 locations. In response to the accident, thousands of environmental samples were collected by Metropolitan Edison, the Commonwealth of Pennsylvania, and agencies of the Federal government.[13] Samples were collected from March 28 to April 16, 1979 from water, air, milk, vegetation, soil, and foodstuffs. These samples confirmed that the releases from the accident were limited to noble gases and a small quantity of radioiodines. As a result of these data, population doses were estimated by several groups and ranged from 300 person-rem to 3500 person-rem, with an average estimate of 1900 person-rem. The dose to the maximum exposed individual offsite was estimated by all groups to be less than 100 mrem. The interpretation of these data and the associated dose estimates has been controversial; however, most studies which have been released to date suggest that no long term or short term effects from the event are to be expected.[13]

2.2.3 Trans-Alaska Pipeline

The Trans-Alaska pipeline is an 800-mile long, 48-inch diameter crude oil pipeline. It took about 38 months to construct. In July 1977 the pipeline began operation, delivering crude oil from the Kuparuk and Prudhoe Bay oil fields to the Valdez Marine Terminal.

The principal abnormal events addressed in the EIA document are crude oil spills and accidental releases to the environment. The impacts of crude oil releases are discussed in light of the terrestrial, aquatic and marine environments potentially impacted by the pipeline. The EIA document assumed that a spill of 25,000 bbl in the summer would cover more than 6.6 acres. The principal predicted impact of spills on land was the death of plants that became coated by the oil. Death of vegetation in areas underlain by ice-rich permafrost would result in permafrost degradation and severe soil erosion. Terrestrial oil spills were not expected to have an important influence on large mammals. No other impacts were identified from terrestrial oil spills in the EIS.[14]

A number of releases of petroleum to the environment have occurred from the Trans-Alaska pipeline. On July 19, 1977 over 2,000 bbl of crude oil were spilled at Valve 7 on the Coastal Plain north of Franklin Bluffs and at Steele Creek in the Goreal Forest south of Fairbanks.[14] Cleanup efforts used primarily hand labor. Although the cleanup efforts helped remove oil from the soil, they also produced one of the major impacts from the Valve 7 spill.[15] Repeated trampling by the workers of the oil-saturated soil degraded soil structure. On February 2, 1978 a spill of about 12,000 bbl of crude oil occurred at Steele Creek following a sabotage explosion. The oil sprayed or flowed out onto surrounding vegetation.[15] A third spill with associated terrestrial vegetation impacts occurred on January 1, 1981 at Check Valve 23, which is located about 125 miles south of Prudhoe Bay. Approximately 1,500 bbl were spilled, and an estimated 800 bbl were recovered during the initial cleanup. The remaining 700 bbl spread over approximately 3/4 acre immediately downslope from the check valve which produced an estimated oil loading of about 1000 bbl/acre.[16]

Spill impact monitoring generally consisted of visual inspections to ascertain areal coverage, depth of soil penetration, and vegetative regrowth. In the Valve 7 spill, site inspection in early August 1977 found that vegetative cover increased with increasing distance from the valve. At a subsequent visit in August 1978, after attempts had been made to reestablish vegetative cover within the heavily impacted area, very little regrowth was observed within the oil impacted area adjacent to the workpad, whereas at a distance of 55 yds, little visible effect on the upright vegetation was observed.[15] For the Steele Creek spill, a site inspection in September 1978 noted that some regrowth of native grasses had occurred within the burned zone.[15] Post-accident evaluations of the impacts of these two events suggest that a large crude oil spill may not kill all vegetation, even in heavily saturated areas. For the Check Valve 23 spill, post-accident monitoring of impacts suggested that vegetation was killed in the spill area. In 1982, the 3/4 acre spill site showed no significant regrowth of vegetation. Most of the heavily oiled area remained black and unvegetated in early summer of 1982 (1 1/2 years after the spill). Mats of hard tar had begun to form in the bermed area. A subsequent revegetation study reestablished vegetation.[16]

2.2.4 Dow Parcperdue Geopressure Design Well

The Dow Parcperdue geopressure design well project was located in Vermilion Parish, Louisiana, about 50 miles southwest of Lake Charles, Louisiana. Site preparation on the 37.5 acres tract began in January 1981. The production well was completed in summer 1981 at a depth of about 13,350 ft, and preliminary flow testing began in October 1981. The injection well was drilled in early 1982 at a depth of about 5,000 ft. The Dow well typically produced about 10,000 bbl of brine per day and about 150,000 ft^3 of gas per day. In February 1983 the well ceased operation, and by April 1983 the wells were plugged and abandoned. Project decommissioning and site restoration were completed in May 1983.

Impacts to soils, surface water, groundwater, land use and ecology from abnormal events were identified and discussed in the project's EIA documentation.[17] The discussion of leaks from mud and brine pits is of principal interest. Spills or leaks in the mud pit liner were identified as being capable of contaminating onsite soils, with the amount of contamination being directly proportional to the magnitude and duration of the accidental release. As a worst-case, it was stated that a release could contaminate the soil to the extent that it could not support vegetation. Under land use, the impacts of a brine spill on agricultural land were addressed. Hindered productivity due to soil salinization was of principal concern.[17] Ecological impacts received the most discussion. It was postulated that minor leaks and spills would be retained within the ring dike, and that resultant impacts from such events should be limited to the injury or death of a few of the small number of plants and animals remaining in the less-disturbed areas of the dike.[17]

During the life of the Dow project, principal abnormal events consisted of leaks from a drilling mud pit and a brine storage pit. In August 1982, during an onsite NEPA follow-up investigation, it was determined that a polyethylene liner in the mud pit, which was used to store water-based drilling mud, drilling tailings and fresh water, had been torn for about 12 months, thus allowing chemical constituents in the mud to contaminate soil and groundwater.[18] A second leak occurred on November 5, 1982, when the 30,000 bbl brine pit liner split, thus allowing brine to escape.

Routine surface and groundwater monitoring conducted throughout the period of the leaking mud pit showed no apparent impacts from constituents likely to be in the mud. Furthermore, aquatic life was sustained in the pit, thus further reducing the likelihood of significant adverse impacts. As a result of the brine leak, a 4-month groundwater and surface water monitoring program was initiated. Data collected on November 15, 1982 indicated conductivity, salinity, and chloride values were substantially above background levels.[19] Data collected at the same wells and the surface water stations in February 1983 showed that chloride levels had decreased over time, and were at or below background levels. As a part of decommissioning of the Dow well, soil analyses in the pit and around its north levee indicated contamination; the entire north levee and about 1 ft of soil on the bottom of the pit were removed for offsite disposal.[18]

3.0 Results

This section presents the results of comparing predicted vs actual impacts at the four case studies, and serves as the basis for drawing conclusions on worst-case analysis.

3.1 West Hackberry Strategic Petroleum Reserve Site

Comparison of impacts from the fire and spill at the West Hackberry SPR facility with those postulated in the EIS do not provide a favorable comparison. The emphasis in the EIS was placed on oil spills during oil transportation. Minor emphasis was placed on fire and explosions. The postulated events associated with fires and explosions were drastic underestimates of the actual events. To some extent this can be related to the fact that the EIS documents were prepared prior to the issuance of the CEQ regulations requiring worst-case analyses in the absence of key information. Another contributing factor is the comparative unique nature of the event that occurred at the West Hackberry facility. To this date no satisfactory explanation has been offered to explain why the packer slipped in the brine piping. The analysis contained in the Supplemental EIS does correctly identify the inflammable nature of spilled crude oil, which is in contrast to the original EIS. However, both EIS's grossly underestimate the magnitude of a potential oil spill associated with a fire and explosion. As a result neither analysis leads to the conclusion that the likely impact from a fire or explosion would be the degradation of marsh habitat. This void in the analysis is even more troublesome given the fact that the site area had already been significantly impacted by oil spills from other operations.

The analysis of abnormal events in the EIS concentrates on events that have not occurred as yet. Few conclusions can be drawn from this observation beyond noting that an apparent lack of balance exists in the analysis. The discussion of the accidential injury to workers concluded that the risk of occupational injury was very small and was not considered further. Obviously, this conclusion is also suspect, given that one death and a serious injury resulted from the accident.

3.2 Three Mile Island

Monitoring and data analysis of the event at Three Mile Island generally supports the analysis contained in the Final Supplement to the Environmental Statement. The event could be fairly described as a large loss of coolant with additional contributing failures. Using a realistic analysis, the population dose estimated in the Environmental Statement of 1100 man-rem for a large loss-of-coolant event without additional failures agrees with the estimates calculated from the monitoring data from the Three Mile Island accident (average of 1900 man-rem). The similarity of the predicted impact with the observed impact is indeed remarkable considering the rather unusual circumstances surrounding the event. The only doubt that arises in the review of the analysis in the Environmental Statement is the stated low probability of occurrence. Regulatory actions since the event at TMI have been directed towards making a recurrence of the events at TMI less likely and more in step with the expectation that these types of events are of low probability.

The event at Three Mile Island corresponded closely to the realistic analysis contained in the Environmental Statement. Had a worst-case analysis been incorporated into the Environmental Statement, a more rigorous monitoring program may have resulted. With a more rigorous monitoring program, the capability of determining the effects of the accident would have been greatly improved. Uncertainties related to the accuracy and completeness of the data collected during the accident have dominated the debate surrounding the consequences of the accident. With the benefit of hindsight, a more comprehensive data base would have been worth an increase in the costs associated with the monitoring. This observation parallels the findings and recommendations of the U.S. NRC Special Inquiry Group.[13] They found that the TLD monitors placed by Metropolitan Edison as part of its environmental radiation monitoring for normal operation were adequate for characterizing the radiation levels attributable to the accident and the supplemental TLD monitors placed after the accident were of limited use. They recommended that NRC reevaluate its requirements for environmental radiation monitoring to ensure that monitoring of normal and accident conditions was at least as adequate as the monitoring that occurred in response to the accident. The recommended reevaluation was to include the number and location of TLD monitors, airborne activity monitoring stations and real time instrumentation for monitoring radiation in the site environs.[13]

3.3 Trans-Alaska Pipeline

Post accident monitoring of impacts from crude oil releases from the Trans-Alaska pipeline in general support the impact assessment done in the EIS. In the cases of the Valve 7 and Steele Creek spills, it appears that the EIS overestimated impacts by stating that vegetation would be killed by a spill. In these two cases, vegetative regrowth was observed after the spill following cleanup of the spilled area. Since the EIS did not discuss any possible beneficial effects from spill clean up, the over-estimate of impacts may be due to the assumption of a direct oil spill with no mitigation. In the case of Check Valve 23, the impacts appeared to generally agree with impacts postulated in the EIS. In this case, even after spill clean up, vegetative recovery did not readily occur. In one case the attempted oil spill clean-up efforts did as much, if not more, damage to the tundra than the spill itself. The EIS did not anticipate damage from attempted measures to mitigate spill impacts.

In comparing predicted vs. actual impacts from crude oil releases at the Trans-Alaska pipeline, it appears that the EIA document included the most likely event (oil spills on land), but devoted more indepth analysis to spills from tankers in port. The analyses of oil spills on tundra identified no unique aspects of the event that would present special problems for mitigating impacts to terrestrial vegetation. No monitoring requirements were identified in the EIS to assist in reducing the environmental impact of a land-based crude oil spill. The land based spills that have been reported were of smaller size and covered less acreage than the values given in the EIS. The oil loading for one actual spill for which data are available (1000 bbl/acre for Check Valve 23) was considerably less than the oil loading postulated in the EIS (about 3500 bbl/acre). However, larger spills and greater impacts are still possible.

3.4 Dow-Parcperdue Geopressure Design Well

A comparison of actual impacts from events at the geopressured well with those predicted indicates that in general the anticipated worst-case impacts did not materialize, and that actual impacts from abnormal events were of lesser magnitude and shorter duration. This is primarily due to a well-run project during normal operation and to effective response during abnormal events. The worst-case event postulated in the EIA documents--a well blowout at 200% of design flow rate--did not occur. No blowouts occurred during the project life; the use of blowout prevention equipment on the well was confirmed during an August 1982 NEPA verification inspection.[18]

Predicted impacts from leaks and spills generally agreed with actual impacts. The EA slightly overestimated the magnitude of the impact from a leak in the mud pit. Even though the mud pit liner had been torn for about 12 months, no serious soil contamination occurred. The principal soil impact of concern from drilling mud release was that the soil would be unable to support vegetation. At the Dow well, the mud not only did not prevent vegetative growth, but it was actually used as a soil amendment during project decommissioning. For the brine leak, actual soil impacts from the brine pit leak confirm the concerns of reduced soil productivity addressed in the EA. After the brine contaminated soil test results were reviewed, the contaminated soil was removed for offsite disposal, and replaced with topsoil. Since the site now supports vegetation, these mitigative measures appear to have had the desired effect.

4.0 Discussion

Drawing conclusions of general value to impact assessment for abnormal events at many projects is difficult with a limited sample size of four case studies. However, a number of conclusions can be drawn that are relevant to the topic of impact assessment in general.

4.1 Novel Technologies

First, the results indicate that the more novel or unique that a given technology is to a given area, then the need is greater for a well-considered analysis of the impact of abnormal events.

In the case of the West Hackberry project, impacts were minimized by the quick response of the project teams to the explosion, fire and spill, and by the familiarity of the response team with this type of event. As a result, a situation that could have been catastrophic was reduced to the level of a major pollution incident. If the existing experience with the handling of crude oil were not so well developed as to require oil spill prevention plans, as required by the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300), the level of environmental impact would have been drastically increased.

As a result of the limited operating experience of the TMI project sponsors, they were not able to foresee a scenario of the nature of the TMI event. This is obvious since the project sponsors, who identified the abnormal events to be considered, did not identify a scenario in the Environmental Statement that had the gravity or complexity of the event that occurred. This resulted in a monitoring program that was not as aggressive as hindsight would suggest or a level of awareness more in step with the needs of nuclear technology. A more conservative basis for decision making may have reduced the consequences of the event by requiring monitoring and mitigation measures similar to those that have been imposed on the nuclear industry since the TMI event. Certainly, a more conservative basis for decision making would have improved the capability of determining the consequences of the event.

In the case of the Dow Parcperdue project, location of the site exerted a similar beneficial effect on minimizing impacts. Although the project per se was unique to the area (for that matter, to any area), technologically it was similar to oil well operation. The fact that it was operated by people with experience in the petrochemical industry in an area that is familiar with the technology was the principal reason that the impacts from the leaks that did occur were contained to temporary water quality effects in the project vicinity.

In the case of the Trans-Alaska pipeline, a lack of familiarity with crude oil spill cleanup on tundra contributed to adverse impacts from spills; thus, the uniqueness of the project to the area led to improper spill cleanup attempts that produced their own adverse impacts. Perhaps the project would have benefited from a more rigorous analysis of the impacts of land-based crude oil spills and requisite clean-up measures.

Favorable site location and a known technology can contribute to mitigation of impacts from abnormal events, regardless of the analyses contained in EIA documents for projects. For technologies without a long history of operation, the role of analyzing abnormal events in EIA documents is much more important.

4.2 Abnormal Event

The results of the four case studies indicate that some EIA documents mentioned the appropriate abnormal event in a list of events that could occur, but then focused their analyses of impacts on events that did not transpire. EIA documents for some of the case studies identified reasonable abnormal events (e.g., crude oil pipeline breaks and leaks in mud pit and brine pit liners) for the technology of interest. Others discussed and analyzed events that did not occur, and did not address catastrophic impacts that did occur. Furthermore, the analyses evaluated show a lack of uniformity in comprehensiveness/completeness, accuracy/skill and emphasis. This suggests that perhaps impact analysis in EIA documents could be improved by using risk assessment to identify, with systematic procedures such as fault tree or event tree analyses, those events that could reasonably occur during the project lifetime. Given the reasonably forseeable events, impacts could then be assessed.

4.3 Operational Plans

Impacts from abnormal events could be more effectively dealt with by incorporating EIA documents into project operation plans and by using the documents for developing response plans for accidents identified in said documents. Familiarity with the potential impacts that could result from an abnormal event would help project designers and facility managers design and operate projects in a manner that would minimize the chances of the event occurring and would also help in responding for clean-up and mitigation. In the case of the Dow Parcperdue project, the facility team was familiar with impact monitoring and mitigation needs (as determined in an on-site NEPA follow-up study),[18] and thus was able to respond quickly to a brine release from the project, thereby minimizing adverse impacts. Examining predicted vs actual impacts for accidents at TMI and the Trans-Alaska Pipeline indicates that impacts with grave consequences should trigger aggressive monitoring programs such that the gravity of a particular accident event can be determined and that appropriate corrective actions can be quickly implemented to limit consequences. Spill response and cleanup for crude oil releases from the Trans-Alaska Pipeline could have been improved by enhanced flow monitoring and leak detection equipment, and by a more detailed understanding of the nature of oil spills in tundra environments. A more aggressive radiation level monitoring program at TMI might have identified attendant problems contributing to the loss of coolant accident, thus helping in earlier identification of the problem and implementation of correction action. The efforts associated with EIA document preparation would benefit from being conducted in conjunction with Safety Analysis Reports prepared for certain technologies (such as nuclear).

It is important to recognize that EIA documents need not be confined to planning and decision making at the beginning of a project, and that they can be very helpful in project implementation and operation. Knowledge of what events could occur, and their associated impacts, would help design mitigation measures and monitoring programs for a given project. While these types of analyses are typical on nuclear projects, it is important to include these events in all EIA documents because typically they are not covered by permit conditions or other requirements enforced by regulatory agencies in the United States.

4.4 Regulatory Requirements

Current regulatory requirements under which many abnormal events are assessed can lead to the analysis of inappropriate events and to the speculation of worst-case impacts. It is important to recognize that the regulations are concerned with identifying a worst-case impact from a reasonable, albeit low probability, event. They do not require formulation of a worst-case event or scenario that is remote to the extent of being speculative. Perhaps it is appropriate to develop a probability criterion for guiding the selection of low probability events for analysis conducted in accordance with regulations. The proposed changes to 40 CFR 1502.22 are an improvement over existing regulations because they will place the assessment of low-probability, high consequence impacts on a firmer scientific base, and thus should result in more useful EIA documents for decision makers, and ultimately, better decisions.

5.0 Conclusions

Even though the case studies reviewed represent a variety of technologies and locations, and reflect EIA documentation prepared at different times in the history of environmental impact assessment in the U.S., the following conclusions can be drawn:

1. For specific projects, analyses of abnormal events are important in characterizing the spectrum of potential impacts postulated for the life of a project, especially where information is lacking on the environmental releases from abnormal events associated with a particular technology.
2. Analyses of abnormal events are meaningful tools in helping to design mitigation measures and monitoring systems that will encompass all reasonably forseeable impacts from a particular project.
3. In light of the broad goals of NEPA, analysis of abnormal events can be used to rationally examine major projects and to provide information to federal decision makers that will help protect the quality of the human environment, provided that the postulated events are reasonable and that the impact assessment is based on credible science rather than speculation.
4. On a generic level, analysis of abnormal events is an effective technology assessment tool for novel technologies or for existing technologies applied to new areas.

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