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ACTUAL VERSUS PREDICTED IMPACTS OF THREE ETHANOL PLANTS ON AQUATIC AND TERRESTRIAL RESOURCES

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ACTUAL VERSUS PREDICTED IMPACTS OF THREE ETHANOL PLANTS ON AQUATIC AND TERRESTRIAL RESOURCES

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INTRODUCTION

To help reduce U.S. dependence on imported petroleum, Congress passed the Energy Security Act of 1980 (Public Law 96-294). This legislation authorized the U.S. Department of Energy (DOE) to promote expansion of the fuel alcohol industry through, among other measures, its Alcohol Fuels Loan Guarantee Program. Under this program, selected proposals for the conversion of plant biomass into fuel-grade ethanol would be granted loan guarantees. Of 57 applications submitted for loan guarantees to build and operate ethanol fuel projects under this program, 11 were considered by DOE to have the greatest potential for satisfying DOE's requirements and goals.

In accordance with the National Environmental Policy Act (NEPA), DOE evaluated the potential impacts of proceeding with the Loan Guarantee Program in a programmatic environmental assessment (DOE 1981) that resulted in a finding of no significant impact (FONSI) (47 *Federal Register* 34, p. 7483). The following year, DOE conducted site-specific environmental assessments (EAs) for 10 of the proposed projects. These EAs predicted no significant environmental impacts from these projects. Eventually, three ethanol fuel projects received loan guarantees and were actually built: the Tennol Energy Company (Tennol; DOE 1982a) facility near Jasper in southeastern Tennessee; the Agrifuels Refining Corporation (Agrifuels; DOE 1985) facility near New Iberia in southern Louisiana; and the New Energy Company of Indiana (NECI; DOE 1982b) facility in South Bend, Indiana. As part of a larger retrospective examination of a wide range of environmental effects of ethanol fuel plants, we compared the actual effects of the three completed plants on aquatic and terrestrial resources with the effects predicted in the NEPA EAs several years earlier. A secondary purpose was to determine:

- Why were there differences, if any, between actual effects and predictions?
- How can assessments be improved and impacts reduced?

NECI, completed in October, 1984, was the first plant to be constructed. It reached full production in June, 1985. The Tennol plant began operation in December, 1985, but production levels never exceeded 50% of design capacity because of technical difficulties. Start-up operations began at the Agrifuels facility in

early 1987, but were halted shortly after due to financial difficulties. The general characteristics of each plant are presented in Table 1.

All three plants produce fuel-grade ethanol for blending with gasoline through conversion of biomass into grain alcohol that is then denatured with gasoline to prevent human consumption. Reduced to its essential elements, the process involves yeast fermentation of sugar/water solution from inexpensive feedstocks such as corn or sugar cane to yield ethanol, carbon dioxide, and water (note that corn starch must first be hydrolyzed by acids or enzymes to sugar). The resulting 8-10% solution of ethanol in water is eventually increased to 100% through distillation and dehydration with an organic solvent. Corn-based ethanol plants can centrifuge and dry the solid/liquid mixture remaining after fermentation to produce a dry solid [distillers dried grains (DDG) or distillers dried grains with solubles (DDGS)] which can be sold for animal feed (Elmore et al. 1982).

APPROACH

Although each plant was designed to produce fuel-grade ethanol, the environmental settings, feedstocks, technologies and processes, and fuel sources differed considerably among the three plants. We based our retrospective evaluations on reviews and analyses of existing data and information, interviews with plant, state, and local government personnel, and site and facility inspections. More specifically, our approach involved three major steps:

1. Review NEPA documents for each project to identify predicted impacts;

2. Visit each site to inspect the project facilities and surrounding environment, gather and review environmental permits and other information on the project and its impacts, and discuss project operations and problems with plant personnel;

3. Contact federal, state, and local agencies for information on project impacts and changes in external circumstances that may have affected projects.

In the first step, EAs and their accompanying Findings of No Significant Impacts (FONSIs) were obtained and reviewed for each project to identify, evaluate, and rank impact predictions in terms of their relative importance, and to seek other information on the most important perceived impacts. This process identified three general types of impact predictions: (1) quantitative (e.g., water consumption from area surface waters); (2) binary, which may be quantitative but are also either right or wrong (e.g., presence or absence of a threatened or endangered species); and (3) primarily qualitative predictions (involving a large element of professional judgement or consensus). The type of prediction is important because it bears on the type of informa-

Table 1. Summary descriptions (as planned) of fuel ethanol projects receiving loan guarantees from the U.S. Department of Energy

	New Energy Company of Indiana	Tennol Energy Company	Agrifuels Refining Corp.
Location	South Bend, Ind.	Jasper, Tenn.	New Iberia, La.
Setting	Suburban	Rural	Rural
Annual capacity (gal x 10^3)	50,000	25,000	35,000
Feedstock	Corn[a]	Corn[b]	Molasses/ syrup
Process heat	Coal	Coal	Bagasse[c] and waste methane
Wastewater disposal	Municipal[d]	Municipal[e]	On-site treatment
Dehydration	Benzene	Diethyl ether	Cyclohexane
By-products sold[f]	DDGS, CO_2	DDGS, CO_2	None

[a]Dry milled.
[b]Wet milled.
[c]Bagasse is the fibrous residue remaining after liquid has been extracted from sugar cane.
[d]Without biochemical oxygen demand (BOD) pretreatment.
[e]Following treatment to reduce BOD.
[f]DDGS = distillers' dried grains with solubles; CO_2 = carbon dioxide.

tion needed to evaluate the prediction's accuracy (e.g., subjective information may not be adequate for verifying quantitative impact predictions).

Next, on-site inspections of each project and its environs, reviews of permit and monitoring files, and discussions with plant personnel were used to obtain information on actual impacts of the projects. As with predicted impacts, the types of information available for characterizing actual impacts varied widely, ranging from quantitative data to purely qualitative information. Generally, quantitative information was derived from monitoring of emissions and effluents measured at the point of release as part of a permit condition. Ambient monitoring was not required at the plants, probably because fuel ethanol production is usually considered a conventional technology that is not perceived as hazardous to public health and safety. For the purposes of this study, the quantitative estimates of emissions and effluents in the EA were compared with actual levels established in permits, or measured by emission and effluent monitoring equipment, or both, and the actual impact on the resource is inferred. In other words, the source terms are used as indicators of environmental impacts.

Finally, more than 30 state and local officials were contacted to gather "external" (i.e., from outside DOE or the plant) information on environmental impacts of a particular facility. Most information was obtained by telephone interviews with agency officials. In some cases, copies of permits, notices of violation, or their documents were obtained to supplement the interviews.

This approach was based on the acquisition and evaluation of available data. No monitoring programs, field studies, or laboratory analyses were possible within the scope of this study. Thus, the evaluation of actual impacts was limited to interviews, visual inspections of sites and facilities, and available data collected for reasons other than for the follow-up study (e.g., to fulfill permit requirements).

The scope of the assessment method involved an evaluation of each project at two different times: one conducted during the planning phase and one taken after construction was completed and operation had begun. Consequently, the results of this study should not be viewed as an exhaustive list of every impact that could occur at a given project, especially those that may occur after long-term (2-5 years) operation. Short-duration impacts that occurred before the follow-up site visit can only be detected and evaluated by reviewing documentation and interviewing personnel who observed construction and operation of the project. Also, impacts not addressed herein may have occurred after the follow-up study and before the project terminated. Finally, it should be noted that two of the authors were involved in the preparation of the NECI EA, and one was involved in the Agrifuels EA.

RESULTS

This paper focuses on the impacts of ethanol plants on aquatic and terrestrial resources, including effects on threatened and endangered species, habitat disturbance and ecosystem alteration, water and land use, and wastewater discharges. Impacts of these facilities on the atmosphere, socioeconomics, cultural/archeological values, and other issues such as noise levels and odors are addressed in detail in Hunsaker et al.(1989).

Aquatic Resources - Generally, the only quantitative information obtained on water resource impacts was wastewater characteristics at the point of discharge and water withdrawal rates at the point of withdrawal from ground or surface water resources. Table 2 summarizes the differences in water-related source terms between predicted and actual operational values.

Two of the plants exhibited substantial differences between predicted and actual water use and wastewater characteristics. The NECI plant withdraws from 150 to 220% of the predicted withdrawal rates for groundwater; the magnitude of the groundwater resource, however, is sufficient to easily satisfy existing demands (Dillon 1988; Greenawalt 1988). Wastewater was discharged to the municipal waste water treatment plant (MWWTP) at nearly three times the predicted rate, while BOD loading and suspended solids were 15-17 and 2.2 times the expected values, respectively. The EA had indicated, based on discussions with MWWTP staff, that the additional wastewater loading was in fact desirable because the MWWTP was underutilized at the time. Instead, the much greater than predicted BOD loading from the ethanol plant and the MWWTP's inadequate state of repair caused several MWWTP upsets and discharges to the St. Joseph River in excess of National Pollutant Discharge Elimination System (NPDES) limits for BOD. Nevertheless, the EA's forecast that NECI would have no significant adverse effects on aquatic ecosystems (the St. Joseph River, in particular) has been confirmed by local and state officials (Leszczynski 1988; Lauer 1988; Bantjes 1988; Duffy 1988; Seketa 1988). Corrective measures taken by both NECI and the MWWTP have reduced the incidence of upsets and noncompliances. Even though the river was reclassified from a warmwater fishery to a trout and salmon migration stream (indicative of higher water quality) the same year the ethanol plant was completed, no fish kills have been reported in the vicinity of South Bend in the 10 years preceding completion of our study (Leszczynski 1988). Interestingly, DOE's programmatic environmental assessment of ethanol fuel production (DOE 1981) indicated that ethanol facilities of this production capacity would produce too high an organic load for most local treatment plants to handle. That assessment appears to have been borne out by the experience of the South Bend MWWTP. The adverse impacts on the MWWTP probably would have been prevented by inclusion of appropriate pretreatment facilities at the ethanol plant such as one or more of the following: a) activated sludge units, b) aerated lagoons, c) high-rate trickling filters, and d) anaerobic digestion.

Table 2. Percent differences in actual water use and discharge vs predicted values used in preparing environmental assessments[a] (All values are percentages.)

Facility[b]	Water use	Wastewater flow	Wastewater BOD[c]	Wastewater TSS[c]
NECI	100	170	450	120
Tennol	-7	-10	NA[d]	NA[d]
Agrifuels	-20	-20	-60[e]	-50[e]

[a]Values are computed as follows: [(actual-predicted)/predicted] X 100%. Overestimates of actual data are shown as negative numbers, underestimates as positive numbers.
[b]NECI = New Energy Company of Indiana.
Tennol = Tennol Energy Company.
Agrifuels = Agrifuels Refining Corp.
[c]BOD = biochemical oxygen demand; TSS = total suspended solids.
[d]No available quantitative forecast.
[e]Reflects difference between permitted levels and forecast values. Actual levels in treated effluent during start-up exceeded forecast values by a factor of 20 for average BOD and a factor of 30 for average TSS.

Estimated groundwater use by the Agrifuels plant, at 1500 gpm, is less than the EA's projected rate of 1900 gpm. No adverse effects on groundwater availability have been reported for this water-rich area (Gregg 1988), where rainfall exceeds evapotranspiration. The Agrifuels EA also predicted that, although some local degradation of water quality in a nearby bayou could be expected, planned runoff and wastewater management would prevent substantial impacts on water resources and aquatic life. Because plant operation has thus far been limited to start-up and maintenance modes, little can be said about wastewater effluents at design operating conditions. During start-up and stand-by conditions, however, plant effluents have often exceeded by considerable amounts NPDES permit limits for BOD, suspended solids, ammonia, and nitrogen. Occasional excursions from permit limits for dissolved oxygen and for oil and grease have also occurred. Plant officials have attributed these instance of non-compliance to inadequately established biological treatment systems used in the waste water treatment facility. Table 3 compares permit limits with actual plant effluent concentrations.

Because of unexpected developments independent of the Agrifuels plant, impacts on aquatic biota of the Bayou Teche are addressed below under "Unanticipated impacts."

The Tennol EA predicted that effects of plant construction and operation on aquatic resources would not be significant. Actual groundwater consumption has been estimated to be about one half of the forecast of 300 gpm. At this rate, even at full operating capacity, the plant would require slightly less than the forecast withdrawal rate. Consumption of potable city water, on the other hand, was almost twice the predicted 2 gpm. Even so, the city has been able to satisfy this demand without adverse effect on other users (total city requirements were less than half its rated maximum withdrawal). Although several episodic events such as plant start-up or temporary operational problems have triggered moderate excursions in wastewater quality, these excursions have been relatively short-lived and without any reported impacts on water quality or aquatic communities of receiving waters. It should be noted, however, that no ambient monitoring studies have been conducted that would confirm whether adverse effects on water quality or aquatic biota have occurred.

Terrestrial resources - The NECI EA predicted that there would be no significant impacts on terrestrial ecosystems, including endangered species, chiefly because of the already-disturbed agricultural/industrial nature of the site. This prediction has proven correct. In fact, some unplanned enhancement to terrestrial resources has occurred as a consequence of (1) construction of a storm water retention basin on the site, and (2) disposal of excavated materials on the site. The retention basin serves as a resting site for migrating waterfowl, and the disposal site has become a grassy hill in a largely hilless area providing structurally different habitat for small mammals.

Table 3. Agrifuels National Pollutant Discharge Elimination System effluent permit limits vs measured concentrations of selected pollutants during start-up[a], April 1987 [Units are mg/L except for flow (mgd)]

Parameter[b]	Minimum	Average	Maximum
Flow			
Measured	NA[c]	0.17	0.22
Predicted	NA	1.6	———
BOD			
Measured	NA	507	1290
Limit	NA	10	15
TSS			
Measured	NA	919	2051
Limit	NA	15	23
Ammonia (as N)			
Measured	NA	39.1	145
Limit	NA	5	7.5
TK nitrogen			
Measured	NA	109	327
Limit	NA	8	12
Oil and grease			
Measured	NA	3.2	12
Limit	NA	5	10
Dissolved O_2			
Measured	1.3	3.3	5.5
Lower limit	5	NA	NA

[a]All measurements except dissolved oxygen (Outfall 001) taken at Outfall 101 [treated process wastewaters and contaminated stornwater runoff (Hamilton, P., Agrifuels Refining Corporation. July 9, 1987. Quarterly Discharge Monitoring Report.)]. mg/L = milligrams per liter; mgd = millions of gallons per day.
[b]BOD = biochemical oxygen demand.
TSS = total suspended solids.
N = nitrogen.
TK nitrogen = total Kjeldahl nitrogen.
O_2 = oxygen.
[c]NA = not available

The Tennol and Agrifuels EAs also forecast no more than minor effects on terrestrial resources, including endangered species. Again, these forecasts were based partly on the previously disturbed nature of the sites. Part of the Tennol site had already been cleared and graded before the project was undertaken, and the remaining area was in an old-field successional state. The available information supports the EA's prediction: about 27 acres of previously disturbed terrestrial habitat is now occupied by the facility, with minimal impacts to terrestrial biota. Other than unanticipated (unforeseen and therefore not addressed at all by the EA) impacts discussed below, no evidence was found of terrestrial effects of the Agrifuels plant beyond those predicted.

Unanticipated Impacts - This category included some of the most important impacts identified in this study. These impacts differ from those discussed earlier in that they were unforeseen and therefore not addressed at all in the NEPA documents, whereas impacts discussed above were identified and evaluated, even if the magnitude or exact nature of the actual impacts was later found to differ from the predictions.

Tennol - Two unexpected impacts associated with solid waste from Tennol operations occurred; both were nonroutine events associated with unique circumstances. The most significant unexpected impact, a fish kill, resulted from an accident during land application of waste stillage on a farm nearly 90 miles from Tennol. The application apparatus of the waste disposal operator contracted to transport and dispose of the waste in a safe manner was left on unattended and excess stillage entered a nearby creek. According to the Tennessee Division of Water Pollution Control, the incident killed 11,886 fish valued at $4962 (using standard cost-determining procedures) over a reach of 11 stream miles (West 1988). Among the dead were sunfish, black bass, white suckers, minnows, carp, catfish, sculpin, darters, freshwater drum, and shad. In the other incident, a large amount of wet cake (distiller's grains) was generated at the plant because of technological problems with the process and was temporarily stored outside. Heavy rains washed some of the material into a ditch that eventually reaches the on-site wetland area located south of the plant; however, Tennol personnel intercepted the wet cake with hay bales to prevent impacts to the wetland, and properly disposed of the solid waste.

Construction of a barge terminal on the Tennessee River apparently was included in early plans for the Tennol plant, but later was dropped before the EA was written. Subsequently, the barge terminal was built by another party, evidently for the purpose of delivering corn to the Tennol plant. As a result, potentially more important but indirect impacts of the Tennol project, floodplain and wetland effects, and the destruction of benthic habitat and resident aquatic life in the vicinity of the barge terminal, did not receive an adequate, formal NEPA review. Nor apparently

was it the subject of formal consultation with the U.S. Fish and Wildlife Service (FWS) as is required by the Endangered Species Act for federal actions. In earlier informal consultations reproduced in the EA, the FWS had raised the possibility of impacts on five endangered species of mussels that may reside in the area, but then dismissed this concern as an issue because the plans for a barge terminal had been dropped. Since then, the range of the federally listed snail darter (threatened) has been found to be considerably greater than formerly believed and may also occur in the vicinity of the barge terminal (Jenkinson 1988).

The Tennessee Valley Authority (TVA 1985, Ahlstedt 1988) did conduct its own brief assessment of barge terminal impacts on mussels in the area, including a brief survey by divers in which no endangered species of mussels were found. Their report made no mention of fish species in the area, including the threatened snail darter. TVA concluded that dredging for the proposed terminal would "destroy a large number of mussel specimens", but "will not have any effect on any endangered mussel species."

Unexpected terrestrial impacts at Tennol also came to light. Construction of a transmission line spur (not planned at the time the EA was written) to connect the main TVA electrical power line to the plant required clearing and maintenance of a right-of-way. Related transmission line impacts that could arise include displacement of other land uses, physical and electrical interference with agricultural operations, and bird collisions. Although the power line did not receive formal NEPA review, such impacts are usually considered to be minor or subject to effective mitigation.

Agrifuels - According to the Agrifuels EA (DOE 1985), impacts of plant construction and operation on aquatic biota of the Bayou Teche would be minimal even though plant effluents may cause decreased oxygen concentrations on occasion. At that time, the bayou often experienced episodes of low flow and low dissolved oxygen; it was therefore reasoned that organisms unable to cope with such conditions would be unlikely to inhabit the bayou in the first place. Moreover, motile organisms would be able to avoid any localized conditions of oxygen depletion. Since then the Teche-Vermilion Water Diversion Project was constructed and now diverts water from the Atchafalaya River to the Bayou Teche, thereby presumably improving water quality, including the maintenance of higher dissolved oxygen levels in the bayou. Furthermore, informal reports by sport and commercial fishermen have suggested that the diversity and numbers of desirable fish in the bayou have improved since the diversion (Tilyou 1988). No studies have been conducted as yet to confirm these reports of better water quality and a better fishery, but such improvements would be expected to follow diversion of Atchafalaya River water to the bayou. If in fact a more desirable fishery less tolerant of low oxygen conditions has developed, then the consequences of continual discharge of an effluent high in BOD and ammonia could become greater than predicted by the EA for the more degraded bayou conditions of the past. In any event, no adverse effects of the

limited operations to date have been reported to the Louisiana Department of Wildlife and Fisheries, (Tilyou 1988; Tucker 1988).

Like Tennol, the Agrifuels plant produced unanticipated impacts related to the construction of a barge dock. In this case, the EA predicted minor aquatic impacts from modification of an existing dock. Our site inspection revealed that a new dock was constructed adjacent to the existing dock. As a result, not only was more aquatic habitat adversely affected, but about 1.5 acres of terrestrial habitat and less than 0.5 acres of riparian habitat were cleared and graveled. Because the areas affected were very small relative to the available habitat area in the vicinity, the impacts were still judged by the authors to be minor.

NECI - The major unanticipated impact of the NECI ethanol plant related to aquatic resources has been the much greater than expected BOD loading discharged to the MWWTP. The resulting upsets and capacity excursions at the MWWTP probably contributed to NPDES permit limit excursions for BOD and ammonia as well. This impact appears to have been mitigated in the past two years by measures taken by both the MWWTP and the ethanol plant. In any event, the degree of impact was unanticipated because the source terms (in particular, wastewater flow and BOD concentration) provided for the assessment of impacts were of much lower value than were realized in actual operations. For apparently the same reason (much greater than anticipated organic loading), sewer gas entering houses nearest the NECI ethanol facility was also an unanticipated impact.

The NECI EA recommended maintenance of a line of large black willow trees along the southern boundary of the NECI site. This recommendation was based on a site visit by and letter consultation with the U.S. Fish and Wildlife Service, which recommended that the trees be left intact to provide habitat for birds and other wildlife. The trees were removed, probably for fence construction, road improvement, site security, and visibility along the boundary. Loss of the habitat represents an unanticipated adverse impact resulting from not implementing planned mitigation.

A minor positive ecological benefit has also been realized as a result of the NECI ethanol facility. The 3.1 ha stormwater retention pond built originally for the facility has developed into aquatic habitat supporting bluegill, other aquatic and amphibious organisms, and some waterfowl. The relatively minor beneficial impacts of the pond, although not exactly unanticipated, were not discussed in the EA because construction of the pond at that time was uncertain and any predictions concerning the benefits of the pond (e.g., aquatic and waterfowl habitat) were perceived as being too speculative.

Unexpected changes in land use occurred at all three projects. At NECI and Tennol, firms unrelated to NECI and Tennol constructed CO_2-recovery plants adjacent to the ethanol plants. At the time

the EAs for the ethanol plants were prepared, no one had expressed firm interest in purchasing CO_2 from the plants; consequently the scope of the EAs did not include impacts from construction and operation of a "typical" CO_2 recovery plant. Inspection of the two facilities at NECI and Tennol indicates that the worst effect is the permanent removal of a few acres of terrestrial habitat. At Agrifuels, an unexpected impact is the planned use of a 22-acre parcel adjacent to the plant site for land farming of sludge from the facility's wastewater treatment plant. The practice was approved by the Louisiana Department of Environmental Quality and should result in only minor (if any) environmental effects beyond the land farming area.

Mitigation - Most mitigative measures identified in the EAs were found to have been satisfactorily implemented. Eight of ten proposed mitigative measures were implemented at the NECI plant, while the Tennol facility put into place all 14 proposed mitigative measures. The Agrifuels plant, on the other hand, implemented only five or six of its nine identified measures for mitigating impacts. One of the most important omissions in implementing mitigation was the failure to preserve the small stand of willows on the NECI site discussed earlier in this paper. Another important measure described in the Agrifuels EA as part of the plant design for mitigating the effects of spills and leaks was never implemented, i.e., a 2-m high dike that was to surround the entire plant. Instead, a ditch that conducts runoff (and any spills that breach or occur outside secondary containment structures) to the Bayou now surrounds the plant. Project personnel at all sites at the time of this study generally were unaware of the EAs or recommended measures for mitigation of impacts. It is no surprise, therefore, that these NEPA documents appear to have had little influence on mitigation, as well as detailed design, construction, or operation of the plants.

Summary and Conclusions

The major recommendation with respect to the assessment of water-related impacts of proposed ethanol facilities is that a process engineer or scientist of equivalent qualifications review the plant design and appropriate processes to determine if the source terms provided by the applicant are reasonable ones before they are actually used in the assessment. The applicant in turn should use the resulting EA or EIS as a resource during further plant design, construction, and operation to aid in minimizing environmental impacts (e.g., follow the recommendations for mitigation of impacts listed in the EA or EIS).

Despite a shortage of appropriate field data, which in some cases made verification of impacts difficult if not impossible, this investigation confirmed the value of follow-up studies of NEPA assessments. We found that, although impacts to aquatic and terrestrial resources for which data were adequate for analysis

generally occurred as predicted, several actual impacts differed substantially from the EA predictions, and a few impacts not anticipated at all by the EAs were identified.

Why did some impacts of plant construction and operation differ substantially from predicted impacts? The differences often resulted from unforeseen factors, including (1) significant alterations in plant design or operation after the EA had been written, but without further NEPA assessment; (2) the use of seriously inaccurate source terms; (3) failure to implement all appropriate mitigative measures; and (4) external environmental changes independent of the ethanol plants, which nevertheless altered the impacts of the plants on the surrounding environment.

How can NEPA documents such as the fuel ethanol EAs be improved and actual environmental impacts, whether from ethanol plants or much larger facilities, be reduced? Measures which could be profitably taken include:

- Ensure that source terms provided for the project are reasonably accurate (e.g., have source terms reviewed by an independent process engineer familiar with the technologies and operations involved).

- Discourage major changes in design and operation of projects (that do not reduce or mitigate environmental impacts) after issuance of the EA or other NEPA document.

- If major changes are necessary, make them contingent upon reassessment of the environmental consequences of the altered project.

- Require personnel responsible for detailed design, construction, and operation of the proposed plant to familiarize themselves with the findings and mitigative measures developed in the NEPA documents for the project.

- Require and monitor implementation of important mitigative measures as conditions for approval of the proposed project. Toward that end, DOE now requires preparation of mitigation action plans (MAPs) for all NEPA documents in which a commitment to mitigation is made before taking any action on the proposed action.

- Implement meaningful ambient monitoring of environmental resources.

Although this study generally supported the more broadly stated predictions of the EAs with respect to most important impacts, it also underscored the need for well-designed project, environmental, and mitigation monitoring programs; reassessment after major design and operational changes; and increased awareness on the part of plant management of the findings of NEPA reviews.

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