figure of 298,000 cubic yards for contaminated soil to be treated and included about $5 million (out of about $20 million) for groundwater pumping and treatment. Thus, the average cost for cleaning the excavated soil was about $0o per cubic yard, a very low price for any kind of contaminated soil treatment. (The ROD did not contain any theoretical or experimental data to show that a very simple form of soil washing could be effective in removing a diverse set of contaminants.)

The cost of the rejected alternative can be recalculated in two ways. First, the unit cost of the treatment can be altered and a range considered for the amount of material to be treated. A figure of $5oo per cubic yard is comparable to an estimate for a similar cleanup in the FS for the Chemical Control site and for the Re-Solve site. The FS for the Crystal City site had a cost of over $1,000 per cubic yard for a soil washing alternative for both organic contaminants and arsenic. And a company with a mobile soil washing technology, not applicable to metal contaminants, has indicated a cost of $450 to $1200 per cubic yard. (Tufts University, "Transportable Treatment Unit Technologies," July 1986.]

The ROD acknowledges the uncertainty about onsite contaminants. If it is assumed that about 100,000 cubic yards of material would be excavated and treated (a figure consistent with information in the ROD), then, at a unit cost of $5oo per cubic yard, the total cost would be about $5o million, about twice what was estimated. For the figure of 298,000 cubic yards from the 1985 and 1987 studies and the cost of $5oo per cubic yard, the ● otal cost is $150 million. Thus, the range is $5o to $150 million.

A second way to recalculate is to ask whether an estimate closer to the ROD's can be obtained? If a volume of contaminated material halfway between the two estimates in the reports is assumed (200,000 cubic yards) and the calculation is based on a un"it cost of soil treatment at $2oo per cubic yard (between the optimistic value of $5o per cubic yard and the above $5oo per cubic yard), the total is $4o million. In this conservative scenario the cost is still about twice that used in the ROD.

The attractiveness of the selected remedy, therefore, rested in part on its certain cost of $21 million relative to the underestimated cost of $24 million for the soil treatment option. The comparable ROD costs appear to remove low cost as a deciding factor, Would the selected remedy seem less attractive from the SARA perspective of preferring a permanent remedy if the soil treatment option was significantly higher in cost? True, there is a legitimate issue for excavating materials and the risks associated with it. But such excavation has been selected at other sites because there are established techniques to mitigate such risks (e.g., wetting materials to avoid dust). A technical case for not excavating materials, given for the Seymour Recycling site in Indiana because of large amounts of volatile chemicals, was not made for Conservation Chemical.

Finally, this case may illustrate the lack of management oversight of RIFSS and RODS in the Superfund program (even if the case does not indicate a high level of interest in reaching a settlement with the PRPs). Even a cursory examination of the data for and of the uncertainties about the volume of treated material and cost would probably have spotted the cost under estimate for the soil treatment alternative.

Case Study 4
Crystal City Airport, Crystal City, Texas, EPA Region 6

Capsule OTA findings.—Excavation of contaminated soils and wastes (which were buried in a previous removal action) and their disposal in an unlined landfill with a cap over it were selected over incineration. No treatability study supported the conclusion that the selected remedy is permanent on the basis of the adsorption of diverse contaminants to site soil. Major failure modes for the landfill were not examined.

Key dates:

. Entered Superfund system: 8/1/83
- pre~iminary Assessment: 3/1/87
- Site Inspection: 9/1/84
- National Priorities List

–proposed date: 10/84
–final date: 6/86
—site rank: #639 out of 770

- RIFS start and completion: 9/28/85 to 7/13/87
- Public comment period before Record of Decision: 8/10/87 to 9/14/87
- Signing of ROD: 9/29/87
- Estimated complete remediation: 8/89

Total time.—6 years

Brief description of site.—"The site is comprised of approximately 120 acres of land. Surrounding the airport property . . . is land used for grazing animals . . . a municipal landfill . . . an elementary and high school as well as a residential area . . . Since 1949 the city has operated the facility as a municipal airport. Several private companies conducted aerial pesticide applicating businesses at the airport untiI 1982."

Major contamination/environmental threat.—''The estimated volume of contaminated soil exceeding 100 parts per million (ppm) total pesticide is 12,000 cubic yards." Although a large number of contaminants have been detected, "The contaminants of greatest concern at the site (toxaphene, DDT, and arsenic) were chosen from the compounds detected based on their widespread distribution over the entire site as well as the relative toxicity and concentration. " There are also buried materials from an earlier removal action and contaminated buildings. Direct contact, surface water, and air emissions are major routes of exposure. The ,worst case exposure scenario is for residents of a.nearby housing project.

HRS scores.—ground~ater 33.01; surface water 12.92; air 43.08; total 32.26

Removal actions.—Immediate removal: 10/31/83 to 11/8/83 for $33,000; 40 cubic yards of waste and between 50 and 70 drums of material were buried in two onsite landfill cells. Second removal: 4/24/84 to 4/25/84 for $25,000; 19 drums (FS says 21 drums) were buried in an offsite landfill, the site was fenced, warning signs were posted, and according to the FS: "eroded areas of the clay caps were repaired. "

Cleanup remedy selected.—In addition to a number of containment alternatives, incineration and critical pressure fluid extraction were evaluated. The ROD described the remedy as: "Onsite consolidation of alI material which exceeds the health-based criteria of 100 milligrams per kilogram (mglkg) total pesticides. Placement of a RCRA cap over the consolidation cell. Monitor site for a minimum of 30 years following construction bf selected remedy. Deep-well injection of decontamination liquids. Five year review of selected remedy. " The argument was made that "By consolidating the contaminated soil away from the runway and taxiways, land use could be maintained." Estimated cost: $1.6 million.

Satisfaction of **SARA statutory requirements:**

1) ***Selection of permanent cleanup.—''The*** selected remedial action is considered permanent. consolidating this 'naturally treated' waste under a hazardous waste cap is . . . considered permanent. " However, while the ROD did not say that an alternative treatment technology was selected, which it was not, the ROD did suggest that alternative treatment would be "inappropriate," No reduction in toxicity or volume was claimed and the ROD correctly noted that these reductions are "not a requirement of the [SARA] provision. " The ROD said that incineration 'did not conform with the Superfund statute as well as the consolidation/capping remedy" and that health and environmental protection is equal for incineration and consolidationl/capping alternatives.

The ROD's case for permanency for consolidation/capping rested on these facts:

- soils [are] characterized by high clay content and extremely low permeabilities."
- . . . [the] aquifer is located 750 feet below the surface of the site and is isolated from the contaiminated surface soils of the site by thick clay layers."
- contaminants are already highly immobilized and fixed within a solid soil matrix."
- . . . arsenic and organic pesticides [are] locked into [the] top foot of the alkaline soils at the site. "

Ž "The degree that contaminents are bound up is of the same degree that would have been achieved if the pure contaminants had been' processed by a solidification technology."

The permanence of consolidation/capping is uncertain for two reasons. First, no sound technical case was made that all of the diverse range of contaminants would be adsorbed tightly to the site soil. A treatability study could have been conducted to demonstrate whether significant leaching of contaminants is likely. No liner will be used to separate the waste from underlying soil. Data on the contaminants and the soil are pertinent. For example: "The primary indicator used to determine the degree to which an organic contaminant binds to soil particles is the organic carbon partition coefficient (Koc),. A higher Koc for an organic compound indicates a greater tendency to adsorb to organic particles in soils, although migration may still occur throughout the site." [Feasibility Study for the Renora site in New Jersey.) K.OC 'data are in the FS for Crystal City but were not fully discussed; site contaminants vary remarkably (by a factor of a million) and some contaminants have low Koc values which suggest poor absorption and the ability to migrate.

Mineral surfaces can also greatly affect the mobility of an organic contaminant. A research paper that found no adsorption of phenol to a mineral has noted the problem of uncertainty about adsorption of organic compounds to clays: "Hemphill and Swanson found phenol adsorption on untreated kaolinite, montmorillonite, and illite. Others did not find any phenol adsorption on untreated clays. Luh and Baker, however, did discover significant adsorption by clays for substituted phenols . . . " (E.C. Yost and M.A. Anderson, ***Environ. Sci. Technol., vol. 18,*** pp. 101-106, 1984.) Another research paper that examined the interactions between organic compounds and clay minerals concluded that in relation to ideal, laboratory conditions "rates and selectivity maybe different and difficult to predict under environmental conditions." (E.A. Voudrias and M. Reinhard, ***Geochemical Processes, at Mineral Surfaces,*** ACS Symposium Series 323, September 1985.) This uncertainty about adsorption is why a treatability study on actual site contaminants and site materials would be necessary to verify that some form of effective natural stabilization would take' place at' the site.

A complication at the Crystal City site is the presence of solvents that can affect be adsorption of other contaminants. EPA research concluded that" . . . the effects of solvents in hazardous waste contaminated soils may include two fadtors: 1) decrease in total sorption'to soils, nd 2) increase in leaching potential through changes in soil struture'U.S: Environmental Protection Agency, Review ***Of In- Place Treatment Techniques for (Contaminated Surface Soils,*** vol. 2, **November"1984]** Also, the FS did not say whether any work was done to identify.the forms) of arsenic at the site. The ability of arsenic to remain immobilized because of adsorption to soil is not'straightforward. Of the two Chemical forms of arsenic, the more toxic arsenite is more mobile,than arsenate and adsorption,is affected by the presence of certain metals in the soil and by the pH which can change overtime. (U.S. Environmental Protection Agency, ***Review of In-Place Treatment Techniques for Contaminated Surface Soils, vol. 2,*** November 1984.)

'Second, not all the site's contaminants are planned to be consolidated. The FS indicated that only half the site's contaminated soil might be capped. The choice of the cleanup criterion of 100 ppm of total pesticide in combination with the decision to continue to allow the site to be used as a municipal airport is questionable. The ROD said that the cancer risk approaches 1 in 100,000 for onsite exposure of 22o days a year, which is possible for onsite workers and which is a higher risk than is the 1 in 1 million usually sought by EPA. Moreover, the FS indicated that a significant health threat would persist if site use was not "limited to 10 to 15 days per year." This issue is important because of the absence of future land use restrictions.

Moreover, no cleanup criterion was established for arsenic, which is significant because in correspondence to government officials EPA

said: “Of the two types of contaminants, arsenic compounds predominate, are more toxic, and more persistent in the environment [than organic pesticides].” EPA also described arsenic as “the most toxic contaminant” at the.site. Also, risks for inhalable dust particles maybe incorrect because such small particles were not tested to determine actual level of contamination.

On the subject of incineration, the ROD said: “Treatment ‘will not significantly reduce ‘the mobility of the contaminants due to both the characteristics of the contaminants as well as the impermeable nature of the soils." **In fact,** incineration would have offered more certain permanence. The case against incineration is flawed for several reasons.

The ROD said: “A secondary treatment technology (soil washing) would be necessary toremove the arsenic compounds from the ‘treated’ soil.” However, no consideration was given to the proven feasibility of using chemical fixation or stabilization for arsenic in incinerator ash followed by landfilling. There is considerable information to support this approach. In August 1987, EPA published extensive information in the ***Federal*** Register on effective treatment of arsenic in the context of the Resource Conservation and Recovery Act regulatory program. EPA said that “all the available data show that the [Extraction procedure] regulatory level of 5.0 [milligrams per liter] for arsenic can be achieved.” (52 Federal Register 29992; Aug. 12, 1987.)

Treatability tests for solvent &traction and chemical fixation of arsenic contaminated soil and sediment from the Vineland Chemical Co. Superfund site in New Jersey have been successful. (These tests were done for the same RIFS contractor as at Crystal City. The reports were filed in December 1987, although the tests were probably planned and executed ‘much earlier.) For some time, a commercial chemical fixation company has made available extensive data on the effectiveness of its treatment on relatively high levels of arsenic in incinerator ash. Treatment costs were said to be between $30 and $55 per ton. (Chemfix Technologies, Inc., testimony before House Subcommittee on Transportation, Tourism; and Hazardous Materials, Dec. 7, **1987.)** Arsenic is a contaminant at the **Tacoma** Tar Pits site in Washington, where stabilization was, selected. Moreover, within the same EPA region as Crystal City, the ROD for the French Limited site in Texas said: “The PCBs and arsenic can be controlled by stabilization of the treatment residues.”

Biological treatment for arsenic is another alternative that could have been examined in a treatability study. Then it would be unnecessary to design a “custom [innovative) system, ” A recent report said: “Arsenic compounds tend to be converted by bacteria into volatile forms that disperse to harmlessly-low concentrations. ” (R.U. Ayres, et. al., ***Toxic Chemicals, Health, and the Environment,*** The Johns Hopkins University Press, 1987, pp. 38-70.) However, not all bacteria could treat arsenic and some development would probably be necessary.

A third alternative is a thermal treatment and recycling facility in Louisiana which has been used to treat a number of cleanup waste soils and sludges. The treatment facility can handle very large volumes of hazardous waste. Its unique process would result in a residual material which appears to safely contain residual metals, such as stabilization does. Moreover, the cost is reported to be relatively low; transportation costs must be added, but even then the total costs might be competitive to mobile incineration with the added advantage that the cleanup at Crystal City might be done quickly.

Moreover, OTA has examined a removal action at Southern Crop Services in Delray Beach, Florida, (not **an** NPL site) in which mobile incineration was selected for cleanup of the same type of pesticide and arsenic contamination. The Florida kite has the same history as Crystal City Airport. EPA noted that a “naturally rich organic layer near the surface of the soil” explains why the pesticides are concentrated and localized and why downward migration of the pesticides into groundwater has been slowed; (U.S. Environmental Protection Agency, Region 4, “Action Memorandum” for Southern Crop Services site, Sept. 8, 1987.) As much as 5,000 cubic yards of contaminated soil over 2.5 acres will be incinerated at a maximum cost

of $2.5 million. ***The EPA document made no mention of any problem with arsenic in the incinerator ash.*** The cost of the incineration is estimated at $300 to $500 per cubic yard. Setup of the mobile incinerator was to begin in November 1987 with completion in August 1988. An EPA Headquarters review on October 9, 1987, of the memorandum by the Regional office added the following: "It was determined that on-site incineration was the most suitable method to cleanup the site because it destroys the hazardous waste and eliminates the need to transport the waste off-site." This memorandum also added that, relative to offsite land disposal at half the cost of incineration, the "additional cost is considered reasonable because incineration provides a permanent solution." Moreover, EPA said: "The disposal of the waste in a landfill represents a less permanent solution to the problem than incineration, and is therefore less desirable in light of SARA emphasis on more permanent solutions."

At Crystal City Airport, the estimated cost of the incineration option of $10.8 million may have been over estimated; $2.9 million was for the arsenic treatment (about $200 per cubic yard). Without the special arsenic treatment, the cost of the alternative would be $7.9 million; thus the incineration option would cost about $575 per cubic yard (total, not unit cost), which is more than the cost range used for the Florida site but which agrees with the FS data for the Davis Liquid Waste site, where incineration was also selected at a cost of about $600 per cubic yard. If the expensive arsenic treatment could be substantially cut, the cost for the incineration alternative at Crystal City might decrease by more than $1.5 million. As noted above, use of the facility in Louisiana would probably reduce costs significantly more.

Moreover, there are instances where the ROD was biased against incineration and its commonly accepted benefits. For example: "organic contaminants may be reduced through an integrated incineration system," and "incineration would ***remove*** the organic contaminants from the solid" (emphasis added). The truth is that incineration would definitely destroy the organic contaminants.

Curiously, the alternative using chemical stabilization was analyzed for cost assuming that a lined landfill would be used for the treated material. The selected remedy uses an unlined landfill for ***untreated*** material. Use of a lined landfill adds an extra $700,000, a cost that was included in the stabilization option but excluded in the selected remedy of onsite consolidation.

2) Accurate assessment of land disposal and containment alternatives.—"Failure of this remedy is unlikely as long as proper maintenance of the cap is conducted. " Nevertheless, many failure modes are possible but were not examined, including the gross, disruption of landfilled material (disposal cell will be about 190 by 190 feet) and its dispersal due to an airplane crash, perhaps with fire and explosion; a natural disaster such as an earthquake, flood, drought, and cracking of the soil that are applicable to the site; the uptake of contaminants by biota, bioaccumulation, and ingestion by animals in the food chain; the undetected or uncorrected erosion of the cap; greatly increased downward transport through highly permeable soils due to large-scale pathways such as cracks and root holes; and the perforation of cap liners by animals and bugs and the subsequent intrusion by water. Without considering these possibilities, the ROD overrates the technical feasibility of the selected remedy,

This ROD and its FS also illustrate another common problem in technology selection—the technical literature, including EPA's own, is rarely researched and cited to support conclusions. For example, in a recent' report, EPA summed up good practice with caps over landfills: "Major storm events must also be considered, since even an arid region can be subjected to infrequent but major storms that cause anomalous ground saturation and percolation to a depth ordinarily not reached. Accordingly, a rather complete review of expectable storm events and their frequencies should be required in preparing the background on the hydrological system." (U.S. Environmental Protection Agency, "Project Summary—Design, Construction, and Maintenance of Cover Systems for

Hazardous Waste: An Engineering Guidance Document," November 1987.)

The ROD was ambiguous about the permanence of the selected remedy: "If however, future migration does occur, appropriate actions will be taken. " The term "significant unforeseen offsite contamination" was also used.

In contrast, the ROD for the Pristine site was realistic: "The lifetime of a RCRA multilayer cap is finite, and the contaminated soils will be left in place to contribute to groundwater contamination at some future time should the cap fail. . . . there are no data available on the long term effectiveness and permanence of RCRA caps." In the. FS for the French Limited site (in the same EPA region as Crystal City), use of a slurry wall and cap to contain hazardous waste was described as a "temporary solution" for which the "volume and toxicity would not be affected . . . [and] . . . the potential would always exist for failure of either the cap or the slurry wall allowing for the movement of unstabilized wastes contained onsite. " In comparison with Crystal City, these are prime examples of inconsistency across Superfund sites.

RIFS contractor.—State led; $218,000 ($726,000 obligated); Ebasco Services Inc.

State **concurrence.** —The ROD said the State "has remained silent. "

Community acceptance.—The ROD indicated that the community favored incineration. There is also a lot of other evidence, because of a Congressional hearing in Crystal City on this issue (Apr. 11, 1988), that the community and others strongly opposed and continue to oppose the remedy chosen by EPA. A large number of local, State, and national government officials and organizations have requested EPA to change its decision.

Special **comments.** —The Preliminary Assessment was completed several years after the Site Inspection, according to CERCLIS; but SCAP indicates that the preliminary assessment started on 9/26/84, slightly after the site inspection,

The first removal action (in 1983) that buried hazardous materials set the precedent for an impermanent remedy and contributed to the need for remedial cleanup today.

Although the ROD said that "the organic compounds will continue to degrade under the cap into less toxic compounds," no actual data or analysis was given to support natural biodegradation under the conditions expected at the site.

The FS gave data that "suggests that the contaminants are migrating offsite through water/ sediment transport." This observation merits more attention and an explanation of the exact mechanism of transport.

The case for concluding that RCRA is not applicable was that "the contaminated material will be consolidated in the unit or area of contamination from which they originated. " This conclusion is inconsistent with decisions at other Superfund sites and means that certain relevant aspects of RCRA on regulatory requirements for hazardous waste landfills, such as liners and leachate collection, were not applied as required by SARA.

The data on contaminant detection frequency in table 2 of the ROD were different than the data given in the FS.

The ROD said no groundwater was encountered, yet the HRS groundwater subscore is not zero.

General conclusions.—No sound technical case supported the conclusion that containing the wastes onsite constitutes a permanent remedy according to the intent of SARA, All of the contaminants may not bind tightly to the site soil, relevant regulatory requirements will not be met, health risks may be greater than normally acceptable levels, and a number of major failure modes of the containment system were not examined;,

The cost of the incineration' alternative was over estimated because of the residual arsenic contamination in the ash. In fact, stabilization of such a contaminant has been successfully demonstrated and is relatively low cost; biological treatment is also known to be feasible. The advantages of incineration over the selected remedy for the organic contaminants

were discounted. **Moreover, in comparison to the decision to use mobile incineration at the Southern Crop Services site with a nearly identical type of pesticide and arsenic contamination, the negative view of incineration at Crystal City Airport seems inconsistent and even contrived.**

Since incineration is proven for the organic contaminants at the Crystal City site and "provides better overall protection than consolidation/capping—contrary to the ROD's claim th`at the two choices are equal—a cost-effective remedy was not chosen. **The justification used by** EPA for picking incineration **at** Southern Crop Services, **in terms of its** greater benefits **over** land disposal, particularly regarding **permanency** of remedy, undercuts the evaluation by EPA **at Crystal City Airport.**

The FS analysis of treatment technologies for the Crystal City Airport illustrates **a** nationwide problem–current technology evaluations and the decisions based on them are not explainable by site-specific conditions. Several technologies rejected for Crystal City could have been justified as well **as they were at other sites** where they were chosen (and are discussed in other case studies in this report). For example, at Crystal City, in situ chemical stabilization was rejected: "Immobilization, chemical treatment, and physical treatments have not been shown to be feasible for in situ treatment of these contaminants as it is not possible to get a good, uniform, well distributed treatment." (This technology was selected for the Chemical Control site in New Jersey and elsewhere.) Biological treatment was rejected: "[it] is generally ineffective for destroying these wastes as the treatment is not performed in a controlled environment. Several processes are being developed which show potential However, none of these processes have been developed past the laboratory stage. Therefore, biological treatment has been ruled out." (This technology was selected for the Renora site in New Jersey.) In situ vitrification was rejected; it was selected for the Pristine site in Ohio.

The Crystal City site illustrates the problem of using a small number of indicator contaminants not just for risk assessment but also for technology selection. The effectiveness of some cleanup technologies depends on specific physical properties which can vary substantially among contaminants. There were a number of contaminants identified-at Crystal City that are not likely to adsorb tightly to the soil. For example, toxaphene is far less likely to bind tightly to soil than DDT. Both DDT and toxaphene pose a problem' for safeguarding water quality because both have laboratory detection limits which are above their water quality limits. (R.H. Plumb and J.R. Parolini, "Organic Contamination of Ground, Water Near Hazardous **Waste** Disposal Sites: A Synoptic Overview," paper presented at a Geological Society of America conference, Phoenix, October 1987.) Moreover, some chemicals—particularly solvents-may affect the adsorption of others present. Adsorption of contaminants to soil was asserted to make the case that containment was similar to solidification treatment, but no analysis or treatability tests were made to confirm the hypothesis. Without such efforts, it is not reasonable to assume adsorption of all the contaminants under all future conditions.

Keeping the cost of remedial cleanup low seems to have been an important goal. The ROD indicated that no responsible party is available to pay for, cleanup. The cost for the selected remedy was estimated at $1.6 million, while incineration was estimated at $11.4 million, The FS contained an unusual statement: "The cost of a cleanup technology is also a factor of concern in the primary screening step." Alternatives were kept in the analysis "if their estimated costs are not more than an order of magnitude higher than an alternative technology which performs to the same approximate extent." Generally, FSS do not cut cleanup alternatives from preliminary screening on the basis of cost.

Invoking cost is done in the ROD when a sound case can be made for equivalent environmental protection among different alternatives. Then, the issue of cost and when to estimate it takes on new importance because of SARA's requirements on technology selection. "It is difficult enough to estimate costs at this early [screening] stage of the feasibility study