TECHNICAL BACKGROUND DOCUMENT

COMPLIANCE COST ESTIMATES FOR THE PROPOSED LAND MANAGEMENT REGULATION OF CEMENT KILN DUST

Prepared for:

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1.0 Introduction

This report presents EPA's compliance cost estimates for the land management of cement kiln dust (CKD) generated by the Portland Cement Industry in support of the Agency's proposed regulation. This proposed regulation is in response to the Regulatory Determination on Cement Kiln Dust (February 7, 1995) pursuant to Section 3001(b)(3)(C) of RCRA that additional control of CKD is warranted.

Executive Order No. 12866 (FR V. 58 No. 170, 51735, October 4, 1993) requires that regulatory agencies determine whether a new regulation constitutes a significant regulatory action. A significant regulatory action is defined as an action likely to result in a rule that may:

- Have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or state, local, or tribal governments or communities;

- Create a serious inconsistency or otherwise interfere with an action taken or planned by another agency;

- Materially alter the budgetary impact of entitlements, grants, user fees, or load programs or the rights and obligations of recipients thereof; or

- Raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in Executive Order 12866.

The Agency in its regulatory determination on CKD concluded that additional control of CKD is warranted because of concerns about the harm to human health and the environment posed by CKD. However, the Agency determined that runoff releases to surface waters are more appropriately controlled under another EPA-administered statute rather the RCRA Subtitle C authority. Under RCRA Subtitle C, EPA is addressing groundwater concerns and fugitive dust emissions from CKD land management operations.

In the 1995 regulatory determination on CKD, the Agency did not establish specific regulatory controls and, therefore, did not assess the potential cost impacts of new land management regulations on the industry. This report presents the methodology and results of EPA's estimate of the potential compliance costs and their relationship to 1995 plant-level and industry-wide value of Portland Cement sales revenue associated with the newly proposed regulatory performance standards.

EPA's intent in this proposed regulation is to apply only those components of Subtitle C that are necessary to control hazards on a plant-specific basis for protection of ground-water resources. As a result, performance standards have been developed specifically for CKD. EPA evaluated the following typical facility responses to the proposed performance standards:

1. CKD Low: If the plant is not located in a karst area, has a "low" net infiltration rate (i.e., precipitation minus evaporation), and the monofill can be constructed above the natural water table, the monofill requires only a compacted CKD liner and final cover;

2. CKD High: If the plant is not located in a karst area, has a relatively high net infiltration rate, and the monofill can be constructed above the natural water table, the monofill would require a compacted CKD liner and final cover and a leachate collection system consisting of a sand drainage layer and associated piping;

3. Municipal Subtitle D Default: If the plant is located in an immature karst area (i.e., shown no evidence of subsidence or sinkholes) and the monofill can be constructed above the natural water table, the monofill must meet the design, closure, and post-closure criteria for Municipal Solid Waste Landfills listed under 40 CFR 258;

4. Off Site: If the plant is located in a mature karst area (i.e., shown evidence of subsidence or sinkholes) or a monofill cannot be constructed above the natural water table, off-site Subtitle D management is required; and

5. No land management regulation applies if the plant does not land dispose CKD.

In addition, EPA had not conducted a Regulatory Flexibility Analysis as part of the 1995 regulatory determination on CKD. The Regulatory Flexibility Act of 1980 requires agencies to assess the effect of regulations on small entities and to examine regulatory alternatives that alleviate any adverse economic effects on this group. Section 603 of the Regulatory Flexibility Act (RFA) requires an Initial Regulatory Flexibility Analysis (IRFA) to be performed to determine whether small entities will be affected by the regulation. If affected small entities are identified, regulatory alternatives that mitigate the potential impacts must be considered. Small entities as described in the Act are only those "businesses, organizations, and governmental jurisdictions subject to regulation." This report also presents the results of the IRFA conducted to meet the requirements of the RFA.

Plant-specific compliance cost estimates were developed for each of the 110 U.S. and Puerto Rican Portland Cement plants affected by the proposed regulation. Data from several sources, such as the American Portland Cement Association (APCA), the U.S. Geological Survey, and other private data sources, were used to develop the cost estimates. Plants were grouped into three baseline CKD management categories based on compaction practices. Costs were estimated for current CKD monofill practices, including placement in quarries, piles, and combination fills. Compliance management methods for groundwater protection were predicted based on plant-specific conditions. Four typical compliance designs were developed: 1) on-site contingent management without a leachate collection system (CKD Low), 2) on-site contingent management with a leachate collection system (CKD High), 3) on-site Subtitle D management (Subtitle D Default), and 4) off-site Subtitle D management (Off Site).

The Agency's solid waste landfill computer cost model, previously developed for the Municipal Solid Waste Landfill regulations, was specifically adapted to estimate costs for CKD monofills. The resulting CKD Monofill Cost Model was used to develop costs for all the varieties of the baseline and compliance management methods noted above. Regression equations were developed from estimated costs for seven plant sizes. The resulting equations were applied to each plant to estimate monofill costs. Equipment and fugitive dust control costs were calculated separately for each plant design. Baseline and projected compliance costs were thus calculated for each individual cement plant - 74 in all - believed to become directly affected by this rule making.

Incremental compliance costs were derived as the difference between the compliance management cost and the baseline management cost for each plant. Off-site Subtitle D management was assumed when it was less expensive than a predicted on-site management method. Costs for each plant were annualized on a before-tax basis, assuming a seven percent discount rate and a 20-year operating life. Plant revenues were estimated based on 1995 reported or estimated clinker production and regional cement prices. Incremental compliance costs were compared to estimated revenues for each plant to determine the initial approximate relative impact of the rule.

Section 2.0 describes general cement plant characteristics together with baseline waste generation and management practices. Cost estimation procedures and model assumptions are defined and explained in Section 3.0. Section 4.0 presents regulatory compliance cost estimates for cement plants affected by the proposed CKD land management standards.

2.0 General Cement Plant Characteristics

2.1 Overview of Cement Kiln Dust, Processes and Products[1]

Cement kiln dust is a fine-grained solid material generated as the primary by-product of the production of cement. During cement production, kiln combustion gases flow countercurrent to the raw feed and exit the kiln under the influence of induced draft fans. The rapid gas flow and continuous raw feed agitation are turbulent processes that result in large quantities of particulate matter being entrained in the combustion gases. The entrained particulate matter (as well as various precipitates) is subsequently removed from the kiln exhaust gases by air pollution control equipment. This particulate matter constitutes CKD. In contrast to many other residues of industrial production, CKD is essentially an “off-specification” product. It more closely resembles the raw material entering and product leaving the operation than many other industrial solid wastes.

The total quantity of CKD collected by air pollution control (APC) equipment (gross generation) may be either recycled back to the kiln, beneficially used off site, or disposed as wasted dust. Net CKD generation is defined as the quantity of CKD wasted and CKD that is not recycled back to the kiln as raw material, but remains either in whole or in part as wasted dust for disposal or shipment off site for beneficial use. CKD management costs in this analysis are based on wasted CKD quantities.

2.2 Data Sources

Data used in this cost analysis were obtained from several sources including the 1990 American Portland Cement Association (APCA) survey, the 1991 and 1995 CKD Surveys, the 1995 APCA Plant Information Summary, and EPA file information. Data sources are noted throughout this report and are listed in each table and attachment.

2.3 Profile of Affected Plants

The *1995 U.S. and Canadian Portland Cement Industry Plant Information Summary* identified 118 U.S. plants, owned by 46 companies, that produced and/or ground clinker as of December 31, 1995. Of these 118 plants, 8 were grinding plants only and would not be affected by these proposed land management standards. Since 1995, 2 of the 110 clinker production plants have closed their kilns and also would not be affected by the proposed CKD rule. Two additional plants in Puerto Rico not included in the APCA plant summary also generate clinker. The resulting total of 110 plants in the universe, with a clinker capacity of 77.048 million metric tons, are potentially subject to proposed CKD regulation.

In cooperation with the Small Business Association and industry representatives, EPA identified 8

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[1] *Report to Congress on Cement Kiln Dust, Volume II: Methods and Findings.* U.S. EPA, Office of Solid Waste. December 1993.

plants owned by 8 companies that qualify as small businesses for purposes of the Small Business Regulatory Enforcement and Fairness Act of 1996. Based on EPA file data, current as of January 1998, 18 of the 110 plants in the analysis burn hazardous waste as fuel. Future compliance scenarios considered in these proposed land management standards include on-site management of CKD.

On-site management may need to be more stringently regulated in areas of Karst terrain or potential areas of land subsidence. The plants that are located in Karst terrain or potential areas of land subsidence were determined by the Agency from available geological mapping studies and consultation with state agency personnel.[2] Of the 110 plants in the analysis, 79 are located in Karst terrain, including a few in potential areas of land subsidence. Attachment 1 presents the baseline information used in this analysis for each of the 110 U.S. and Puerto Rican cement plants presently operating cement kilns.

2.4 CKD Generation

Net, wasted, and beneficially used CKD quantities were reported by most plants. Net CKD is the total of wasted and beneficially used CKD. Baseline and compliance costs are based on reported or estimated wasted CKD quantities. Wasted CKD quantities were reported in the 1995 APCA Survey by 101 of the 110 plants affected by the proposed land management standards.[3] Wasted CKD quantities were reported by an additional 7 plants in the 1991 APCA Survey.[4] These 1991 quantities were assumed to be representative of 1995 quantities. Wasted CKD quantity data were not available for two plants. The net CKD quantities were estimated for these two plants based on average net CKD to clinker production ratios for reporting plants. Average net CKD generation ratios vary depending on kiln type. Table 2-1 presents the average net CKD generation ratios. Wasted CKD quantities for the two non-reporting plants were conservatively assumed to be equal to the net CKD estimates (e.g., no beneficial use of CKD was assumed). Table 2-2 summarizes the reported and estimated net, beneficially used, and wasted CKD quantities. Plant-specific wasted CKD quantities are presented in Attachment 1.

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[2] SAIC Incorporated. *Mapping Cement Facilities to Ground-Water Controls*. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, June 27, 1997.

[3] American Portland Cement Association, 1997. APCA 1995 CKD Survey.

[4] American Portland Cement Association, 1993. APCA 1991 CKD Survey.

Table 2-1. Average Net CKD Generation Ratios by Kiln Type

Kiln Type	Average Net CKD to Clinker Production Ratio
Non-hazardous Fuel Kiln	
Dry Process	0.060
Dry Preheater/Precalciner Process	0.024
Wet Process	0.107
Hazardous Fuel Kiln	
Dry Process	0.061
Dry Preheater/Precalciner Process	0.038
Wet Process	0.166

Source: American Portland Cement Association, 1997. APCA 1995 CKD Survey.

Table 2-2. Net, Beneficially Used, and Wasted CKD Quantities

	Plants	Net CKD (MT/yr)	Beneficially Used CKD (MT/yr)	Wasted CKD (MT/yr)
1995 CKD Quantities				
Small Companies	8	148,641	40,700	107,941
Large Companies	93	3,757,152	649,210	3,107,942
1991 CKD Quantities				
Small Companies	0	0	0	0
Large Companies	7	160,438	77,829	82,609
Estimated Quantities				
Small Companies	0	0	0	0
Large Companies	2	18,162	0	18,162
Subtotal Small Companies	8	148,641	40,700	107,941
Subtotal Large Companies	102	3,935,752	727,039	3,208,713
Total All Companies	**110**	**4,084,393**	**767,739**	**3,316,654**

Sources: American Portland Cement Association, 1997. APCA 1995 CKD Survey.
American Portland Cement Association, 1993. APCA 1991 CKD Survey.

2.5 Baseline CKD Management Practices

Minimal baseline management information is available for 60 of the 110 plants in the analysis. A limited amount of information was provided for compaction, leachate collection, surface water controls, and fugitive dust controls. Of these management methods, the method with the most critical impact to the final cost estimate is compaction because compacted waste density determines the size of the required monofill and also is a necessary requirement for compliance with proposed fugitive dust controls. Costs for other CKD management components, such as surface water controls and groundwater monitoring specifications, are small in comparison to costs related to compacted waste density. In order to limit the number of plant-specific baseline management categories modeled, categories were developed based on compaction methods (which have a critical impact to final costs) and not on other relatively low-cost components.

Based on general summary data provided by APCA from the 1995 Survey, three baseline management categories were developed: Baseline Low, Baseline Medium, and Baseline High. Plants were assigned a baseline management category based on reported compaction information, if available. Plants reporting no compaction were assigned to the Baseline Low category. Plants reporting some compaction were assigned to the Baseline Medium category. Plants reporting compaction of pelletized CKD were assigned to the Baseline High category.

Each of these three categories was further subdivided by type of land placement design: quarry (placement in an unused quarry area), pile (placement primarily above ground), and combination fill (placement below and above ground). The most appropriate of these three designs was assigned to each reporting plant based on available information from the 1990 American Portland Cement Association Survey and the APCA 1995 CKD Survey.

The most commonly reported baseline management method assigned for reporting plants was Baseline Medium Quarry. This baseline management method was assumed for the 13 plants that generate wasted CKD for which no management data were available. The remaining 37 plants reported either recycling all CKD back to the kiln (24 plants) or shipping all generated CKD off site for beneficial uses (13 plants). Therefore, a baseline management method of "None" was assigned. Table 2-3 summarizes the baseline management methods. Plant-specific baseline management methods for each of the 110 U.S. and Puerto Rican cement plants are presented in Attachment 1.

Table 2-3. Baseline Management Methods

Baseline Management Method	Number of Plants
Low - Quarry	7
Medium - Quarry	12
High - Quarry	9
Low - Combination Fill	6
Medium - Combination Fill	3
High - Combination Fill	2
Low - Pile	9
Medium - Pile	9
High - Pile	3
Unknown (assumed Medium - Quarry)	13
None (no CKD wasted)[1]	37
Total	**110**

[1] One plant reported a small quantity of wasted CKD in 1995 that is temporarily stored for future beneficial use.
Source: 1990 and 1995 American Portland Cement Association Surveys

3.0 CKD Land Disposal Cost Estimating Methodology and Assumptions

3.1 CKD Monofill Cost Model and Fugitive Dust Controls

DPRA developed a municipal solid waste landfill (MSWLF) computer cost model for EPA, Office of Solid Waste. The model was developed to estimate baseline and compliance costs at existing and new facilities under the proposed Subtitle D rules and regulatory alternatives considered by EPA during its rule making process. This model simulates the cost to design, construct, operate, close, and provide post-closure care for a MSWLF under a variety of regulatory and technical scenarios. This model was used in the development of EPA's proposed revisions to the Subtitle D criteria for MSWLFs to analyze the costs of regulatory alternatives as presented in the OSW report *Draft Regulatory Impact Analysis of Revisions to Subtitle D Criteria for Municipal Solid Waste Landfills*, dated August 5, 1988.

DPRA has modified appropriate design criteria and unit costs in the original MSWLF cost model to represent design and costs specific to CKD monofills. This CKD Monofill Cost Model allows the user to enter design and operating components such as waste capacity, waste density, liner and final cover specifications, and years of operation and post-closure activities. The user also may enter unit costs for cost components such as labor rates, groundwater monitoring well installation, placement of soil for liner and final cover systems, and various fees, including engineering, inspection and testing, contractor overhead and profit, and contingency.

Costs for equipment, such as bulldozers, compactors, water trucks, and dump trucks for hauling, were estimated separately from the CKD Monofill Cost Model because the equipment specifications in the original MSWLF Cost Model were inherently specific to requirements of municipal solid waste. Appendix A provides details on the equipment assumptions and costs used in this analysis. Costs and assumptions for these equipment costs are based on equipment operating parameters, professional judgement, and *Cost Functions for Alternative CKD Control Technologies - Draft* by ICF, dated July 19, 1996.

Fugitive dust control technologies, including water spray on roads, covers on trucks, and pelletization, also were included in this analysis. Costs for these technologies were estimated separately from the model and were incorporated into the final baseline and compliance costs for each plant. In addition, monofill equipment and fugitive dust control technology specifications interrelate. For example, the fugitive dust control technology of placing covers on trucks is related to the number of trucks required for hauling CKD to the monofill. Because of these interrelationships, details on the fugitive dust control technologies and costs used in this analysis are presented in Appendix A with the equipment assumptions and costs. Costs and assumptions for fugitive dust control technologies are based on *Cost Functions for Alternative CKD Control Technologies - Draft* by ICF, dated July 19, 1996.

3.2 Baseline and Regulatory Compliance Landfill Designs

Three generic baseline CKD monofill types have been specified for this analysis: quarry, pile, and combination fill. For the quarry, it is assumed that an excavated area already exists for the placement of most of the waste below grade. A pile includes a limited amount of excavation with most of the waste placed above grade. A combination fill includes excavation with waste placed below and above grade. Attachments 2, 3, and 4 present the CKD Monofill Cost Model inputs for quarries, piles, and combination fills, respectively.

The four categories of compliance management were: CKD Low, CKD High, Subtitle D default, and Off-Site. The CKD Low category assumes a contingent management scenario of a CKD monofill operating without a leachate collection system. The CKD High category assumes a contingent management scenario of a CKD monofill operating with a leachate collection system. The Subtitle D category assumes on-site management by existing RCRA Subtitle D landfill regulations. The Off-Site category assumes off-site transportation and Subtitle D landfilling in a commercial landfill capable of accepting contaminated soil.

The category of compliance management required for each plant that generates wasted CKD was estimated by SAIC based on facility-specific data including CKD production rates, CKD management practices, and site-specific hydrogeologic and climatic conditions.[5] The required compliance management categories specified in this document were assumed for each plant unless off-site Subtitle D management was less expensive than the predicted on-site management category.

For compliance management, combination fill and pile designs were considered for each plant. For the plants where on-site management is less expensive than off-site management, the pile design is always less expensive than the combination fill design. Therefore, the compliance costs for each plant with an on-site monofill represent pile designs. Table 3-1 summarizes the predicted compliance management methods based on SAIC's analysis. Plant-specific compliance management methods are presented in Attachments 10, 11, and 12.

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[5] SAIC Incorporated. *Mapping Cement Facilities to Ground-Water Controls*. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, June 27, 1997.

Table 3-1. Compliance Management Methods

Compliance Management Method	**Number of Plants**
CKD Low - Pile	7
CKD High - Pile	5
On-site Subtitle D - Pile	44
Off-site Subtitle D Management	18
None (no CKD wasted)[1]	36
Total	**110**

[1] Excludes one plant that reported generating a small amount of wasted CKD in 1995 that is temporarily stored for future beneficial use. A future compliance management method was assumed for this plant.
Source: SAIC Incorporated. *Mapping Cement Facilities to Ground-Water Controls.* Prepared for U.S. Environmental Protection Agency, Office of Solid Waste, June 27, 1997.

3.3 On-site Management Cost Estimation

Baseline and compliance costs were estimated for each category (i.e., Baseline Low, Baseline Medium, Baseline High, CKD Low, CKD High, and Subtitle D) and each design (i.e., quarry, combination fill, and pile for baseline and combination fill and pile for compliance). As a default assumption, the quarry design was not considered for the compliance scenarios because quarry bases are often below the water table.

Monofill baseline and compliance costs were calculated for seven plant sizes: 1,000 tons/yr (907 MT/yr); 10,000 tons/yr (9,074 MT/yr); 20,000 tons/yr (18,149 MT/yr); 30,000 tons/yr (27,223 MT/yr); 50,000 tons/yr (45,372 MT/yr); 100,000 tons/yr (90,744 MT/yr); and 250,000 tons/yr (226,860 MT/yr). Costs were annualized at a real rate of return of 7 percent on a before-tax basis. A regression equation, as a function of annual CKD quantity, was developed for each baseline and compliance scenario. Attachment 5 presents the regression equations that were applied to each plant to estimate plant-specific monofill costs based on reported or estimated wasted CKD quantity. Monofill equipment and fugitive dust control technology costs are based on reported or estimated wasted CKD quantity and were estimated for each plant. Regression equations were not used for monofill equipment or fugitive dust control technology cost estimates. Cost equations used for monofill equipment and fugitive dust control technologies are presented in Appendix A.

Regionalization factors for labor and materials were applied to the resulting on-site management costs for each plant. Because most of the unit costs used in the CKD Monofill Cost Model are based on costs in the 1995 *R.S. Means Site Work & Landscape Cost Data*, city cost indexes from this source were used as regionalization factors. The assumed regionalization factor for each plant is the cost index reported for the nearest city to the plant location.

3.4 Off-Site Subtitle D Management Cost Estimation

Off-site Subtitle D management costs are estimated for each plant. However, off-site management is assumed only when proposed as the management method because of mature Karst terrain or potential areas of land subsidence or when off-site management is less expensive than the predicted on-site management method.

A cost of $32.81/MT is assumed for transportation of wasted CKD to an off-site Subtitle D landfill. This cost includes loading and hauling wasted CKD a round-trip distance of 200 miles in a 20 cubic yard dump truck. Costs for transportation of contaminated soil were used as a reasonable proxy for transportation of CKD. An uncompacted, non-pelletized CKD density of 60 pounds per cubic foot (pcf) is assumed. Unit costs are based on data from *Environmental Restoration Unit Cost Books* and *Site Work & Landscape Cost Data* published by R.S. Means Company, Inc.

As a reasonable proxy for off-site regulated disposal, landfill tipping fees are weighted averages by state for disposal of contaminated soil in appropriate landfills in May 1995, as published by Chartwell Information Publishers. Weighted averages for each state were calculated considering the average daily intake of each landfill to obtain a representative unit price for the available disposal capacity in each state. For example, the tipping fee of a large landfill was weighted higher than the tipping fee for a small landfill. Tipping fees reported in cubic yards were converted to tons using the uncompacted, non-pelletized CKD density of 60 pcf. Tipping fees that were considerably higher than other tipping fees for the same state were not included in the average. Reported prices varied considerably for different states, ranging from about $10 per metric ton in Idaho and Colorado to over $65 per metric ton in Florida, New York , and Washington. Prices for most states ranged from $20 to $40 per metric ton. Attachment 6 presents the average landfill tipping fees for contaminated soil by state for May 1995.

3.5 Engineering Design Conditions and Assumptions

CKD Density

The density of a substance is the mass per unit volume including any water present, expressed in units such as grams per cubic centimeter (g/cm^3), kilogram per cubic meter (kg/m^3) or pounds per cubic foot (pcf). In the information reviewed concerning the engineering properties of CKD, the density of CKD is reported in units of pounds per cubic foot. The in-situ density of CKD will depend on specific gravity of the soil particles, the volume of pore space (void space) in the matrix, and the degree to which the pore space is saturated with water.

The properties of soil and CKD may be significantly altered by compaction. Standard tests are available to establish the relationships between density, water content, and compactive effort. The Standard Proctor Test (ASTM D698) and Modified Proctor Test (ASTM D1557) are widely used to determine these relationships. In these tests, samples of soils are placed in standard size containers and subjected to compaction using standardized means. The water content of soil samples are varied and resulting densities (unit weights) are plotted to determine the moisture content at which density is maximized. The resulting maximum density is referred to as the maximum dry density, and the moisture content at which this density occurs is referred to as the optimum moisture content. Densities of at least 95 percent of the maximum dry density determined from Proctor Tests are specified in the construction of compacted fills.[6] In the data reviewed on compaction of CKD, 95 percent of Proctor maximum dry density (or "95% Proctor") is frequently specified.

In most of the actual field test data available, maximum dry density is determined by Standard Proctor tests and field verification of density is determined indirectly using a nuclear density gauge. Where field tests show less than required density, recompaction may be required.

A typical range of maximum dry densities for CKD was reported in the closure of the Independent Cement Corporation CKD landfill in Greene County, New York.[7] In twelve tests conducted, the maximum dry density determined by the Standard Proctor Test (ASTM D698) ranged from 73.8 pcf with a corresponding moisture content of 36.2% to 88.6 pcf with a corresponding moisture content of 23.3% (average of 79 pcf at 34% moisture).

In the laboratory tests conducted by Todres et al, for the Portland Cement Association,[8] maximum dry density was determined using a compaction method similar to the Standard Proctor Test (see medium compaction tests). In these tests, the following maximum dry densities were determined:

- long wet rotary kiln dust: 93.7 pcf
- long dry rotary kiln dust: 83.0 pcf
- precalciner dust: 81.0 pcf

Subsequent field compaction and permeability research by Todres[9] at the Ash Grove Cement plant in Chanute, Kansas, indicated a maximum dry density of 89.5 pcf at an optimum moisture content of 29% for fresh (dry) material, and similar results (88.5 pcf, 28% moisture content) for weathered material from the field. At Lehigh Portland Cement Company's Cementon Plant (New York), fresh cement kiln dust was found to have a maximum dry density of 99.9 pcf at an

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[6] Merritt, Frederick S. *Standard Handbook for Civil Engineers*. McGraw-Hill Book Company, New York, Second Edition, 1976.

[7] Malcolm Pirnie, Inc. *Certification Report, Independent Cement Corporation, Catskill, New York*, Draft, February 1997.

[8] Todres, H., Mishulovich, A. And Ahmed, J. *Cement Kiln Dust Management: Permeability*. Research and Development Bulletin RD103T. Portland Cement Association, Skokie, Illinois, 1992.

[9] Todres, H.A. *Cement Kiln Dust: Field Compaction and Resulting Permeability*. Research and Development Bulletin RD 106T. Portland Cement Association, Skokie, Illinois, 1992.

optimum moisture content of 21%.[10] Tests conducted at this same plant in 1991 reported a maximum dry density of 90 pcf for fresh CKD.[11]

Based on the data reviewed in the sources presented above, the maximum dry density of CKD ranged from approximately 74 pcf to 100 pcf. Averaging the reported values results in a maximum dry density of 88 pcf. Assuming that CKD specified for use in compacted liner and cover materials would require a minimum of 95% of the Standard Proctor, the resulting in-place density of the “engineered” material would be approximately 84 pcf. To support this assumption, field dry densities (measured by a nuclear density gauge) at the Ash Grove plant test strips to assess the compaction and permeability of CKD using various compaction techniques, reported maximum dry densities ranging from 71.9 pcf (81% Proctor) to 90.2 pcf (102% Proctor), with an average of 82.3 pcf (93% Proctor).

Data on the density of uncompacted CKD is less prevalent in the literature reviewed for this analysis. At the Lehigh Cementon plant, permeability tests on 32 dust samples taken in 1992 and 1993 indicate a range of dry unit weights of 45.3 pcf to 76.5 pcf, with an average value of 63 pcf, which corresponds to a Proctor of generally 70%, based on a maximum dry density of approximately 90 pcf.[12] At Ash Grove’s plant in Chanute, Kansas, CKD samples taken from an existing monofill area, subject to normal weathering and settling, had densities of approximately 70% Proctor.[13] This corresponds to a density of 62 pcf. This same reference, however, also reports that dry densities of uncompacted material from the existing monofill range from 56 pcf to 58.7 pcf. Based on this data, it was assumed for cost modeling purposes that the uncompacted density of CKD is 60 pcf.

Density results for varying degrees of compaction, other than what unit weight is necessary to achieve 95% of the Standard Proctor for CKD, must be inferred from limited data and engineering judgement. The field dry densities reported at the Ash Grove plant[14] for various compaction practices, which range from 72 pcf to 90 pcf (81-102% Proctor), reflect the range of outcomes from some compaction (approximately 80% Proctor) to an engineered placement of material (95% Proctor or greater). At less than 80% of the Standard Proctor, the material is assumed to be dumped in either an existing landfill or pile, receiving some compaction from

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[10] Spectra Engineering, P.C. *Lehigh Portland Cement Company, Alsen Dust Disposal Facility, Closure Certification Report*, Appendix A. February 1995.

[11] Spectra Engineering, P.C. *Lehigh Portland Cement Company, Alsen Dust Disposal Facility, Closure Certification Report*, Appendix B. February 1995.

[12] Spectra Engineering, P.C. *Lehigh Portland Cement Company, Alsen Dust Disposal Facility, Closure Certification Report*, Appendix I. February 1995.

[13] Todres, H.A. *Cement Kiln Dust: Field Compaction and Resulting Permeability*. Research and Development Bulletin RD 106T. Portland Cement Association, Skokie, Illinois, 1992.

[14] Ibid.

trucks and/or dozers associated with placement and grading activities only. The density of CKD for this "light" compactive effort is assumed for modeling purposes to be 68 pcf, which corresponds to 75-80% of the Standard Proctor. Above this level, but less than the compactive effort necessary to reach 95% Proctor necessary for liner and cover specification, is the concept of "conditioned placement of CKD." Under this scenario, plants would condition (i.e., wet) their CKD in the field and provide moderate compaction to achieve an assumed 85-90% Proctor, which corresponds to 77 pcf.[15] This value was used to model the in-place density of plants disposing CKD in new landfills subject to regulatory requirements.

In summary, the following densities and their corresponding Proctors, based on a maximum dry density of 88 pcf for CKD (i.e., Standard Proctor) were assumed for cost modeling purposes:

CKD Management Practice	Pounds/Cubic Feet	Proctor (%)
Unpelletized truck transport	60	70 (or less)
Quarry (no compaction)	60	70 (or less)
Baseline combination fill or pile	68	75-80
Conditioned placement	77	85-90
Pelletizing	77	85-90
Engineered placement (liners and covers only)	84	95 (or greater)

Depth of Fill Below Grade

For combination fills, the depth of fill below grade is assumed to be 15 feet. The depth of fill below grade for piles is assumed to be 1 foot. The depth of quarries is assumed to be 25 feet for 1,000 tpy plants, 75 feet for 250,000 tpy plants, and 50 feet for the remaining plants modeled.

Percent of Fill Below Grade

For combination fills, the percent of fill below grade is assumed to be 50 percent. The percent of fill below grade for piles is 10 percent for 1,000 tpy plants and 5 percent for the remaining plants modeled. The percent of fill below grade for quarries is assumed to be 95 percent.

Below Grade Side Slope

The below grade side slope of all monofill types is assumed to be 3 run to 1 rise based on typical landfill operations to accommodate equipment operation and promote slope stability.

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[15] This same density was assumed for plants that pelletize CKD.

Containment Layers

Based on CKD management data reported in the 1995 APCA Survey, containment layers are not included for the baseline scenarios. The containment layers reported in the Survey data are not engineered containment systems designed to limit infiltration of leachate, but are generally described as native materials such as bedrock or recompacted shale.

The containment system assumed for the CKD Low compliance scenario is 4 feet of compacted CKD. For the CKD High compliance scenario, a leachate collection system is added resulting in assumed containment layers of 4 feet compacted CKD, 1 foot sand, and geotextile filter fabric. The containment system assumed for the Subtitle D compliance scenario is based on existing RCRA Subtitle D landfill regulations and consists of 2 feet compacted clay, 60 mil HDPE liner, 1 foot sand, and geotextile filter fabric.

Groundwater Monitoring

Groundwater monitoring is not included in the Baseline Low and Baseline Medium scenarios. One upgradient and two downgradient groundwater monitoring well clusters, each having three wells, are assumed in modeling the Baseline High scenario.

One upgradient and two downgradient groundwater monitoring well clusters, each having three wells, are assumed for the CKD Low and CKD High compliance scenarios. The number of groundwater monitoring well clusters assumed for the Subtitle D compliance scenario is one upgradient well cluster and a minimum of three downgradient well clusters for the first 300 feet of operating side length plus one well cluster for each additional 150 feet. For example, 12 wells are assumed for 1,000 tpy plants, 21 wells are assumed for 30,000 tpy plants, and 30 wells are assumed for 100,000 tpy plants. Therefore, the number of wells assumed for the Subtitle D compliance scenario should be sufficient for monitoring in Karst terrain.

Leachate Collection

Based on summary data from the 1995 APCA Survey, leachate collection is not included for the baseline scenarios. Leachate collection also is not assumed for the CKD Low compliance scenario. For the CKD High scenario, 0.026 inch of leachate (approximately 700 gal/acre/year) is assumed to be collected each year during monofill operation. This leachate volume is based on average post-closure leakage (exfiltration) data reported in Table 3 of SAIC's analysis. The leakage rates for New Hampshire and Oregon were not included in the average leachate volume because it is assumed that the CKD High compliance scenario would not be appropriate for plants with relatively high leakage rates. For the CKD High compliance scenario, collected leachate is assumed to be trucked off-site for treatment. Based on the average leakage rates reported for Subtitle D monofills in Table 3 of SAIC's analysis, no leachate is assumed to be collected for the Subtitle D compliance scenario.

Run-on/Run-off Controls

Based on management data from the 1995 APCA Survey, surface water run-on/run-off controls are assumed for the Baseline Medium and Baseline High scenarios, but not for the Baseline Low scenario. Run-on/run-off controls are assumed for all compliance scenarios. The run-on/run-off controls include a ditch surrounding the active area of the monofill and an excavated basin. The basin design assumes a 6-foot deep unlined basin with a 6-foot high vegetated earthen berm surrounding it. The basin capacity is sized for 2.5 inches of rain falling over the monofill active area and a 31-foot buffer around the active area.

Fugitive Dust Controls

Based on management data from the 1995 APCA Survey, 56 of 63 reporting plants (89 percent) reported using water spray for road dust control. Therefore, water spray on roads was included in all baseline scenarios. Pelletizing was reported by 36 of 63 reporting plants (57 percent). Therefore, pelletizing also was included in the Baseline High scenario.

An emissions reduction analysis was conducted by ICF[16] on several fugitive dust control technologies: enclosure, covers on piles, pelletization, water addition to unpaved road surface, covers on trucks, cleaning of trucks and covers, water addition to temporary storage piles, chemical (latex) addition to temporary storage piles, covering temporary storage piles with soil, monofill compaction, water addition to the monofill, and chemical (latex) addition to the monofill. These data were reviewed and used to make preliminary recommendations for fugitive dust control technologies presented in this analysis.

Monofill compaction and water addition to the monofill are basic components in the CKD Monofill Cost Model and, therefore, are not treated as separate fugitive dust controls. Conditioned placement of CKD is a basic design condition for all compliance scenarios. Water addition to the monofill is necessary for compaction of CKD to the specifications of "conditioned placement." ICF determined that water addition to the disturbed monofill area would result in control efficiencies between 55 and 75 percent. DPRA did not add costs for additional water above the cost assumed for water required during compaction because the costs for incidental water addition that may be necessary beyond that required for compaction are negligible compared to equipment and operating labor costs associated with compaction.

Water addition to unpaved roads, the only control technology for fugitive dust control on unpaved roads used in this study, was determined to have a control efficiency between 70 and 99 percent. This technology currently is being used by a 89 percent of plants in the industry according to the 1995 APCA Survey. Therefore, this technology is included for all baseline and compliance scenarios.

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[16] ICF, Incorporated. Memorandum to William Schoenborn (USEPA) from LuAnn Gardner, Cynthia Steiner, Liz Nixon, and Larry Huffman (ICF Incorporated), entitled "Revised Results of Emissions Reduction Analysis, Task 10, Work Assignment 215, Contract No. 68-W4-0030," February 14, 1997.

DPRA considered enclosure, pelletization, covers on trucks, cleaning of trucks and covers, and water addition to temporary storage piles for fugitive dust control technologies for the compliance scenarios. Based on the emissions reduction analysis, it appears that pelletization is the best overall dust control technology. Pelletization has been estimated to have a 92 percent control efficiency for dust from temporary storage piles, between 50 and 57 percent control efficiency for dust in a disturbed area of the monofill, a 99 percent control efficiency for dust during handling, between 95 and 96 percent control efficiency for dust during bulldozing, and between 81 and 87 percent control efficiency for dust during truck transport. The somewhat lower dust control efficiency of pelletization in a disturbed area of the monofill will be greatly increased with the combination of this technology and water addition to the monofill. The dust control efficiency of covers on trucks for non-pelletized CKD is 90 percent. The combination of pelletization and covers on trucks should increase the dust control efficiency during transport above 90 percent. Water addition to temporary storage piles is less expensive than pelletization, but the dust control efficiency is much lower. Total enclosure of interim storage piles was estimated to have a dust control efficiency of 99 percent, which is slightly higher than that of pelletization. However, the additional cost of total enclosure may be high compared to the incremental dust control benefit of this technology. Cleaning trucks and covers increased the dust control efficiency of covers on trucks by 5 percent. However, the basis of this estimate was non-pelletized CKD. The additional dust control efficiency benefit of cleaning trucks and covers above the combination of pelletization and covers on trucks is unlikely to be worth the additional cost. Therefore, the estimates assumed only pelletization and covers on trucks for CKD handling prior to and during transport to points of destination for all on-site compliance scenarios.

Chemical (latex or other) addition to temporary storage piles or to the monofill was not considered in this analysis, nor was covering temporary storage piles with soil. Based on the emissions reduction analysis, pelletization appears to be a better overall solution for fugitive dust control.

Final Cover Layers

Survey data regarding proposed final cover layers for currently active CKD monofills in the industry are not available. In the absence of information, no final cover is assumed for the Baseline Low scenario, a final cover of 0.5 foot topsoil and vegetation for the Baseline Medium scenario, and a final cover of two feet compacted CKD, 0.5 foot topsoil, and vegetation for the Baseline High scenario. Final cover layers are not included in the costs for the Baseline Quarry scenarios because quarry fills are below grade and are assumed to have typical active lives beyond the 20-year scope of this analysis.

The final cover for the CKD Low compliance scenario (without leachate collection) includes two feet compacted CKD, 0.5 foot topsoil, and vegetation. The final cover for the CKD High compliance scenario (with leachate collection) includes two feet of compacted CKD, 0.5 foot sand, geotextile filter fabric, 0.5 foot slope and earth fill, 0.5 foot topsoil, and vegetation. The final cover for the Subtitle D compliance scenario is based on existing RCRA Subtitle D landfill closure requirements and includes a 60 mil HDPE liner, 1.5 feet sand, geotextile filter fabric, 0.5 foot topsoil, and vegetation.

Slope of Final Cover

The slope of the final cover is assumed to be 2 percent, which is consistent with the modeling analyses done by SAIC. A 2 to 4 percent slope is typically chosen to reduce soil loss due to erosion.

Toe Slope of Final Cover

The toe slope of the final cover is 4 run to 1 rise. This slope is based on documentation provided in the closure report for the Lehigh Portland Cement Company which states that problems with equipment occurred with cover side slopes of 3 to 1 constructed of compacted CKD.[17] Therefore, a lower slope of 4 to 1 was assumed.

Post-Closure Groundwater Monitoring

The active-life groundwater monitoring specifications are assumed to continue for the entire post-closure duration of 30 years.

Post-Closure Leachate Collection

Leachate collection systems included in the CKD High and Subtitle D compliance scenarios continue operation for the first 5 years of post-closure. Five years is assumed to allow any leachate remaining in the monofill at the time the final cover is placed to reach the leachate collection system.

3.6 Cost Accounting and Unit Pricing

All unit costs have been updated to 1995 dollars. Attachment 7 presents unit costs used in the CKD Monofill Cost Model.

Plant revenue is based on clinker production and cement prices. For this study, white cement or regional gray cement prices were taken from Tables 11 and 13 of the Cement Chapter of the1995 *USGS Minerals Yearbook*. Three plants produce white cement, which has a much higher price (averaging \$174.66/MT in 1995) than gray cement (average \$66.89/MT, range \$55.78/MT to \$90.12/MT). For the three regions in which white cement is produced (Northern Texas, Eastern Pennsylvania, and Southern California), the white cement price was removed from the average for the region to estimate the gray cement price. Attachment 8 presents regional gray cement prices for all regions in 1995.

Individual cement plant revenues were estimated by multiplying individual plant 1995 clinker production quantities (as reported in the 1996 Portland Cement Association Survey) and the 1995

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[17] Spectra Engineering, P.C. *Lehigh Portland Cement Company, Alsen Dust Disposal Facility, Closure Certification Report*. February 1995.

white or regional gray cement prices, as appropriate (Attachment 8). Plant-level clinker production data has been treated as confidential by the Agency for purposes of this analysis. For 17 non-reporting plants, clinker production and revenues were based on the plants' clinker capacity and the regional average 1995 capacity utilization, as reported in Table 4 of the Cement Chapter of the 1995 *USGS Minerals Yearbook.* Attachment 9 presents regional clinker capacity utilization for all cement producing regions.

4.0 Estimated Regulatory Compliance Costs

Baseline and compliance costs were calculated for each affected plant, considering the baseline management method assumed, the most economical predicted compliance management method, and the quantity of CKD wasted. Capital, recurring capital, operating, closure, and post-closure costs were annualized on a before-tax basis assuming a discount rate of 7 percent and a 20-year operating life. Appendix B provides details on the annualization procedure. Costs for individual plants were estimated in million dollars per year, cost per metric ton of CKD wasted, cost per metric ton of cement produced, and percent of 1995 revenue. Attachments 10, 11, and 12 present the baseline, total compliance, and incremental compliance cost estimates, respectively, for 110 plants. Incremental compliance costs are calculated as the difference between the total compliance cost and the baseline cost for each plant. The annual total before-tax baseline, compliance, and incremental compliance costs for all plants affected by the proposed CKD land management standards are $54.9 million, $98.5 million, and $43.7 million, respectively.

The total national cost due to the proposed regulation for the land management of cement kiln dust is approximately $43.7 million per year. Compliance cost increases are expected at 68 of 110 plants (62%). Estimated compliance management costs are approximately the same or less than estimated baseline management costs for 6 of 110 plants (5%). For the remaining 36 plants (33%), all cement kiln dust is reported to be recycled to the kiln or beneficially used, so these plants are not directly affected by the proposed regulation, although some off-site use as an agricultural soil conditioner could be affected by the proposed standards for that off-site application.

The average annualized cost for the 68 negatively affected plants per year due to the proposed regulation is $646,000. The 68 negatively affected plants are estimated to generate a total wasted CKD quantity of 3.3 million metric tons per year and incur an incremental compliance cost of $43.9 million. The average cost per metric ton of CKD for these negatively affected plants is $19.96. These 68 plants are estimated to generate a total of 43.6 million metric tons per year of cement. The average cost per metric ton of cement for these negatively affected plants is $1.12.

The estimated total revenue of the 68 negatively affected plants is $2.945 billion per year. Therefore, the estimated cost of compliance for the proposed regulation is estimated at 1.5 percent of revenues for these 68 plants. Of 110 plants, 20 plants (18%) owned by 10 companies are estimated to be impacted at an annual cost-to-sales ratio greater than 2 percent. Seventeen of these plants have a predicted compliance management of on-site Subtitle D landfill. The remaining three plants have predicted compliance managements of off-site Subtitle D landfill (2 plants) and CKD High (1 plant). Eight of these 20 plants have diversified their operations and burn hazardous waste as fuel. Therefore, they may have additional revenues that were not considered in this analysis. None of these 20 plants are small companies. Table 4-1 presents a summary of incremental compliance costs as a percent of 1995 plant revenue.

Table 4-1. Incremental Compliance Costs as a Percent of Plant Revenue[1]

Incremental Compliance Cost / Plant Revenue	Small Companies			Large Companies			All Companies		
	Number of Plants	Percent of Plants	Cumulative Percent	Number of Plants	Percent of Plants	Cumulative Percent	Number of Plants	Percent of Plants	Cumulative Percent
Zero Cost[2]	3	38%	38%	33	32%	32%	36	33%	33%
Cost Benefit[3]	1	12%	50%	5	5%	37%	6	5%	38%
>0 to 1%	3	38%	88%	26	25%	62%	29	26%	64%
>1 to 2%	1	12%	100%	18	18%	80%	19	17%	81%
>2 to 3%	0	0%	100%	9	9%	89%	9	8%	89%
>3 to 4%	0	0%	100%	4	4%	93%	4	4%	93%
>4 to 5%	0	0%	100%	3	3%	96%	3	3%	96%
>5 to 6%	0	0%	100%	3	3%	99%	3	3%	99%
>6 to 7%	0	0%	100%	1	1%	100%	1	1%	100%
Total	8	100%	---	102	100%	---	110	100%	---

[1] Percentages are based on before-tax incremental compliance costs in 1995 dollars. Plant revenues are based on 1995 reported or estimated clinker production quantities and regional cement prices. Clinker production quantities are reported in the PCA 1996 Survey or are estimated based on plant capacity as reported in the 1995 PCA *U.S. and Canadian Portland Cement Industry: Plant Information Summary* and regional capacity utilization factors as reported in the 1995 *USGS Minerals Yearbook*, Cement Chapter, Table 4. White or regional gray cement prices are reported in the 1995 *USGS Minerals Yearbook*, Cement Chapter, Tables 11 and 13.

[2] Plants that do not generate CKD that is wasted (land disposed) have no incremental compliance cost.

[3] Estimated baseline management costs are greater than estimated compliance costs, resulting in incremental compliance cost benefits.

Attachment 1. Baseline Characteristics for U.S. Portland Cement Plants[1]

Company	Location		Small Company	Burns Hazardous Waste	Karst Terrain	1995 Clinker Capacity (MT)	Baseline CKD Management
Alamo Cement Company	San Antonio	TX	No	No	Yes	740,000	No Waste
Allentown Cement Company	Blandon	PA	No	No	Yes	844,000	No Waste
Armstrong Cement & Supply	Cabot	PA	Yes	No	Yes	294,000	No Waste
Ash Grove Cement Company	Chanute	KS	No	Yes	No	478,000	High Q
Ash Grove Cement Company	Durkee	OR	No	No	No	422,000	No Waste
Ash Grove Cement Company	Foreman	AR	No	Yes	Yes	910,000	Med P
Ash Grove Cement Company	Inkom	ID	No	No	Yes	205,000	Med P
Ash Grove Cement Company	Louisville	NE	No	No	No	885,000	Low P
Ash Grove Cement Company	Montana City	MT	No	No	Yes	289,000	Med P
Ash Grove Cement Company	Nephi	UT	No	No	Yes	570,000	No Waste
Ash Grove Cement Company	Seattle	WA	No	No	No	681,000	No Waste
Blue Circle Inc.	Atlanta	GA	No	No	No	546,000	No Waste
Blue Circle Inc.	Calera	AL	No	No	Yes	578,000	***Med Q***
Blue Circle Inc.	Harleyville	SC	No	No	Yes	644,000	No Waste
Blue Circle Inc.	Ravena	NY	No	No	Yes	1,596,000	High CF
Blue Circle Inc.	Tulsa	OK	No	No	Yes	544,000	***Med Q***
Calaveras Cement Company	Redding	CA	No	No	No	590,000	No Waste
Calaveras Cement Company	Tehachapi	CA	No	No	No	818,000	No Waste
California Portland Cement	Colton	CA	No	No	No	680,000	***Med Q***
California Portland Cement	Mojave	CA	No	No	No	1,126,000	No Waste
California Portland Cement	Rillito	AZ	No	No	No	1,171,000	No Waste
Capitol Aggregates, Inc.	San Antonio	TX	No	No	Yes	775,000	Low Q
Capitol Cement Corporation	Martinsburg	WV	Yes	No	Yes	868,000	High P
Centex	Fernley	NV	No	No	No	418,000	No Waste
Centex	Laramie	WY	No	No	Yes	606,000	No Waste
Centex	LaSalle	IL	No	No	No	498,000	No Waste
Continental Cement Co., Inc.	Hannibal	MO	Yes	Yes	Yes	544,000	High Q
Dacotah Cement	Rapid City	SD	No	No	Yes	812,000	Med Q
Dixon-Marquette	Dixon	IL	No	No	Yes	474,000	Med Q
Dragon Products Company	Thomaston	ME	No	No	No	392,000	Low Q

Company	Location		Small Company	Burns Hazardous Waste	Karst Terrain	1995 Clinker Capacity (MT)	Baseline CKD Management
ESSROC Materials	Bessemer	PA	No	No	Yes	518,000	Low Q
ESSROC Materials	Frederick	MD	No	No	Yes	338,000	***Med Q***
ESSROC Materials	Logansport	IN	No	Yes	Yes	412,000	High Q
ESSROC Materials	Nazareth	PA	No	No	Yes	1,067,000	No Waste
ESSROC Materials (Lone Star)	Nazareth	PA	No	No	Yes	530,000	Low P
ESSROC Materials	Speed	IN	No	No	Yes	921,000	Med Q
Florida Crushed Stone	Brooksville	FL	Yes	No	Yes	537,000	No Waste
Giant Cement Holding, Inc.	Harleyville	SC	No	Yes	Yes	788,000	Low P
Giant Cement Holding (Keystone)	Bath	PA	No	Yes	Yes	546,000	***Med Q***
Glens Falls Cement Co., Inc.	Glens Falls	NY	No	No	Yes	463,000	Low P
Holnam Inc.	Ada	OK	No	No	No	562,000	Med CF
Holnam Inc.	Artesia	MS	No	Yes	Yes	463,000	Low P
Holnam Inc.	Clarksville	MO	No	Yes	Yes	1,179,000	High Q
Holnam Inc.	Dundee	MI	No	No	Yes	956,000	No Waste
Holnam Inc.	Florence	CO	No	No	Yes	761,000	Low Q
Holnam Inc.	Fort Collins	CO	No	No	Yes	422,000	Med Q
Holnam Inc.	Holly Hill	SC	No	Yes	Yes	967,000	Med Q
Holnam Inc.	Mason City	IA	No	No	Yes	835,000	No Waste
Holnam Inc.	Midlothian	TX	No	No	Yes	953,000	No Waste
Holnam Inc.	Morgan	UT	No	No	Yes	288,000	No Waste
Holnam Inc.	Seattle	WA	No	No	No	404,000	No Waste
Holnam Inc.	Theodore	AL	No	No	Yes	1,362,000	No Waste
Holnam Inc.	Three Forks	MT	No	No	Yes	327,000	***Med Q***
Independent Cement Corporation	Catskill	NY	No	No	Yes	544,000	High P
Independent Cement Corporation	Hagerstown	MD	No	No	Yes	463,000	Low P
Kaiser Cement Corporation	Permanente	CA	No	No	No	1,451,000	No Waste
Kosmos Cement Company	Kosmosdale	KY	No	No	No	707,000	No Waste
Kosmos Cement Company	Pittsburgh	PA	No	No	Yes	349,000	No Waste
Lafarge Corporation	Alpena	MI	No	Yes	No	2,094,000	Med Q
Lafarge Corporation	Buffalo	IA	No	No	No	843,000	Med P
Lafarge Corporation	Fredonia	KS	No	Yes	No	349,000	High Q
Lafarge Corporation	Grand Chain	IL	No	No	Yes	1,050,000	Low CF
Lafarge Corporation	Paulding	OH	No	Yes	Yes	432,000	Low Q
Lafarge Corporation	Sugar Creek	MO	No	No	Yes	478,000	Low P

Company	Location		Small Company	Burns Hazardous Waste	Karst Terrain	1995 Clinker Capacity (MT)	Baseline CKD Management
Lafarge Corporation	Whitehall	PA	No	No	Yes	791,000	No Waste
Lehigh Portland Cement	Leeds	AL	No	No	Yes	644,000	No Waste
Lehigh Portland Cement	Mason City	IA	No	No	Yes	731,000	Med Q
Lehigh Portland Cement	Mitchell	IN	No	No	Yes	661,000	Med P
Lehigh Portland Cement	Union Bridge	MD	No	No	Yes	900,000	Low P
Lehigh Portland Cement	Waco	TX	No	No	Yes	78,000	Low CF
Lehigh Portland Cement	York	PA	No	No	Yes	91,000	No Waste
Lone Star Industries	Cape Girardeau	MO	No	Yes	Yes	1,032,000	Med Q
Lone Star Industries	Greencastle	IN	No	Yes	Yes	616,000	Med Q
Lone Star Industries	Oglesby	IL	No	No	No	522,000	Med Q
Lone Star Industries	Pryor	OK	No	No	Yes	631,000	Med CF
Lone Star Industries	Sweetwater	TX	No	No	Yes	435,000	No Waste
Medusa Cement Company	Charlevoix	MI	No	No	Yes	1,237,000	Low CF
Medusa Cement Company	Clinchfield	GA	No	No	Yes	731,000	No Waste
Medusa Cement Company	Demopolis	AL	No	Yes	Yes	735,000	Low Q
Medusa Cement Company	Wampum	PA	No	Yes	Yes	638,000	No Waste
Mitsubishi Cement Corporation	Lucerne Valley	CA	No	No	No	1,547,000	Med P
Monarch Cement Company	Humboldt	KS	Yes	No	No	611,000	Low CF
National Cement Co. of Alabama	Ragland	AL	No	No	Yes	811,000	No Waste
National Cement Co. of California	Lebec	CA	No	No	No	590,000	Med P
North Texas Cement	Midlothian	TX	No	No	Yes	768,000	***Med Q***
Pennsuco Cement Co. (Tarmac)	Medley	FL	No	No	Yes	881,000	Low P
Phoenix Cement Company	Clarkdale	AZ	Yes	No	Yes	639,000	No Waste
Puerto Rico Cement	Ponce	PR	Yes	No	No	880,000	Low CF
RC Cement Co. (Heartland)	Independence	KS	No	Yes	Yes	292,000	Med CF
RC Cement Co. (Hercules)	Stockertown	PA	No	No	Yes	828,000	***Med Q***
RC Cement Co. (River Cement)	Festus	MO	No	No	Yes	1,102,000	High P
RC Cement Co. (Signal)	Chattanooga	TN	No	No	Yes	398,000	Low CF
Rinker Portland Cement Corp.	Miami	FL	No	No	Yes	500,000	Med P
Rio Grande Cement (Holnam)	Tijeras	NM	No	No	Yes	432,000	High Q
Riverside Cement Company	Oro Grande	CA	No	No	No	1,070,000	Med Q
Riverside Cement Company	Riverside	CA	No	No	No	100,000	***Med Q***
RMC Lonestar	Davenport	CA	No	No	No	726,000	***Med Q***
Roanoke Cement Company	Cloverdale	VA	No	No	Yes	899,000	High CF

Company	Location		Small Company	Burns Hazardous Waste	Karst Terrain	1995 Clinker Capacity (MT)	Baseline CKD Management
Royal Cement Company, Inc.	Logandale	NV	Yes	No	No	177,000	Med P
San Juan Cement	Dorado	PR	No	No	No	650,000	***Med Q***
Southdown Inc.	Brooksville	FL	No	No	Yes	1,102,000	***Med Q***
Southdown Inc.	Fairborn	OH	No	No	Yes	544,000	No Waste
Southdown Inc.	Knoxville	TN	No	No	Yes	580,000	High Q
Southdown Inc.	Lyons	CO	No	No	Yes	380,000	High Q
Southdown Inc.	Odessa	TX	No	No	Yes	478,000	Low Q
Southdown Inc.	Victorville	CA	No	No	No	1,461,000	No Waste
Sunbelt Cement Corp. (Lafarge)	New Braunfels	TX	No	No	Yes	880,000	Med Q
Texas Industries	Midlothian	TX	No	Yes	Yes	1,144,000	High Q
Texas Industries	New Braunfels	TX	No	No	Yes	760,000	***Med Q***
Texas-Lehigh Cement Company	Buda	TX	No	No	Yes	988,000	No Waste
Total	**110**		**8**	**18**	**79**	**77,048,000**	

[1] Portland Cement Industry companies, plant locations, and 1995 clinker capacity data are as reported in the PCA *U.S. and Canadian Portland Cement Industry: Plant Information Summary*, December 31, 1995. Small company status is based on EPA file data and information provided by the American Portland Cement Alliance and the Non-hazwaste Burner CKD Coalition. Hazardous waste burning status is based on EPA file information as of January 1998. Karst terrain data are from *Mapping Cement Facilities to Ground Water Controls* by SAIC dated June 27, 1997. For plants disposing CKD on site, baseline CKD management for most plants is based on data from the 1990 Portland Cement Association Survey. The most common baseline CKD management type of "Med Q" is assumed as a default for non-reporting plants (in bold italics). A baseline CKD management of "No Waste" is assigned to plants that do not generate net CKD or all CKD is beneficially used off site. Baseline CKD management monofill designs of "Low", "Med", and "High" were developed to represent management with no compaction, some compaction, and pelletization and compaction, respectively. Monofill types of "Q", "P", and "CF" represent quarries, piles, and combination fills, respectively.

Attachment 2. CKD Monofill Cost Model Inputs - Quarry

Variable	Baseline - Low	Baseline - Med	Baseline - High	CKD - Low	CKD - High	Subtitle D
ACTIVE LIFE (20 Years[1])						
Compacted Waste Density	No compaction (60 lb/cf)	Some compaction with dozers (68 lb/cf)	Compaction of pelletized CKD with dozers (77 lb/cf)	NA	NA	NA
Depth of Fill Below Grade	50 ft (25 ft for 1,000 TPY and 75 ft for 250,000 TPY)	50 ft (25 ft for 1,000 TPY and 75 ft for 250,000 TPY)	50 ft (25 ft for 1,000 TPY and 75 ft for 250,000 TPY)	NA	NA	NA
Percent of Fill Below Grade	95%	95%	95%	NA	NA	NA
Below Grade Side Slope	3 run: 1 rise	3 run: 1 rise	3 run: 1 rise	NA	NA	NA
Containment Layers	None	None	None	NA	NA	NA
Groundwater Monitoring	None	None	User Specified: All monofill sizes have 1 upgradient and 2 downgradient well clusters; each of these well clusters consists of 3 wells	NA	NA	NA
Leachate Collection	None	None	None	NA	NA	NA
Run-on/Run-off Controls	None	Included	Included	NA	NA	NA
Fugitive Dust Controls	Water spray on roads	Water spray on roads	Water spray on roads Pelletization	NA	NA	NA

Variable	Baseline - Low	Baseline - Med	Baseline - High	CKD - Low	CKD - High	Subtitle D
CLOSURE						
Final Cover Layers	NA	NA	NA	NA	NA	NA
Slope of Final Cover	NA	NA	NA	NA	NA	NA
Toe Slope of Final Cover	NA	NA	NA	NA	NA	NA
POST-CLOSURE (30 Years)						
Groundwater Monitoring	NA	NA	NA	NA	NA	NA
Leachate Collection	NA	NA	NA	NA	NA	NA

[1] The active life of a quarry is assumed to be 20 years for an equivalent comparison to piles and combination fills. Closure and post-closure costs are not included because they are expected to be incurred beyond the scope of this analysis.

Attachment 3. CKD Monofill Cost Model Inputs - Pile

Variable	Baseline - Low	Baseline - Med	Baseline - High	CKD - Low	CKD - High	Subtitle D
ACTIVE LIFE (20 Years)						
Compacted Waste Density	No compaction (60 lb/cf)	Some compaction with dozers (68 lb/cf)	Compaction of pelletized CKD with dozers (77 lb/cf)	Conditioned placement (77 lb/cf)	Conditioned placement (77 lb/cf)	Conditioned placement (77 lb/cf)
Depth of Fill Below Grade	1 ft	1 ft	1 ft	1 ft	1 ft	1 ft
Percent of Fill Below Grade	5% (10% for 1,000 TPY)	5% (10% for 1,000 TPY)	5% (10% for 1,000 TPY)	5% (10% for 1,000 TPY)	5% (10% for 1,000 TPY)	5% (10% for 1,000 TPY)
Below Grade Side Slope	3 run: 1 rise	3 run: 1 rise	3 run: 1 rise	3 run: 1 rise	3 run: 1 rise	3 run: 1 rise
Containment Layers	None	None	None	4 ft Compacted CKD	Geotextile Filter Fabric 1 ft Sand 4 ft Compacted CKD	Geotextile Filter Fabric 1 ft Sand 60 mil HDPE 2 ft On-site Clay
Groundwater Monitoring	None	None	User Specified: All monofill sizes have 1 upgradient and 2 downgradient well clusters; each of these well clusters consists of 3 wells	User Specified: All monofill sizes have 1 upgradient well cluster and 2 downgradient well clusters; each of these well clusters consists of 3 wells	User Specified: All monofill sizes have 1 upgradient well cluster and 2 downgradient well clusters; each of these well clusters consists of 3 wells	Model Specified: 1 upgradient well cluster; minimum of 3 downgradient well clusters for the first 300 feet of operating side length plus 1 well for each additional 150 feet; each of these well clusters consists of 3 wells
Leachate Collection	None	None	None	None	0.026 inch of leachate collected per year; leachate trucked off-site for treatment	Leachate collection system exists but no leachate is collected.
Run-on/Run-off Controls	None	Included	Included	Included	Included	Included
Fugitive Dust Controls	Water spray on roads	Water spray on roads	Water spray on roads Pelletization	Water spray on roads Pelletization Covers on trucks	Water spray on roads Pelletization Covers on trucks	Water spray on roads Pelletization Covers on trucks

Variable	Baseline - Low	Baseline - Med	Baseline - High	CKD - Low	CKD - High	Subtitle D
CLOSURE						
Final Cover Layers	None	Vegetation 0.5 ft Topsoil	Vegetation 0.5 ft Topsoil 2 ft Compacted CKD	Vegetation 0.5 ft Topsoil 2 ft Compacted CKD	Vegetation 0.5 ft Topsoil 0.5 ft Slope and Earth Fill Geotextile Filter Fabric 0.5 ft Sand 2 ft Compacted CKD	Vegetation 0.5 ft Topsoil Geotextile Filter Fabric 1.5 ft Sand 60 mil HDPE
Slope of Final Cover	NA	2 percent	2 percent	2 percent	2 percent	2 percent
Toe Slope of Final Cover	NA	4 run: 1 rise	4 run: 1 rise	4 run: 1 rise	4 run: 1 rise	4 run: 1 rise
POST-CLOSURE (30 Years)						
Groundwater Monitoring	None	None	Continued for 30 years	Continued for 30 years	Continued for 30 years	Continued for 30 years
Leachate Collection	None	None	None	None	Continued for 5 years	Continued for 5 years

Attachment 4. CKD Monofill Cost Model Inputs - Combination Fill

Variable	Baseline - Low	Baseline - Med	Baseline - High	CKD - Low	CKD - High	Subtitle D
ACTIVE LIFE (20 Years)						
Compacted Waste Density	No compaction (60 lb/cf)	Some compaction with dozers (68 lb/cf)	Compaction of pelletized CKD with dozers (77 lb/cf)	Conditioned placement (77 lb/cf)	Conditioned placement (77 lb/cf)	Conditioned placement (77 lb/cf)
Depth of Fill Below Grade	15 ft	15 ft	15 ft	15 ft	15 ft	15 ft
Percent of Fill Below Grade	50%	50%	50%	50%	50%	50%
Below Grade Side Slope	3 run: 1 rise	3 run: 1 rise	3 run: 1 rise	3 run: 1 rise	3 run: 1 rise	3 run: 1 rise
Containment Layers	None	None	None	4 ft Compacted CKD	Geotextile Filter Fabric 1 ft Sand 4 ft Compacted CKD	Geotextile Filter Fabric 1 ft Sand 60 mil HDPE 2 ft On-site Clay
Groundwater Monitoring	None	None	User Specified: All monofill sizes have 1 upgradient and 2 downgradient well clusters; each of these well clusters consists of 3 wells	User Specified: All monofill sizes have 1 upgradient well cluster and 2 downgradient well clusters; each of these well clusters consists of 3 wells	User Specified: All monofill sizes have 1 upgradient well cluster and 2 downgradient well clusters; each of these well clusters consists of 3 wells	Model Specified: 1 upgradient well cluster; minimum of 3 downgradient well clusters for the first 300 feet of operating side length plus 1 well for each additional 150 feet; each of these well clusters consists of 3 wells
Leachate Collection	None	None	None	None	0.026 inch of leachate collected per year; leachate trucked off-site for treatment	Leachate collection system exists but no leachate is collected.
Run-on/Run-off Controls	None	Included	Included	Included	Included	Included
Fugitive Dust Controls	Water spray on roads	Water spray on roads	Water spray on roads Pelletization	Water spray on roads Pelletization Covers on trucks	Water spray on roads Pelletization Covers on trucks	Water spray on roads Pelletization Covers on trucks

Variable	Baseline - Low	Baseline - Med	Baseline - High	CKD - Low	CKD - High	Subtitle D
CLOSURE						
Final Cover Layers	None	Vegetation 0.5 ft Topsoil	Vegetation 0.5 ft Topsoil 2 ft Compacted CKD	Vegetation 0.5 ft Topsoil 2 ft Compacted CKD	Vegetation 0.5 ft Topsoil 0.5 ft Slope and Earth Fill Geotextile Filter Fabric 0.5 ft Sand 2 ft Compacted CKD	Vegetation 0.5 ft Topsoil Geotextile Filter Fabric 1.5 ft Sand 60 mil HDPE
Slope of Final Cover	NA	2 percent	2 percent	2 percent	2 percent	2 percent
Toe Slope of Final Cover	NA	4 run: 1 rise	4 run: 1 rise	4 run: 1 rise	4 run: 1 rise	4 run: 1 rise
POST-CLOSURE (30 Years)						
Groundwater Monitoring	None	None	Continued for 30 years	Continued for 30 years	Continued for 30 years	Continued for 30 years
Leachate Collection	None	None	None	None	Continued for 5 years	Continued for 5 years

Attachment 5. CKD Monofill Cost Equations[1]
($1995)

	1,000 tpy 907 mtpy	10,000 tpy 9,074 mtpy	20,000 tpy 18,149 mtpy	30,000 tpy 18,149 mtpy	50,000 tpy 45,372 mtpy	100,000 tpy 90,744 mtpy	250,000 tpy 226,860 mtpy	Cost Equation
Baseline Low - Quarry								
Initial Capital	$7,536	$22,525	$35,373	$46,995	$68,458	$117,129	$193,242	$\$ = 108.64\ MT^{0.6013}$
Annual O&M	$0	$0	$0	$0	$0	$0	$0	$ = 0
Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0
Post-Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0
Baseline Medium - Quarry								
Initial Capital	$12,141	$35,980	$55,246	$72,178	$102,669	$169,593	$271,194	$\$ = 215.06\ MT^{0.5751}$
Annual O&M	$0	$0	$0	$0	$0	$0	$0	$ = 0
Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0
Post-Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0
Baseline High - Quarry								
Initial Capital	$49,598	$71,976	$90,604	$106,981	$136,470	$201,130	$293,612	$\$ = 571.90\ MT^{0.5} + 20{,}111$
Annual O&M	$3,500	$3,500	$3,500	$3,500	$3,500	$3,500	$3,500	$ = 3,500
Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0
Post-Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0

	1,000 tpy 907 mtpy	**10,000 tpy 9,074 mtpy**	**20,000 tpy 18,149 mtpy**	**30,000 tpy 18,149 mtpy**	**50,000 tpy 45,372 mtpy**	**100,000 tpy 90,744 mtpy**	**250,000 tpy 226,860 mtpy**	**Cost Equation**
Baseline Low - Combination								
Initial Capital	$157,611	$998,282	$1,866,669	$2,746,424	$4,495,185	$8,666,209	$21,368,987	$ = 93.57 MT + 164,906
Annual O&M	$0	$0	$0	$0	$0	$0	$0	$ = 0
Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0
Post-Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0
Baseline Medium - Combination								
Initial Capital	$148,935	$904,195	$1,680,323	$2,465,042	$4,022,517	$7,730,837	$19,007,771	$ = 83.17 MT + 166,866
Annual O&M	$0	$0	$0	$0	$0	$0	$0	$ = 0
Closure	$21,492	$149,385	$281,426	$410,787	$665,787	$1,293,976	$3,096,018	$\$ = 43.12\ \text{MT}^{0.9010}$
Post-Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0
Baseline High - Combination								
Initial Capital	$221,620	$1,127,074	$2,041,677	$2,963,268	$4,786,494	$9,111,447	$22,227,610	$ = 96.96 MT + 273,843
Annual O&M	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$ = 1,400
Closure	$37,624	$236,903	$438,537	$634,870	$1,020,295	$1,930,392	$4,664,591	$\$ = 89.98\ \text{MT}^{0.8724}$
Post-Closure	$1,618	$1,658	$1,698	$1,736	$1,812	$1,998	$2,543	$\$ = 4.07\text{x}10^{-3}\ \text{MT} + 1{,}623$
Baseline Low - Pile								
Initial Capital	$111,938	$298,495	$507,159	$707,284	$1,095,862	$1,998,135	$4,687,061	$ = 20.14 MT + 140,190
Annual O&M	$0	$0	$0	$0	$0	$0	$0	$ = 0
Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0
Post-Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0

	1,000 tpy 907 mtpy	10,000 tpy 9,074 mtpy	20,000 tpy 18,149 mtpy	30,000 tpy 18,149 mtpy	50,000 tpy 45,372 mtpy	100,000 tpy 90,744 mtpy	250,000 tpy 226,860 mtpy	Cost Equation
Baseline Medium - Pile								
Initial Capital	$109,623	$288,830	$485,830	$673,132	$1,034,491	$1,867,037	$4,329,651	$ = 18.55 MT + 147,012
Annual O&M	$0	$0	$0	$0	$0	$0	$0	$ = 0
Closure	$38,642	$188,434	$371,858	$554,763	$919,665	$1,797,033	$4,472,006	$ = 19.63 MT + 18,435
Post-Closure	$0	$0	$0	$0	$0	$0	$0	$ = 0
Baseline High - Pile								
Initial Capital	$215,889	$642,973	$1,145,112	$1,604,165	$2,551,096	$4,879,207	$11,520,330	$ = 49.97 MT + 236,611
Annual O&M	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$ = 1,400
Closure	$63,933	$294,306	$572,270	$848,200	$1,396,999	$2,711,760	$6,708,831	$ = 29.41 MT + 42,114
Post-Closure	$1,624	$1,669	$1,724	$1,778	$1,886	$2,154	$2,951	$ = 5.88x10^{-3} MT + 1,618
Compliance CKD Low - Pile								
Initial Capital	$274,836	$859,992	$1,513,490	$2,166,125	$3,448,027	$6,593,321	$15,556,131	$ = 67.55 MT + 307,891
Annual O&M	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$1,400	$ = 1,400
Closure	$63,933	$294,306	$572,270	$848,200	$1,396,999	$2,711,760	$6,708,831	$ = 29.41 MT + 42,114
Post-Closure	$1,864	$2,895	$4,111	$5,318	$7,718	$13,684	$31,486	$ = 0.131 MT + 1,742

	1,000 tpy 907 mtpy	**10,000 tpy 9,074 mtpy**	**20,000 tpy 18,149 mtpy**	**30,000 tpy 18,149 mtpy**	**50,000 tpy 45,372 mtpy**	**100,000 tpy 90,744 mtpy**	**250,000 tpy 226,860 mtpy**	**Cost Equation**
Compliance CKD High - Pile								
Initial Capital	$383,838	$1,254,665	$2,243,128	$3,236,669	$5,188,281	$9,791,227	$23,735,152	$ = 103.13 MT + 384,264
Annual O&M	$1,576	$1,730	$1,914	$2,103	$2,437	$3,179	$5,534	$ = 1.74×10^{-2} MT + 1,599
Closure	$119,867	$534,223	$1,033,825	$1,526,596	$2,458,681	$4,835,546	$11,689,391	$ = 51.19 MT + 111,721
Post-Closure (first 5 yrs)	$1,923	$3,143	$4,587	$6,018	$8,863	$15,929	$36,999	$ = 0.155 MT + 1,783
Post-Closure (next 5 yrs)	$1,880	$2,931	$4,163	$5,382	$7,805	$13,817	$31,727	$ = 0.132 MT + 1,775
Compliance Subtitle D - Pile								
Initial Capital	$526,979	$1,580,435	$2,800,907	$4,004,013	$6,376,458	$11,923,446	$28,699,385	$ = 124.37 MT + 554,570
Annual O&M	$3,690	$5,182	$5,971	$6,764	$8,310	$10,659	$16,410	$ = 28.76 $MT^{0.5}$ + 2,324
Closure	$169,475	$802,523	$1,546,501	$2,299,254	$3,797,472	$7,524,621	$18,315,310	$ = 80.43 MT + 115,803
Post-Closure	$4,206	$6,795	$8,788	$10,773	$14,732	$23,034	$46,291	$ = 0.183 MT + 5,452

[1] CKD Monofill costs presented in this table do not include costs for equipment (i.e., hauling trucks, bulldozers, and water trucks) or fugitive dust control equipment (i.e., compactors and pelletizers). Combination monofills (above and below ground) were not considered for compliance scenarios because it is assumed that plants will choose the less expensive pile design. Costs are in 1995 dollars.

Attachment 6. Average Landfill Tipping Fees for Contaminated Soil by State May 1995 (Dollars per metric ton)[1]

State	Tipping Fee ($/MT)
Alabama	$44.59
Alaska*	$50.01
Arizona	$34.61
Arkansas	$15.13
California	$40.93
Colorado	$11.22
Connecticut*	$77.02
Delaware*	---
Florida	$67.70
Georgia	$33.23
Hawaii*	$40.53
Idaho	$9.64
Illinois	$19.38
Indiana	$26.28
Iowa	$37.69
Kansas	$26.01
Kentucky	$24.71
Louisiana*	$49.71
Maine	---
Maryland	$65.44
Massachusetts*	$81.22
Michigan	$32.73
Minnesota*	$103.46
Mississippi	$30.48
Missouri	$27.42

State	Tipping Fee ($/MT)
Montana	$16.07
Nebraska	$34.93
Nevada	$28.07
New Hampshire*	$74.15
New Jersey*	$88.28
New Mexico	$40.06
New York	$69.37
North Carolina*	$49.09
North Dakota*	$26.98
Ohio	$28.29
Oklahoma	$12.98
Oregon	$25.79
Pennsylvania	$51.27
Rhode Island*	---
South Carolina	$38.40
South Dakota	$15.16
Tennessee	$28.15
Texas	$15.98
Utah	$22.65
Vermont*	$51.02
Virginia	$51.29
Washington	$66.19
West Virginia	$39.35
Wisconsin*	$36.56
Wyoming	$29.46

[1] Source: Contaminated Soil Facility Index from *Remediation Report*, Chartwell Information Publishers, May 1995. For tipping fees reported in cubic yards, the uncompacted CKD density (60 pcf) was used to convert the fee to dollars per metric ton. States having no clinker production or CKD generation are denoted by an asterisk (*).

Attachment 7. CKD Monofill Cost Model Unit Costs

Unit Cost Description	Unit Cost ($1995)
Operator	$39.50/hour
Manager	$45.00/hour
Clerical	$20.00/hour
Unskilled Labor	$19.00/hour
Professional Labor (Consultant)	$65.00/hour
Technician	$32.00/hour
Land	$1,000/acre
Clearing and Grubbing	$7,465/acre
Hydrogeologic Study	$12,000/acre
Temporary Road	$28.58/m
Fencing	$49.70/m
Excavation	$\$6.00/\text{m}^3$
Berm Core Trenching	$\$5.68/\text{m}^3$
Diversion Ditch	$8.69/m
Compacted CKD (for liner and final cover)	$\$4.81/\text{m}^3$
Compacted Clay On-site Off-site	$\$12.95/\text{m}^3$ $\$39.28/\text{m}^3$
Compacted Soil Topsoil Slope and earth fill	$\$25.13/\text{m}^3$ $\$8.21/\text{m}^3$
Compacted Sand	$\$17.88/\text{m}^3$
Compacted Gravel	$\$17.87/\text{m}^3$
Synthetic Membrane 30 mil HDPE 40 mil HDPE 60 mil HDPE 80 mil HDPE 100 mil HDPE	$\$5.11/\text{m}^2$ $\$5.65/\text{m}^2$ $\$6.19/\text{m}^2$ $\$7.27/\text{m}^2$ $\$8.34/\text{m}^2$
Geotextile Filter fabric Support fabric	$\$1.51/\text{m}^2$ $\$3.07/\text{m}^2$
Synthetic Drainage Net	$\$3.09/\text{m}^2$

Unit Cost Description	Unit Cost ($1995)
Installed Pipe Leachate Branch	$18.60/m^2
Leachate Header	$39.73/m^2
Cover Drainage	$12.80/m^2
Manhole	$1,060/each
Manhole Extension	$357.61/m
Groundwater Well Cluster (3 wells)	$26,269/cluster
Revegetation	$1,895/acre
Tree	$45.00/tree
Landscape Maintenance	$62/acre
Trucked Off-site Leachate Treatment	$0.05/gal
Monitoring Groundwater	$108/sample
Surface Water	$108/sample
License Fees	$10,000/year
Electricity	$0.09/KWH
Propane	$3.06/MBTU
Engineering Fee	10%
Inspection and Testing Fee	5%
Contractor Fee	15%
Spare Parts Inventory	1%
Construction and Field Expenses	5%
Contingency	10%
Quality Assurance	15%
Equipment Capital Cost Escalator (from 1986)	28%
Equipment O&M Cost Escalator (from 1986)	25%
General Escalator (from 1986)	28%
Discount Rate	7%
Debt Life	20 years
Interest Rate	7%

Attachment 8. 1995 Regional Gray Cement Prices

Region	Price ($/MT)
New York, Maine	$78.99
Eastern Pennsylvania	$59.34
Western Pennsylvania	$66.72
Illinois	$66.04
Indiana	$61.54
Michigan	$66.78
Ohio	$69.28
Iowa, Nebraska, South Dakota	$69.30
Kansas	$63.03
Missouri	$61.81
Florida, Puerto Rico	$80.54
Georgia, South Carolina	$71.81
Maryland, Virginia, West Virginia	$65.87
Alabama	$69.70
Kentucky, Mississippi, Tennessee	$66.73
Arkansas, Oklahoma	$63.27
Northern Texas	$61.93
Southern Texas	$59.78
Arizona, New Mexico	$69.32
Colorado, Wyoming	$81.19
Idaho, Montana, Nevada, Utah	$76.16
Alaska, Hawaii, Oregon, Washington	$90.12
Northern California	$68.67
Southern California	$55.78
National Average	**$66.89**

Source: Tables 11 and 13 of the 1995 USGS Minerals Yearbook, Cement Chapter.

Attachment 9. 1995 Regional Clinker Capacity Utilization

Region	Percent Capacity Utilized
New York, Maine	100.4
Eastern Pennsylvania	95.2
Western Pennsylvania	88.1
Illinois	93.5
Indiana	85.3
Michigan	93.0
Ohio	82.4
Iowa, Nebraska, South Dakota	84.3
Kansas	91.5
Missouri	95.7
Florida	93.1
Georgia, South Carolina	87.3
Maryland, Virginia, West Virginia	83.1
Alabama	82.5
Kentucky, Mississippi, Tennessee	97.0
Arkansas, Oklahoma	95.8
Northern Texas	94.5
Southern Texas	97.9
Arizona, New Mexico	87.1
Colorado, Wyoming	92.6
Idaho, Montana, Nevada, Utah	103.7
Alaska, Hawaii, Oregon, Washington	116.6
Northern California	98.6
Southern California	93.4
Puerto Rico	80.5
National Average (excluding Puerto Rico)	**92.4**

Source: Table 4 of the 1995 USGS Minerals Yearbook, Cement Chapter.

Attachment 10. Baseline CKD Land Management Costs for U.S. Portland Cement Plants[1]

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
1	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
2	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
3	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
4	No	Yes	Med Q	Sub D	22,788	22,788	$0.333	$14.60	$0.50	<1%
5	No	No	Med Q	CKD Low	100,380	93,167	$1.387	$14.89	$1.50	2%
6	No	No	***Med Q***	CKD High	12,558	12,558	$0.278	$22.16	$0.50	<1%
7	No	No	Med Q	Off-Site	726	726	$0.071	$97.37	$0.00	<1%
8	No	Yes	Low Q	Sub D	62,880	62,880	$0.767	$12.20	$2.00	2%
9	No	No	Med P	CKD Low	37,199	37,199	$0.671	$18.04	$1.50	2%
10	No	No	Low Q	Sub D	33,593	33,593	$0.420	$12.50	$0.50	1%
11	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
12	No	No	Med Q	Sub D	61,634	61,634	$0.844	$13.69	$1.50	1%
13	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
14	No	No	Low P	Sub D	15,248	13,562	$0.183	$13.52	$0.00	<1%
15	No	No	***Med Q***	Off-Site	11,656	4,507	$0.095	$21.18	$0.00	<1%
16	No	No	Low P	Sub D	23,503	23,503	$0.374	$15.89	$0.50	<1%
17	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
18	No	No	No Waste	No Waste	761	0	$0.000	$0.00	$0.00	0%
19	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
20	Yes	No	No Waste	No Waste	5,800	0	$0.000	$0.00	$0.00	0%
21	No	No	Low Q	Sub D	73,508	66,259	$0.830	$12.52	$2.00	2%
22	No	No	Med P	Sub D	28,116	28,116	$0.506	$17.99	$2.00	2%
23	No	No	No Waste	No Waste	4,335	0	$0.000	$0.00	$0.00	0%
24	No	No	No Waste	No Waste	30,454	0	$0.000	$0.00	$0.00	0%
25	No	No	High P	Sub D	113,585	93,114	$2.200	$23.62	$4.00	5%
26	No	No	Med CF	Sub D	97,249	97,068	$1.947	$20.06	$3.00	4%
27	Yes	No	Low CF	CKD High	22,697	16,221	$0.449	$27.69	$0.50	<1%
28	No	Yes	Med CF	Sub D	7,320	4,295	$0.125	$29.03	$0.50	<1%
29	No	No	Med Q	Sub D	8,444	7,511	$0.106	$14.07	$0.00	<1%
30	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
31	No	Yes	High Q	CKD High	99,790	99,790	$1.670	$16.74	$4.00	6%
32	No	No	***Med Q***	Sub D	34,721	33,779	$0.485	$14.35	$1.50	2%
33	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
34	No	Yes	High Q	Sub D	110,859	110,859	$1.735	$15.65	$1.50	2%
35	No	No	***Med Q***	Sub D	99,527	90,483	$1.174	$12.98	$1.50	2%
36	No	Yes	High Q	Sub D	295,777	294,052	$4.547	$15.46	$4.50	7%
37	Yes	No	High P	Sub D	57,046	53,580	$1.139	$21.25	$1.50	2%
38	No	Yes	Low P	Sub D	50,402	31,356	$0.447	$14.26	$1.00	1%
39	No	No	Low P	Off-Site	37,427	435	$0.121	$277.43	$0.00	<1%
40	No	No	High P	Sub D	63,179	63,179	$1.404	$22.23	$1.50	2%
41	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
42	Yes	No	No Waste	No Waste	11,797	0	$0.000	$0.00	$0.00	0%
43	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
44	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
45	Yes	Yes	High Q	Sub D	33,010	33,010	$0.603	$18.25	$1.00	1%
46	No	Yes	Med Q	Sub D	306,010	277,095	$3.452	$12.46	$3.50	5%
47	No	No	Med P	Sub D	32,973	31,920	$0.566	$17.74	$1.00	1%
48	No	No	High Q	Sub D	24,857	22,680	$0.439	$19.34	$0.50	1%
49	No	Yes	No Waste	No Waste	22,680	0	$0.000	$0.00	$0.00	0%
50	Yes	No	Med P	Off-Site	3,630	3,630	$0.177	$48.81	$1.00	1%
51	No	No	Med Q	Sub D	56,168	30,088	$0.430	$14.28	$0.50	<1%
52	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
53	No	No	No Waste	No Waste	30,223	0	$0.000	$0.00	$0.00	0%
54	No	Yes	Low Q	Sub D	38,680	38,246	$0.428	$11.19	$0.50	<1%
55	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
56	No	Yes	Med P	Sub D	52,585	52,585	$0.810	$15.40	$1.00	1%
57	No	No	Med Q	Off-Site	25,075	23,775	$0.419	$17.63	$1.00	1%
58	No	No	No Waste	No Waste	25,418	0	$0.000	$0.00	$0.00	0%
59	No	No	Low CF	Sub D	65,670	6,152	$0.150	$24.35	$0.50	<1%
60	No	No	No Waste	Off-Site	454	454	$0.000	$0.00	$0.00	0%
61	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
62	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
63	No	No	Med P	Off-Site	1,222	1,222	$0.036	$29.42	$0.00	<1%
64	No	No	Low Q	Sub D	52,243	52,243	$0.747	$14.30	$1.50	2%

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
65	No	Yes	Med Q	Off-Site	19,051	19,051	$0.272	$14.26	$0.50	<1%
66	No	No	Med P	Off-Site	907	907	$0.117	$129.32	$0.50	<1%
67	No	No	Low CF	Off-Site	2,058	2,058	$0.070	$34.23	$1.00	<1%
68	No	No	Low Q	Sub D	73,434	70,927	$0.838	$11.81	$1.00	1%
69	No	Yes	High Q	Sub D	37,739	37,739	$0.705	$18.67	$2.00	3%
70	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
71	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
72	No	No	***Med Q***	Sub D	28,759	28,045	$0.437	$15.58	$1.50	1%
73	Yes	No	No Waste	No Waste	13,162	0	$0.000	$0.00	$0.00	0%
74	No	No	No Waste	No Waste	2,449	0	$0.000	$0.00	$0.00	0%
75	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
76	No	No	***Med Q***	Off-Site	116	116	$0.002	$16.22	$0.00	<1%
77	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
78	No	No	Low P	Sub D	17,831	9,770	$0.147	$15.01	$0.50	<1%
79	No	No	Low P	Off-Site	36,550	18,275	$0.300	$16.39	$1.00	1%
80	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
81	No	No	Low P	CKD Low	71,577	71,577	$0.965	$13.49	$1.50	2%
82	No	No	Med Q	Sub D	52,472	45,075	$0.676	$15.00	$2.00	2%
83	No	No	Med Q	Off-Site	2,632	2,632	$0.038	$14.51	$0.00	<1%
84	No	No	***Med Q***	CKD Low	5,604	5,604	$0.195	$34.77	$2.00	1%
85	No	No	Low Q	Sub D	10,526	9,986	$0.113	$11.35	$0.50	<1%
86	No	Yes	High Q	CKD High	35,568	35,568	$0.661	$18.57	$2.00	3%
87	Yes	No	Low CF	Off-Site	1,500	1,500	$0.148	$98.66	$0.50	<1%
88	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
89	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
90	No	No	Low P	Off-Site	227	227	$0.017	$76.36	$0.00	<1%
91	No	No	Med P	Sub D	36,280	20,861	$0.434	$20.80	$0.50	<1%
92	No	No	No Waste	No Waste	40,823	0	$0.000	$0.00	$0.00	0%
93	No	No	Med P	Off-Site	91	91	$0.017	$188.38	$0.00	<1%
94	No	Yes	Med Q	CKD Low	199,208	199,208	$2.543	$12.76	$1.50	1%
95	No	No	High Q	Sub D	97,609	84,683	$1.397	$16.50	$3.50	4%
96	No	No	High CF	Sub D	91,766	82,036	$1.987	$24.22	$2.50	3%
97	No	No	Low CF	Sub D	46,560	44,274	$0.883	$19.94	$1.00	1%
98	No	No	No Waste	No Waste	29,537	0	$0.000	$0.00	$0.00	0%

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
99	No	No	Med CF	CKD High	176,286	124,305	$2.562	$20.61	$5.00	7%
100	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
101	No	No	***Med Q***	Sub D	10,336	7,178	$0.107	$14.94	$0.00	<1%
102	No	Yes	Low P	Sub D	153,393	99,790	$1.233	$12.36	$2.00	2%
103	No	No	High CF	Sub D	149,240	91,288	$2.525	$27.66	$1.50	2%
104	No	No	Low CF	Off-Site	8,163	8,163	$0.285	$34.93	$0.50	<1%
105	No	No	***Med Q***	Off-Site	907	907	$0.083	$91.00	$0.00	<1%
106	No	No	***Med Q***	CKD Low	7,766	4,331	$0.114	$26.30	$0.00	<1%
107	No	Yes	***Med Q***	Sub D	118,996	88,361	$1.283	$14.53	$2.50	4%
108	No	No	High Q	Sub D	3,030	3,030	$0.107	$35.46	$0.50	<1%
109	No	No	***Med Q***	CKD Low	35,093	34,088	$0.537	$15.74	$1.00	1%
110	No	No	***Med Q***	Sub D	61,291	35,689	$0.494	$13.83	$1.00	1%
Total	**8**	**18**			**4,084,394**	**3,316,654**	**$54.854**			

[1] Baseline costs are in 1995 dollars and are presented as annualized present values on a before-tax basis, assuming a 7 percent discount rate, with regional adjustments. Monofill costs (excluding equipment costs) for seven plant sizes were developed with the CKD Monofill Cost Model. A curve-fit equation developed from these costs was applied to each plant. Equipment costs are based on the quantity of CKD managed and are calculated for each plant. For reporting plants, clinker production quantities (not presented) are 1995 values as reported in the 1996 Portland Cement Association (PCA) survey. Clinker production quantities for non-reporting plants are estimated by EPA based on 1995 clinker capacity and regional utilization factors reported in the 1995 *USGS Minerals Yearbook*. Plant revenue (not presented) is based on white cement or regional gray cement prices presented in the 1995 *USGS Minerals Yearbook* and reported or estimated clinker production in 1995. Net and wasted CKD quantities for reporting plants are 1995 quantities from the 1995 CKD Survey. Quantities from the 1991 CKD Survey were assumed for non-reporting plants. Two plants did not report quantities in either survey. Quantities for these two plants are based on average net CKD to clinker production ratios by kiln type, which were calculated from reporting plants. For plants disposing CKD on site, baseline CKD management for most plants is based on data from the 1990 Portland Cement Association Survey. The most common baseline CKD management type of “Med Q” is assumed as a default for non-reporting plants (in bold italics). A baseline management of “No Waste” is assigned to plants that do not generate net CKD or all CKD is beneficially used off site. Baseline CKD management monofill designs of “Low”, “Med”, and “High” were developed to represent management with no compaction, some compaction, and pelletization and compaction, respectively. Monofill types of “Q”, “P”, and “CF” represent quarries, piles, and combination fills, respectively. The predicted CKD compliance management practice for each plant is based on data presented in *Mapping Cement Facilities to Ground Water Controls* by SAIC dated 6/27/97. Off-site Subtitle D management of CKD was assumed when estimated to be less expensive than on-site management.

Attachment 11. Total CKD Compliance Management Costs for U.S. Portland Cement Plants[1]

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
1	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
2	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
3	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
4	No	Yes	Med Q	Sub D	22,788	22,788	$0.797	$34.96	$1.50	2%
5	No	No	Med Q	CKD Low	100,380	93,167	$2.370	$25.44	$2.50	4%
6	No	No	***Med Q***	CKD High	12,558	12,558	$0.563	$44.83	$1.00	1%
7	No	No	Med Q	Off-Site	726	726	$0.035	$48.79	$0.00	<1%
8	No	Yes	Low Q	Sub D	62,880	62,880	$1.878	$29.87	$5.00	7%
9	No	No	Med P	CKD Low	37,199	37,199	$1.010	$27.14	$2.50	4%
10	No	No	Low Q	Sub D	33,593	33,593	$1.054	$31.37	$1.50	2%
11	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
12	No	No	Med Q	Sub D	61,634	61,634	$1.780	$28.88	$2.50	3%
13	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
14	No	No	Low P	Sub D	15,248	13,562	$0.506	$37.32	$0.50	<1%
15	No	No	***Med Q***	Off-Site	11,656	4,507	$0.220	$48.79	$0.50	<1%
16	No	No	Low P	Sub D	23,503	23,503	$0.786	$33.45	$1.00	1%
17	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
18	No	No	No Waste	No Waste	761	0	$0.000	$0.00	$0.00	0%
19	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
20	Yes	No	No Waste	No Waste	5,800	0	$0.000	$0.00	$0.00	0%
21	No	No	Low Q	Sub D	73,508	66,259	$2.076	$31.33	$5.50	6%
22	No	No	Med P	Sub D	28,116	28,116	$0.971	$34.53	$3.50	4%
23	No	No	No Waste	No Waste	4,335	0	$0.000	$0.00	$0.00	0%
24	No	No	No Waste	No Waste	30,454	0	$0.000	$0.00	$0.00	0%
25	No	No	High P	Sub D	113,585	93,114	$2.958	$31.77	$5.50	6%
26	No	No	Med CF	Sub D	97,249	97,068	$2.685	$27.66	$4.00	6%
27	Yes	No	Low CF	CKD High	22,697	16,221	$0.652	$40.22	$1.00	1%
28	No	Yes	Med CF	Sub D	7,320	4,295	$0.243	$56.56	$1.00	1%
29	No	No	Med Q	Sub D	8,444	7,511	$0.318	$42.31	$0.50	<1%
30	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
31	No	Yes	High Q	CKD High	99,790	99,790	$2.636	$26.42	$6.00	9%
32	No	No	***Med Q***	Sub D	34,721	33,779	$1.061	$31.40	$3.50	5%
33	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
34	No	Yes	High Q	Sub D	110,859	110,859	$3.022	$27.26	$3.00	4%
35	No	No	***Med Q***	Sub D	99,527	90,483	$2.531	$27.98	$3.50	5%
36	No	Yes	High Q	Sub D	295,777	294,052	$8.028	$27.30	$7.50	12%
37	Yes	No	High P	Sub D	57,046	53,580	$1.550	$28.92	$2.50	3%
38	No	Yes	Low P	Sub D	50,402	31,356	$1.003	$31.98	$2.50	3%
39	No	No	Low P	Off-Site	37,427	435	$0.026	$60.23	$0.00	<1%
40	No	No	High P	Sub D	63,179	63,179	$1.932	$30.58	$2.00	2%
41	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
42	Yes	No	No Waste	No Waste	11,797	0	$0.000	$0.00	$0.00	0%
43	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
44	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
45	Yes	Yes	High Q	Sub D	33,010	33,010	$1.050	$31.81	$2.00	3%
46	No	Yes	Med Q	Sub D	306,010	277,095	$7.057	$25.47	$7.50	10%
47	No	No	Med P	Sub D	32,973	31,920	$1.076	$33.72	$1.50	2%
48	No	No	High Q	Sub D	24,857	22,680	$0.740	$32.64	$1.00	1%
49	No	Yes	No Waste	No Waste	22,680	0	$0.000	$0.00	$0.00	0%
50	Yes	No	Med P	Off-Site	3,630	3,630	$0.221	$60.88	$1.00	1%
51	No	No	Med Q	Sub D	56,168	30,088	$0.987	$32.82	$1.50	2%
52	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
53	No	No	No Waste	No Waste	30,223	0	$0.000	$0.00	$0.00	0%
54	No	Yes	Low Q	Sub D	38,680	38,246	$1.132	$29.60	$1.50	2%
55	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
56	No	Yes	Med P	Sub D	52,585	52,585	$1.467	$27.90	$2.00	2%
57	No	No	Med Q	Off-Site	25,075	23,775	$1.241	$52.19	$3.00	4%
58	No	No	No Waste	No Waste	25,418	0	$0.000	$0.00	$0.00	0%
59	No	No	Low CF	Sub D	65,670	6,152	$0.301	$48.91	$1.00	1%
60	No	No	No Waste	Off-Site	454	454	$0.033	$73.74	$0.00	<1%
61	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
62	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
63	No	No	Med P	Off-Site	1,222	1,222	$0.052	$42.45	$0.50	<1%
64	No	No	Low Q	Sub D	52,243	52,243	$1.839	$35.20	$4.00	6%

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
65	No	Yes	Med Q	Off-Site	19,051	19,051	$1.147	$60.23	$1.00	1%
66	No	No	Med P	Off-Site	907	907	$0.091	$100.51	$0.00	<1%
67	No	No	Low CF	Off-Site	2,058	2,058	$0.100	$48.79	$1.50	<1%
68	No	No	Low Q	Sub D	73,434	70,927	$2.159	$30.44	$3.00	3%
69	No	Yes	High Q	Sub D	37,739	37,739	$1.208	$32.01	$3.00	5%
70	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
71	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
72	No	No	***Med Q***	Sub D	28,759	28,045	$0.967	$34.49	$3.00	3%
73	Yes	No	No Waste	No Waste	13,162	0	$0.000	$0.00	$0.00	0%
74	No	No	No Waste	No Waste	2,449	0	$0.000	$0.00	$0.00	0%
75	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
76	No	No	***Med Q***	Off-Site	116	116	$0.012	$100.51	$0.00	<1%
77	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
78	No	No	Low P	Sub D	17,831	9,770	$0.387	$39.64	$1.00	1%
79	No	No	Low P	Off-Site	36,550	18,275	$1.536	$84.08	$5.00	8%
80	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
81	No	No	Low P	CKD Low	71,577	71,577	$1.568	$21.90	$2.50	3%
82	No	No	Med Q	Sub D	52,472	45,075	$1.535	$34.05	$4.00	5%
83	No	No	Med Q	Off-Site	2,632	2,632	$0.137	$52.19	$0.50	<1%
84	No	No	***Med Q***	CKD Low	5,604	5,604	$0.333	$59.47	$3.50	2%
85	No	No	Low Q	Sub D	10,526	9,986	$0.380	$38.08	$1.00	1%
86	No	Yes	High Q	CKD High	35,568	35,568	$1.027	$28.89	$3.00	4%
87	Yes	No	Low CF	Off-Site	1,500	1,500	$0.088	$58.82	$0.00	<1%
88	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
89	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
90	No	No	Low P	Off-Site	227	227	$0.023	$102.18	$0.00	<1%
91	No	No	Med P	Sub D	36,280	20,861	$0.810	$38.84	$1.00	1%
92	No	No	No Waste	No Waste	40,823	0	$0.000	$0.00	$0.00	0%
93	No	No	Med P	Off-Site	91	91	$0.007	$73.74	$0.00	<1%
94	No	Yes	Med Q	CKD Low	199,208	199,208	$4.052	$20.34	$2.00	3%
95	No	No	High Q	Sub D	97,609	84,683	$2.656	$31.36	$7.00	8%
96	No	No	High CF	Sub D	91,766	82,036	$2.264	$27.60	$3.00	4%
97	No	No	Low CF	Sub D	46,560	44,274	$1.307	$29.52	$1.00	1%
98	No	No	No Waste	No Waste	29,537	0	$0.000	$0.00	$0.00	0%

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
99	No	No	Med CF	CKD High	176,286	124,305	$3.120	$25.10	$6.00	9%
100	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
101	No	No	***Med Q***	Sub D	10,336	7,178	$0.317	$44.12	$0.50	<1%
102	No	Yes	Low P	Sub D	153,393	99,790	$2.678	$26.84	$4.50	6%
103	No	No	High CF	Sub D	149,240	91,288	$2.878	$31.52	$2.00	2%
104	No	No	Low CF	Off-Site	8,163	8,163	$0.426	$52.19	$0.50	<1%
105	No	No	***Med Q***	Off-Site	907	907	$0.076	$84.08	$0.00	<1%
106	No	No	***Med Q***	CKD Low	7,766	4,331	$0.240	$55.31	$0.50	<1%
107	No	Yes	***Med Q***	Sub D	118,996	88,361	$2.885	$32.65	$5.50	9%
108	No	No	High Q	Sub D	3,030	3,030	$0.204	$67.49	$0.50	<1%
109	No	No	***Med Q***	CKD Low	35,093	34,088	$0.943	$27.67	$1.50	2%
110	No	No	***Med Q***	Sub D	61,291	35,689	$1.087	$30.47	$2.00	3%
Total	**8**	**18**			**4,084,394**	**3,316,654**	**$98.539**			

[1] Compliance costs are in 1995 dollars and are presented as annualized present values on a before-tax basis, assuming a 7 percent discount rate, with regional adjustments. Monofill costs (excluding equipment costs) for seven plant sizes were developed with the CKD Monofill Cost Model. A curve-fit equation developed from these costs was applied to each plant. Equipment costs are based on the quantity of CKD managed and are calculated for each plant. For reporting plants, clinker production quantities (not presented) are 1995 values as reported in the 1996 Portland Cement Association (PCA) survey. Clinker production quantities for non-reporting plants are estimated by EPA based on 1995 clinker capacity and regional utilization factors reported in the 1995 *USGS Minerals Yearbook*. Plant revenue (not presented) is based on white cement or regional gray cement prices presented in the 1995 *USGS Minerals Yearbook* and reported or estimated clinker production in 1995. Net and wasted CKD quantities for reporting plants are 1995 quantities from the 1995 CKD Survey. Quantities from the 1991 CKD Survey were assumed for non-reporting plants. Two plants did not report quantities in either survey. Quantities for these two plants are based on average net CKD to clinker production ratios by kiln type, which were calculated from reporting plants. For plants disposing CKD on site, baseline CKD management for most plants is based on data from the 1990 Portland Cement Association Survey. The most common baseline CKD management type of “Med Q” is assumed as a default for non-reporting plants (in bold italics). A baseline management of “No Waste” is assigned to plants that do not generate net CKD or all CKD is beneficially used off site. Baseline CKD management monofill designs of “Low”, “Med”, and “High” were developed to represent management with no compaction, some compaction, and pelletization and compaction, respectively. Monofill types of “Q”, “P”, and “CF” represent quarries, piles, and combination fills, respectively. The predicted CKD compliance management practice for each plant is based on data presented in *Mapping Cement Facilities to Ground Water Controls* by SAIC dated 6/27/97. Off-site Subtitle D management of CKD was assumed when estimated to be less expensive than on-site management.

Attachment 12. Incremental CKD Compliance Management Costs for U.S. Portland Cement Plants[1]

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
1	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
2	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
3	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
4	No	Yes	Med Q	Sub D	22,788	22,788	$0.464	$20.36	$1.00	1%
5	No	No	Med Q	CKD Low	100,380	93,167	$0.983	$10.55	$1.00	1%
6	No	No	***Med Q***	CKD High	12,558	12,558	$0.285	$22.67	$0.50	<1%
7	No	No	Med Q	Off-Site	726	726	($0.035)	($48.59)	($0.00)	<0%
8	No	Yes	Low Q	Sub D	62,880	62,880	$1.111	$17.67	$3.00	4%
9	No	No	Med P	CKD Low	37,199	37,199	$0.339	$9.11	$1.00	1%
10	No	No	Low Q	Sub D	33,593	33,593	$0.634	$18.87	$1.00	1%
11	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
12	No	No	Med Q	Sub D	61,634	61,634	$0.937	$15.20	$1.50	2%
13	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
14	No	No	Low P	Sub D	15,248	13,562	$0.323	$23.80	$0.50	<1%
15	No	No	***Med Q***	Off-Site	11,656	4,507	$0.124	$27.61	$0.00	<1%
16	No	No	Low P	Sub D	23,503	23,503	$0.413	$17.56	$0.50	<1%
17	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
18	No	No	No Waste	No Waste	761	0	$0.000	$0.00	$0.00	0%
19	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
20	Yes	No	No Waste	No Waste	5,800	0	$0.000	$0.00	$0.00	0%
21	No	No	Low Q	Sub D	73,508	66,259	$1.246	$18.81	$3.50	4%
22	No	No	Med P	Sub D	28,116	28,116	$0.465	$16.55	$1.50	2%
23	No	No	No Waste	No Waste	4,335	0	$0.000	$0.00	$0.00	0%
24	No	No	No Waste	No Waste	30,454	0	$0.000	$0.00	$0.00	0%
25	No	No	High P	Sub D	113,585	93,114	$0.758	$8.14	$1.50	1%
26	No	No	Med CF	Sub D	97,249	97,068	$0.738	$7.60	$1.00	1%
27	Yes	No	Low CF	CKD High	22,697	16,221	$0.203	$12.52	$0.50	<1%
28	No	Yes	Med CF	Sub D	7,320	4,295	$0.118	$27.53	$0.50	<1%
29	No	No	Med Q	Sub D	8,444	7,511	$0.212	$28.24	$0.50	<1%
30	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
31	No	Yes	High Q	CKD High	99,790	99,790	$0.966	$9.68	$2.00	4%
32	No	No	***Med Q***	Sub D	34,721	33,779	$0.576	$17.05	$2.00	3%
33	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
34	No	Yes	High Q	Sub D	110,859	110,859	$1.287	$11.61	$1.00	1%
35	No	No	***Med Q***	Sub D	99,527	90,483	$1.357	$15.00	$2.00	2%
36	No	Yes	High Q	Sub D	295,777	294,052	$3.480	$11.84	$3.50	5%
37	Yes	No	High P	Sub D	57,046	53,580	$0.411	$7.67	$0.50	<1%
38	No	Yes	Low P	Sub D	50,402	31,356	$0.556	$17.72	$1.50	2%
39	No	No	Low P	Off-Site	37,427	435	($0.094)	($217.20)	($0.00)	<0%
40	No	No	High P	Sub D	63,179	63,179	$0.528	$8.36	$0.50	<1%
41	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
42	Yes	No	No Waste	No Waste	11,797	0	$0.000	$0.00	$0.00	0%
43	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
44	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
45	Yes	Yes	High Q	Sub D	33,010	33,010	$0.447	$13.55	$1.00	1%
46	No	Yes	Med Q	Sub D	306,010	277,095	$3.605	$13.01	$4.00	5%
47	No	No	Med P	Sub D	32,973	31,920	$0.510	$15.99	$1.00	1%
48	No	No	High Q	Sub D	24,857	22,680	$0.301	$13.29	$0.50	<1%
49	No	Yes	No Waste	No Waste	22,680	0	$0.000	$0.00	$0.00	0%
50	Yes	No	Med P	Off-Site	3,630	3,630	$0.044	$12.07	$0.00	<1%
51	No	No	Med Q	Sub D	56,168	30,088	$0.558	$18.53	$1.00	1%
52	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
53	No	No	No Waste	No Waste	30,223	0	$0.000	$0.00	$0.00	0%
54	No	Yes	Low Q	Sub D	38,680	38,246	$0.704	$18.41	$1.00	1%
55	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
56	No	Yes	Med P	Sub D	52,585	52,585	$0.657	$12.49	$1.00	1%
57	No	No	Med Q	Off-Site	25,075	23,775	$0.822	$34.56	$2.00	2%
58	No	No	No Waste	No Waste	25,418	0	$0.000	$0.00	$0.00	0%
59	No	No	Low CF	Sub D	65,670	6,152	$0.151	$24.57	$0.50	<1%
60	No	No	No Waste	Off-Site	454	454	$0.033	$73.74	$0.00	<1%
61	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
62	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
63	No	No	Med P	Off-Site	1,222	1,222	$0.016	$13.03	$0.00	<1%
64	No	No	Low Q	Sub D	52,243	52,243	$1.092	$20.90	$2.50	3%

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
65	No	Yes	Med Q	Sub D	19,051	19,051	$0.876	$45.97	$1.00	<1%
66	No	No	Med P	Off-Site	907	907	($0.026)	($28.82)	($0.00)	<0%
67	No	No	Low CF	Off-Site	2,058	2,058	$0.030	$14.56	$0.50	<1%
68	No	No	Low Q	Sub D	73,434	70,927	$1.321	$18.63	$2.00	2%
69	No	Yes	High Q	Sub D	37,739	37,739	$0.503	$13.34	$1.50	2%
70	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
71	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
72	No	No	***Med Q***	Sub D	28,759	28,045	$0.530	$18.90	$1.50	2%
73	Yes	No	No Waste	No Waste	13,162	0	$0.000	$0.00	$0.00	0%
74	No	No	No Waste	No Waste	2,449	0	$0.000	$0.00	$0.00	0%
75	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
76	No	No	***Med Q***	Off-Site	116	116	$0.010	$84.29	$0.00	<1%
77	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
78	No	No	Low P	Sub D	17,831	9,770	$0.241	$24.63	$0.50	<1%
79	No	No	Low P	Off-Site	36,550	18,275	$1.237	$67.68	$4.00	6%
80	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
81	No	No	Low P	CKD Low	71,577	71,577	$0.602	$8.41	$1.00	1%
82	No	No	Med Q	Sub D	52,472	45,075	$0.859	$19.05	$2.50	2%
83	No	No	Med Q	Off-Site	2,632	2,632	$0.099	$37.68	$0.00	<1%
84	No	No	***Med Q***	CKD Low	5,604	5,604	$0.138	$24.70	$1.50	<1%
85	No	No	Low Q	Sub D	10,526	9,986	$0.267	$26.73	$0.50	<1%
86	No	Yes	High Q	CKD High	35,568	35,568	$0.367	$10.32	$1.00	1%
87	Yes	No	Low CF	Off-Site	1,500	1,500	($0.060)	($39.84)	($0.00)	<0%
88	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
89	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
90	No	No	Low P	Off-Site	227	227	$0.006	$25.82	$0.00	<1%
91	No	No	Med P	Sub D	36,280	20,861	$0.376	$18.04	$0.50	<1%
92	No	No	No Waste	No Waste	40,823	0	$0.000	$0.00	$0.00	0%
93	No	No	Med P	Off-Site	91	91	($0.010)	($114.65)	($0.00)	<0%
94	No	Yes	Med Q	CKD Low	199,208	199,208	$1.509	$7.58	$1.00	1%
95	No	No	High Q	Sub D	97,609	84,683	$1.259	$14.86	$3.50	4%
96	No	No	High CF	Sub D	91,766	82,036	$0.277	$3.38	$0.50	<1%
97	No	No	Low CF	Sub D	46,560	44,274	$0.424	$9.58	$0.50	<1%
98	No	No	No Waste	No Waste	29,537	0	$0.000	$0.00	$0.00	0%

Plant	Small Company	Burns Hazardous Waste	Baseline CKD Management	Predicted Compliance CKD Management	1995 Net CKD (MT)	1995 CKD Wasted (MT)	$Million/ Year	$/MT CKD Wasted	$/MT Cement	Cost/ Revenue
99	No	No	Med CF	CKD High	176,286	124,305	$0.558	$4.49	$1.00	1%
100	No	No	No Waste	No Waste	0	0	$0.000	$0.00	$0.00	0%
101	No	No	***Med Q***	Sub D	10,336	7,178	$0.209	$29.17	$0.50	<1%
102	No	Yes	Low P	Sub D	153,393	99,790	$1.445	$14.48	$2.50	3%
103	No	No	High CF	Sub D	149,240	91,288	$0.353	$3.86	$0.00	<1%
104	No	No	Low CF	Off-Site	8,163	8,163	$0.141	$17.27	$0.00	<1%
105	No	No	***Med Q***	Off-Site	907	907	($0.006)	($6.92)	($0.00)	<0%
106	No	No	***Med Q***	CKD Low	7,766	4,331	$0.126	$29.01	$0.00	<1%
107	No	Yes	***Med Q***	Sub D	118,996	88,361	$1.601	$18.12	$3.00	5%
108	No	No	High Q	Sub D	3,030	3,030	$0.097	$32.02	$0.00	<1%
109	No	No	***Med Q***	CKD Low	35,093	34,088	$0.407	$11.94	$0.50	1%
110	No	No	***Med Q***	Sub D	61,291	35,689	$0.594	$16.63	$1.00	1%
Total	**8**	**18**			**4,084,394**	**3,316,654**	**$43.685**			

[1] Incremental compliance costs are in 1995 dollars and are presented as annualized present values on a before-tax basis, assuming a 7 percent discount rate, with regional adjustments. Monofill costs (excluding equipment costs) for seven plant sizes were developed with the CKD Monofill Cost Model. A curve-fit equation developed from these costs was applied to each plant. Equipment costs are based on the quantity of CKD managed and are calculated for each plant. For reporting plants, clinker production quantities (not presented) are 1995 values as reported in the 1996 Portland Cement Association (PCA) survey. Clinker production quantities for non-reporting plants are estimated by EPA based on 1995 clinker capacity and regional utilization factors reported in the 1995 *USGS Minerals Yearbook*. Plant revenue (not presented) is based on white cement or regional gray cement prices presented in the 1995 *USGS Minerals Yearbook* and reported or estimated clinker production in 1995. Net and wasted CKD quantities for reporting plants are 1995 quantities from the 1995 CKD Survey. Quantities from the 1991 CKD Survey were assumed for non-reporting plants. Two plants did not report quantities in either survey. Quantities for these two plants are based on average net CKD to clinker production ratios by kiln type, which were calculated from reporting plants. For plants disposing CKD on site, baseline CKD management for most plants is based on data from the 1990 Portland Cement Association Survey. The most common baseline CKD management type of “Med Q” is assumed as a default for non-reporting plants (in bold italics). A baseline management of “No Waste” is assigned to plants that do not generate net CKD or all CKD is beneficially used off site. Baseline CKD management monofill designs of “Low”, “Med”, and “High” were developed to represent management with no compaction, some compaction, and pelletization and compaction, respectively. Monofill types of “Q”, “P”, and “CF” represent quarries, piles, and combination fills, respectively. The predicted CKD compliance management practice for each plant is based on data presented in *Mapping Cement Facilities to Ground Water Controls* by SAIC dated 6/27/97. Off-site Subtitle D management of CKD was assumed when estimated to be less expensive than on-site management.

APPENDIX A

EQUIPMENT ASSUMPTIONS FOR THE CKD MONOFILL COST MODEL INCLUDING FUGITIVE DUST CONTROL TECHNOLOGIES

Hauling with Dump Trucks

CKD is transported to the waste management area by dump trucks for the baseline and the compliance scenarios. A model assumption is that Portland Cement plants currently use dump trucks to haul raw materials from a quarry to the plant for processing. It is reasonable to assume that the same dump trucks will be used for hauling raw materials and CKD. Therefore, only a percentage of dump truck capital and operational costs are assumed to be associated with hauling CKD in the model.

CKD hauling costs are estimated for hauling bulk CKD (at 60 lb/cf) and pelletized CKD (at 77 lb/cf). A truck capacity of 10 cy with 10 percent freeboard is assumed, yielding a load capacity of 9 cy. It is assumed that truck loading and unloading will require a total of 30 minutes, and trucks will travel a round-trip distance of 3 miles at 20 miles per hour. Therefore, 0.65 hour is required for each load. Assuming operations occur for 8 hours per day and 300 days per year, the maximum number of hours available per year is 2,400. The operating life of dump trucks is assumed to be 5 years. The number of dump trucks required for hauling CKD is estimated as follows:

$$\text{Bulk CKD Hauling Trucks} = \frac{(\text{MT/yr CKD})(2{,}204\ \text{lb/MT})(0.65\ \text{hr/load})}{(60\ \text{lb/cf})(27\ \text{cf/cy})(9\ \text{cy/load})(2{,}400\ \text{hr/yr})}$$

$$\text{Pelletized CKD Hauling Trucks} = \frac{(\text{MT/yr CKD})(2{,}204\ \text{lb/MT})(0.65\ \text{hr/load})}{(77\ \text{lb/cf})(27\ \text{cf/cy})(9\ \text{cy/load})(2{,}400\ \text{hr/yr})}$$

The result of these equations is the number of trucks required for hauling CKD. For example, less than one truck (i.e., 37 percent) is required for hauling 10,000 tons per year (9,074 MT/yr) of bulk CKD. Similarly, 2.89 trucks (or two dedicated trucks and 89 percent of a third truck) are required for hauling 100,000 tons per year (90,744 MT/yr) of pelletized CKD. The estimated cost per 10 cy truck in 1995 dollars is $275,000. The capital cost estimated for CKD hauling is the result of the above equations multiplied by the cost of one truck.

Annual operating costs for hauling include labor and truck maintenance. It is assumed that two laborers will be required for each haul load - one driver (at $31.50 per hour) and one additional laborer (at $19 per hour) to assist with loading and unloading. The labor costs associated with CKD hauling are estimated as follows:

$$\text{Bulk CKD Labor} = \frac{(\text{MT/yr CKD})(2{,}204\ \text{lb/MT})(0.65\ \text{hr/load})(\$31.50/\text{hr} + \$19/\text{hr})}{(60\ \text{lb/cf})(27\ \text{cf/cy})(9\ \text{cy/load})}$$

$$\text{Pelletized CKD Labor} = \frac{\text{(MT/yr CKD)(2,204 lb/MT)(0.65 hr/load)(\$31.50 + \$19/hr)}}{\text{(77 lb/cf)(27 cf/cy)(9 cy/load)}}$$

Truck maintenance costs (including fuel costs) are estimated as follows:

$$\text{Bulk CKD Maintenance} = \frac{\text{(MT/yr)(2,204 lb/MT)(3 miles/load)(\$0.50/mile)}}{\text{(60 lb/cf)(27 cf/cy)(9 cy/load)}}$$

$$\text{Pelletized CKD Maintenance} = \frac{\text{(MT/yr)(2,204 lb/MT)(3 miles/load)(\$0.50/mile)}}{\text{(77 lb/cf)(27 cf/cy)(9 cy/load)}}$$

The results of the above capital and annual cost equations are applied, as appropriate, to each plant in the analysis, according to the reported or assumed baseline CKD management methods and the predicted compliance management methods.

Management of CKD with Dozers

CKD is moved within the waste management area by dozers for the baseline and the compliance scenarios. A model assumption is that Portland Cement plants currently use dozers to move raw materials in quarries. It is reasonable to assume that the same dozers will be used for moving raw materials and CKD. Therefore, only a percentage of dozer capital and operational costs are assumed to be associated with the management of CKD in the model.

Capital and annual costs for dozers are estimated for both bulk and pelletized CKD. A model assumption is that there will be minimal difference in cost for management of bulk and pelletized CKD since the dozers will break the pellets during management. It is assumed that 300 hp dozers are currently in use in quarries for all plant sizes. Assuming operations occur for eight hours per day and 300 days per year, the maximum number of hours available per year is 2,400. The operating life of dozers is assumed to be five years. The rate at which a 300 hp dozer can move CKD is estimated to be 68 tons per hour. The number of dozers required for management of CKD is estimated as follows:

$$\text{CKD Management Dozers} = \frac{\text{(MT/yr)(1.102 ton/MT)}}{\text{(68 tons/hr)(2,400 hr/yr)}}$$

The result of this equation is the number of dozers required only for CKD management. For example, 6 percent of one dozer is required for management of 10,000 tons per year (9,074 MT/yr) of bulk or pelletized CKD. Similarly, 1.23 dozers (or one dedicated dozer and 23 percent of a second dozer) are required for hauling 200,000 tons per year (181,488 MT/yr) of bulk or pelletized CKD. The estimated cost per 300 hp dozer in 1995 dollars is $375,000. The capital cost estimated for CKD management is the result of the above equations multiplied by the cost of one dozer.

Annual operating costs for hauling include labor, fuel, and truck maintenance. The cost for these activities, which is based on equipment specifications, is estimated to be $36.48 per hour. The operating cost associated with CKD management with dozers is estimated as follows:

$$\text{Annual CKD Management} = \frac{(\text{MT/yr})(1.102\ \text{ton/MT})(\$36.48/\text{hr})}{(68\ \text{tons/hr})}$$

The results of the above capital and annual cost equations are applied to each plant in the analysis for baseline and compliance scenarios.

Compaction Equipment

CKD is compacted in the waste management area by self-propelled sheepsfoot rollers for the compliance scenarios. Compaction is required to reach the CKD density specified for conditioned placement. A model assumption is that Portland Cement plants currently do not currently use equipment of this type in quarries or CKD management areas. It is reasonable to assume that compaction equipment would only be used for CKD management. Therefore, all capital and operational costs for compaction are assumed to be associated with CKD management.

In order to attain the CKD density required for conditioned placement, a model cost assumption is that four passes are made by the roller in 6-inch lifts. With these assumptions, the roller can compact approximately 1,300 cy of CKD per day. Another model assumption is that there will be minimal difference in cost for management of bulk and pelletized CKD since the dozers will break the pellets during management.

Since compaction equipment is assumed to be used only for CKD management, purchasing equipment is not economical for all CKD management quantities. A model assumption is that plants that will utilize compaction equipment less than eight hours per week will not purchase equipment. Instead, these plants will contract the compaction work as needed. The operating life of purchased compaction equipment is assumed to be five years. The number of sheepsfoot rollers required is estimated as follows:

$$\text{Rollers} = \frac{(\text{MT/yr})(2{,}204\ \text{lb/MT})}{(60\ \text{lb/cf})(27\ \text{cf/cy})(1{,}300\ \text{cy/day})(300\ \text{days/yr})}$$

Based on the above equation, all plants that manage less than approximately 316,000 tons per year CKD will require only one sheepsfoot roller, at a cost of $75,000 in 1995 dollars. In addition, all plants that manage less than approximately 55,000 tons per year (50,000 MT/yr) CKD will contract the compaction work rather than purchase compaction equipment.

Plants that purchase compaction equipment will incur annual costs for equipment operation ($0.63/cy) and maintenance. Maintenance costs are assumed to be 5 percent of capital costs multiplied by the percent of time that the roller is used. Plants that contract compaction work will incur operational costs only, including the costs of contractor overhead and profit ($0.79/cy) and mobilization/demobilization of equipment ($300 per job) as necessary. Annual costs for compaction are estimated as follows:

$$\text{Cost if Rollers Purchased} = \frac{(\text{MT/yr})(2{,}204\ \text{lb/MT})(\$0.63/\text{cy})}{(60\ \text{lb/cf})(27\ \text{cf/cy})} + \$75{,}000*0.05*\text{Rollers}$$

$$\text{Cost if Contracted} = \frac{(\text{MT/yr})(2{,}204\ \text{lb/MT})(\$0.79/\text{cy} + \$300\ /\ 1{,}300\ \text{cy})}{(60\ \text{lb/cf})(27\ \text{cf/cy})}$$

Water Truck for Compaction

CKD is wetted in the waste management area by water trucks for the compliance scenarios. Addition of water during compaction is required to reach the CKD density specified for conditioned placement. A model assumption is that Portland Cement plants currently use water trucks to control dust on roads. It is reasonable to assume that the same water trucks will be used for the roads and the CKD management unit. Therefore, only a percentage of water truck capital and operational costs are assumed to be associated with CKD in the model.

One water truck for compaction and water spray on roads is estimated to be sufficient for all plant sizes in the model (see Water Spray on Roads for explanation). The cost of a water truck is assumed to be $101,000. A model assumption is that a percentage of the truck capital cost is associated with compaction and the remaining percentage is associated with water spray on roads. Since water trucks are assumed to be used at plants currently for water spray on roads, any capital costs for unused water truck time are included in the water spray on roads capital cost. A model assumption is that a water truck will be necessary for compaction 50 percent of the time required by the compaction equipment. The water truck operating life is assumed to be five years. The water truck time for compaction is estimated as follows:

$$\text{Water Truck Time for Compaction} = \frac{(\text{MT/yr})(2{,}204\ \text{lb/MT})(8\ \text{hr/day})(0.5)}{(60\ \text{lb/cf})(27\ \text{cf/cy})(1{,}300\ \text{cy/day})}$$

The water truck capital cost associated with compaction is estimated as follows, where 1,200 hr/yr is the time required for water spray on roads (as estimated in Water Spray on Roads):

$$\text{Water Truck Capital} = \frac{(\text{Water Truck hr/yr for Compaction}) * \$101{,}000}{(\text{Water Truck hr/yr for Compaction}) + (1{,}200\ \text{hr/yr})}$$

The operating costs for baseline water spray for compaction are estimated assuming that the truck travels approximately five miles per day, for each day used, with a fuel consumption of five miles per gallon at a fuel cost of $1.15 per gallon. The truck is assumed to operate 50 percent of the hours required for compaction (see Compaction Equipment). The daily water volume used is assumed to be 10,000 gallons, at a cost of $2 per 1,000 gallons. The baseline annual cost associated with CKD management is estimated as follows:

$$\text{Annual Cost} = \frac{\text{(MT/yr)(2,204 lb/MT)(0.5)}}{\text{(60 lb/cf)(27 cf/cy)(1,300 cy/day)}} * [\text{(8hr/day)(\$31.50/hr)} + \text{(5 mi/day)(\$1.15/gal)/(5 mi/gal)} + \text{(10,000 gal/day)(\$2/1,000 gal)}]$$

Covers on Trucks[18]

Covers are required on hauling trucks as a fugitive dust control technology for the compliance scenarios. A model assumption is that Portland Cement plants currently do not use covers on trucks. Therefore, covers are required to be purchased for the number of trucks used for CKD hauling only, as determined in the section discussing hauling with trucks.

Capital costs for this dust control technology include the cost of the roll-on tarp mechanism and the installation of this mechanism. Capital costs for covers on trucks are estimated as follows:

$$\text{Bulk CKD Cost} = \text{Round Up}\left[\frac{\text{(MT/yr)(2,204 lb/MT)(0.65 hr/load)}}{\text{(60 lb/cf)(27 cf/cy)(9 cy/load)(2,400 hr/yr)}}\right] * \text{(\$4,800)}$$

$$\text{Pelletized CKD Cost} = \text{Round Up}\left[\frac{\text{(MT/yr)(2,204 lb/MT)(0.65 hr/load)}}{\text{(77 lb/cf)(27 cf/cy)(9 cy/load)(2,400 hr/yr)}}\right] * \text{(\$4,800)}$$

Annual costs for this dust control technology include the cost of the tarps and the cost to replace the tarps. Tarps are estimated to be replaced every 150 loads. Replacement of a tarp is estimated to require 15 minutes. Annual costs for covers on trucks are estimated as follows:

$$\text{Bulk CKD Cost} = \frac{\text{(MT/yr)(2,204 lb/MT)(\$155/tarp + 0.25hr/tarp*\$19/hr)}}{\text{(60 lb/cf)(27 cf/cy)(9 cy/load)(150 load/tarp)}}$$

$$\text{Pelletized CKD Cost} = \frac{\text{(MT/yr)(2,204 lb/MT)(\$155/tarp + 0.25hr/tarp*\$19/hr)}}{\text{(77 lb/cf)(27 cf/cy)(9 cy/load)(150 load/tarp)}}$$

Pelletization[19]

Pelletization of CKD is required as a fugitive dust control technology for the compliance scenarios. A model assumption is that Portland Cement plants currently do not use pelletization, unless specified as baseline management. Pelletization costs are associated only with CKD management. Therefore, all capital costs for pelletization are included, regardless of the

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[18] The cost of tarps, tarp mechanisms, and installation of the mechanisms, as well as the life of each tarp were estimated by ICF in *Cost Functions for Alternative CKD Control Technologies (Draft)*, dated July 19, 1996.

[19] The sizes, costs, and operating life of pelletizers and conveyors were estimated by ICF in *Cost Functions for Alternative CKD Control Technologies (Draft)*, dated July 19, 1996.

percentage the equipment is actually used.

Two sizes of pelletizer units are considered in the model - five tons per hour and 40 tons per hour. Small pelletizers are assumed for plants processing up to five tons per hour of CKD. One or more large pelletizers are assumed for plants processing more than five tons per hour. Assuming operations occur for eight hours per day and 300 days per year, the maximum number of hours available per year is 2,400. The operating life of pelletizers is assumed to be 50 years. A conveyor is assumed to be necessary to transport material from the pelletizer to an intermediate storage area. The operating life of a conveyor is assumed to be five years. Capital costs for pelletization are estimated as follows:

$$\text{Capital Cost } (\text{MT/yr} \leq 11{,}000) = \$150{,}000 + \$6{,}625$$

$$\text{Capital Cost } (11{,}000 < \text{MT/yr} \leq 87{,}000) = \$500{,}000 + \$6{,}625$$

$$\text{Capital Cost } (\text{MT/yr} > 87{,}000) = \text{Round Up}\left[\frac{(\text{MT/yr})(1.102 \text{ ton/MT})}{(2{,}400 \text{ hr/yr})(40 \text{ tons/hr})}\right] * \$500{,}000 + \$8{,}550$$

Annual operating costs for pelletizers and conveyors include labor, electricity, and maintenance. Labor and electricity costs are estimated based on the actual time the equipment is operated. The combined power consumption for the small pelletizer and conveyor is estimated to be 50 HP. The combined power consumption for each large pelletizer and conveyor is assumed to be 100 HP. Maintenance costs for pelletizers are assumed to be 5 percent of the capital cost multiplied by the percentage of time the equipment is actually operated. Maintenance costs for conveyors are assumed to be 5 percent of the capital cost. Annual operating costs are estimated as follows:

$$\text{Annual Cost } (\text{MT/yr} \leq 11{,}000) = \frac{(\text{MT/yr})[(50 \text{ hp})(0.75 \text{ kwh/hp-hr})(\$0.09/\text{kwh}) + \$19/\text{hr}]}{(5 \text{ tons/hr})/(1.102 \text{ ton/MT})} + (\text{Capital Cost})(0.05)$$

$$\text{Annual Cost } (\text{MT/yr} > 11{,}000) = \frac{(\text{MT/yr})[(100 \text{ hp})(0.75 \text{ kwh/hp-hr})(\$0.09/\text{kwh}) + \$19/\text{hr}]}{(40 \text{ tons/hr})/(1.102 \text{ ton/MT})} + (\text{Capital Cost})(0.05)$$

Water Spray on Roads[20]

Water spray on roads is required as a fugitive dust control technology for the compliance scenarios. A model assumption is that Portland Cement plants currently have water trucks and use water spray on roads as a baseline management practice. Water spray on roads is used to reduce fugitive dust associated with quarry operations as well as CKD management. Therefore,

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[20] Water truck capacity, refill time, and spray width were estimated by ICF in *Cost Functions for Alternative CKD Control Technologies (Draft)*, dated July 19, 1996.

only a percentage of water spraying capital and operational costs are assumed to be associated with water spray for CKD fugitive dust control in the model.

A model assumption is that dust control is required for a road length of 1.5 miles (3 miles round-trip), with a road width of 10 meters. The water truck capacity is assumed to be 5,000 gallons and requires approximately one hour to fill. The water truck can spray a width of five meters at an assumed speed of 10 miles per hour.

For the baseline scenario, a model assumption is that the entire water volume (5,000 gallons) will be sprayed on each pass of the truck along one side of the road (i.e., 1.5 miles x 5 meters). The resulting water volume per road area, averaged over the 1.25 hours required to spray the road and refill the truck, is approximately 2.5 times that of the average hourly daytime evaporation rate. Therefore, water spray on roads will be required 3 times per day.

The water volume sprayed per road area is estimated as follows:

$$\text{Water per Area} = (1.5\ \text{mi})(5{,}280\ \text{ft/mi})(0.3048\ \text{m/ft})(10\ \text{m})(5{,}000\ \text{gal})(3.785\ \text{L/gal}) = 0.784\ \text{L/m}^2$$

The time required for the water truck to be filled, spray along both sides of the road, and return for refilling is estimated as follows:

$$\text{Time} = (1\ \text{hour}) + (3\ \text{miles})/(10\ \text{miles/hour}) = 1.3\ \text{hour}$$

Therefore, the total time for one pass is assumed to be 1 hour and 15 minutes. The average rate of water spray is estimated as follows:

$$\text{Spray Rate} = \frac{(0.784\ \text{L/m}^2)(1{,}000\ \text{ml/L})(\text{cm}^3/\text{ml})(1{,}000\ \text{mm/m})}{(100\ \text{cm/m})^3(1.25\ \text{hr})} = 0.6272\ \text{mm/hr}$$

The average hourly daytime evaporation rate is approximately 0.25 mm/hr. Therefore, the water spray rate is approximately 2.5 times the evaporation rate. Since the total time required for water spray (1.25 hour) times 2.5 is approximately 3, a model assumption is that water spray on roads is required approximately every 3 hours. In order to coordinate the water truck use for road spray and compaction for CKD conditioned placement, it is assumed that the truck alternates between these two requirements during the day. Therefore, over a nine-hour day (eight working hours plus one hour for lunch), roads are sprayed 3 times, requiring a total of approximately 4 hours.

Baseline Costs

A model assumption is that all plants currently have one water truck that is used for water spray on roads. The cost of a water truck is assumed to be $101,000, with an operating life of five years. For the baseline scenario, the water truck is used only for water spray on roads. Therefore, the capital cost of the truck is divided between the cost associated with quarry operations dust control and CKD hauling dust control. In order to estimate the capital cost division, the number of trucks hauling CKD are compared to the number of trucks hauling raw materials from the quarry. The mass of raw materials from the quarry is assumed to equal the mass of clinker produced plus the gross CKD mass (wasted + beneficially used + recycled + emitted through stacks). A raw material density of 94 lb/cf is used, which is approximately the density of quarried limestone. The number of raw material loads per year is estimated as follows:

$$\text{Raw Materials Loads} = \frac{(\text{Raw MT/yr})(2{,}204\ \text{lb/MT})}{(94\ \text{lb/cf})(27\ \text{cf/cy})(9\ \text{cy/load})}$$

$$= (\text{Raw MT/yr}) / 10.364$$

The number of CKD hauling loads is estimated as follows:

$$\text{CKD Loads} = \frac{(\text{CKD MT/yr})(2{,}204\ \text{lb/MT})}{(60\ \text{lb/cf})(27\ \text{cf/cy})(9\ \text{cy/load})}$$

$$= (\text{CKD MT/yr}) / 6.615$$

The percentage of CKD hauling is estimated as follows:

$$\%\ \text{CKD Hauling} = \frac{(\text{CKD MT/yr}) / 6.615}{[(\text{Raw MT/yr}) / 10.364] + [(\text{CKD MT/yr}) / 6.615]} * 100$$

The model calculates this percentage for each plant and multiplies it by the water truck capital cost to estimate the baseline water truck capital cost associated with CKD management.

The operating costs for baseline water spray on roads are estimated assuming that the truck travels approximately 10 miles per day with a fuel consumption of five miles per gallon at a fuel cost of $1.15 per gallon. The truck is assumed to operate 300 days per year for four hours per day. The daily water volume used is assumed to be 15,000 gallons, at a cost of $2 per 1,000 gallons. Maintenance costs are assumed to be 5 percent of the capital cost per year. The baseline annual costs are estimated as follows:

$$\begin{aligned}\text{Annual Cost} &= (10\ \text{mi/day})(\$1.15/\text{gal})(300\ \text{days/yr}) / (5\ \text{miles/gal}) \\ &\quad + (15{,}000\ \text{gal})(300\ \text{days/yr})(\$2/1{,}000\ \text{gal}) \\ &\quad + (4\ \text{hr/day})(\$31.50/\text{hr})(300\ \text{days/yr}) + (\$101{,}000)(0.05) \\ &= \$52{,}540 / \text{yr}\end{aligned}$$

This annual cost is multiplied by the percentage of CKD hauling estimated above, to estimate the percentage of the annual watering costs associated with CKD management.

Compliance Costs

For compliance options, the water truck is used for water spray on roads and for conditioned placement of CKD in a monofill. Therefore, a higher proportion of the truck costs are associated with CKD management. For the baseline scenario, the model assumes that the entire water capacity of 5,000 gallons will be sprayed on the roads 3 times per day. For the compliance scenario, it is assumed that less water will be sprayed on the roads more frequently to allow the water truck also to be used for compaction at the CKD monofill. For the plants with relatively small quantities of CKD, the water truck will be used for compaction only on days when CKD is placed in the monofill. For the plants with relatively large quantities of CKD, the water truck will be used daily for compaction. One water truck per plant is assumed to be sufficient for water spray on roads and compaction. However, the percentage of capital and annual costs associated with water spray on roads under the compliance scenario will vary according to the frequency of use for compaction. It is assumed that water spray for compaction will be required for 50 percent of the time estimated for compaction. Water spray on roads is estimated to require four hours per day for 300 days per year. The water truck capital cost associated with water spray on roads is estimated as follows, where the time required for compaction is described above in Water Truck for Compaction:

$$\text{Water on Roads Capital} = \frac{(1{,}200\ \text{hr/yr}) * \$101.000}{(\text{Water Truck hr/yr for Compaction}) + (1{,}200\ \text{hr/yr})}$$

The percentage of this cost associated with CKD hauling is estimated by multiplying the result of the above equation by the percent of CKD hauling as discussed previously:

$$\%\ \text{CKD Hauling} = \frac{(\text{CKD MT/yr}) / 6.615}{[(\text{Raw MT/yr}) / 10.364] + [(\text{CKD MT/yr}) / 6.615]} * 100$$

Annual costs associated with water spray on roads for the compliance scenario are the same as those estimated for the baseline scenario:

$$\begin{aligned}\text{Annual Cost} &= (10\ \text{mi/day})(\$1.15/\text{gal})(300\ \text{days/yr}) / (5\ \text{miles/gal}) \\ &\quad + (15{,}000\ \text{gal})(300\ \text{days/yr})(\$2/1{,}000\ \text{gal}) \\ &\quad + (4\ \text{hr/day})(\$31.50/\text{hr})(300\ \text{days/yr}) + (\$101{,}000)(0.05) \\ &= \$52{,}540\ /\ \text{yr}\end{aligned}$$

This annual cost is multiplied by the percentage of CKD hauling estimated above, to estimate the percentage of the annual watering costs associated with CKD management.

APPENDIX B

ANNUALIZATION OF BEFORE-TAX COMPLIANCE COSTS

Under Executive Order 12866, EPA must determine whether a regulation constitutes a "significant regulatory action." One of the criteria for defining a significant regulatory action, as defined under the Executive Order, is if the rule has an annual effect on the economy of $100 million or more. To determine whether the proposed CKD land management standards are a significant regulatory action under this criteria, all costs are annualized on a before-tax basis assuming a seven percent real rate of return. The savings attributable to corporate tax deductions or depreciation on capital expenditures for equipment are not considered in calculating before-tax costs.

A plant-specific annualized before-tax cost analysis was conducted for 110 plants which generate CKD and are affected by the proposed rulemaking. Annual before-tax baseline, compliance, and incremental compliance costs were estimated for each plant. Before-tax incremental compliance costs were used because they represent a resource or social cost of the rulemaking, measured before any business expense tax deductions that are available to affected companies. In reformulating the social costs of compliance, a discount rate of seven percent was used, assuming a 20-year borrowing period, a 5-year operating life for monofill equipment (i.e., bulldozers, compactors, water trucks, and hauling trucks), and a 20-year operating life for pelletization equipment.

The following formula was used to determine the before-tax annualized costs:

Annual Before-Tax Costs =

$$
\begin{aligned}
&(\text{Capital and One-Time Initial Costs})(\text{CRF}_{20}) + [(\text{5-yr Capital Costs}) + (\text{5-yr Capital Costs}/1.07^{5})\\
&+ (\text{5-yr Capital Costs}/1.07^{10}) + (\text{5-yr Capital Costs}/1.07^{15})](\text{CRF}_{20}) + (\text{Annual O\&M Costs})\\
&+ (\text{Closure Costs}/1.07^{20})(\text{CRF}_{20}) + (\text{5-yr Post-Closure Costs}/\text{CRF}_{5}/1.07^{20})(\text{CRF}_{20})\\
&+ (\text{25-yr Post-Closure Costs}/\text{CRF}_{25}/1.07^{25})(\text{CRF}_{20})
\end{aligned}
$$

Where: CRF_n = Capital recovery factor (i.e., the amount of each future annuity payment required to accumulate a given present value) based on a 7 percent real rate of return (i) and a 20-year borrowing period (n) as follows:

$$\frac{(1+i)^n(i)}{(1+i)^n-1} = 0.09439 \quad \text{when } n = 20$$