



Regulatory Impact Analysis: Application of Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes

**APPLICATION OF PHASE IV
LAND DISPOSAL RESTRICTIONS
TO NEWLY IDENTIFIED
MINERAL PROCESSING WASTES**

REGULATORY IMPACT ANALYSIS

**OFFICE OF SOLID WASTE
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY**

APRIL 15, 1997

REPORT DOCUMENTATION PAGE	1. Report No. EPA530-R-97-036	2.	
4. Title and Subtitle REGULATORY IMPACT ANALYSIS: APPLICATION OF THE PHASE IV LAND DISPOSAL RESTRICTIONS TO NEWLY IDENTIFIED MINERAL PROCESSING WASTES		5. Report Date April 15, 1997	6.
7. Author(s)		8. Performing Organization Rept. No.	
9. Performing Organization Name and Address U.S. EPA OFFICE OF SOLID WASTE 401 M STREET, SW WASHINGTON, DC 20460		10. Project/Task/Work Unit No.	
		11. Contract © or Grant (G) No. © (G)	
12. Sponsoring Organization Name and Address		13. Type of Report & Period Covered TECHNICAL REPORT	
		14.	
15. Supplementary Notes			
16. Abstract (Limit: 200 words) ESTIMATES THE COSTS, ECONOMIC IMPACTS, AND BENEFITS OF THE SUPPLEMENTAL PROPOSED RULE APPLYING PHASE IV LAND DISPOSAL RESTRICTIONS [LDR] TO NEWLY IDENTIFIED HAZARDOUS MINERAL PROCESSING WASTES. DISCUSSES THE PROPOSED REGULATORY OPTIONS FOR MINERAL PROCESSING WASTES NO LONGER EXEMPT FROM SUBTITLE C REQUIREMENTS UNDER THE BEVILL EXEMPTION. ADDRESSES UNIVERSAL TREATMENT STANDARDS (UTS). INCLUDES METHODOLOGIES USED.			
17. Document Analysis a. Descriptors			
b. Identifiers/Open-Ended Terms			
c. COSATI Field Group			
18. Availability Statement RELEASE UNLIMITED	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 325	20. Security Class (This Page) UNCLASSIFIED
		22. Price	

TABLE OF CONTENTS

	<u>Page</u>
MINERAL PROCESSING WASTES FORMERLY EXEMPT UNDER THE BEVILL AMENDMENT	1
Background	1
1. REGULATORY OPTIONS	2
1.1 Specific Options	2
1.2 Discussion of Options and Implications for the Regulatory Impact Analysis ...	7
2. DEFINING THE UNIVERSE AND ESTIMATING WASTE VOLUMES	9
3. COST AND ECONOMIC IMPACTS OF THE RULE	10
3.1 Methods	10
3.1.1 Waste Management Assumptions	12
3.1.2 Cost Modeling Assumptions	15
3.1.3 Economic Impact Analysis	20
3.2 Results	21
3.2.1 Cost Analysis Results	22
3.2.2 Economic Impact Analysis Results	28
4. BENEFITS ASSESSMENT	43
4.1 Risk and Benefits Assessments Methodologies	43
4.1.1 Overview of Risk and Benefits Assessment Activities	43
4.1.2 Risk and Benefits Assessment Methods for Nonrecycled Materials ..	45
4.1.3 Risk and Benefits Assessment Methods for the Storage of Recycled Materials	45
4.2 Risk and Benefits Assessment Results	49
4.2.1 Risks and Benefits Associated With the Disposal of Mineral Processing Wastes	49

TABLE OF CONTENTS (continued)

4.2.2	Risk Assessment Results for Recycled Materials Storage: Groundwater Pathway	53
4.2.3	Potential Benefits From Control of Stored Materials: Groundwater Pathway	55
4.2.4	Risk Assessment Results for Storage of Recycled Materials: Non-Groundwater Pathways	60
4.2.5	Potential Health Benefits from Regulation of Storage of Recycled Materials: Non-Groundwater Pathways	64
4.3	Uncertainties and Limitations in the Risk and Benefits Assessment for the Modified Prior Treatment Baseline	64
5.	Other Administrative Requirements	68
6.	Conclusions	69
6.1	The Affected Universe	69
6.2	Cost and Economic Impacts of the Rule	69
6.3	Health Benefits of the Proposed LDR	71
APPENDIX A:	ANALYSIS OF OPTIONS UNDER ALTERNATIVE BASELINES	
APPENDIX B:	SUMMARY OF MINERAL PROCESSING FACILITIES PRODUCING HAZARDOUS WASTE STREAMS	
APPENDIX C:	MINERAL PROCESSING WASTE TREATMENT AND DISPOSAL COSTS: LOW-COST ANALYSIS	
APPENDIX D:	DEVELOPMENT OF COSTING FUNCTIONS	
APPENDIX E:	TYPE OF UNIT RECEIVING RECYCLED MATERIAL	
APPENDIX F:	EXPLANATION OF COST MODELING CALCULATIONS	
APPENDIX G:	MINERAL PROCESSING COST MODEL EXAMPLE CALCULATION: TITANIUM AND TITANIUM DIOXIDE SECTOR	
APPENDIX H:	RISK AND BENEFITS ASSESSMENT FOR THE STORAGE OF RECYCLED MATERIALS	

TABLE OF CONTENTS (continued)

APPENDIX I: METHODOLOGY

APPENDIX J: CONSTITUENT CONCENTRATION DATA FOR RECYCLED MATERIALS

MINERAL PROCESSING WASTES FORMERLY EXEMPT UNDER THE BEVILL AMENDMENT

This regulatory impact analysis (RIA) estimates the costs, economic impacts, and benefits of the supplemental proposed rule applying Phase IV Land Disposal Restrictions (LDRs) to newly identified hazardous mineral processing wastes. Today's proposal modifies potential waste management requirements that were originally proposed on January 25, 1996 (61 FR 2338).

In today's notice, EPA is proposing standards for mineral processing wastes no longer exempt from Subtitle C requirements under the Bevill exemption. Under the provisions of today's proposal, previously exempt Bevill mineral processing wastes destined for disposal would need to be treated to meet RCRA Universal Treatment Standards (UTS) before management or disposal in a land-based unit. At the same time, however, operators could reclaim hazardous mineral processing residues and store them in non-land based units prior to reclamation without complying with full Subtitle C requirements, under certain specified conditions.

Background

This component of the Phase IV Land Disposal Restrictions rule is one in a series of regulations that restricts the continued land disposal of hazardous wastes under the 1984 Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA). At the time HSWA was enacted, EPA was required to promulgate treatment and disposal standards by May 8, 1990 for wastes already identified or listed as hazardous. EPA completed development of treatment standards and waste management practices for these wastes in 1990. EPA also is required to develop treatment standards for wastes subsequently identified or listed as hazardous. EPA is addressing these "newly identified" wastes in several "phases." EPA has finalized rules for three phases and proposed the Phase IV rule in two parts in August 1995 and January 1996.

Under the provisions of the Mining Waste Exclusion of RCRA, solid waste from the extraction, beneficiation, and processing of ores and minerals is exempt from regulation as hazardous waste under Subtitle C of RCRA, as amended. The Mining Waste Exclusion was established in response to the so-called "Bevill Amendment," which was added in the 1980 Solid Waste Disposal Act Amendments. The Bevill Amendment precluded EPA from regulating these wastes until the Agency performed a study and submitted a Report to Congress. Following a process of litigation and rulemakings that took place over several years, the Agency promulgated final rules on September 1, 1989 (54 FR 36592) and January 23, 1990 (55 FR 2322) establishing that only 20 specific mineral processing wastes fulfilled the newly promulgated special wastes criteria; all other mineral processing wastes were removed from the Mining Waste Exclusion.

These newly identified non-exempt wastes have the same regulatory status as any other industrial solid waste. Thus, if they exhibit characteristics of hazardous waste or are listed as hazardous wastes, they must be managed in accordance with RCRA Subtitle C or equivalent state standards. Existing waste characterization data suggest that many of these wastes may exhibit the characteristic of toxicity for metals (waste codes D004-D011), corrosivity (D002), and/or reactivity (D003).

EPA considers these wastes to be "newly identified" because they were brought into the RCRA Subtitle C system after the date of enactment of the HSWA on November 8, 1984. EPA did not include the newly identified wastes within the scope of the LDRs for Subtitle C characteristic hazardous wastes published in June 1990, deciding instead to promulgate additional treatment standards (Best Demonstrated Available Technology, or BDAT) in several phases. At the time, EPA had not performed the technical analyses necessary to determine whether the treatment standards being promulgated for characteristic hazardous wastes were feasible for the newly non-exempt mineral processing wastes. In addition, the list of non-exempt wastes was not yet final, because the regulatory determination for the 20 wastes studied in the 1990 Report to Congress had not yet been promulgated. The boundaries of the Exclusion have now been firmly established, and the Agency is ready to characterize and establish treatment standards for all newly identified hazardous mineral processing wastes.

Today's rule contains elements that are related to non-HSWA provisions of the statute (e.g., the conditional exclusion from the definition of solid waste for storage of mineral processing residues) as well as elements that are related to HSWA provisions (the proposed universal treatment standards for land disposed mineral processing wastes). The definition of solid waste provisions of this rule are not being promulgated pursuant to HSWA. Thus, these federal requirements will take effect only in states that do not have final RCRA authorization. In contrast, the universal treatment standards for land disposed mineral processing wastes are being promulgated pursuant to HSWA. Therefore, these treatment standard provisions will take effect in all states upon the effective date of the rule regardless of final authorization status.

1. REGULATORY OPTIONS

This section presents the options that EPA is considering for applying LDR standards to newly identified hazardous mineral processing wastes. All of these options are examined in depth in this Regulatory Impact Analysis, and have been selected for analysis because they reflect the views of various interested parties and will enable EPA to effectively solicit public comment on appropriate management standards for the subject wastes. Section 1.1 summarizes the key features of each option. Section 1.2 discusses their implications for the RIA.

1.1 Specific Options

Summarized below are the four options that are the focus of analysis in this RIA. In addition to the option-specific details outlined below, several of the options share the following common features:

- In all four options, mineral processing wastes being disposed must be treated to UTS levels prior to disposal in Subtitle D disposal units;
- Operators of facilities that generate and manage hazardous mineral processing wastes must comply with simplified recordkeeping and reporting requirements under all four options;
- Secondary mineral processing materials destined for recycling may be stored for up to one year under all four options; and
- Recycling of non-mineral processing materials outside of RCRA Subtitle C jurisdiction is prohibited, i.e., the conditional exclusions for certain activities

provided in Options 2, 3, and 4 (as described below) are available only for mineral processing residues.

Option 1 -- Subtitle C Jurisdiction

Option 1 represents a comprehensive approach for ensuring that land storage of secondary materials destined for reprocessing does not contribute to the "waste management problem" and that recycling claims by the mineral processing industry are legitimate and not simply a mechanism for disposal of mineral processing wastes outside RCRA Subtitle C jurisdiction. This option is similar to the first option in the January 1996 supplemental proposal, though it now restricts reintroduction of mineral processing secondary materials into beneficiation or Bevill process units. The option consists of the following features:

1. Subtitle C jurisdiction would be extended to cover characteristic sludges and by-products, even when these materials are reclaimed; i.e., these materials would be considered solid wastes and thus subject to RCRA jurisdiction in the same manner that spent materials are currently classified.
2. Storage on land of secondary materials destined for recycling or reprocessing would not be permitted for materials generated at rates of less than 45,000 metric tons of solids or one million metric tons of liquids per year.
3. If materials are stored on land, the land-based storage units must not contribute to significant groundwater contamination through discard. This condition might be met in one of three ways:¹
 - The facility operator demonstrates that he/she is not polluting groundwater at levels exceeding the Maximum Contaminant Level (MCL) for any hazardous constituent likely to be in the secondary materials stored (i.e., the toxic metals listed in Appendix VIII of Part 261 and cyanide). The demonstration would be made by means of groundwater monitoring. If a release were detected that exceeded MCLs, unit-specific corrective action would be required.
 - The unit storing the materials is designed in a manner that obviates the need for a demonstration that MCLs are not being exceeded. Specifically, surface impoundment units would need to be constructed to have the transmissivity equivalent of a 40 mil geomembrane liner on a surface of 12 inches of 10^{-5} cm/sec hydraulic conductivity soil. Storage of solids in piles located on concrete, asphalt, or soil with the

¹ Note that for the purposes of this RIA, EPA has modeled only the cost of complying with the second of the three alternative conditions (i.e., installation of liners). Throughout the RIA, the Agency has assumed that operators will choose the least-cost option for compliance, and upon consideration, has determined that installing liners in previously unlined land-based units is likely to be the least-cost means for most operators to continue storing secondary materials on land. Installing liners obviates the need to implement groundwater monitoring and allows the operator to avoid triggering corrective action requirements.

transmissivity equivalent of three feet of clay with 10^{-7} cm/sec hydraulic conductivity also would be permitted.

- The facility obtains a determination from an authorized state or (in unauthorized states) from the Regional Administrator, that a management practice or alternative design provides adequate assurance that the unit provides effective containment and will not become part of the waste disposal problem through discard.
4. All non-land based storage units (i.e., tanks, containers, and containment buildings (TCBs)) must meet applicable 40 CFR Part 265 standards (standards for interim status facilities).
 5. Facility owners and operators would have to demonstrate that legitimate recycling is occurring at the facility in the following two ways:
 - Demonstrate that the recycled secondary material complies with a quantitative minimum material content standard; or
 - Demonstrate that hazardous constituents different from those normally found in customarily used raw materials are not present in secondary materials, thereby precluding the presence of "toxics along for the ride" or "TAR."

Facilities that fail to meet conditions for legitimate recycling would be subject to Subtitle C treatment and storage permitting, along with associated financial responsibility and facility-wide corrective action requirements.

6. Hazardous mineral processing residues could not be recycled to primary beneficiation operations/units or Bevill process units without loss of the Bevill exempt status of any beneficiation or other special wastes generated by such units. That is, these operations would become regulated Subtitle C units and resulting wastes from these units would lose their Bevill status when mineral processing residues were mixed with ores, minerals, or beneficiated ores or minerals.

Option 2 -- Conditional Exemption from RCRA Jurisdiction (But Including Bevill Unit Recycling Prohibition)

Option 2 represents an attempt to both (1) stimulate greater resource recovery in the minerals industry by not classifying recoverable mineral processing residuals as wastes if they are recovered in process units, and (2) ensure that appropriate waste treatment standards and technologies are applied to hazardous mineral processing wastes destined for land disposal, thereby protecting human health and the environment. This option is new (i.e., it was not included in the January 1996 proposed rule). It differs from Option 1 in two ways: Option 2 does not include a legitimacy test for recycled materials, and it allows storage in tanks, containers, and buildings that do not meet RCRA part 265 subpart I, J, and DD standards. The option consists of the following features:

1. A conditional exclusion from the definition of solid waste would apply to non-exempt mineral processing residues stored in tanks, containers, or buildings

(TCBs) prior to reinsertion into a mineral processing production unit. TCBs would not be required to meet any additional design requirements to be eligible for the conditional exclusion.

2. Storage on land of secondary materials destined for recycling or reprocessing would not be permitted for materials generated at rates less than 45,000 metric tons of solids or one million metric tons of liquids per year.
3. If materials are stored on land, the land-based storage units must not contribute to significant groundwater contamination through discard. This condition might be met in one of three ways:²
 - The facility operator demonstrates that he/she is not polluting groundwater at levels exceeding the Maximum Contaminant Level (MCL) for any hazardous constituent likely to be in the secondary materials stored (i.e., the toxic metals listed in Appendix VIII of Part 261 and cyanide). The demonstration would be made by means of groundwater monitoring. If a release were detected that exceeded MCLs, unit-specific corrective action would be required.
 - The unit storing the materials is designed in a manner that obviates the need for a demonstration that MCLs are not being exceeded. Specifically, surface impoundment units would need to be constructed to have the transmissivity equivalent of a 40 mil geomembrane liner on a surface of 12 inches of 10^{-5} cm/sec hydraulic conductivity soil. Storage of solids in piles located on concrete, asphalt, or soil with the transmissivity equivalent of three feet of clay with 10^{-7} cm/sec hydraulic conductivity also would be permitted.
 - The facility obtains a determination from an authorized state or (in unauthorized states) from the Regional Administrator, that a management practice or alternative design provides adequate assurance that the unit provides effective containment and will not become part of the waste disposal problem through discard.
4. Hazardous mineral processing residues could not be recycled to primary beneficiation operations/units or Bevill process units without loss of the Bevill status of any beneficiation or other special wastes generated by such units. That is, these operations would become regulated Subtitle C units and resulting wastes from these units would lose their Bevill status when mineral processing residues were mixed with ores, minerals, or beneficiated ores or minerals.

² See previous footnote.

Option 3 -- Conditional Exclusion from RCRA Jurisdiction (Excluding Bevill Unit Recycling Prohibition)

Option 3 includes all of the Option 2 provisions, with one significant exception. The prohibition on recycling hazardous mineral processing residues through beneficiation or Bevill process units (the last feature listed in Option 2) would not apply. This option includes the following features:

1. A conditional exclusion from the definition of solid waste would apply to non-exempt mineral processing residues stored in tanks, containers, or buildings (TCBs) prior to reinsertion into a mineral processing production unit. TCBs would not be required to meet any additional design requirements to be eligible for the conditional exclusion.
2. Storage on land of secondary materials destined for recycling or reprocessing would not be permitted for materials generated at rates less than 45,000 metric tons of solids or one million metric tons of liquids per year.
3. If materials are stored on land, the land-based storage units must not contribute to significant groundwater contamination through discard. This condition might be met in one of three ways:³
 - The facility operator demonstrates that he/she is not polluting groundwater at levels exceeding the Maximum Contaminant Level (MCL) for any hazardous constituent likely to be in the secondary materials stored (i.e., the toxic metals listed in Appendix VIII of Part 261 and cyanide). The demonstration would be made by means of groundwater monitoring. If a release were detected that exceeded MCLs, unit-specific corrective action would be required.
 - The unit storing the materials is designed in a manner that obviates the need for a demonstration that MCLs are not being exceeded. Specifically, surface impoundment units would need to be constructed to have the transmissivity equivalent of a 40 mil geomembrane liner on a surface of 12 inches of 10^{-5} cm/sec hydraulic conductivity soil. Storage of solids in piles located on concrete, asphalt, or soil with the transmissivity equivalent of three feet of clay with 10^{-7} cm/sec hydraulic conductivity also would be permitted.
 - The facility obtains a determination from an authorized state or (in unauthorized states) from the Regional Administrator, that a management practice or alternative design provides adequate assurance that the unit provides effective containment and will not become part of the waste disposal problem through discard.

³ See footnote 1.

Option 4 -- Unconditional Exclusion from RCRA Jurisdiction

This option is based on approaches advanced by the mineral processing industry and would maximize the ability of industry to recycle secondary materials without triggering *any* additional requirements. This option was included as Option 3 in the January 1996 proposal. This option includes the following features:

1. All outputs from mineral processing facilities would be unconditionally excluded from RCRA jurisdiction regardless of how the materials are stored. Consequently, there would be no special requirements for any type of unit storing secondary materials.
2. Facility operators would not be required to comply with a legitimacy test for mineral processing residues being recycled.
3. Hazardous mineral processing residues could be recycled to primary beneficiation operations/units without risk to the Bevill status of any beneficiation wastes generated by such units. These residues would not be required to meet a "significantly affected" test.

1.2 Discussion of Options and Implications for the Regulatory Impact Analysis

The Agency has performed a detailed analysis of each of the four options described above, assuming each of three alternative baselines. The baseline discussed in the remainder of this RIA is the one the Agency believes best reflects actual operator behavior. EPA refers to this baseline as the "modified prior treatment" baseline (because it is a variation on the "prior treatment baseline", one of the two baselines modeled in the December 1995 RIA). A description of the assumptions underlying the alternative baselines (prior treatment and no prior treatment), and the resulting costs and impacts can be found in Appendix A.

The modified prior treatment baseline assumes that all generators of hazardous mineral processing wastes currently dispose those wastes in compliance with Subtitle C treatment standards (except for LDRs). The least-cost method for attaining compliance for most operators would be to lime neutralize and/or cement-stabilize their waste(s) to remove the hazardous characteristic(s).⁴ Because this method also would be used to achieve UTS, there would be essentially no new treatment required upon promulgation of the LDRs, and hence, no costs or benefits associated with the LDR portion of the rule. The baseline also allows for consideration of apparent confusion within the regulated community as to requirements that currently apply to their mineral processing operations. Operators are assumed to temporarily store characteristic spent materials in unlined land-based units prior to reinsertion into a mineral processing production unit. This alternative reflects the Agency's belief that some operators do not clearly understand the Subtitle C regulations that apply to their secondary materials, i.e., that spent materials intended for recycling are not currently excluded from Subtitle C regulation.

⁴ As discussed in Section 2 below, the vast majority of hazardous mineral processing wastes exhibit the characteristics of corrosivity and/or toxicity. EPA has shown that cement stabilization (in some cases preceded by neutralization), which is the basis for the UTS standards, is an effective treatment technology for removing these hazardous waste characteristics.

Generally, the Agency believes that the four options described above characterize the range of alternatives available for addressing storage of secondary materials intended for reinsertion into mineral production processes, in terms of the trade-offs among costs, economic impacts, and benefits. Costs to industry would be highest under Option 1, which would impose a number of additional requirements on facilities recycling secondary materials, while potential benefits in terms of environmental protection could be greater under Option 1 than under the other three options. At the same time, the restriction against recycling secondary material through beneficiation or Bevill units, legitimacy tests, and storage unit standards may serve as a disincentive to recycling, thus discouraging the reuse of these materials at mineral processing facilities.

Option 2 would impose costs similar to Option 1, driven primarily by the prohibition against recycling secondary materials to beneficiation or Bevill process units. Two factors make this option slightly less expensive than Option 1: the absence of a legitimacy test for recycling materials through mineral processing units; and the provision allowing storage of secondary materials in non-RCRA tanks, containers, and buildings prior to recycling. As a result of these two factors, Option 2 may be seen as slightly less protective of the environment (i.e., because the possibility of "sham recycling" exists and because storage units, though generally assumed to be sturdy, would not have secondary containment). This option would create a mild disincentive for recycling material through non-Bevill units.

One additional feature of Options 1 and 2 is worthy of more extensive discussion. Either of these options, if promulgated, would not only prohibit the reintroduction of hazardous mineral processing wastes into production units that generate Bevill wastes, they also would remove the special waste status of all extraction, beneficiation, and processing wastes that are generated by units that receive *any* other non-Bevill waste streams, irrespective of their hazard characteristics. EPA believes that the effect of this new, broad-spectrum regulatory control would be that facility operators would cease the practice of reinserting secondary materials, of any kind, into Bevill production units. Given the substantial degree of material recycling and resource recovery conducted within the primary minerals industry, adoption of Options 1 or 2 might therefore impose profound effects on the materials handling and production processes in use within this industry. Indeed, one result might be that resource recovery would decline in parallel with a significant increase in the quantities of solid and hazardous wastes generated at mineral production facilities.

In addition, several other industries that send secondary materials to Bevill production units could also be affected under Options 1 and 2. Prominent examples of non-mineral processing secondary materials that are recovered in Bevill units by mineral processors include F006 (wastewater treatment sludge from electroplating operations), foundry sands, cathode ray tubes, and circuit boards. EPA has not attempted to quantify the magnitude or distribution of any potential operational, financial, or environmental impacts associated with the prohibition against recycling *any* non-Bevill waste stream through Bevill production units, due to a lack of sufficient data. Nonetheless, the Agency believes that the logistical and financial impacts on the facility operator associated with enactment of either of these options might be severe in some cases.

Option 3 is the least expensive non-land based storage option considered. As stated earlier, the only difference between Option 3 and Option 2 is that Option 3 does not prohibit recycling through beneficiation or Bevill process units. As a result, although it may impose a slight disincentive to recycling, Option 3 is protective of the environment, without interfering excessively with resource recovery.

Option 4 would impose no additional requirements for management of secondary materials to be recycled, regardless of where they are stored. Consequently, this option represents the least cost approach for industry and may provide greater incentives for materials reuse than the other three options. At the same time, this option does little to ensure that recycling is legitimate and also does not impose any standard to ensure that land-based storage of materials prior to reinsertion into the process does not result in releases that contribute to the "waste management problem." This option, therefore, could be expected to result in greater releases of hazardous constituents to the environment and greater human exposure to those constituents.

2. DEFINING THE UNIVERSE AND ESTIMATING WASTE VOLUMES

EPA developed a step-wise methodology for both defining the universe of mineral processing sectors, facilities, and waste streams potentially affected by the Phase IV Land Disposal Restrictions and estimating the volumes of wastes potentially affected under the various implementation options being considered by the Agency. The Agency's methodology began with the broadest possible scope of inquiry in order to ensure that EPA captured all of the potentially affected mineral commodity sectors and waste streams.⁵ The Agency then narrowed the focus of its data gathering and analysis as it completed each subsequent step. This six-step methodology is described in detail in the Appendix I.

The Agency's data sets and underlying mineral commodity sector reports were made available to the regulated community during the comment period following the January 1996 proposal. In some cases, reviewers supplied the Agency with additional or more current information about a particular commodity sector. Where appropriate, EPA has revised the sector reports and incorporated new information into its analysis. In addition, since the rule was proposed in January 1996, EPA has obtained other information that it has used to update some of the sector reports. This information also has been incorporated into the analysis presented in this RIA.

EPA has developed a bounded cost analysis, providing an expected cost (expected value case), as well as a lower bound cost (minimum value case), and an upper bound cost (maximum value case) for each of the options considered. EPA used two factors, uncertainty about generation rate and uncertainty about hazardous characteristics, to develop these three cost cases. All other steps in the cost modeling process are applied consistently across the three cost cases.

As in the December 1995 RIA, EPA began with the three estimates of generation rates potentially affected by this rulemaking for every waste stream: a minimum generation rate, an expected generation rate, and a maximum generation rate. In some cases, there is no variation in the three estimates because the generation rate of the stream was known (e.g., it was reported in literature). For a number of these waste streams EPA also lacked data about hazardous characteristics. To address these uncertainties, EPA weighted the volume estimates for each waste stream to account for the degree of certainty that the particular waste stream exhibited one or more of the RCRA hazardous waste characteristics. As shown in Exhibit 2-1, 100 percent of each waste stream known to be hazardous was included in the minimum, expected, and maximum value scenarios. For streams that were only suspected of being hazardous, however, none, 50 percent and 100 percent of the generation rate is included in the minimum, expected, and maximum value case. That is, the generation rate in each of the cost scenarios was multiplied by a percentage considered to be hazardous in this analysis, based on the certainty that the wastestream is hazardous. The remaining "nonhazardous" portion drops out of the analysis. Exhibit 2-2 presents the

⁵ Appendix B lists the mineral processing facilities affected by this rulemaking.

average facility levels of waste assumed to be "hazardous" in each sector, for the minimum, expected, and maximum value cases.

Exhibit 2-1

**Portion of Waste Stream Considered to Be Hazardous
(in Percent)**

Costing Scenario	Hazard Characteristic(s)	
	Y	Y?
Minimum	100	0
Expected	100	50
Maximum	100	100

Notes:

Y means that EPA has actual analytical data demonstrating that the waste exhibits one or more of the RCRA hazardous waste characteristics.

Y? means that EPA, based on professional judgment, believes that the waste may exhibit one or more of the RCRA hazardous waste characteristics.

3. COST AND ECONOMIC IMPACTS OF THE RULE

This section presents the methodology and results of EPA's analysis of the cost and economic impacts arising from today's proposed rule. Section 3.1 begins by describing the methods employed to determine the costs of complying with the four options described above and to compute the screening-level economic impact measures employed in this analysis. Section 3.2 presents and describes the results of the analysis.

3.1 Methods

This section describes the methodology used to calculate the costs and impacts of managing the affected mineral processing wastes under each of the four regulatory options. The basic analytical construct used throughout this analysis is that facility operators will choose the least-cost option that complies with the law. For today's proposal the Agency has conducted a *dynamic* analysis of shifts in recycling that models shifts in types or quantities of mineral processing residues between treatment/disposal and storage/recycling/reclamation.⁶ For Options 1, 2, and 3 the analysis examines various shifts that may diminish recycling, while for Option 4 the analysis assumes no change in recycling.

To analyze each option, EPA employed a number of steps and assumptions, some of which exert a major influence on the results obtained. The following sub-sections discuss these major analytical steps.

⁶ In contrast, data limitations did not allow the Agency to conduct analysis of potential shifts in recycling for the RIA that accompanied the January 1996 proposal.

Exhibit 2-2

Average Facility Waste Type Input Data

Commodity	Minimum Cost Scenario				Expected Cost Scenario				Maximum Cost Scenario			
	Number of Facilities	Waste Water (mt/yr)	1 - 10% Solids (mt/yr)	Solids (mt/yr)	Number of Facilities	Waste Water (mt/yr)	1 - 10% Solids (mt/yr)	Solids (mt/yr)	Number of Facilities	Waste Water (mt/yr)	1 - 10% Solids (mt/yr)	Solids (mt/yr)
Alumina and Aluminum	23.0	-	-	3,330	23.0	-	-	3,330	23.0	-	-	3,330
Antimony	6.0	53	-	3,532	6.0	4,500	-	3,532	6.0	9,000	-	3,532
Beryllium	2.0	100	-	100	2.0	50,000	-	23,000	2.0	1,000,000	-	45,000
Bismuth	1.0	200	200	3,300	1.0	12,300	12,200	10,020	1.0	24,200	24,000	25,200
Cadmium	2.0	285	190	570	2.0	2,850	1,900	5,700	2.0	28,500	19,000	57,000
Calcium	1.0	-	-	40	1.0	-	-	40	1.0	-	-	40
Coal Gas	-	-	-	-	-	-	-	-	1.0	-	65,000	-
Copper	10.0	-	530,000	600	10.0	-	530,000	600	10.0	-	530,000	600
Elemental Phosphorus	2.0	560,000	2,000	230	2.0	560,000	2,000	230	2.0	560,000	2,000	230
Fluorspar and Hydrofluoric Acid	-	-	-	-	3.0	5,000	-	-	3.0	15,000	-	-
Germanium	4.0	200	-	10	4.0	1,100	-	161	4.0	2,000	-	302
Lead	4.0	880,000	-	100,770	4.0	880,000	-	123,345	4.0	880,000	-	153,095
Magnesium and Magnesia from Brines	2.0	-	-	13,038	2.0	-	-	13,380	2.0	-	-	16,800
Mercury	7.0	9,000	-	12	7.0	11,000	-	12	7.0	60,000	-	12
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	11.0	91	-	100	11.0	91	-	23,000	11.0	91	-	45,000
Platinum Group Metals	3.0	200	-	2	3.0	1,140	-	15	3.0	2,000	-	150
Pyrobitumens, Mineral Waxes, and Natural Asphalts	2.0	1	-	1	2.0	5,000	-	23,000	2.0	10,000	-	45,000
Rare Earths	1.0	21,200	-	170	1.0	1,021,000	-	3,000	1.0	2,021,000	-	11,500
Rhenium	2.0	-	-	44,000	2.0	50	-	44,000	2.0	100	-	44,000
Scandium	7.0	200	-	-	7.0	1,120	-	-	7.0	2,000	-	-
Selenium	3.0	22,000	-	68	3.0	22,000	-	680	3.0	22,000	-	6,800
Synthetic Rutile	1.0	30,000	-	75,000	1.0	30,000	-	75,000	1.0	30,000	-	75,000
Tantalum, Columbium, and Ferrocolumbium	2.0	-	75,000	1,500	2.0	-	75,000	1,500	2.0	-	75,000	1,500
Tellurium	2.0	200	-	200	2.0	11,000	-	2,000	2.0	30,000	-	9,000
Titanium and Titanium Dioxide	7.0	55,289	-	65,114	7.0	75,876	-	68,243	7.0	96,289	-	71,671
Tungsten	6.0	370	-	-	6.0	730	-	-	6.0	5,000	-	-
Uranium	17.0	300	-	100	17.0	1,250	-	650	17.0	2,200	-	1,200
Zinc	3.0	3,243,417	-	16,600	3.0	3,243,417	-	16,600	3.0	3,243,417	-	16,600
Zirconium and Hafnium	2.0	17,100	-	-	2.0	521,000	-	-	2.0	2,256,000	-	-

April 15, 1997

3.1.1 Waste Management Assumptions

The costs imposed by a particular regulatory option are measured as the difference in cost between the current, or baseline, management practices and the lowest-cost alternative practice allowed under the option. In this analysis, therefore, EPA identified what it believes to be the current management practices that are applied to the waste streams of interest and then determined the costs of these practices. These baseline costs are then subtracted from the costs of complying with the least-cost management practice allowed under each of the four options. Exhibit 3-1 summarizes the pre- and post-rule behavior that is discussed in more detail below.

Exhibit 3-1
Assumed Management Practices

Baseline or Option	Wasted Portion	Secondary Materials Recycled through Bevill Units	Secondary Materials Recycled through Processing units
Baseline	Treated to TC levels, disposed	Stored in unlined land-based units	Stored in unlined land-based units
Option 1	Treated to UTS levels, disposed	No longer recycled, now treated to UTS levels and disposed	Stored in RCRA tanks, containers, and buildings (must pass legitimacy test)
Option 2	Treated to UTS levels, disposed	No longer recycled, now treated to UTS levels and disposed	Stored in tanks, containers, and buildings
Option 3	Treated to UTS levels, disposed	Stored in tanks, containers, and buildings	Stored in tanks, containers, and buildings
Option 4	Treated to UTS levels, disposed	Stored in unlined units	Stored in unlined units

Pre-LDR Behavior (Baseline)

In the baseline, operators are assumed to be in full compliance with RCRA Subtitle C requirements (but not LDRs) for managing waste materials. The baseline assumes that the operator has chosen the least-cost option for compliance with these requirements: corrosive and/or TC toxic wastewaters and slurries are treated (generally with lime) in tanks; and TC toxic solids, sludges, and other materials are cement stabilized within 90 days of being generated, and disposed (generally on site) in a Subtitle D unit.⁷ Fundamentally, these assumptions are based upon the feasibility of mineral processing residue treatment by lime neutralization for wastewaters and slurries and cement stabilization for sludges and solids. These methods, along with high temperature metals recovery (HTMR), are part of the basis for the UTS standards.

⁷ To comply with current regulations, facility operators also could dispose of these wastes in a Subtitle C permitted landfill. Appendix C presents a break-even analysis showing that treatment and Subtitle D disposal is less expensive than Subtitle C disposal without treatment, in most cases.

A point of further interest and critical importance to the analysis presented below is the fact that the very same technologies can be used to treat wastes to the point of removing the hazardous characteristic(s) and to meet the UTS standards; the difference between achieving removal of the hazardous characteristic and the UTS standards is simply one of degree. Since the January 1996 supplemental proposed rule, EPA received numerous comments on the use of existing UTS levels for mineral processing wastes. These comments suggested that some of the existing UTS levels were inappropriate for mineral processing wastes. In response to these comments, the Agency analyzed additional stabilization data provided by the commenters and, in light of this new information, is proposing revised UTS levels for mineral processing wastes. Exhibit 3-2 presents the TC levels, existing UTS levels, and revised UTS levels. Based on the revised levels, EPA believes that mineral processing facilities treating wastes using cement stabilization will not incur any additional costs in order to achieve UTS levels.

**Exhibit 3-2
Existing and Revised UTS Levels
(Nonwastewater Metals)**

Waste Code	Constituent	TC Level (mg/l)	Existing UTS level (mg/l TCLP)	Proposed UTS Level (Revised)
D004	Arsenic	5.0	5.0	5.0
D005	Barium	100.	7.6	21
D006	Cadmium	1.0	0.19	0.20
D007	Chromium	5.0	0.86	0.85
D008	Lead	5.0	0.37	0.75
D009	Mercury - Retort residue	0.20	0.20	0.20
D009	Mercury - all others	.2	0.025	.025
D010	Selenium	1.0	0.16	5.7
D011	Silver	5.0	0.30	0.11
-----	Antimony	-----	2.1	0.07
-----	Beryllium	-----	0.014	0.02
-----	Nickel	-----	5.0	13.6
-----	Thallium	-----	0.078	0.20
-----	Vanadium	-----	0.23	1.6
-----	Zinc	-----	5.3	4.3

In the baseline, all secondary materials destined for recycling, including spent materials, are assumed to be stored in unlined, land-based units for some period of time prior to reinsertion into the

process. This assumption reflects apparent confusion in the regulated community concerning the status of spent materials, and the proper methods for storing them prior to disposal or reuse.⁸ (Because sludges and by-products that are reclaimed are not solid wastes, and hence, not hazardous wastes, there are currently no standards regulating storage units for sludges and by-products.)

Post-Rule Compliance Behavior

To determine the incremental impact of the Phase IV LDR standards, EPA first predicted cost-minimizing behavior by affected facility operators that would be in compliance with the provisions of each option analyzed.

Under Option 1, facility operators are expected to move material destined for recycling from unlined land-based storage units to TCBs that meet Subtitle C standards,⁹ provided these materials are not recycled through a beneficiation or other Bevill process unit. These materials could be stored in TCBs for up to one year in the absence of a RCRA Subtitle C permit.¹⁰ EPA assumes facility operators will stop recycling materials through beneficiation or Bevill process units rather than lose the Bevill exempt or special waste status of the wastes generated by those beneficiation or Bevill process units. Material formerly recycled through beneficiation or Bevill process units would then be treated and disposed. Facility operators would continue treating the wasted portion using cement stabilization or neutralization and dewatering. In addition, facility operators might stop recycling other materials rather than risk failing a legitimacy test, because facilities that fail to meet conditions for legitimate recycling would be subject to Subtitle C treatment and storage permitting, along with associated financial responsibility and facility-wide corrective action requirements.

Under Option 2, facility operators are expected to move material destined for recycling from unlined land-based storage units to non-RCRA TCBs, provided these materials are not recycled through a beneficiation or Bevill process unit. These materials could be stored in TCBs for up to one year in the absence of a RCRA Subtitle C permit.¹¹ EPA assumes that facility operators would stop recycling materials through beneficiation or Bevill process units, rather than lose the Bevill exempt or special waste status of the wastes generated by those beneficiation or Bevill process units. Material formerly recycled through beneficiation or other Bevill process units would be treated and disposed. Facility operators would continue treating the wasted portion using cement stabilization or neutralization and dewatering.

Under Option 3, facility operators are expected to move material destined for recycling from unlined land-based storage units to non-RCRA TCBs. These materials could be stored in TCBs for up to

⁸ Spent materials destined for recycling, if stored, must be stored in tanks, containers, or buildings for less than 90 days prior to recycling, unless they are stored at a RCRA permitted treatment, storage, or disposal facility.

⁹ These standards can be found in 40 CFR 265 subparts I, J, and DD.

¹⁰ Note that for purposes of the cost model, although storage for up to one year is possible under this option, the Agency assumed that facilities only have capacity to store solids for 90 days and liquids for 30 days.

¹¹ See footnote 10.

one year in the absence of a RCRA Subtitle C permit.¹² Facility operators would continue treating the wasted portion using cement stabilization or neutralization and dewatering.

Under Option 4, facility operators are expected to continue storing material destined for recycling in unlined land-based storage units. These materials could be stored for up to one year in the absence of a RCRA Subtitle C permit.¹³ Facility operators would continue treating the wasted portion using cement stabilization or neutralization and dewatering.

Dynamic Shifts

As a refinement to the analysis originally prepared for the December 1995 RIA, the Agency has used a dynamic analysis to model changes in the management of newly-identified mineral processing wastes that might be induced by the new LDR requirements. Specifically, the dynamic analysis accounts for shifts in the amount of material that is recycled rather than being treated and disposed.

For Options 1 and 2, the analysis assumes that rather than lose the Bevill exclusion for wastes generated in beneficiation units and process units, facility operators would stop recycling all mineral processing secondary materials through these units. Option 1 also might create a moderate disincentive for recycling newly-identified mineral processing wastes through processing units, due to the imposition of a legitimacy test and more stringent storage unit standards. Option 2 might impose a mild disincentive for recycling newly-identified mineral processing wastes through processing units due to more stringent storage unit standards. Option 3 could cause a similar minor disincentive for all recycled wastes, regardless of the point of reintroduction to the manufacturing process because of the additional storage unit requirements. Option 4, which does not impose any new storage requirements, would neither increase nor decrease the amount of materials recycled (which are assumed to be stored in land based units without restriction in the baseline).

3.1.2 Cost Modeling Assumptions

EPA estimated the implementation costs of the options for hazardous waste streams from mineral processing by calculating the difference between the estimated pre- and post-LDR costs. Because of data limitations, EPA used sector-wide averages and totals for estimating the impacts of the rule. Sector-wide estimates were developed on an average facility basis, however, so as to correctly address facility-level economies of scale. Detailed cost model calculations and results are bound in a separate document.

Cost Functions

To calculate the costs of managing the affected wastes under the baseline and the four options, EPA developed and applied cost-estimating functions for treatment and disposal, as well as storage prior to recycling. Appendix D provides a detailed discussion of these cost functions. The cost functions address the capital and O&M costs associated with each technology, as well as decommissioning costs for on-site tank treatment and stabilization. These costing equations are expressed as a function of the waste generation rate (in metric tons/year). In addition, the costing functions provide a means of estimating the break-even point between off-site and on-site land disposal costs.

¹² See Footnote 10.

¹³ See Footnote 10.

The application of new technologies for treating wastes often involves the procurement and installation of new capital equipment, as well as changes in periodic operating costs. Because this new equipment is used over an extended period of time (i.e., not consumed), it is necessary to allocate its procurement and installation costs over its useful operating life. EPA addressed this issue by annualizing the initial capital costs over the operating life of the durable equipment, and then adding the discounted value of the annualized initial capital costs to the annual (recurring) capital, operating, and maintenance costs associated with the technology, in order to obtain a total annualized cost. This yields a measure of cost impact that can be compared directly with data reflecting the ability of the affected firms to bear this incremental cost (e.g., earnings, value of product shipments).

The costing functions incorporate the following general assumptions:

- *Operating Life.* The analysis assumes a 20-year operating life for waste management units and facilities. With a positive and even moderately significant discount rate, extending the operating life beyond this period adds complexity but little tangible difference in estimated costs.
- *Tax Rate.* Costs are estimated on a before-tax basis to facilitate comparisons with available data related to predicting ultimate economic impacts.
- *Discount Rate.* The analysis uses a discount rate of seven percent, in keeping with current Office of Management and Budget (OMB) guidance.¹⁴
- *Inflation Rate.* The analysis is conducted in real terms and, consequently, assumes an inflation rate of zero.

General Approach to Developing Waste Management Costs

Based on the assumed incentives and/or disincentives for increase recycling, as well as each stream's certainty of recycling, EPA estimated the percentage of hazardous material sent to treatment and disposed for each baseline and option. The remaining hazardous material is considered to be recycled.¹⁵ The dynamic analysis results from the shifts in management in each baseline-option combination. Exhibit 3-3 presents the percentages of hazardous mineral processing waste streams that are sent to treatment and disposal, in both the baseline and post-rule options. Exhibit 3-4 presents the percentages of hazardous mineral processing wastes that are recycled. In response to public comment suggesting that several mineral processing facilities currently recycle material to beneficiation units, EPA attempted to determine the point in the production process where each recycled material is reintroduced. Appendix E lists this information.

EPA then aggregated the non-reclaimed hazardous streams by solids content, based on the assumption that a facility would not build a separate stabilization facility and on-site landfill for each

¹⁴ OMB, 1992. *Circular A-94*.

¹⁵ EPA developed the recycling assumptions (percentages) using limited empirical data on the recycling of two listed wastes, K061 (emission control dust from electric arc steel furnaces) and F006 (wastewater treatment sludge from electroplating operations). More information on the derivation of the percentages in the tables can be found in Appendix A.

individual waste stream but would instead handle all wastes requiring neutralization, dewatering, stabilization, and disposal in common treatment and disposal units. That is, the facility operator would take advantage of scale economies and co-manage similar waste types. Therefore, EPA calculated the "model facility" generation rate by *mineral processing sector* (e.g., lead, copper) for hazardous waste streams containing 1 to 10 percent solids (i.e., slurries), hazardous waste streams having greater than 10 percent solids, and hazardous wastewaters.¹⁶

In contrast, quantities of residues destined for recycling were assumed to require segregation, so as to promote efficient resource recovery. EPA made the conservative assumption that each material to be recovered would require storage prior to reclamation and, therefore, that each would require its own storage unit. Consequently, for each recycled stream, EPA divided the total sector quantity stored prior to recycling by the number of facilities generating that waste stream to determine the "average facility" quantity recycled. The significant difference in the calculation of the "model facility" totals for treatment and disposal and "average facility" quantities of materials stored prior to recycling are due to the difference in management assumption, i.e., streams to be treated are co-mingled while streams to be recycled are not.

Exhibit 3-3

Proportions of Waste Streams Sent to Treatment and Disposal (in percent)

Baseline or Option	Affected Material	Percent Disposed				
		Certainty of Recycling				
		Y	Y?	YS	YS?	N
Baseline	All	0	15	25	80	100
Option 1	Bevill	100	100	100	100	100
	Non-Bevill	30	65	100	100	100
Option 2	Bevill	100	100	100	100	100
	Non-Bevill	0	25	35	85	100
Option 3	All	0	25	35	85	100
Option 4	All	0	15	25	80	100

¹⁶ EPA added the total sector generation rate of each type of waste and divided these totals by the maximum number of facilities in the sector producing waste requiring treatment. More information on this totaling process can be found in Appendix F. An example of the cost model calculations for a single sector can be found in Appendix G.

Exhibit 3-4

Proportions of Waste Streams Stored Prior to Recycling (in percent)

Baseline or Option	Affected Material	Percent Recycled				
		Certainty of Recycling				
		Y	Y?	YS	YS?	N
Baseline	All	100	85	75	20	0
Option 1	Bevill	0	0	0	0	0
	Non-Bevill	70	35	0	0	0
Option 2	Bevill	0	0	0	0	0
	Non-Bevill	100	75	65	15	0
Option 3	All	100	75	65	15	0
Option 4	All	100	85	75	20	0

Notes for Exhibits 3-3 and 3-4:

- Y** means that EPA has information indicating that the waste stream is fully recycled.
- Y?** means that EPA, based on professional judgment, believes that the waste stream could be fully recycled.
- YS** means that EPA has information indicating that a portion of the waste stream is fully recycled.
- YS?** means that EPA, based on professional judgment, believes that a portion of the waste stream could be fully recycled.
- Bevill** means that secondary materials are recycled through beneficiation or Bevill process units.
- Non-Bevill** means that secondary materials are not recycled through beneficiation or Bevill process units.

Having derived the "model facility" quantity of each type of waste (wastewaters, 1-10 percent solids, and more than 10 percent solids) going to treatment and disposal, and the "average facility" quantities of individual streams going to storage prior to recycling in each sector, EPA calculated the cost associated with each of these activities.

Development of Treatment Costs

In the analysis, the Agency made the following assumptions about waste treatment and disposal practices:

- Management of hazardous mineral processing wastes containing more than 10 percent solids involves non-permitted treatment followed by disposal of the stabilized mass in a Subtitle D unit. Treatment consists of cement stabilization, which increases the mass of waste destined for disposal to 175 percent of the mass entering stabilization.

- Management of hazardous mineral processing wastewaters and wastes containing 1 to 10 percent solids involves non-permitted treatment followed by disposal of the stabilized mass in a Subtitle D unit. Treatment consists of neutralization, followed by dewatering of the precipitated solids, and cement stabilization of the dewatered sludge. The precipitated mass from neutralization is 15 percent of the original waste stream, while the dewatered mass is 15 percent of the precipitated mass (or 2.25 percent of the original waste stream). Stabilization increases the mass of the dewatered sludge by 55 percent (or 155 percent of the mass entering stabilization).

These assumptions and their factual basis are documented in Appendix D and Appendix F.

The Agency has assumed that both pre- and post-LDR management of treated residues would occur in (primarily) on-site Subtitle D waste disposal piles, because under the baseline, affected operators would have constructed such units to be in compliance with (i.e., avoid) pre-LDR Subtitle C waste management requirements. For low volume wastes (less than or equal to 879 metric tons solids/year or 350 metric tons liquids/year), EPA has assumed that the operator would send the waste to an off-site Subtitle C facility for treatment (stabilization) and ultimate disposal in a Subtitle D unit. The Agency did not include non-hazardous waste streams in the analysis because the treatment standards in the supplemental proposed Phase IV LDR rule will not affect those wastes.

The first step in determining the cost of treatment was to compute the quantity of waste requiring each *type* of treatment at a "model facility" in each sector, because each treatment technology generates a residue which must either be further treated or disposed. For example, both wastewaters and wastes with a 1 to 10 percent solids content are assumed to be neutralized and dewatered in the same units, while the sludge (residue) generated from dewatering is mixed with waste with more than 10 percent solids, stabilized in a single stabilization unit, and disposed in a single Subtitle D waste pile. Once EPA determined the quantities of waste going to each-treatment unit (accounting for volume changes brought about by each treatment step), the Agency used costing equations (described in detail in Appendix D) to determine the capital, operating and maintenance, and closure costs of each of the treatment and disposal units. These costs were then annualized and totaled. In some sectors, there was not enough waste to justify on-site treatment and disposal, so the Agency used a unit cost to reflect shipping the waste off-site for treatment and disposal. The "model facility" treatment cost was multiplied by the number of facilities treating and disposing waste to get the total sector treatment cost.

Development of Storage Costs

To determine the costs associated with storing wastes prior to recycling, EPA assumed that wastes to be recycled are stored for 30 days or less in drums or tanks if they are liquid and for less than 90 days in drums, roll-off containers, or buildings if they have a solids content of more than 10 percent.¹⁷ To estimate the impacts of the material reclamation practices outlined above, the Agency used unit cost functions (described in detail in Appendix D) to calculate the costs associated with storing wastes in piles, surface impoundments, RCRA TCBs, and non-RCRA TCBs. Again, and in contrast to waste treatment operations, EPA determined recycling costs on a per waste stream basis, rather than a per facility basis,

¹⁷ Some of the options allow a longer period of storage: because, however, facility operators would have to build larger and more expensive storage units to take advantage of these longer periods of storage, EPA has assumed that they would attempt to minimize storage time.

because it is important in many cases that the wastes to be recycled not be commingled. To determine the total sector storage cost, EPA multiplied the cost of storage for each stream by the number of facilities generating that stream and summed these total sector stream costs.

Development of Total Costs

EPA then calculated incremental treatment and disposal costs by subtracting total sector pre-LDR treatment and disposal costs from total sector post-LDR treatment and disposal costs. EPA calculated total sector incremental storage costs in a similar manner. EPA calculated the total sector costs by adding the total sector incremental treatment costs to the total sector incremental storage costs. EPA divided this total sector cost by the number of facilities in the sector to determine the average facility costs.

3.1.3 Economic Impact Analysis

To evaluate the significance of increased waste management costs on affected facilities and industry sectors, EPA employed simple ratio analyses to yield first-order economic impact estimates. The Agency compared sector-wide estimated regulatory compliance costs with three different measures of economic activity.¹⁸

First, EPA compared regulatory costs for each sector to the estimated *value of shipments* from the plants in that sector. This provides a rough measure of the extent to which gross margins would be reduced by the increased waste management costs, or alternatively, the amount by which the affected commodity price would need to increase to maintain existing margins. The Agency recognizes that this approach produces only a very crude and preliminary estimate of ultimate economic impact on affected facilities. Unfortunately, however, this is the only ratio analysis for which the needed data were available for all of the industry sectors. EPA calculated the ratio of annualized incremental cost to the value of shipments for all four options, has defined the screening level threshold for significant impact as three percent.

Second, for 16 industry sectors where data were available, EPA compared estimated regulatory costs for each sector to the estimated *value added* by that sector. A ratio of regulatory costs to value added may be more useful in assessing regulatory impacts than a ratio of regulatory costs to shipments. In particular, a mineral processing sector (such as the primary copper industry) generally incurs substantial costs to purchase or produce the raw materials (such as copper concentrate) used in mineral processing activities. The total dollar value of shipments for a mineral processing industry thus includes not only the costs of production and profit, but also the costs of raw materials. In contrast, the value added in manufacturing measures the sales revenue minus the cost of raw materials. Thus, it presents a clearer picture of the extent of economic activity at the regulated operation, and the basis on which the firm may make profits attributable to that operation. EPA obtained value added data for copper and aluminum from

¹⁸ EPA did not consider the extent to which industry sectors may be able to pass on to their customers the costs of regulation. An industry sector's ability to pass on costs depends on two factors: (1) the elasticity of demand (if demand changes little with a change in price, industry has a greater opportunity to pass on most of the costs), and (2) the extent of the world market represented by U.S. suppliers (if U.S. suppliers represent a small portion of the world market, most of the market is unaffected by U.S. regulations and U.S. suppliers cannot pass through the costs).

a Census Bureau publication.¹⁹ The Agency obtained value added data for 14 industry sectors categorized as "primary nonferrous metals, not elsewhere classified" from the same publication, and apportioned the total value added to each of the 14 sectors according to that sector's proportion of the total value of shipments for the 14 sectors.²⁰ For this analysis, EPA used a screening level of 10 percent for significant impact.

Third, for five industry sectors where data were available, EPA compared estimated regulatory costs for each sector to the estimated profits of that sector. This ratio analysis permits a direct comparison of regulatory costs to profits, and indicates the maximum extent to which the regulation will reduce industry profits if industry cannot pass on any of the regulatory costs to customers. To conduct this analysis, EPA obtained profits data for firms known to be engaged primarily or exclusively in processing a single type of mineral. The Agency obtained these data from the Disclosure on-line commercial database, for the most recent year available in the database. (The Disclosure database, in turn, contains data taken from 10K forms that publicly-held firms must file with the Securities and Exchange Commission.) EPA based its estimate of profitability for each of the five industry sectors on the weighted average profitability of the firms in each sector for which data were available.²¹ For this analysis, EPA selected a screening level threshold for severe impacts of 100 percent.

3.2 Results

This section presents EPA's estimates of the cost and screening-level economic impacts of Options 1, 2, 3, and 4. These estimates are provided in-turn by option, followed by some brief comparisons between options. Please note that the detailed discussion of cost and economic results presented in Sections 3.2.1 and 3.2.2 focuses on the expected value case. Exhibit 3-5 highlights the differences between the minimum, expected, and maximum value cases.

Exhibit 3-5

Summary of Cost Results

	Minimum	Expected	Maximum
Option 1	\$46,000,000	\$58,000,000	\$75,000,000
Option 2	\$37,000,000	\$45,000,000	\$55,000,000
Option 3	\$5,200,000	\$8,400,000	\$13,000,000
Option 4	\$71,000	\$190,000	\$190,000

¹⁹ Bureau of the Census, U.S. Department of Commerce, *1992 Census of Manufactures, Industry Series, Smelting and Refining of Nonferrous Metals and Alloys, Industries 3331, 3334, 3339, and 3341* (Washington, DC: U.S. Department of Commerce), p. 33C-9.

²⁰ The Agency's background calculations are provided in Appendix G of the *Regulatory Impact Analysis of the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes*, December 1995.

²¹ See previous footnote.

EPA's use of the dynamic analysis contributes to some counter-intuitive results such as savings in some sectors where costs are expected. The unexpected consequences result from relative economies of scale and a low-volume wastewater treatment unit cost gap. Both are discussed further.

- *The dynamic shift and relative economies of scale.* The overall cost for an option will depend on the amount and type of material moving from treatment and disposal to recycling, the storage requirements, and the relative unit costs. For most options, at any given generation rate storage prior to recycling is less expensive than treatment and disposal. Because quantities to be treated and disposed are aggregated, while quantities to be recycled need to be stored in dedicated units, moving small quantities of materials from treatment and disposal to recycling may not produce a cost savings due to relative scale economies. For example, if a facility were treating and disposing two wastewater streams in the baseline, one generated at 100,000 mt/yr and one at 150 mt/yr, these two streams would be commingled and the unit cost of treatment in the baseline would be based on treating 100,150 mt/yr. If after the rule went into effect the smaller stream was then fully recycled, the *unit cost* of storing 150 mt/yr in a dedicated unit might be higher than the *unit cost* of treating those 150 mt/yr in the baseline (when the unit cost was based on treating 100,150 mt/yr).
- *Low-volume wastewater treatment unit cost gap.* In addition to the problem of relative scale economies, there is a low volume wastewater treatment unit cost gap. That is, using available information on pertinent treatment technologies, the smallest treatment system that can reasonably be built on-site has a capacity of 350 mt/yr, resulting in an annualized cost of about \$100 per metric ton, while off-site treatment and disposal costs \$175 per metric ton. Therefore, for facilities treating and disposing small quantities of wastewater in the baseline, a slight increase in the quantity treated and disposed (and, therefore, a slight decrease in the quantity recycled) may shift treatment from off-site to on-site. Because off-site treatment is significantly more expensive, the result of this shift is a decreased cost, rather than an increase (as would be expected).

3.2.1 Cost Analysis Results

Cost impact results are presented in Exhibits 3-6 through 3-9. The options are discussed in order from the most to the least costly.

Option 1

Under Option 1, EPA anticipates that the total expected incremental cost will be \$58,000,000, as seen in Exhibit 3-6. Twenty-six of the 29 industry sectors (90 percent) are projected to experience increased costs, one (three percent) is expected to have no additional costs, and two (seven percent) are anticipated to have cost savings. On a sector basis, the cost changes range from an expected savings of \$43,000 (tungsten) to a cost increase of \$27,000,000 (lead). Note that the cost impacts of this option fall disproportionately on the lead sector; the cost impacts estimated for the lead sector account for more than 46 percent of the total cost impacts estimated under this option.²² EPA expects five of the sectors (17 percent) to have total incremental costs greater than \$1,000,000 (alumina and aluminum, copper, elemental phosphorus, lead, and zinc). Three sectors (10 percent) are expected to have total costs between \$500,000 and \$1,000,000 (mercury, synthetic rutile, and titanium and titanium dioxide). Only

²² EPA is currently conducting additional analyses to determine whether costs to the lead sector may be overstated by the cost model.

Exhibit 3-6

Option 1 Incremental Costs

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	1,400,000	62,000	2,400,000	100,000	2,900,000	130,000
Antimony	-	-	55,000	9,200	81,000	14,000
Beryllium	-	-	40,000	20,000	800,000	400,000
Bismuth	-	-	39,000	39,000	72,000	72,000
Cadmium	-	-	63,000	31,000	2,500,000	1,200,000
Calcium	-	-	4,300	4,300	7,300	7,300
Coal Gas	-	-	-	-	220,000	220,000
Copper	10,000,000	1,000,000	10,000,000	1,000,000	10,000,000	1,000,000
Elemental Phosphorus	3,400,000	1,700,000	3,400,000	1,700,000	3,400,000	1,700,000
Fluorspar and Hydrofluoric Acid	-	-	190,000	63,000	330,000	110,000
Germanium	-	-	39,000	9,700	45,000	11,000
Lead	21,000,000	5,200,000	27,000,000	6,700,000	32,000,000	8,100,000
Magnesium and Magnesia from Brines	2,800	1,400	3,100	1,500	240,000	120,000
Mercury	-	-	680,000	97,000	1,800,000	260,000
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	16,000	1,400	16,000	1,400
Platinum Group Metals	-	-	5,900	2,000	38,000	13,000
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	140,000	68,000	170,000	83,000
Rare Earths	9,800	9,800	200,000	200,000	1,100,000	1,100,000
Rhenium	-	-	9,500	4,700	31,000	15,000
Scandium	-	-	(22,000)	(3,100)	170,000	25,000
Selenium	81,000	40,000	140,000	46,000	300,000	100,000
Synthetic Rutile	-	-	560,000	560,000	1,000,000	1,000,000
Tantalum, Columbium, and Ferrocolumbium	540,000	270,000	390,000	200,000	390,000	200,000
Tellurium	-	-	150,000	75,000	180,000	90,000
Titanium and Titanium Dioxide	170,000	83,000	920,000	130,000	1,400,000	200,000
Tungsten	-	-	(43,000)	(7,200)	73,000	12,000
Uranium	-	-	220,000	13,000	1,100,000	63,000
Zinc	9,700,000	3,200,000	11,000,000	3,700,000	13,000,000	4,200,000
Zirconium and Hafnium	-	-	210,000	110,000	1,200,000	610,000
Total	46,000,000		58,000,000		75,000,000	

Exhibit 3-7

Option 2 Incremental Costs

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	310,000	14,000	810,000	35,000	1,500,000	64,000
Antimony	-	-	24,000	4,000	38,000	6,400
Beryllium	-	-	19,000	9,300	350,000	180,000
Bismuth	-	-	10,000	10,000	22,000	22,000
Cadmium	-	-	53,000	27,000	570,000	280,000
Calcium	-	-	4,300	4,300	7,300	7,300
Coal Gas	-	-	-	-	220,000	220,000
Copper	10,000,000	1,000,000	10,000,000	1,000,000	10,000,000	1,000,000
Elemental Phosphorus	3,400,000	1,700,000	3,400,000	1,700,000	3,400,000	1,700,000
Fluorspar and Hydrofluoric Acid	-	-	52,000	17,000	84,000	28,000
Germanium	-	-	15,000	3,800	17,000	4,300
Lead	21,000,000	5,200,000	27,000,000	6,700,000	32,000,000	8,100,000
Magnesium and Magnesia from Brines	2,800	1,400	3,900	2,000	49,000	25,000
Mercury	-	-	680,000	97,000	1,800,000	260,000
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	16,000	1,400	16,000	1,400
Platinum Group Metals	-	-	4,600	1,500	11,000	3,700
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	46,000	23,000	57,000	28,000
Rare Earths	9,800	9,800	200,000	200,000	980,000	980,000
Rhenium	-	-	9,500	4,700	31,000	15,000
Scandium	-	-	(94,000)	(13,000)	44,000	6,300
Selenium	81,000	40,000	100,000	34,000	160,000	54,000
Synthetic Rutile	-	-	80,000	80,000	150,000	150,000
Tantalum, Columbium, and Ferrocolumbium	170,000	86,000	130,000	67,000	130,000	67,000
Tellurium	-	-	12,000	5,800	40,000	20,000
Titanium and Titanium Dioxide	76,000	38,000	240,000	34,000	380,000	55,000
Tungsten	-	-	(43,000)	(7,200)	73,000	12,000
Uranium	-	-	47,000	2,700	100,000	6,200
Zinc	1,500,000	490,000	2,400,000	790,000	2,700,000	890,000
Zirconium and Hafnium	-	-	100,000	50,000	320,000	160,000
Total	37,000,000		45,000,000		55,000,000	

Exhibit 3-8

Option 3 Incremental Costs

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	310,000	14,000	810,000	35,000	1,500,000	64,000
Antimony	-	-	24,000	4,000	38,000	6,400
Beryllium	-	-	19,000	9,300	350,000	180,000
Bismuth	-	-	10,000	10,000	22,000	22,000
Cadmium	-	-	24,000	12,000	490,000	250,000
Calcium	-	-	1,400	1,400	1,400	1,400
Coal Gas	-	-	-	-	68,000	68,000
Copper	2,600,000	260,000	2,500,000	250,000	2,600,000	260,000
Elemental Phosphorus	480,000	240,000	480,000	240,000	480,000	240,000
Fluorspar and Hydrofluoric Acid	-	-	52,000	17,000	84,000	28,000
Germanium	-	-	15,000	3,800	17,000	4,300
Lead	59,000	15,000	1,100,000	280,000	2,100,000	510,000
Magnesium and Magnesia from Brines	2,800	1,400	3,900	2,000	49,000	25,000
Mercury	-	-	190,000	27,000	520,000	74,000
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	16,000	1,400	16,000	1,400
Platinum Group Metals	-	-	4,600	1,500	11,000	3,700
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	46,000	23,000	57,000	28,000
Rare Earths	5,200	5,200	94,000	94,000	320,000	320,000
Rhenium	-	-	3,700	1,800	6,200	3,100
Scandium	-	-	(94,000)	(13,000)	44,000	6,300
Selenium	30,000	15,000	44,000	15,000	130,000	44,000
Synthetic Rutile	-	-	80,000	80,000	150,000	150,000
Tantalum, Columbium, and Ferrocolumbium	170,000	86,000	130,000	67,000	130,000	67,000
Tellurium	-	-	12,000	5,800	40,000	20,000
Titanium and Titanium Dioxide	76,000	38,000	240,000	34,000	380,000	55,000
Tungsten	-	-	27,000	4,400	36,000	6,100
Uranium	-	-	47,000	2,700	100,000	6,200
Zinc	1,500,000	490,000	2,400,000	790,000	2,700,000	890,000
Zirconium and Hafnium	-	-	100,000	50,000	320,000	160,000
Total	5,200,000		8,400,000		13,000,000	

Exhibit 3-9

Option 4 Incremental Costs

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	32,000	1,400	32,000	1,400	32,000	1,400
Antimony	-	-	8,500	1,400	8,500	1,400
Beryllium	-	-	2,800	1,400	2,800	1,400
Bismuth	-	-	1,400	1,400	1,400	1,400
Cadmium	-	-	2,800	1,400	2,800	1,400
Calcium	-	-	1,400	1,400	1,400	1,400
Coal Gas	-	-	-	-	1,400	1,400
Copper	14,000	1,400	14,000	1,400	14,000	1,400
Elemental Phosphorus	2,800	1,400	2,800	1,400	2,800	1,400
Fluorspar and Hydrofluoric Acid	-	-	4,200	1,400	4,200	1,400
Germanium	-	-	5,600	1,400	5,600	1,400
Lead	5,600	1,400	5,600	1,400	5,600	1,400
Magnesium and Magnesia from Brines	2,800	1,400	2,800	1,400	2,800	1,400
Mercury	-	-	9,900	1,400	9,900	1,400
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	16,000	1,400	16,000	1,400
Platinum Group Metals	-	-	4,200	1,400	4,200	1,400
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	2,800	1,400	2,800	1,400
Rare Earths	1,400	1,400	1,400	1,400	1,400	1,400
Rhenium	-	-	2,800	1,400	2,800	1,400
Scandium	-	-	9,900	1,400	9,900	1,400
Selenium	2,800	1,400	4,200	1,400	4,200	1,400
Synthetic Rutile	-	-	1,400	1,400	1,400	1,400
Tantalum, Columbium, and Ferrocolumbium	2,800	1,400	2,800	1,400	2,800	1,400
Tellurium	-	-	2,800	1,400	2,800	1,400
Titanium and Titanium Dioxide	2,800	1,400	9,900	1,400	9,900	1,400
Tungsten	-	-	8,500	1,400	8,500	1,400
Uranium	-	-	24,000	1,400	24,000	1,400
Zinc	4,200	1,400	4,200	1,400	4,200	1,400
Zirconium and Hafnium	-	-	2,800	1,400	2,800	1,400
Total	71,000		190,000		190,000	

one sector, coal gas, is expected to experience no cost changes. Finally, EPA projects that the scandium and tungsten sectors will experience cost savings of \$22,000 and \$43,000, respectively.

On a per facility basis, average expected incremental costs range from a savings of \$7,300 (tungsten) to an increase of \$6,700,000 (lead). EPA projects that facilities in four sectors (14 percent) will incur impacts in excess of \$1,000,000 (copper, elemental phosphorus, lead, and zinc). Facilities in only one other sector (three percent) are expected to have average impacts between \$500,000 and \$600,000 (synthetic rutile), while facilities in another five sectors (17 percent) are projected to have average impacts between \$100,000 and \$200,000 (alumina and aluminum; rare earths; tantalum columbium and ferrocolumbium; titanium and titanium dioxide; tellurium, and zirconium and hafnium). The average expected savings for facilities in the scandium and tungsten sectors are \$3,100 and \$7,200, respectively.

Option 2

Under Option 2, EPA expects the total incremental cost to be \$45,000,000, as shown in Exhibit 3-7. Twenty-six of the industry sectors (90 percent) are projected to experience increased costs, one (three percent) is expected to have no additional costs, and two (seven percent) are anticipated to see cost savings. On a sector basis, incremental costs range from an expected savings of \$94,000 (scandium) to a cost increase of \$27,000,000 (lead). Again, as was the case for Option 1, cost impacts fall disproportionately on the lead sector; lead sector cost impacts account for sixty percent of total industry impacts under this option.²³ EPA expects four sectors (14 percent) to have total incremental costs greater than \$1,000,000 (copper, elemental phosphorus, lead, and zinc) and two (seven percent) to have total costs between \$500,000 and \$800,000 (alumina and aluminum, and mercury). As with Option 1, only one sector, coal gas, is expected to experience no cost changes. Finally, EPA expects that the scandium and tungsten sectors will incur cost savings of \$94,000 and \$43,000, respectively.

On a per facility basis, average incremental costs range from a savings of \$13,000 (scandium) to a cost increase of \$6,700,000 (lead). EPA expects facilities in three sectors (10 percent) to incur impacts in excess of \$1,000,000 (copper, elemental phosphorus, and lead) and facilities in one other sector (three percent) to have cost increases of more than \$700,000 (zinc). Facilities in one sector (rare earths) are expected to incur average impacts of \$200,000. Facilities in the remainder of the sectors (83 percent) are expected to have average cost increases of less than \$100,000, except for those in coal gas (no impacts), scandium (savings of \$13,000), and tungsten (savings of \$7,200).

Option 3

Under Option 3, the total expected incremental cost is \$8,400,000; these impacts are shown in Exhibit 3-8. Twenty-seven of the industry sectors (93 percent) are projected to experience increased costs, one sector (three percent) is expected to have no additional costs, and one (three percent) is anticipated to realize cost savings. On a sector basis, incremental costs range from an expected savings of \$94,000 (scandium) to an increase of \$2,500,000 (copper). EPA expects three sectors (10 percent) to experience total incremental costs greater than \$1,000,000 (copper, lead, and zinc) and one (three percent) to have total costs of more than \$800,000 (alumina and aluminum). The one sector with no expected costs is coal gas. Finally, EPA expects that the only sector to experience cost savings will be the scandium sector (\$94,000).

²³ See previous footnote.

On a per facility basis, average incremental expected costs range from a savings of \$13,000 (scandium) to an increase of \$790,000 (zinc). Facilities in three other industry sectors (10 percent) are expected to have cost increases between \$100,000 and \$500,000 (copper, elemental phosphorus, and lead). Facilities in the remainder of the sectors (83 percent) are expected to have cost increases of less than \$100,000, except for coal gas (no impacts) and scandium (savings of \$13,000).

Option 4

Under Option 4, the total expected incremental cost to industry is \$190,000, significantly lower than for the other options. These impacts are shown in Exhibit 3-9. Twenty-eight sectors are projected to experience increased costs, with one sector experiencing no change in costs. Expected incremental costs range from zero (coal gas) to \$32,000 (alumina and aluminum). Four sectors under this option are expected to experience costs of more than \$10,000 (alumina and aluminum; copper; molybdenum, ferromolybdenum, and ammonium molybdate; and uranium).

On a per facility basis, average incremental expected costs range from zero (coal gas) to \$1,400 for all other sectors. The reason for the uniformity in per facility costs is that the only costs that the Agency estimates will be incurred by industry under this option are recordkeeping and reporting requirements. No other cost impacts are estimated for any of the sectors because the Agency expects that under this option, management practices will not change, relative to the baseline. For example, facility operators will continue to store materials to be recycled in unlined land-based units, so no new costs attributable to storage are expected.

3.2.2 Economic Impact Analysis Results

As described above, EPA conducted three ratio analyses comparing regulatory costs to the following three financial indicators: (1) value of shipments, (2) value added, and (3) gross profits. Data were available to determine the ratio of regulatory costs to value of shipments for all 29 industry sectors affected. However, data were available for only 16 industry sectors to determine the ratio using value added and for only six industry sectors to determine the ratio using gross profits. This section presents the results of the three analyses.

Ratio of Regulatory Costs to Value of Shipments

Exhibits 3-10 through 3-13 present the results of the value of shipments analysis.

Economic impacts expressed as a ratio of regulatory costs to the value of shipments suggest that Options 1 and 2 impose the most significant impact on affected industries and Option 4 imposes the least impact. Option 1 imposes significant cost impacts (defined as 3 percent of the value of shipments for the sake of this analysis) on five of the 29 industrial sectors (seventeen percent of the affected sectors) in the expected value case. EPA projects significantly affected sectors to include cadmium (6 percent impact), lead (13 percent), mercury (176 percent), pyrobitumens, mineral waxes, and natural asphalt (56 percent), and selenium (5 percent). The remaining 24 sectors (83 percent of all affected sectors) are expected to experience economic impacts of three percent or less.

Option 2 would impose burdens very similar to those estimated for Option 1. Like Option 1, Option 2 imposes significant cost impacts on five of the 29 industrial sectors in the expected value case. As was the case for Option 1 as well, EPA expects significantly affected sectors to include cadmium (5 percent), lead (13 percent), mercury (176 percent), pyrobitumens, mineral waxes, and natural asphalt (18

Exhibit 3-10

Option 1 Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	1,400,000	2,400,000	2,900,000	0.03	0.06	0.07
Antimony	18,000	1,764	31,752,000	-	55,000	81,000	0.00	0.17	0.26
Beryllium	159	352,640	56,069,760	-	40,000	800,000	0.00	0.07	1.43
Bismuth	1,100	7,824	8,606,400	-	39,000	72,000	0.00	0.45	0.84
Cadmium	1,050	992	1,041,600	-	63,000	2,500,000	0.00	6.05	240.02
Calcium	1,200	4,605	5,526,000	-	4,300	7,300	0.00	0.08	0.13
Coal Gas			170,000,000	-	-	220,000	0.00	0.00	0.13
Copper	1,770,000	2,029	3,591,330,000	10,000,000	10,000,000	10,000,000	0.28	0.28	0.28
Elemental Phosphorus	311,000	1,833	570,063,000	3,400,000	3,400,000	3,400,000	0.60	0.60	0.60
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	190,000	330,000	0.00	1.64	2.85
Germanium	10	1,060,000	10,600,000	-	39,000	45,000	0.00	0.37	0.42
Lead	290,000	706	204,740,000	21,000,000	27,000,000	32,000,000	10.26	13.19	15.63
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	2,800	3,100	240,000	0.00	0.00	0.05
Mercury	70	5,512	385,840	-	680,000	1,800,000	0.00	176.24	466.51
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	16,000	16,000	0.00	0.01	0.01
Platinum Group Metals			53,203,971	-	5,900	38,000	0.00	0.01	0.07
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	140,000	170,000	0.00	56.00	68.00
Rare Earths			57,372,120	9,800	200,000	1,100,000	0.02	0.35	1.92
Rhenium	5	1,200,000	6,000,000	-	9,500	31,000	0.00	0.16	0.52
Scandium	25	1,500,000	37,500,000	-	(22,000)	170,000	0.00	-0.06	0.45
Selenium	250	11,246	2,811,500	81,000	140,000	300,000	2.88	4.98	10.67
Synthetic Rutile	140,000	345	48,300,000	-	560,000	1,000,000	0.00	1.16	2.07
Tantalum, Columbium, and Ferrocolumbium			60,897,400	540,000	390,000	390,000	0.89	0.64	0.64
Tellurium	60	59,508	3,570,480	-	150,000	180,000	0.00	4.20	5.04
Titanium and Titanium Dioxide			2,516,300,000	170,000	920,000	1,400,000	0.01	0.04	0.06
Tungsten	9,408	40	376,240	-	(43,000)	73,000	0.00	-11.43	19.40
Uranium			40,734,000	-	220,000	1,100,000	0.00	0.54	2.70
Zinc	505,000	1,014	512,070,000	9,700,000	11,000,000	13,000,000	1.89	2.15	2.54
Zirconium and Hafnium			379,899,000	-	210,000	1,200,000	0.00	0.06	0.32
Total				46,000,000	58,000,000	75,000,000			

April 15, 1997

Exhibit 3-11

Option 2 Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	310,000	810,000	1,500,000	0.01	0.02	0.03
Antimony	18,000	1,764	31,752,000	-	24,000	38,000	0.00	0.08	0.12
Beryllium	159	352,640	56,069,760	-	19,000	350,000	0.00	0.03	0.62
Bismuth	1,100	7,824	8,606,400	-	10,000	22,000	0.00	0.12	0.26
Cadmium	1,050	992	1,041,600	-	53,000	570,000	0.00	5.09	54.72
Calcium	1,200	4,605	5,526,000	-	4,300	7,300	0.00	0.08	0.13
Coal Gas			170,000,000	-	-	220,000	0.00	0.00	0.13
Copper	1,770,000	2,029	3,591,330,000	10,000,000	10,000,000	10,000,000	0.28	0.28	0.28
Elemental Phosphorus	311,000	1,833	570,063,000	3,400,000	3,400,000	3,400,000	0.60	0.60	0.60
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	52,000	84,000	0.00	0.45	0.73
Germanium	10	1,060,000	10,600,000	-	15,000	17,000	0.00	0.14	0.16
Lead	290,000	706	204,740,000	21,000,000	27,000,000	32,000,000	10.26	13.19	15.63
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	2,800	3,900	49,000	0.00	0.00	0.01
Mercury	70	5,512	385,840	-	680,000	1,800,000	0.00	176.24	466.51
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	16,000	16,000	0.00	0.01	0.01
Platinum Group Metals			53,203,971	-	4,600	11,000	0.00	0.01	0.02
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	46,000	57,000	0.00	18.40	22.80
Rare Earths			57,372,120	9,800	200,000	980,000	0.02	0.35	1.71
Rhenium	5	1,200,000	6,000,000	-	9,500	31,000	0.00	0.16	0.52
Scandium	25	1,500,000	37,500,000	-	(94,000)	44,000	0.00	-0.25	0.12
Selenium	250	11,246	2,811,500	81,000	100,000	160,000	2.88	3.56	5.69
Synthetic Rutile	140,000	345	48,300,000	-	80,000	150,000	0.00	0.17	0.31
Tantalum, Columbium, and Ferrocolumbium			60,897,400	170,000	130,000	130,000	0.28	0.21	0.21
Tellurium	60	59,508	3,570,480	-	12,000	40,000	0.00	0.34	1.12
Titanium and Titanium Dioxide			2,516,300,000	76,000	240,000	380,000	0.00	0.01	0.02
Tungsten	9,406	40	376,240	-	(43,000)	73,000	0.00	-11.43	19.40
Uranium			40,734,000	-	47,000	100,000	0.00	0.12	0.25
Zinc	505,000	1,014	512,070,000	1,500,000	2,400,000	2,700,000	0.29	0.47	0.53
Zirconium and Hafnium			379,899,000	-	100,000	320,000	0.00	0.03	0.08
Total				37,000,000	45,000,000	55,000,000			

April 15, 1997

Exhibit 3-12

Option 3 Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	310,000	810,000	1,500,000	0.01	0.02	0.03
Antimony	18,000	1,764	31,752,000	-	24,000	38,000	0.00	0.08	0.12
Beryllium	159	352,640	56,069,760	-	19,000	350,000	0.00	0.03	0.62
Bismuth	1,100	7,824	8,606,400	-	10,000	22,000	0.00	0.12	0.26
Cadmium	1,050	992	1,041,600	-	24,000	490,000	0.00	2.30	47.04
Calcium	1,200	4,605	5,526,000	-	1,400	1,400	0.00	0.03	0.03
Coal Gas			170,000,000	-	-	68,000	0.00	0.00	0.04
Copper	1,770,000	2,029	3,591,330,000	2,600,000	2,500,000	2,600,000	0.07	0.07	0.07
Elemental Phosphorus	311,000	1,833	570,063,000	480,000	480,000	480,000	0.08	0.08	0.08
Fluorspar and Hydrofluoric Acid	80,000	193	11,580,000	-	52,000	84,000	0.00	0.45	0.73
Germanium	10	1,060,000	10,600,000	-	15,000	17,000	0.00	0.14	0.16
Lead	290,000	706	204,740,000	59,000	1,100,000	2,100,000	0.03	0.54	1.03
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	2,800	3,900	49,000	0.00	0.00	0.01
Mercury	70	5,512	385,840	-	190,000	520,000	0.00	49.24	134.77
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	16,000	16,000	0.00	0.01	0.01
Platinum Group Metals			53,203,971	-	4,600	11,000	0.00	0.01	0.02
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	46,000	57,000	0.00	18.40	22.80
Rare Earths			57,372,120	5,200	94,000	320,000	0.01	0.16	0.56
Rhenium	5	1,200,000	6,000,000	-	3,700	6,200	0.00	0.06	0.10
Scandium	25	1,500,000	37,500,000	-	(94,000)	44,000	0.00	-0.25	0.12
Selenium	250	11,246	2,811,500	30,000	44,000	130,000	1.07	1.57	4.62
Synthetic Rutile	140,000	345	48,300,000	-	80,000	150,000	0.00	0.17	0.31
Tantalum, Columbium, and Ferrocolumbium			60,897,400	170,000	130,000	130,000	0.28	0.21	0.21
Tellurium	60	59,508	3,570,480	-	12,000	40,000	0.00	0.34	1.12
Titanium and Titanium Dioxide			2,516,300,000	76,000	240,000	380,000	0.00	0.01	0.02
Tungsten	9,406	40	376,240	-	27,000	36,000	0.00	7.18	9.57
Uranium			40,734,000	-	47,000	100,000	0.00	0.12	0.25
Zinc	505,000	1,014	512,070,000	1,500,000	2,400,000	2,700,000	0.29	0.47	0.53
Zirconium and Hafnium			379,899,000	-	100,000	320,000	0.00	0.03	0.08
Total				5,200,000	8,400,000	13,000,000			

April 15, 1997

Exhibit 3-13

Option 4 Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	32,000	32,000	32,000	0.00	0.00	0.00
Antimony	18,000	1,764	31,752,000	-	8,500	8,500	0.00	0.03	0.03
Beryllium	159	352,640	56,069,760	-	2,800	2,800	0.00	0.00	0.00
Bismuth	1,100	7,824	8,606,400	-	1,400	1,400	0.00	0.02	0.02
Cadmium	1,050	992	1,041,600	-	2,800	2,800	0.00	0.27	0.27
Calcium	1,200	4,605	5,526,000	-	1,400	1,400	0.00	0.03	0.03
Coal Gas			170,000,000	-	-	1,400	0.00	0.00	0.00
Copper	1,770,000	2,029	3,591,330,000	14,000	14,000	14,000	0.00	0.00	0.00
Elemental Phosphorus	311,000	1,833	570,063,000	2,800	2,800	2,800	0.00	0.00	0.00
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	4,200	4,200	0.00	0.04	0.04
Germanium	10	1,060,000	10,600,000	-	5,600	5,600	0.00	0.05	0.05
Lead	290,000	708	204,740,000	5,600	5,600	5,600	0.00	0.00	0.00
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	2,800	2,800	2,800	0.00	0.00	0.00
Mercury	70	5,512	385,840	-	9,900	9,900	0.00	2.57	2.57
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	16,000	16,000	0.00	0.01	0.01
Platinum Group Metals			53,203,971	-	4,200	4,200	0.00	0.01	0.01
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	2,800	2,800	0.00	1.12	1.12
Rare Earths			57,372,120	1,400	1,400	1,400	0.00	0.00	0.00
Rhenium	5	1,200,000	6,000,000	-	2,800	2,800	0.00	0.05	0.05
Scandium	25	1,500,000	37,500,000	-	9,900	9,900	0.00	0.03	0.03
Selenium	250	11,246	2,811,500	2,800	4,200	4,200	0.10	0.15	0.15
Synthetic Rutile	140,000	345	48,300,000	-	1,400	1,400	0.00	0.00	0.00
Tantalum, Columbium, and Ferrocolumbium			60,897,400	2,800	2,800	2,800	0.00	0.00	0.00
Tellurium	60	59,508	3,570,480	-	2,800	2,800	0.00	0.08	0.08
Titanium and Titanium Dioxide			2,516,300,000	2,800	9,900	9,900	0.00	0.00	0.00
Tungsten	9,408	40	376,240	-	8,500	8,500	0.00	2.26	2.26
Uranium			40,734,000	-	24,000	24,000	0.00	0.06	0.06
Zinc	505,000	1,014	512,070,000	4,200	4,200	4,200	0.00	0.00	0.00
Zirconium and Hafnium			379,899,000	-	2,800	2,800	0.00	0.00	0.00
Total				71,000	190,000	190,000			

April 15, 1997

percent), and selenium (3.5 percent). The remaining 24 sectors (83 percent) are expected to experience economic impacts between zero and three percent. Note that the impact of Option 2, expressed as a percentage of the value of shipments, is nearly the same under Options 1 and 2.

Option 3 imposes significantly smaller impacts across all sectors. Significant impacts are expected for only three sectors (ten percent of the affected sectors) in the expected value case. These sectors are: mercury (49 percent), pyrobitumens, mineral waxes, and natural asphalt (18 percent), and tungsten (7 percent). In addition, fourteen sectors are expected to realize negative impacts of less than one tenth of a percent under this option. The remaining 12 sectors (41 percent of the affected sectors) are expected to experience economic impacts between one tenth of a percent and three percent.

Finally, Option 4 is projected to impose the lowest cost burden on affected industrial sectors of any of the options. EPA estimates that no sectors would experience significant impacts under Option 4. The most heavily affected sector under this option would be the mercury sector (approximately 2.5 percent), and the second most affected sector would be the tungsten sector (approximately 2 percent). Impacts would be negligible for most other sectors; 24 of the 29 sectors would experience an impact of less than one tenth of a percent.

The severity of predicted economic impacts does not in all cases reflect the magnitude of increased waste treatment costs estimated in this analysis. Facilities in several sectors are projected to experience significant cost increases but are not expected to suffer serious economic impact, because of high production rates and/or because the commodities that they produce have a high unit market price. Examples include alumina and aluminum, copper, magnesium, molybdenum, titanium, and zinc. Plants in other sectors (e.g., calcium, platinum group metals) are projected to experience low impacts because estimated incremental waste treatment costs are relatively modest.

In contrast, the sectors that are projected to experience the most significant impacts have both moderate to high incremental waste management costs and low commodity production rates, a low commodity price, or both. Prominent examples in this category include cadmium, selenium, and particularly, pyrobitumens, mineral waxes, and natural asphalt. It is worthy of note, however, that several of these commodities are co-products. That is, their principal or sole source of production is another, generally much larger mineral production operation. Consequently, while new waste management controls (and their costs) might threaten the economic viability of production of these commodities, they would generally not threaten the viability of the larger operation. This phenomenon is critically important to evaluating potential impacts on a number of sectors projected to experience significant cost/economic impacts in this analysis. Exhibit 3-14 displays the relationships between some of these sectors and their larger associated commodity production operation(s).

Ratio of Regulatory Costs to Value Added

Because value added is less than value of shipments, the ratio of regulatory costs to value added will be higher than the ratio of regulatory costs to shipments. EPA obtained data on value added for 16 mineral industry sectors. Detailed results of the value-added impact analysis are presented in Exhibits 3-15 through 3-18.

Exhibit 3-14

Relationships Among Mineral Commodity Production Operations

Affected Commodity Sector	Primary Associated Commodity
Cadmium	Zinc
Mercury	Gold
Selenium	Copper
Antimony	Lead, silver/copper
Bismuth	Lead, copper/lead
Rhenium	Molybdenum
Tellurium	Copper

Analysis of costs as a percentage of value added indicates that as with cost impacts and other economic impacts, Option 1 is the most burdensome and Option 4 is the least burdensome. For the sake of this analysis, EPA defined significant economic impacts as greater than 10 percent. For Option 1, EPA anticipates that five of the 16 industry sectors (31 percent of the sectors included in this analysis) will be significantly affected (lead, cadmium, selenium, tellurium, and zinc). Under Option 2, three of the 16 sectors (19 percent of the sectors analyzed) are expected to be significantly affected (lead, cadmium and selenium). EPA estimates that Option 3 will significantly impact the cadmium and selenium sectors (13 percent of the sectors analyzed). Finally, EPA expects Option 4 would result in no economic impacts for any of the 16 sectors examined.

Ratio of Regulatory Costs to Profits

Comparing regulatory costs to profits allows one to estimate how the costs of regulations will affect an industry's bottom line. Incremental costs that exceed a company's or industry's profits over an extended period generally will result in facility closures and exit from the industry in question. EPA obtained limited data on profits for five industry sectors.

Results of the screening level economic impact analysis using profits data are presented in Exhibits 3-19 through 3-22. None of the five industry sectors for which data were available are projected to have severe cost impacts (defined as costs that were greater than estimated industry profits) under any option. In fact, impacts exceed one percent in the expected value case only for the copper sector and only under Options 1 and 2. Even under the maximum value case, impacts exceed five percent only for the beryllium sector under Option 1. The Agency recognizes the limitations inherent in this approach, principally the likelihood that the reported gross income (before tax) for the companies comprising the five sector sample includes earnings from activities that may be unaffected by today's proposal, and therefore, may be overestimated for purposes of analyzing economic impacts.

Exhibit 3-15
Option 1 Impacts (Value Added Analysis)

Sector	Incremental Sector Cost				Economic Impact		
	Estimated Value Added	Minimum	\$		(Percent of Value Added)		
			Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	1,609,800,000	1,400,000	2,400,000	2,900,000	0.1%	0.1%	0.2%
Antimony	3,381,146	-	55,000	81,000	0.0%	1.6%	2.4%
Beryllium	5,970,650	-	40,000	800,000	0.0%	0.7%	13.4%
Bismuth	916,462	-	39,000	72,000	0.0%	4.3%	7.9%
Cadmium	110,916	-	63,000	2,500,000	0.0%	56.8%	2254.0%
Copper	947,900,000	10,000,000	10,000,000	10,000,000	1.1%	1.1%	1.1%
Germanium	1,128,753	-	39,000	45,000	0.0%	3.5%	4.0%
Lead	21,801,962	21,000,000	27,000,000	32,000,000	96.3%	123.8%	146.8%
Magnesium and Magnesia from Brines	49,702,916	2,800	3,100	240,000	0.0%	0.0%	0.5%
Platinum Group Metals	5,665,483	-	5,900	38,000	0.0%	0.1%	0.7%
Rhenium	638,917	-	9,500	31,000	0.0%	1.5%	4.9%
Selenium	299,386	81,000	140,000	300,000	27.1%	46.8%	100.2%
Tellurium	380,206	-	150,000	180,000	0.0%	39.5%	47.3%
Titanium and Titanium Dioxide	267,950,952	170,000	920,000	1,400,000	0.1%	0.3%	0.5%
Zinc	54,528,333	9,700,000	11,000,000	13,000,000	17.8%	20.2%	23.8%
Zirconium and Hafnium	40,453,960	-	210,000	1,200,000	0.0%	0.5%	3.0%

Exhibit 3-16
Option 2 Impacts (Value Added Analysis)

Sector	Incremental Sector Cost				Economic Impact		
	Estimated Value Added	Minimum	\$		(Percent of Value Added)		
			Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	1,609,800,000	310,000	810,000	1,500,000	0.0%	0.1%	0.1%
Antimony	3,381,146	-	24,000	38,000	0.0%	0.7%	1.1%
Beryllium	5,970,650	-	19,000	350,000	0.0%	0.3%	5.9%
Bismuth	916,462	-	10,000	22,000	0.0%	1.1%	2.4%
Cadmium	110,916	-	53,000	570,000	0.0%	47.8%	513.9%
Copper	947,900,000	10,000,000	10,000,000	10,000,000	1.1%	1.1%	1.1%
Germanium	1,128,753	-	15,000	17,000	0.0%	1.3%	1.5%
Lead	21,801,962	21,000,000	27,000,000	32,000,000	96.3%	123.8%	146.8%
Magnesium and Magnesia from Brines	49,702,916	2,800	3,900	49,000	0.0%	0.0%	0.1%
Platinum Group Metals	5,665,483	-	4,600	11,000	0.0%	0.1%	0.2%
Rhenium	638,917	-	9,500	31,000	0.0%	1.5%	4.9%
Selenium	299,386	81,000	100,000	160,000	27.1%	33.4%	53.4%
Tellurium	380,206	-	12,000	40,000	0.0%	3.2%	10.5%
Titanium and Titanium Dioxide	267,950,952	76,000	240,000	380,000	0.0%	0.1%	0.1%
Zinc	54,528,333	1,500,000	2,400,000	2,700,000	2.8%	4.4%	5.0%
Zirconium and Hafnium	40,453,960	-	100,000	320,000	0.0%	0.2%	0.8%

April 15, 1997

Exhibit 3-17
Option 3 Impacts (Value Added Analysis)

Sector	Incremental Sector Cost				Economic Impact		
	Estimated Value Added	Minimum	Expected	Maximum	(Percent of Value Added)		
					Minimum	Expected	Maximum
Alumina and Aluminum	1,609,800,000	310,000	810,000	1,500,000	0.0%	0.1%	0.1%
Antimony	3,381,146	-	24,000	38,000	0.0%	0.7%	1.1%
Beryllium	5,970,650	-	19,000	350,000	0.0%	0.3%	5.9%
Bismuth	916,462	-	10,000	22,000	0.0%	1.1%	2.4%
Cadmium	110,916	-	24,000	490,000	0.0%	21.6%	441.8%
Copper	947,900,000	2,600,000	2,500,000	2,600,000	0.3%	0.3%	0.3%
Germanium	1,128,753	-	15,000	17,000	0.0%	1.3%	1.5%
Lead	21,801,962	59,000	1,100,000	2,100,000	0.3%	5.0%	9.6%
Magnesium and Magnesia from Brines	49,702,916	2,800	3,900	49,000	0.0%	0.0%	0.1%
Platinum Group Metals	5,665,483	-	4,600	11,000	0.0%	0.1%	0.2%
Rhenium	638,917	-	3,700	6,200	0.0%	0.6%	1.0%
Selenium	299,386	30,000	44,000	130,000	10.0%	14.7%	43.4%
Tellurium	380,206	-	12,000	40,000	0.0%	3.2%	10.5%
Titanium and Titanium Dioxide	267,950,952	76,000	240,000	380,000	0.0%	0.1%	0.1%
Zinc	54,528,333	1,500,000	2,400,000	2,700,000	2.8%	4.4%	5.0%
Zirconium and Hafnium	40,453,960	-	100,000	320,000	0.0%	0.2%	0.8%

April 15, 1997

Exhibit 3-18
Option 4 Impacts (Value Added Analysis)

Sector	Estimated Value Added	Incremental Sector Cost \$			Economic Impact (Percent of Value Added)		
		Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	1,609,800,000	32,000	32,000	32,000	0.0%	0.0%	0.0%
Antimony	3,381,146	-	8,500	8,500	0.0%	0.3%	0.3%
Beryllium	5,970,650	-	2,800	2,800	0.0%	0.0%	0.0%
Bismuth	916,462	-	1,400	1,400	0.0%	0.2%	0.2%
Cadmium	110,916	-	2,800	2,800	0.0%	2.5%	2.5%
Copper	947,900,000	14,000	14,000	14,000	0.0%	0.0%	0.0%
Germanium	1,128,753	-	5,600	5,600	0.0%	0.5%	0.5%
Lead	21,801,962	5,600	5,600	5,600	0.0%	0.0%	0.0%
Magnesium and Magnesia from Brines	49,702,916	2,800	2,800	2,800	0.0%	0.0%	0.0%
Platinum Group Metals	5,665,483	-	4,200	4,200	0.0%	0.1%	0.1%
Rhenium	638,917	-	2,800	2,800	0.0%	0.4%	0.4%
Selenium	299,386	2,800	4,200	4,200	0.9%	1.4%	1.4%
Tellurium	380,206	-	2,800	2,800	0.0%	0.7%	0.7%
Titanium and Titanium Dioxide	267,950,952	2,800	9,900	9,900	0.0%	0.0%	0.0%
Zinc	54,528,333	4,200	4,200	4,200	0.0%	0.0%	0.0%
Zirconium and Hafnium	40,453,960	-	2,800	2,800	0.0%	0.0%	0.0%

April 15, 1997

Exhibit 3-19
Option 1 Impacts (Profits Analysis)

Sector	Estimated Profits \$	Incremental Sector Cost \$			Economic Impact (Percent of Profits)		
		Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	720,221,231	1,400,000	2,400,000	2,900,000	0.19	0.33	0.40
Beryllium	14,904,254	0	40,000	800,000	0.00	0.27	5.37
Copper	956,454,882	10,000,000	10,000,000	10,000,000	1.05	1.05	1.05
Platinum Group Metals	8,229,711	-	5,900	38,000	0.00	0.07	0.46
Titanium and Titanium Dioxide	1,480,901,274	170,000	920,000	1,400,000	0.01	0.06	0.09

Exhibit 3-20
Option 2 Impacts (Profits Analysis)

Sector	Estimated Profits \$	Incremental Sector Cost \$			Economic Impact (Percent of Profits)		
		Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	720,221,231	310,000	810,000	1,500,000	0.04	0.11	0.21
Beryllium	14,904,254	0	19,000	350,000	0.00	0.13	2.35
Copper	956,454,882	10,000,000	10,000,000	10,000,000	1.05	1.05	1.05
Platinum Group Metals	8,229,711	-	4,600	11,000	0.00	0.06	0.13
Titanium and Titanium Dioxide	1,480,901,274	76,000	240,000	380,000	0.01	0.02	0.03

Exhibit 3-21
Option 3 Impacts (Profits Analysis)

Sector	Estimated Profits \$	Sector Cost \$			Economic Impact (Percent of Profits)		
		Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	720,221,231	310,000	810,000	1,500,000	0.04	0.11	0.21
Beryllium	14,904,254	0	19,000	350,000	0.00	0.13	2.35
Copper	956,454,882	2,600,000	2,500,000	2,600,000	0.27	0.26	0.27
Platinum Group Metals	8,229,711	-	4,600	11,000	0.00	0.06	0.13
Titanium and Titanium Dioxide	1,480,901,274	76,000	240,000	380,000	0.01	0.02	0.03

3.3 Regulatory Flexibility Analysis

This section describes EPA's initial assessment of the small business impacts expected to be incurred by mineral processing firms as a result of the Phase IV Land Disposal Restrictions (LDRs). Approximately 22 small businesses owning approximately 24 facilities may be affected by the rule. The first subsection describes the methodology EPA used in conducting the analysis. The second subsection presents the results of the analysis. In brief, the analysis concludes that no significant small business

**Exhibit 3-22
Option 4 Impacts (Profits Analysis)**

Sector	Estimated Profits \$	Sector Cost \$			Economic Impact (Percent of Profits)		
		Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	720,221,231	32,000	32,000	32,000	0.00	0.00	0.00
Beryllium	14,904,254	0	2,800	2,800	0.00	0.02	0.02
Copper	956,454,882	14,000	14,000	14,000	0.00	0.00	0.00
Platinum Group Metals	8,229,711	-	4,200	4,200	0.00	0.05	0.05
Titanium and Titanium Dioxide	1,480,901,274	2,800	9,900	9,900	0.00	0.00	0.00

impacts are anticipated as a result of the rule and, therefore, preparation of a formal Regulatory Flexibility Analysis is unnecessary.

3.3.1 Methodology

An initial assessment of small business impacts involves four major tasks: (1) defining "small entities" for the rule being analyzed, (2) determining what number constitutes a "substantial number" of these entities, (3) determining how "significant impacts" will be measured, and (4) completing a screening analysis. If the initial assessment determines that a substantial number of small entities may face significant impacts as a result of the rule being analyzed, then a formal Regulatory Flexibility Analysis may be required.

Defining "Small Entities" Affected by the Rule

The Phase IV LDRs will affect those mineral processing entities that currently (i.e., prior to the rule) generate hazardous waste. For purposes of this analysis, "small entity" refers to any such mineral processing business concern that has 750 or fewer employees including itself and all of its domestic and foreign affiliates (1000 or fewer employees for entities in the copper and aluminum sectors). This definition is consistent with the size standards established by the Small Business Administration (SBA) in 13 CFR Sections 121.103 and 121.201 on January 31, 1996. EPA does not believe that other types of small entities, such as non-profit organizations or local governments, will be affected by the application of Phase IV LDRs to mineral processing activities.

Determining What Number Constitutes a Substantial Number

This initial assessment applies a figure corresponding to 20 percent of small entities in determining whether a "substantial number" of small entities are likely to be impacted by the rule. For sensitivity analysis purposes, EPA has also applied an alternate figure corresponding to five percent of small entities.

Measuring "Significant Impacts"

To evaluate the impact that a small entity is expected to incur as a result of the rule, this analysis calculates the entity's ratio of annualized compliance costs as a percentage of sales. Entities are classified as facing potentially "significant" impacts if this ratio exceeds three percent. For sensitivity analysis purposes, EPA has also applied an alternate figure of one percent.

Conducting the Screening Analysis

The final task of the initial assessment is to conduct the screening analysis and determine whether, using the criteria established above, the rule is expected to result in significant impacts on a substantial number of small entities. The screening analysis involves four steps:

- (1) Identify Facilities Generating Hazardous Mineral Processing Waste. EPA compiled a list of the facilities generating hazardous mineral processing waste based on information contained in the technical background document Identification and Description of Mineral Processing Sectors and Waste Streams, U.S. EPA Office of Solid Waste, December 1995, and on information obtained from public comments on the proposed rule. Where uncertainty existed regarding whether certain facilities currently generate hazardous mineral processing waste, EPA included the facility in this analysis to avoid understating impacts (even if doing so meant exceeding the number of facilities estimated in the cost model). Approximately 22 small businesses owning approximately 24 facilities may be affected by the rulemaking.
- (2) Obtain Employee And Sales Data For The Business Concerns Owning Each Facility. Using the list of facilities developed in the preceding step, EPA researched the number of employees and total sales for each business concern owning one or more facility. (As noted earlier, a "business concern" includes not only the company owning a given facility, but all of its domestic and foreign affiliates.) EPA obtained data from a variety of public and commercial sources.
- (3) Obtain Compliance Cost Data For Each Small Business Concern. For each facility owned by a small business concern, EPA applied its most current estimate for the "average" sector-specific facility cost, in the expected value case, of complying with Option 2 under the assumed baseline. In the few cases where a small business concern owns multiple facilities, EPA added the compliance costs for the individual facilities to obtain a total compliance cost for the small business owner. For example, if one company owns two facilities, the costs of these facilities are added together to determine the total compliance cost to the company.
- (4) Compute Small Business Impacts. Finally, using the data obtained in the preceding steps, EPA calculated each small business concern's ratio of total annualized compliance costs as a percentage of sales. EPA then compared the ratios to the threshold value for significant impacts of three percent, and to the sensitivity threshold of one percent.

3.3.2 Results

As described above, EPA examined the potential for small business impacts by comparing, for each small business, the total annualized compliance costs as a percentage of sales and comparing the ratio to a threshold of three percent. Approximately 22 small businesses owning approximately 24 facilities may be affected by the rule. These facilities fall into the following sectors: alumina/aluminum, antimony, cadmium, coal gas, germanium, fluorspar/hydrofluoric acid, molybdenum/ferromolybdenum/ammonium molybdate, platinum group metals, pyrobitumens/mineral waxes/natural asphalts, scandium, tungsten, and/or zinc. EPA's analysis finds that the proposed rule would not result in a significant impact

on a substantial number of small mineral processing entities.²⁴ In fact the proposed rule is unlikely to result in a significant impact on *any* small mineral processing entities, and some small business owners would incur cost savings under the option. Two possible - but unlikely - exceptions to this finding arise as a result of data limitations. Because this analysis was unable to obtain sales data for certain small businesses, the analysis could not directly estimate impacts on these companies. Nevertheless, significant impacts on these businesses are unlikely, as discussed below:

- One company processing hydrofluoric acid is expected to incur annual costs of only \$17,000. Therefore, this company will not incur significant impacts unless it has sales of less than \$566,667 (i.e., $\$17,000/0.03$) or, using the alternate threshold of one percent, less than \$1,700,000 (i.e., $\$17,000/0.01$). Because higher sales can be expected for a sustained business venture conducting mineral processing,²⁵ EPA believes that this small business will not incur significant impacts.
- Similarly, the analysis does not address small business concerns that may own one or more of the 17 facilities in the uranium sector. The average annual cost to such facilities is \$2,700. Thus, if any of the 17 facilities are owned by small business concerns, significant small business impacts would arise only for those concerns with sales of less than \$90,000 (i.e., $\$2,700/0.03$) or, using the alternate threshold of one percent, less than \$270,000 (i.e., $\$2,700/0.01$).²⁶ Assuming the total sales of a small business owning a uranium processing facility are at least as great as the lowest confirmed sales figure (\$2,100,000) among all other small businesses in the analysis, then no impacts arise in the uranium sector under either threshold.

Even in the unlikely event that any company incurs significant impacts under the scenarios described above, the rule would not generate significant impacts on a *substantial number* of small businesses unless 20 percent or more of small mineral processing firms (five percent or more under the alternative threshold for "substantial number") incur significant impacts. This corresponds to five entities (two under the alternative threshold), and seems highly unlikely.²⁷

It is worth noting that actual impacts may be even less than estimated above because the facilities owned by small business concerns may incur smaller than average compliance costs. This could reasonably occur if small business concerns tend to own smaller than average facilities.

²⁴ This analysis was conducted based on the average costs to facilities in a given sector under Option 2. The findings, however, also apply to the less costly options (option 3 and option 4).

²⁵ For example, the lowest confirmed sales figure among all other small businesses in the analysis exceeds \$2 million

²⁶ This assumes that only one uranium processing facility is owned per small business concern.

²⁷ Even if this had occurred, however, it would not necessarily constitute a substantial number of entities. Such a determination might also require consideration of other factors, such as the sectors in which the entities operate and the absolute number of facilities affected.

4. BENEFITS ASSESSMENT

The potential human health and ecological benefits of the proposed LDRs for mineral processing arise from reduced releases of toxic waste constituents to the environment as a result of regulatory controls. These reductions in release translate into reduced human exposures and reduced risks to human health. This section describes the approaches that have been taken to evaluating risks to human health associated with waste disposal and with storage of recycled materials. Risks have been assessed under the modified prior treatment baseline, and reductions in risks that may be associated with the various regulatory options are also identified.

4.1 Risk and Benefits Assessments Methodologies

4.1.1 Overview of Risk and Benefits Assessment Activities

In developing this RIA, a number of efforts have been undertaken to evaluate the risks associated with mineral processing wastes disposal and storage and to assess the health benefits associated with changes in management practices under the proposed LDRs. These efforts have evolved in parallel with changes in the definitions of the baseline assumptions and with changes in the regulatory options that have occurred during the regulatory development process. Much of the work done early in the development of the rule analyzes baseline assumptions and regulatory options that are to some degree different from those currently being considered. Most significantly, the modified prior treatment baseline has only quite recently become the focus of risk assessment efforts while the initial focus of the risk and benefit assessment was the no prior treatment baseline.

In evaluating the results of these analyses, it is important to understand that all of the risk assessment activities described below employ screening methodologies, and do not provide definitive information about health risks or risk reduction benefits for actual exposed populations. The screening level methodologies are not site-specific, and they employ generic assumptions about facility characteristics, exposure pathways, receptors, and receptor behavior. Exposed populations living near actual mineral processing facilities have not been identified or enumerated, and the applicability of the various exposure pathways that are evaluated to these populations has not been verified. Cancer risks and noncancer hazards are calculated for hypothetical individuals under the generic exposure conditions. The assumptions used in the risk assessment have been derived by EPA in the course of numerous regulatory analyses under RCRA, and they are generally considered to provide conservative, but plausible estimates of individual exposures and risks.

A brief summary of the risk and benefits assessment efforts is provided below to show the relationships between the risk assessments for the various activities, baselines, and regulatory options. The major risk assessment efforts have included (in chronological order):

Risk and Benefits Assessment for the Waste Disposal Using Non-Constituent Specific DAFs

This effort involved the development of risk and risk reduction estimates for the wasted (unrecycled) portions of the mineral processing waste streams. Data regarding constituent concentrations were available for 38 waste streams, and the risk and benefits assessment were limited to those streams. The 28 streams comprised approximately 80 percent, by volume, of the total wastes generated by the mineral processing industry. The assessment was also limited only to health risks arising from groundwater exposures. Risks were estimated for the no prior treatment baseline (which was then considered to be a prudently conservative assumption, reasonable representative of current practice), and

risk reductions were estimated for all three of the regulatory options that were then being considered. Since under all three options (and under all four current options), treatment to UTS levels would be required prior to disposal of any of the waste streams, the benefit calculations for all three options were the same.

In this initial analysis, groundwater exposure concentrations were calculated using dilution-attenuation factor values (DAFs) derived by EPA for use in previous regulatory analyses. The DAFs were based solely on unit characteristics, and did not take into account the geochemical properties of the waste constituents. Risks were calculated using mean constituent concentrations estimated for each waste stream, and benefits were estimated in terms of "facility-waste stream combinations," which are the estimated numbers of facilities at which given risk reduction would be achieved. Through imposition of the LDRs. *The results of this assessment are summarized in the October 1995 Draft Mineral Processing LDRs RIA.*

Waste Disposal Risk and Benefits Assessment Using Sample-Specific Concentration Estimates

Subsequent to the October 1995 RIA, EPA conducted sensitivity analyses to better evaluate potential sources of uncertainty in the risk and benefits assessment for the RIA. These analyses indicated the use of mean constituent concentration values obscured important variations in constituent concentrations within some of the waste streams, as well as variations in the risks that might be associated with the management of these streams. As a result of this finding, the risk and benefits assessment were revised, using constituent concentrations from individual waste samples, instead of mean values, to calculate risks. As in the previous effort, the benefits were calculated relative to the no prior treatment baseline. Thus, risk reduction benefits were again the same under all three options, except that one option would have excluded two spent materials streams from regulation under the no prior treatment baseline. *This analysis was presented in the December 1995 RIA.*

Waste Disposal Risk and Benefits Assessment Using Constituent-Specific DAFs

For this analysis, EPA employed DAF values that were derived specifically for waste management units from the mineral processing industry and which took into account differences in geochemical properties of the waste constituents. Except for this, this assessment was identical to that described in the previous paragraph, and evaluated benefits from changes in waste disposal relative to the no prior treatment baseline. *The methods used and results are also described in more detail in Appendix A of this RIA.*

Risk Assessment for the Storage of Recycled Streams

The latest risk assessment effort, discussed in this document, is the first which has focused on the recycled streams, and on the risks associated with storage, rather than only with the disposal of the wasted portions of the streams. In this effort, EPA has assessed health risks both for groundwater exposure, as in the previous analysis, and for non-groundwater direct and indirect exposure pathways.

Risks are assessed for 14 waste streams that EPA has identified as being recycled and for which constituent concentration data were available. These 14 streams account for 40 percent of the total mineral processing waste generation, and for about 65 percent of the recycled volume. Analogous to the methods used in the August RIA, EPA derived groundwater DAF values specifically for land-based recycling units, and specifically for each waste constituent. EPA assessed non-groundwater risks associated with the

storage of recycled materials using methods generally similar to those used to derive the proposed Exit Concentrations under the Hazardous Waste Identification Rule. These methods are described in detail in Appendix H.

No quantitative benefits assessment has been performed for the stored materials. This is because, under three of the four regulatory options currently being considered, recycled materials would be stored in tanks, containers, or buildings (TCBs), and no data or satisfactory models are available which would allow the estimation of risks associated with these management units. Under Option 4, it is again assumed that recycled materials would be stored in land-based units, and no health benefits from improved storage would be realized relative to the baseline.

Thus, for recycled materials management, EPA has estimated only baseline risks. These risks represent upper-bound estimates of the achievable health benefits if releases to the environment are completely abolished under the regulatory options under the modified prior treatment baseline. The degree of potential risk reduction associated with the various options differs only in that recycling of secondary materials through Bevill units would not be allowed under Options 1 and 2.

In the discussion that follows, the primary focus will be on risks relative to the modified prior treatment baseline, but the risk and benefits assessment for waste disposal, relative to no prior treatment is also discussed, as it provides information useful in the estimation of disposal risks and risk reductions under the modified prior treatment baseline.

4.1.2 Risk and Benefits Assessment Methods for Nonrecycled Materials

As noted in the previous section, all of the quantitative risk and benefits assessment work performed by EPA for the non-recycled portion of the mineral processing waste streams has focused on the management of these wastes under the no prior treatment baseline. Thus, the baseline risks have been assessed for final disposal of untreated materials in unlined units, and regulatory benefits have been evaluated in terms of the risk reduction achievable by initial treatment of all streams to UTS levels prior to disposal.

Under the modified prior treatment baseline, however, which EPA has recently identified as being most representative of current practice, it is assumed that all wastes would be stabilized to comply with TC regulatory levels prior to disposal, even in the absence of LDRs. Thus, potential baseline risks would be lower than when no prior treatment is assumed. Also, the regulatory benefits, which under this baseline would represent the difference between waste treatment to TC levels and waste treated to UTS levels, would be considerably lower than the benefits estimated relative to the no prior treatment baseline.

EPA has not quantitatively evaluated the risks associated with the disposal of waste at the TC levels, and thus has not developed quantitative estimates of benefits associated with changes in waste disposal practices in relation to the modified prior treatment baseline. The baseline health risks and risk reduction benefits calculated for the alternative baselines (no prior treatment, prior treatment) are discussed in detail in Appendix A.2. However, as will be discussed in Section 4.2.1, these estimates provide a useful basis for evaluating the modified prior treatment baseline.

4.1.3 Risk and Benefits Assessment Methods for the Storage of Recycled Materials

As discussed in Section 4.1.1, a quantitative risk assessment has been performed for the storage of recycled materials under the modified prior treatment baseline. Under this baseline, (as under the no prior

treatment baseline), all recycled streams are assumed to be stored in unlined land storage units prior to recycling. Streams were included in the analysis if EPA identified them as having non-zero recycled volumes under the "expected" cost scenario. Waste streams were also eliminated from the risk assessment if the estimated annual recycled volume was so low (less than 500 tons per year) that storage in land units would not be cost-effective. Based on these criteria, 14 streams were included in the risk assessment for stored materials, as shown in Exhibit 4-1.

Exhibit 4-1
Recycled Streams Included in the Storage Risk Analysis

Commodity	Recycled Stream
Aluminum and Alumina	Cast House Dust
Beryllium	Chip Treatment Wastewater
Copper	Acid Plant Blowdown
Elemental Phosphorus	AFM Rinsate
Elemental Phosphorus	Furnace Scrubber Blowdown
Rare Earths	Process Wastewater
Selenium	Plant Process Wastewater
Tantalum, Columbium, and Ferrocolumbium	Process Wastewater
Titanium and Titanium Oxide	Leach Liquor and Sponge Wastewater
Titanium and Titanium Oxide	Scrap Milling Scrubber Water
Zinc	Waste Ferrosilicon
Zinc	Spent Surface Impoundment Liquids
Zinc	Waste Water Treatment Plant Liquid Effluent
Zinc	Process Wastewater

All but two of these streams are wastewaters (WW) or liquid nonwastewaters (LNWW), for which the least-cost management unit is a surface impoundment. The remaining two streams (aluminum cast house dust and zinc waste ferrosilicon) are nonwastewaters (NWW), for which the least-cost management unit is a waste pile.

Constituent concentration data were available from a total of 187 samples from the recycled materials, only three of which are of the two NWW streams, with the remainder representing WW and LNWW streams. Among these, 145 were bulk analytical results, and 42 were EP extraction analysis. Of the available samples, 135 had concentration data for constituents having toxicity criteria values that could be used in quantitative risk assessment. Again, three of the samples were from NWW streams. The data used to derive DAFs are summarized in Appendix J.

Although storage risks were calculated for only 14 of the 118 total mineral processing waste streams, these streams represent substantial proportions of the total generated wastes and an even higher

proportion of the recycled wastes. Depending on which estimate of waste generation is used (minimum, expected, or maximum), the 14 recycled streams included in the risk analysis represent between 32 and 42 percent of the total waste generation, and account for between 57 and 68 percent of the total recycled volume. This is because constituent concentration data are available for a substantial proportion of the high-volume waste streams. The extent of coverage of the storage risk assessment for the various commodity sectors is discussed in Appendix H.

To estimate groundwater exposure concentrations, bulk concentrations or adjusted EP constituent concentrations from each waste sample were divided by central tendency (CT) and high-end (HE) DAF values. The DAF values were derived specifically for the size and configuration of units (waste piles and surface impoundments) estimated in the cost and economic analysis as being necessary to contain recycled materials at representative size facilities in each commodity sector. DAF derivations were performed employing regionally representative ground-water transport parameters and climatological data for those facilities where these data were not available, or whose location was not known.

In evaluating risks, the 75th percentile constituent-specific DAFs were used to estimate central tendency (CT) groundwater concentrations. The rationale for using the 75th percentile DAFs rather than, for example, the 50th percentile value was that the EPACMTP model used to derive DAFs does not consider fractured or channeled flow or other facilitated transport mechanisms which may occur at some sites, resulting in higher groundwater concentrations than those predicted for homogeneous flow processes modeled by EPACMTP. The 95th percentile constituent-specific DAF values were used to estimate high-end (HE) groundwater concentrations, in keeping with the definition of a high-end receptor as someone exposed at levels between the 90th and 99th percentiles of all exposed individuals.

Risks for groundwater exposures were calculated assuming groundwater would be used as a drinking water supply by residents living near the management units for substantial proportions of their lives. Cancer risks were calculated for exposures to inorganic arsenic²⁸ using the Cancer Slope Factor (CSF) value from EPA's IRIS data base. For all other constituents, noncancer hazard quotients were calculated using EPA's ingestion pathway Reference Doses (RfDs). The DAF values derived for mineral processing storage units, along with the exposure factor values and equations used to estimate groundwater pathway risks, are provided in Appendix H.1.

Non-groundwater pathway risks for land storage of recycled materials were estimated using a variety of models, most of which generally follow the methods described in EPA's Technical Support Document for the proposed "HWIR-Waste" exit level derivation.²⁹ Exhibit 4-2 identifies the non-groundwater release events and exposure pathways for which risks were evaluated, and provides brief descriptions of the methods used to estimate exposures and risks. The release events that were evaluated for waste piles include air particulate generation by wind disturbance and materials handling, and surface

²⁸ Consistent with previous risk assessment efforts for mineral processing wastes, EPA chose not to model the potential ingestion pathway cancer risks associated with exposure to beryllium because, although beryllium has an approved Cancer Slope Factor in the IRIS data base, the value is currently under review, and there is a substantial degree of uncertainty surrounding the activity of beryllium as an ingestion pathway carcinogen.

²⁹ U.S. EPA, *Technical Support Document for the Hazardous Waste Identification Rule: Risk Assessment for Human and Ecological Receptors*, Office of Solid Waste, August 1995.

EXHIBIT 4-2. RELEASE AND EXPOSURE PATHWAY MODELING SUMMARY FOR MINERAL PROCESSING STORAGE RISK ASSESSMENT

UNIT TYPE	RELEASE EVENT/ MEDIUM	TRANSPORT MEDIUM I	TRANSPORT MEDIUM II	TRANSPORT MEDIUM III	EXPOSURE PATHWAY	RECEPTORS	MODELING APPROACHES
Waste Pile	Particulate Generation by Wind, Materials Handling	Air	--	--	Inhalation	Adult Resident	SCREEN3 (Emissions) ISCST3 (Deposition) HWIR (Exposure/Risk)
		Air	Soil (deposition)	--	Ingestion	Child/Adult Resident	HWIR-Waste (Exposure/Risk)
					Dermal	Child Resident	HWIR-Waste
		Air	Soil (deposition)	Crops	Ingestion	Subsistence Farmer	HWIR-Waste, modified for non-steady-state conditions (concentration in crops, vegetable intake, risk)
		Air	Soil/Water	Surface Water/Fish	Ingestion	Subsistence Fisher	Bounding analysis (100 percent deposition in water body)
Waste Pile	Runoff	Soil	--	--	Ingestion	Child Resident	Bounding analysis; 100 percent runoff to adjacent garden/yard, HWIR-Waste (exposure and risk)
		Soil	--	--	Dermal	Child Resident	Bounding analysis; 100 percent runoff to adjacent garden/yard, HWIR-Waste (exposure and risk)
		Soil	Crops	--	Ingestion	Subsistence Farmer	Bounding Analysis; HWIR- Waste
		Soil	--	Surface Water/Fish	Ingestion	Subsistence Fisher	Bounding analysis (100 percent deposition in water body)
Surface Impoundment	Control/Berm Failure	Surface Water	--	--	Ingestion	Adult Resident	HWIR-Waste (Release algorithms, exposure, drinking water ingestion)
		Surface Water	Fish	--	Ingestion	Subsistence Fisher	HWIR-Waste (Releases, dilution, fish ingestion, risk)

87

run-off caused by rainfall. For surface impoundments, releases due to run-on and inlet/outlet control failure events were evaluated. Owing to the nature of the constituents being evaluated (all inorganics), volatilization release events were not considered.

The transport and exposure media which were evaluated included air, soils, home-grown vegetables, surface water, and game fish. Exposure pathways and exposure factor values were generally consistent with the child/adult resident, subsistence farmer, and subsistence fisher receptors used in the HWIR Waste exit level determination. Cancer risks and noncancer hazard quotients were calculated for all pathways using standard pathway models and ingestion and inhalation pathway toxicological parameters from IRIS. The methods used to estimate exposures and to evaluate risks from the storage of recycled materials through non-groundwater pathways are described in detail in Appendix H.2.

4.2 Risk and Benefits Assessment Results

4.2.1 Risks and Benefits Associated With the Disposal of Mineral Processing Wastes

As noted previously, the estimated benefits associated with the proposed LDRs under the no prior treatment baseline are substantial, in terms of the numbers of facility-waste stream combinations that move from high-risk categories under baseline assumptions to lower risk categories under that requirement wastes be treated to UTS levels prior to disposal. These benefits, which would be realized under all four regulatory options, are summarized in Exhibits 4-3 and 4-4, and are discussed in detail in Appendix A.2. It can be seen from these exhibits that there are substantial numbers of waste stream-facility combinations for which estimated individual cancer risks through groundwater exposures exceed 10^{-5} and for which the estimated noncancer hazard quotient values exceed 1.0 under the no prior treatment baseline. This is true both under central tendency (CT) and high-end (HE) exposure assumptions. In contrast, post-LDR (where treatment to UTS levels would be required for all wastes), there are no waste stream-facility combinations for which these risk or hazard quotient levels are exceeded under either CT or HE assumptions.

Under the modified prior treatment baseline (and under the prior treatment baseline), the baseline risks and risk reduction associated with the first three regulatory options would be considerably lower than those derived assuming no treatment. This is because treatment to the TC regulatory levels prior to disposal, as assumed for modified prior treatment, in and of itself is sufficient to reduce the risks for most of the risk-driving constituents to below levels of concern for groundwater ingestion. In addition, the TC regulatory level and the UTS leachate level for arsenic, the sole ingestion pathway carcinogen among the constituents and a frequent risk driver, are the same. Thus, going from treatment to TC levels under modified prior treatment to UTS levels under the regulatory Options 1 through 4, will yield few benefits, in terms of reduced groundwater risks.

This is illustrated in Exhibit 4-3 where, post-LDR, cancer risks for all waste stream-facility combinations (which are all due to arsenic exposures) are below 10^{-5} . Thus, there are no baseline cancer risks above levels of concern under the modified prior treatment baseline even without LDRs. This, along with the equality of the TC and UTS treatment levels, means that no reduction in cancer risks would occur through the LDRs under the assumptions used to define the modified prior treatment baseline and the regulatory options.

EXHIBIT 4-3 RISK AND BENEFITS SUMMARY FOR MINERAL PROCESSING WASTE DISPOSAL

Distribution of Waste Stream-Facility Combinations by Groundwater Risk Category: Cancer Risks

Commodity	Waste Stream	Number of Waste Stream-Facility Combinations* #		Central Tendency										High End												
				Pre-LDR					Post-LDR					Pre-LDR					Post-LDR							
				10-5	10-4	10-3	10-2		10-5	10-4	10-3	10-2		10-5	10-4	10-3	10-2		10-5	10-4	10-3	10-2				
		Central	High	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to				
		Tendency	End	<10-5	10-4	10-3	10-2	10-1	>10-1	<10-5	10-4	10-3	10-2	10-1	>10-1	<10-5	10-4	10-3	10-2	10-1	>10-1	<10-5	10-4	10-3	10-2	10-1
Al and Alumina	Cast house dust	23	23	23	0	0	0	0	0	23	0	0	0	0	0	23	0	0	0	0	0	23	0	0	0	0
Sb	Autoclave filtrate	4	7	0	0	0	2	2	0	4	0	0	0	0	0	0	0	0	0	4	4	7	0	0	0	0
Be	Spent barren filtrate streams	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0
Be	Chip treatment WW	1	2	1	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0
Cu	Acid plant blowdown	7	7	2	0	2	1	0	1	7	0	0	0	0	0	0	1	0	2	1	1	7	0	0	0	0
Cu	Scrubber blowdown	10	10	3	0	7	0	0	0	10	0	0	0	0	0	0	3	0	7	0	0	10	0	0	0	0
Elemental Phosphorus	AFM rinsate	2	2	1	1	0	0	0	0	2	0	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0
Elemental Phosphorus	Furnace offgas solids	2	2	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0
Elemental Phosphorus	Furnace scrubber blowdown	2	2	1	1	0	0	0	0	2	0	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0
Elemental Phosphorus	Slag quenchwater	2	2	0	2	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0
Ge	Waste acid wash/rinse water	2	4	2	0	0	0	0	0	2	0	0	0	0	0	0	4	0	0	0	0	4	0	0	0	0
Ge	Chlorinator wet air poll. ctrl. sludge	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0
Ge	Hydrolysis filtrate	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0
Ge	Waste still liquor	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0
Mg and Magnesia (brine)	Smut	2	2	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0
Mo, FeMo, Amm. Mo	Liquid residues	1	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0
Rare Earths	Spent ammon. nitrate proc. sol.	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
Rare Earths	PWW	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
Se	Plant PWW	2	2	0	2	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0
Ta, Columbium, and FeCol.	PWW	2	2	1	0	0	0	0	0	2	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0
Titanium and TiO2	Pickle liquor & wash water	2	3	1	1	0	0	0	0	2	0	0	0	0	0	0	2	2	0	0	0	3	0	0	0	0
Titanium and TiO2	Leach liquor & sponge wash water	1	2	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0
Titanium and TiO2	Scrap milling scrubber water	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
Titanium and TiO2	Spent s.i. liquids	4	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Titanium and TiO2	Spent s.i. solids	4	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Titanium and TiO2	Waste acids (Sulfate process)	1	2	0	1	0	0	0	0	1	0	0	0	0	0	1	0	2	0	0	0	2	0	0	0	0
Titanium and TiO2	WWTP sludge/solids	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	Spent acid & rinse water	3	6	2	0	2	0	0	0	3	0	0	0	0	0	0	3	0	3	0	0	6	0	0	0	0
Zn	Waste ferrosilicon	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zn	Spent s.i. liquids	3	3	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0
Zn	WWTP solids	3	3	3	0	0	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0
Zn	Spent synthetic gypsum	3	3	3	0	0	0	0	0	3	0	0	0	0	0	2	0	2	0	0	0	3	0	0	0	0
Zn	WWTP liquid effluent	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zn	Zinc lean slag	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
TOTALS*		108	133	56	11	11	8	2	1	89	0	0	0	0	0	46	20	14	13	10	5	108	0	0	0	0

* Sums by risk category may not add to the number of central or high-end waste stream/facility combinations due to rounding.

EXHIBIT 4-4 RISK AND BENEFITS SUMMARY FOR MINERAL PROCESSING WASTE DISPOSAL
Distribution of Waste Stream-Facility Combinations by Groundwater Hazard Category: Non-Cancer Hazards

Commodity	Waste Stream	Number of Waste Stream-Facility Combinations*		Central Tendency												High End											
				Pre-LDR						Post-LDR						Pre-LDR						Post-LDR					
				1	10	100	1k			1	10	100	1k			1	10	100	1k			1	10	100	1k		
		Central Tendency	High End	to	to	to	to	to	>10k	to	to	to	to	to	>10k	to	to	to	to	to	>10k	to	to	to	to	to	>10k
Al and Alumina	Cast house dust	23	23	23	0	0	0	0	0	23	0	0	0	0	0	23	0	0	0	0	0	23	0	0	0	0	0
Sb	Autoclave filtrate	4	7	0	0	0	3	1	0	4	0	0	0	0	0	0	0	0	2	2	2	7	0	0	0	0	0
Be	Spent barren filtrate streams	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
Be	Chip treatment WW	1	2	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0
Cu	Acid plant blowdown	7	7	1	2	2	1	1	0	7	0	0	0	0	0	0	1	1	2	1	1	7	0	0	0	0	0
Cu	Scrubber blowdown	10	10	0	3	7	0	0	0	10	0	0	0	0	0	0	0	0	10	0	0	10	0	0	0	0	0
Elemental Phosphorus	AFM rinsate	2	2	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0
Elemental Phosphorus	Furnace offgas solids	2	2	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0
Elemental Phosphorus	Furnace scrubber blowdown	2	2	1	1	0	0	0	0	2	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0
Elemental Phosphorus	Slag quenchwater	2	2	2	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0
Ge	Waste acid wash/rinse water	2	4	2	0	0	0	0	0	2	0	0	0	0	0	0	0	4	0	0	0	4	0	0	0	0	0
Ge	Chlorinator wet air poll. ctrl. sludge	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0
Ge	Hydrolysis filtrate	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0
Ge	Waste still liquor	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0
Mg and Magnesia (brine)	Smut	2	2	2	0	0	0	0	0	2	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0
Mo, FeMo, Amm. Mo	Liquid residues	1	2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0
Rare Earths	Spent ammon. nitrate proc. sol.	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Rare Earths	PWW	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Se	Plant PWW	2	2	1	1	0	0	0	0	2	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0
Ta, Columbium, and FeCol.	PWW	2	2	1	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0
Titanium and TiO2	Pickle liquor & wash water	2	3	0	2	0	0	0	0	2	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0
Titanium and TiO2	Leach liquor & sponge wash water	1	2	0	1	1	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0
Titanium and TiO2	Scrap milling scrubber water	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Titanium and TiO2	Spent s.i. liquids	4	7	4	0	0	0	0	0	4	0	0	0	0	0	7	0	0	0	0	0	7	0	0	0	0	0
Titanium and TiO2	Spent s.i. solids	4	7	4	0	0	0	0	0	4	0	0	0	0	0	5	2	0	0	0	0	7	0	0	0	0	0
Titanium and TiO2	Waste acids (Sulfate process)	1	2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0
Titanium and TiO2	WWTP sludge/solids	7	7	7	0	0	0	0	0	7	0	0	0	0	0	4	4	0	0	0	0	7	0	0	0	0	0
W	Spent acid & rinse water	3	6	2	1	0	0	0	0	3	0	0	0	0	0	3	2	0	2	0	0	6	0	0	0	0	0
Zn	Waste ferrosilicon	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Zn	Spent s.i. liquids	3	3	0	1	1	0	1	0	3	0	0	0	0	0	0	1	0	1	0	1	3	0	0	0	0	0
Zn	WWTP solids	3	3	3	0	0	0	0	0	3	0	0	0	0	0	1	1	1	0	0	0	3	0	0	0	0	0
Zn	Spent synthetic gypsum	3	3	3	0	0	0	0	0	3	0	0	0	0	0	2	2	0	0	0	0	3	0	0	0	0	0
Zn	WWTP liquid effluent	3	3	0	1	1	0	0	1	3	0	0	0	0	0	0	0	2	0	0	1	3	0	0	0	0	0
Zn	Zinc lean slag	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
TOTALS*		108	133	68	16	14	4	4	1	108	0	0	0	0	0	63	15	19	24	4	8	133	0	0	0	0	0

* Sums by hazard category may not add to the number of central or high-end waste stream/facility combinations due to rounding.

In the case of noncarcinogenic constituents, the situation is very similar. Again (see Exhibit 4-4), treatment of all of the waste streams to UTS levels prior to disposal (post-LDR) results in all waste stream-facility combinations having noncancer hazard quotients less than 1.0. Unlike the case for arsenic, however, the UTS concentrations for many of the constituents are lower than the TC concentrations. Even in these cases, however, screening calculations indicate that, with one possible exception, treatment to the TC level, as required under the modified prior treatment baseline, would results in hazard quotient values less than 1.0 for all of the waste samples. The basis for this argument is shown in Exhibit 4-5.

It can be seen from this exhibit that the estimated exposure concentrations in groundwater, calculated using HE constituent-specific DAF values for surface impoundments³⁰, are all below levels corresponding to noncancer hazard quotient values of 1.0, with the exception of barium, for which the exposure concentration corresponding to the TC leachate regulatory level just exceeds the health-based level. Barium is rarely a risk-driving constituent in the waste disposal risk assessment, and review of the data base of constituent concentrations indicates that no EP leachate sample from any waste stream has a barium concentration exceeding the TC level, even prior to treatment, and most of the EP extraction analytical results are many orders of magnitude below the TC level. Further, only five bulk samples from any of the waste streams have barium concentrations exceeding 100 mg/kg, and four of these samples are from nonwastewater streams that would be managed in waste piles rather than in surface impoundments. The HE DAF for barium release from waste piles is many orders of magnitude lower than the value for surface impoundments, and thus the calculated groundwater exposure concentrations would also be much lower for these samples.

The findings presented above provide a high degree of assurance that the groundwater pathway risks associated with the presence of TC analytes in the disposed mineral processing wastes would pose low risks under the modified prior treatment baseline. Consequently, the health benefits of the regulatory options relative to this baseline from reduced groundwater exposures would be minimal for most constituents, and would be zero for arsenic, for which the TC and the UTS levels are the same.

Exhibit 4-5

Groundwater Concentrations Resulting from Releases of Noncarcinogenic Constituents at TC Concentrations Compared to Health-Based Levels

Constituent	Health-Based Level (Groundwater Concentration corresponding to HQ = 1) (mg/l)	TC Regulatory Level (mg/l)	HE Groundwater Concentration Corresponding to Release at TC Regulatory Level (mg/l) ²
Barium	2.5	100	6.8
Cadmium	0.035	1	0.00031
Chromium (VI)	0.18	5	0.031
Lead	0.015 ¹	5	6X10 ⁻⁹
Mercury	0.011	0.025	6X10 ⁻⁶
Selenium	0.18	1	0.0023
Silver	0.18	5	0.010

¹ The HBL for lead is the Safe Drinking Water Act MCL.

² Calculates using the constituent-specific HE DAF value for surface impoundments

³⁰ This is the lowest DAF value used in the analysis, and gives the highest risks.

A similar blanket statement cannot be made for the other constituents (antimony, beryllium, cyanide, nickel, thallium, vanadium, and zinc) for which TC regulatory levels have not been set, but which have UTS levels. In these cases, the benefits associated with going from the modified prior treatment baseline to regulatory options 1-4 could be higher. In the extreme case, (where treatment to reduce the mobility of the TC analytes does not reduce the mobility of the other UTS constituents), the baseline risks and regulatory benefits could be almost as high as those shown in Exhibit 4-4. It is likely, however, that under the modified prior treatment baseline, treatment to reduce leaching of the TC analytes would also reduce the mobility of the other UTS analytes to a substantial degree. Thus, the baseline groundwater pathway risks, and the risk reduction benefits under this baseline are likely to be much lower than those indicated in Exhibit 4-4.

Finally, the risk assessment for mineral processing waste disposal has not addressed non-groundwater pathway risks. It is not known to what extent these risks would be reduced by LDRs compared to the modified prior treatment baseline.

4.2.2 Risk Assessment Results for Recycled Materials Storage: Groundwater Pathway

Exhibit 4-6 summarizes the carcinogenic groundwater risk results for the 75 samples identified as containing arsenic, the sole ingestion pathway carcinogen among the waste constituents. Using the CT DAF values, the calculated cancer risks for 49 of these samples were less than 10^{-5} , the level of regulatory concern, and the risks for 26 of the samples exceeded this value. Cancer risks exceeded 10^{-5} for one or more samples from only four waste streams; copper acid plant blowdown, elemental phosphorus furnace scrubber blowdown, tantalum, columbium, and ferrocolumbium process wastewater, and zinc spent surface impoundment liquids. The highest cancer risks were associated with three samples of copper acid plant blowdown (10^{-3} to 10^{-2}). This waste stream accounted for 14 of the 16 samples with the highest CT cancer risks. The next highest risks (in the 10^{-4} to 10^{-3} range) were associated with one sample each from tantalum process wastewater and zinc spent surface impoundment liquids.

Using the high-end (HE) DAF values, cancer risks calculated for the groundwater pathway exceeded 10^{-5} for 50 of the 75 samples. Under this set of assumptions, risks for at least one sample exceeded 10^{-5} for 10 of the 14 waste streams evaluated. The highest risks (25 of 30 samples $> 10^{-5}$, highest risk category $> 10^{-1}$) were again associated with copper acid plant blowdown, with the next highest risk (10^{-2} to 10^{-1}) being associated with the single sample of zinc spent surface impoundment liquids. Of the wastes whose CT cancer risks were below 10^{-5} for all samples, six (elemental phosphorus AFM rinsate, rare earths process wastewater, selenium plant wastewater, titanium/TiO₂ leach liquor and sponge wash water and scrap milling scrubber water, and zinc process wastewaters), had at least one sample with HE cancer risks above this level.

Cancer risks for most of the samples increased about two orders of magnitude from the CT to HE case. This is consistent with the difference between the CT and HE DAF values for arsenic managed in surface impoundments. In the case of the NWW waste streams managed in piles, both the CT and HE cancer risks for all samples were below 10^{-5} . For aluminum/alumina cast house dust, this reflected the much higher CT and HE DAF values for arsenic managed in waste piles, compared to surface impoundments. Arsenic was not detected in the single sample of waste ferrosilicon from zinc production. Thus, no carcinogenic risks were calculated for this waste. The two other streams for which all HE sample-specific cancer risks were below 10^{-5} were beryllium chip treatment wastewater and zinc wastewater treatment plant liquid effluent.

April 15, 1997

EXHIBIT 4-6 RISK SUMMARY FOR STORAGE OF RECYCLED MATERIALS
Distribution of Samples by Groundwater Risk Category: Cancer Risks

Commodity	Waste Stream	Number of Samples with Cancer Risk	Central Tendency							High End							
			10-5	10-4	10-3	10-2				10-5	10-4	10-3	10-2				
			to	to	to	to	<10-5	10-4	10-3	10-2	10-1	>10-1	<10-5	10-4	10-3	10-2	10-1
Aluminum, Alumina	Cast house dust	2	2	0	0	0	0	0		2	0	0	0	0	0		
Beryllium	Chip treatment WW	1	1	0	0	0	0	0		1	0	0	0	0	0		
Copper	Acid plant blowdown	30	9	7	8	3	3	0		5	3	5	8	5	4		
Elemental Phosphorus	AFM rinsate	2	2	0	0	0	0	0		0	1	1	0	0	0		
Elemental Phosphorus	Furnace scrubber blowdown	8	7	1	0	0	0	0		3	3	2	0	0	0		
Rare Earths	PWW	2	2	0	0	0	0	0		0	2	0	0	0	0		
Selenium	Plant PWW	2	2	0	0	0	0	0		0	1	1	0	0	0		
Tantalum, etc. ¹	PWW	13	10	2	1	0	0	0		7	3	0	3	0	0		
Titanium and TiO2	Leach liquor & sponge wash water	2	2	0	0	0	0	0		0	1	1	0	0	0		
Titanium and TiO2	Scrap milling scrubber water	1	1	0	0	0	0	0		0	1	0	0	0	0		
Zinc	Waste ferrosilicon	0	0	0	0	0	0	0		0	0	0	0	0	0		
Zinc	Spent s.i. liquids	1	0	0	1	0	0	0		0	0	0	0	1	0		
Zinc	WWTP liquid effluent	0	0	0	0	0	0	0		0	0	0	0	0	0		
Zinc	Process wastewater	11	11	0	0	0	0	0		7	1	3	0	0	0		
Total		75	49	10	10	3	3	0		25	16	13	11	6	4		

1. Tantalum, Columbium, and Ferrocolumbium

Noncancer hazard quotient values for the groundwater pathway for the individual samples of recycled materials are summarized in Exhibit 4-7. Using the CT DAF values, hazard quotients exceeding 1.0 were calculated for 43 of 135 total samples from the 14 waste streams. As was the case for cancer risks, copper acid plant blowdown had the highest number of samples with noncancer hazard quotients above 1.0 (18 of 35 samples), and had the highest number of samples (4) in the highest-risk category ($HQ = 100$ to 1000). Samples from zinc production (11 of 22 for spent surface impoundment liquids and 8 of 16 for process wastewater) account for the bulk of the remaining hazard quotients above 1.0. The only other waste streams with CT hazard quotients above 1.0 included beryllium chip treatment wastewater (one sample), elemental phosphorus furnace scrubber blowdown (one sample), tantalum, process waste water (three samples), and zinc wastewater treatment plant liquid effluent (one sample).

When the HE DAF values are used to calculate exposures, hazard quotients exceed 1.0 for 100 of the 135 samples. As was the case for cancer risks, most of the hazard quotient values for individual samples are increased one to two orders of magnitude in the HE case compared to the CT case, reflecting the higher HE DAF values for the risk-driving constituents managed in surface impoundments. As for cancer risks, both the CT and HE DAF values for waste piles for all of the constituents are so high that no samples of either of the two streams stored in waste piles have hazard quotients exceeding 1.0 in either the CT or HE case. Hazard quotient values for one or more samples from five waste streams (elemental phosphorus AFM rinsate, rare earths process wastewater, selenium process wastewater, and titanium/TiO₂ leach liquor and sponge wash water and scrap milling scrubber sludge) which were all below 1.0 in the CT case exceeded 1.0 in the HE case.

4.2.3 Potential Benefits From Control of Stored Materials: Groundwater Pathway

The cancer risk results for the individual samples, distributed across the numbers of facilities generating and storing the wastes, are summarized in Exhibit 4-8. Using the methods described in Section 1.1.2, EPA has estimated that CT groundwater pathway cancer risks would exceed 10^{-5} at approximately 10 of the 57 facility-waste stream facilities.³¹ All of these facility-waste stream combinations were managing either copper acid plant blowdown (7 facility-waste stream combinations) or zinc spent surface impoundment liquids (3 combinations). These results, of course generally reflect the pattern of sample-specific risk results for the various commodity sectors. It should be noted, however, that for two waste streams, findings of one or more sample with greater than 10^{-5} risks did not translate into any facility-waste combinations above 10^{-5} risks. In the case of elemental phosphorus furnace scrubber blowdown, only one of seven samples had a cancer risk of just above 10^{-5} . Distributed across only two facilities estimated to be storing this waste, this result (one-seventh of the samples having risks above 10^{-5}) was rounded down to zero. Similarly, in the case of tantalum process wastewater, three of thirteen samples with risks above 10^{-5} were again rounded downward to zero of two facility-waste stream combinations. This occurrence is the almost inevitable result of having so few facilities in some of the commodity sectors, and the fact that non-integral numbers of waste-stream facility combinations are meaningless as risk or benefit indicators. It would be reasonable to interpret these results as indicating that either zero or one facility in these industries might have a CT cancer risk above 10^{-5} .

³¹ Note that the totals in the risk categories do not sum exactly due to rounding. This is true for the following exhibit as well.

EXHIBIT 4-7 RISK SUMMARY FOR STORAGE OF RECYCLED MATERIALS
Distribution of Samples by Groundwater Hazard Category: Non-Cancer Hazards

Commodity	Waste Stream	Number of Samples with Non-cancer Hazard	Central Tendency						High End					
			1	10	100	1k			1	10	100	1k		
			to	to	to	to			to	to	to	to		
			<1	10	100	1k	10k	>10k	<1	10	100	1k	10k	>10k
Aluminum, Alumina	Cast house dust	2	2	0	0	0	0	0	2	0	0	0	0	0
Beryllium	Chip treatment WW	1 ¹	0	0	1	0	0	0	0	0	0	0	1	0
Copper	Acid plant blowdown	35	17	10	4	4	0	0	3	7	12	7	4	2
Elemental Phosphorus	AFM rinsate	2	2	0	0	0	0	0	0	0	2	0	0	0
Elemental Phosphorus	Furnace scrubber blowdown	14	13	1	0	0	0	0	4	4	5	1	0	0
Rare Earths	PWW	4	4	0	0	0	0	0	2	2	0	0	0	0
Selenium	Plant PWW	2	2	0	0	0	0	0	0	2	0	0	0	0
Tantalum, etc. ¹	PWW	21	18	3	0	0	0	0	13	3	0	5	0	0
Titanium and TiO ₂	Leach liquor & sponge wash water	2	2	0	0	0	0	0	0	1	1	0	0	0
Titanium and TiO ₂	Scrap milling scrubber water	1	1	0	0	0	0	0	0	1	0	0	0	0
Zinc	Waste ferrosilicon	1	1	0	0	0	0	0	1	0	0	0	0	0
Zinc	Spent s.i. liquids	22	11	5	4	2	0	0	4	3	2	7	2	4
Zinc	WWTP liquid effluent	3	2	0	0	1	0	0	0	1	1	0	0	1
Zinc	Process wastewater	24	16	7	1	0	0	0	5	4	5	8	2	0
Totals		134	91	26	10	7	0	0	34	28	28	28	9	7

1. Tantalum, Columbium, and Ferrocolumbium

EXHIBIT 4-8 RISK SUMMARY FOR STORAGE OF RECYCLED MATERIALS
Distribution of Waste Stream/Facility Combinations by Groundwater Risk Category:
Cancer Risks

Commodity	Waste Stream	Number of Waste Stream- Facility Combinations		Central Tendency						High End					
		Central Tendency	High End	10-5	10-4	10-3	10-2	>10-1		10-5	10-4	10-3	10-2	>10-1	
				to <10-5	to 10-4	to 10-3	to 10-2			to <10-5	to 10-4	to 10-3	to 10-2	to 10-1	to >10-1
Aluminum, Alumina	Cast house dust	23	23	23	0	0	0	0	0	23	0	0	0	0	0
Beryllium	Chip treatment WW	2	2	2	0	0	0	0	0	2	0	0	0	0	0
Copper	Acid plant blowdown	10	10	3	2	3	1	1	0	2	1	2	2	2	2
Elemental Phosphorus	AFM rinsate	2	2	2	0	0	0	0	0	0	1	1	0	0	0
Elemental Phosphorus	Furnace scrubber blowdown	2	2	2	0	0	0	0	0	1	1	1	0	0	0
Rare Earths	PWW	1	1	1	0	0	0	0	0	0	1	0	0	0	0
Selenium	Plant PWW	2	2	2	0	0	0	0	0	0	1	1	0	0	0
Tantalum, etc. ¹	PWW	2	2	2	0	0	0	0	0	1	1	0	0	0	0
Titanium and TiO2	Leach liquor & sponge wash water	2	2	2	0	0	0	0	0	0	1	1	0	0	0
Titanium and TiO2	Scrap milling scrubber water	1	1	1	0	0	0	0	0	0	1	0	0	0	0
Zinc	Waste ferrosilicon	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Zinc	Spent s.i. liquids	3	3	0	0	3	0	0	0	0	0	0	0	3	0
Zinc	WWTP liquid effluent	3	3	0	0	0	0	0	0	0	0	0	0	0	0
Zinc	Process wastewater	3	3	3	0	0	0	0	0	2	0	1	0	0	0
TOTAL 2		57	57	42	3	6	1	1	0	30	8	6	3	5	2

1. Tantalum, Columbium, and Ferrocolumbium

2. Sums by risk category may not add to the number of central or high-end waste stream/facility combinations due to rounding.

When HE DAF values are used, the number of facility-waste stream combinations with cancer risks above 10^{-5} increases to 24 of 57 facilities. Under HE assumptions, most of the waste streams show one or more facilities at risk levels above 10^{-5} . The exceptions include both the two NWW streams that would be stored in waste piles, as well as beryllium chip treatment wastewater and zinc wastewater treatment plant liquid effluent. As noted previously, arsenic is not reported as a constituent of the latter waste.

The distribution of facility-waste stream combinations by noncancer risk category is summarized in Exhibit 4-9. Using the CT DAF values, 12 facility-waste stream combinations are identified as having noncancer hazard quotients greater than 1.0. Five of these facilities are managing copper acid plant blowdown, two are managing beryllium chip treatment wastewater, and two of the facility-waste stream combinations are associated with the management of zinc spent surface impoundment liquids.

Using HE DAF values, 28 facility-waste stream combinations are identified as being associated with noncancer hazard quotients above 1.0. Again, four waste streams have no facility-waste stream combinations with hazard quotients above levels of concern: aluminum/alumina cast house dust, rare earth chip treatment wastewater, tantalum process wastewater, and zinc spent waste ferrosilicon.

As discussed previously, if regulatory options completely abolish releases from the mineral processing storage units, post-LDR risks for all of the waste stream-facility combinations would drop below levels of concern. Thus, the numbers of facilities above levels of concern in Exhibits 4-7 and 4-8 provide an upper-bound estimate of the regulatory benefits, in terms of groundwater risk reduction, that might be achieved by Option 3, under which all recycled materials would be stored in tanks, containers, and buildings. Under Options 1 and 2, the recycling of secondary materials in Bevill units would be prohibited. The risks associated with the storage of these wastes (copper acid plant blowdown, and elemental phosphorus AFM rinsate and furnace scrubber blowdown) would definitely be reduced to below levels of concern, since these streams would need to be managed in Subtitle C units.

The extent to which these benefits might actually be realized is difficult to predict without explicit modeling of releases from the tanks, containers, and buildings. These technologies would probably provide substantial risk reduction for most wastes, but EPA does not have sufficient data to estimate the level of risk reduction. Probably those streams with storage risks which just exceed levels of concern would be more likely to fall below levels of concern if managed in TCBs than those streams for which risks exceed levels of concern by many orders of magnitude, because a lower degree of control would be necessary to control these risks. EPA also believes that it will be easier to manage the low-volume recycled streams to achieve high levels of control than it will be to manage the higher volume streams.

EXHIBIT 4-9 RISK SUMMARY FOR STORAGE OF RECYCLED MATERIALS
Distribution of Waste Stream/Facility Combinations by Groundwater Hazard Category:
Non-Cancer Hazards

Commodity	Waste Stream	Number of Waste Stream- Facility Combinations		Central Tendency						High End					
		Central Tendency	High End												
				1 to <1	10 to 10	100 to 100	1k to 1k	1k to 10k	>10k	1 to <1	10 to 10	100 to 100	1k to 1k	1k to 10k	>10k
Aluminum, Alumina	Cast house dust	23	23	23	0	0	0	0	0	23	0	0	0	0	0
Beryllium	Chip treatment WW	2	2	0	0	2	0	0	0	0	0	0	0	2	0
Copper	Acid plant blowdown	10	10	4	3	1	1	0	0	1	2	3	2	1	1
Elemental Phosphorus	AFM rinsate	2	2	2	0	0	0	0	0	0	0	2	0	0	0
Elemental Phosphorus	Furnace scrubber blowdown	2	2	2	0	0	0	0	0	1	1	1	0	0	0
Rare Earths	PWW	1	1	1	0	0	0	0	0	1	0	0	0	0	0
Selenium	Plant PWW	2	2	2	0	0	0	0	0	0	2	0	0	0	0
Tantalum, etc. ¹	PWW	2	2	2	0	0	0	0	0	1	0	0	0	0	0
Titanium and TiO2	Leach liquor & sponge wash water	2	2	2	0	0	0	0	0	0	1	1	0	0	0
Titanium and TiO2	Scrap milling scrubber water	1	1	1	0	0	0	0	0	0	1	0	0	0	0
Zinc	Waste ferrosilicon	1	1	1	0	0	0	0	0	1	0	0	0	0	0
Zinc	Spent s.i. liquids	3	3	2	0	1	1	0	0	0	0	0	1	0	1
Zinc	WWTP liquid effluent	3	3	2	0	0	1	0	0	0	1	1	0	0	1
Zinc	Process wastewater	3	3	2	1	0	0	0	0	1	1	1	1	0	0
TOTAL 2		57	57	45	5	4	3	0	0	29	9	9	4	4	2

1. Tantalum, Columbium, and Ferrocolumbium

2. Sums by hazard category may not add to the number of central or high-end waste stream/facility combinations due to rounding.

4.2.4 Risk Assessment Results for Storage of Recycled Materials: Non-Groundwater Pathways

The health risks associated with recycled materials storage that were calculated for most of the non-groundwater release events and exposure pathways under the modified prior treatment baseline were below levels of concern (lifetime cancer risk less than 10^{-5} , hazard quotients less than 1.0). All risks under HE and CT assumptions were below these levels for the following release events/exposure pathway combinations:

- Inhalation of airborne particulate;
- Ingestion and dermal contact with soil contaminated by airborne particulate;
- Ingestion of crops grown in soil contaminated by airborne particulate;
- Ingestion and dermal contact with soil contaminated by surface run-off;
- Ingestion of crops grown on soil contaminated by surface run-off;
- Ingestion of surface water contaminated by airborne particulate and surface run-off and;
- Ingestion of game fish harvested from surface water contaminated by airborne particulate and surface run-off.

All of the pathways identified are complete only for waste piles. Thus, these findings indicate, as was the case for the groundwater pathway, that all non-groundwater risks for the two recycled streams stored in waste piles are less than levels of concern. In almost all cases, estimated cancer risks and noncancer hazard quotients were far (greater than one order of magnitude, and sometimes many more) below the defined levels of concern. The only exception among all of these pathways was the HE inhalation pathway hazard quotient for barium inhalation from aluminum cast house dust, which was 0.19, or five times below the level of concern. Detailed risk results for these pathways are given in Appendix H.2.

The only pathways for which some risks exceeded levels of concern were ingestion of surface water contaminated by surface impoundment failure, and ingestion of fish harvested from waters contaminated by surface impoundment failures. Exhibit 4-10 summarizes the results of the comparison of surface water concentrations from impoundment releases to HBLs for the water ingestion pathway.

Because there are multiple samples available for most of the waste streams managed in surface impoundments, the results of the comparison to HBLs are reported in terms of the numbers of samples and recycled streams for which the HE and CT surface water concentrations from impoundment releases exceed the HBLs, presented in order-of-magnitude categories.

EXHIBIT 4-10 RISK SUMMARY FOR STORAGE OF RECYCLED MATERIALS

**COMPARISON OF SURFACE WATER CONCENTRATIONS DUE TO SURFACE IMPOUNDMENT RELEASES
TO HEALTH-BASED LEVELS ¹
DRINKING WATER PATHWAY**

				High-End Surface Water Concentration from Bulk Samples		High-End Surface Water Concentration from EP Extraction Samples			Central Tendency Surface Water Concentration from Bulk Samples		Central Tendency Surface Water Concentration from EP Extraction Samples	
				Samples Exceeding HBL by:		Samples Exceeding HBL by:			Samples Exceeding HBL by:		Samples Exceeding HBL by:	
Constituent	Commodity	Wastestream	Total Samples	1-10x	10-100x	1-10x	10-100x	100-1000x	1-10x	10-100x	1-10x	10-100x
Arsenic	Copper	Acid Plant blowdown	40	3	1			1			1	
Cadmium	Zinc	Spent Surface Impoundment Liquids	24	1								
Lead	Copper	Acid Plant Blowdown	40	1								
	Zinc	Spent Surface Impoundment Liquids	24	1	1							

1. The HBL for Arsenic corresponds to a 10-5 lifetime cancer risk.. The HBL for cadmium corresponds to a noncancer hazard quotient of 1.0, and the HBL for lead is the MCL.

Releases from surface impoundment failures were modeled as resulting in potential exceedances of HBLs for water ingestion for three constituents: arsenic, cadmium, and lead. Under high-end dilution assumptions, the arsenic concentrations in five samples (four bulk samples, one EP extraction) would exceed the drinking water HBL by up to one thousand-fold. (This is equivalent, in this case, to saying that the estimated cancer risks under HE assumptions would exceed the 10^{-5} level of concern by up to a factor of 1000.) All of these samples came from the copper acid plant blowdown stream, and under CT dilution assumptions the surface water concentration for arsenic exceeds the HBL for only one of the 40 total samples of this stream.

The concentration of cadmium in one of 24 samples from the zinc spent surface impoundment liquid stream results in surface water concentrations exceeding the drinking water HBL under HE assumptions. The HBL is exceeded by a factor of ten or less. Under CT assumptions, there are no surface water exceedances for cadmium. For cadmium, an HBL exceedance corresponds to a hazard quotient value exceeding 1.0 for its critical toxic effect on kidney function. The lead concentrations in bulk samples from two waste streams result in estimated surface water concentrations exceeding the drinking water HBL. One sample of copper acid plant blowdown shows a concentration of lead such that the HE concentrations exceeds the HBL by a factor of less than ten. Under CT assumptions, this sample no longer exceeds the HBL. Two bulk samples of zinc spent surface impoundment liquids result in HE lead concentrations in surface water that exceed the HBL by a factor of up to 100. Again, under the CT dilution assumptions, the predicted lead concentrations in surface water are reduced to below the drinking water HBL. As noted previously, the HBL for lead is simply the Drinking Water MCL of 15 ug/l.

As shown in Exhibit 4-11, the predicted surface water concentrations of six contaminants released from surface impoundments also were such that HBLs derived for the ingestion of fish by subsistence fishers were exceeded. Six arsenic samples (again all from copper acid plant blowdown) resulted HE surface water concentrations exceeding the fish consumption HBLs by up to a factor of 1000. Four of these were bulk samples, and the remainder were EP extraction samples. Under CT assumptions, only one sample exceeded the arsenic fish ingestion HBL.

A total of 20 samples (one EP extraction, the rest bulk) contained cadmium concentrations which resulted in HE surface water concentrations exceeding the fish ingestion HBL by up to 1000-fold. These samples came from zinc spent surface impoundment liquids (10), zinc process wastewater (6), copper acid plant blowdown (2 samples), and one sample each from rare earths process wastewater and zinc wastewater treatment plant liquid effluent. Under CT dilution assumptions, the number of samples exceeding the HBL is reduced to 3 samples, and the maximum level of exceedance is reduced to less than 100-fold.

Under HE assumptions, five samples give mercury concentrations in surface water exceeding the fish ingestion HBL. These samples come from copper acid plant blowdown (3) and zinc spent surface impoundment liquids (2), and under CT assumptions, none of these samples exceeds the fish HBL. In the case of mercury, an HBL exceedance is equivalent to a hazard quotient greater than 1.0 for reproductive effects.

A single sample result for selenium in copper acid plant blowdown results in surface water concentrations above the HBL, as do two thallium results (one each from titanium/TiO₂ leach liquor and sponge wash water and from copper acid plant blowdown). For all of these samples, no exceedances occur under CT dilution assumptions. The same is true for the six analytical results for zinc (all from zinc commodity streams). All six of the samples exceed the fish ingestion HBL under HE but not under CT dilution assumptions.

EXHIBIT 4-11 RISK SUMMARY FOR STORAGE OF RECYCLED MATERIALS

COMPARISON OF SURFACE WATER CONCENTRATIONS FROM SURFACE IMPOUNDMENT RELEASES TO HEALTH-BASED LEVELS 1 FISH INGESTION PATHWAY

				High-End Surface Water Concentration from Bulk Samples			High-End Surface Water Concentration from EP Extraction Samples			Central Tendency Surface Water Concentration from Bulk Samples		Central Tendency Surface Water Concentration from EP Extraction Samples	
				Samples Exceeding HBL by:			Samples Exceeding HBL by:			Samples Exceeding HBL by:		Samples Exceeding HBL by:	
Constituent	Commodity	Wastestream	Total No. Samples	1-10x	10-100x	100-1000x	1-10x	10-100x	100-1000x	1-10x	10-100x	1-10x	10-100x
Arsenic	Copper	Acid Plant Blowdown	40	2	2		1		1			1	
Cadmium	Copper	Acid Plant Blowdown	40	2									
	Rare Earths	Process Wastewater	8				1						
	Zinc	Process Wastewater	40	6									
	Zinc	Spent Surface Impoundment Liquids	24	6	3	1				1	1		
	Zinc	WWTP Liquid Effluent	5			1					1		
Mercury	Copper	Acid Plant Blowdown	40	2			1						
	Zinc	Spent Surface Impoundment Liquids	24	1	1								
Selenium	Copper	Acid Plant Blowdown	40	1									
Thallium	Titanium and TiO ₂	Leach liquid & sponge wash water	8	1									
	Copper	Acid Plant Blowdown	40				1						
Zinc	Zinc	Spent Surface Impoundment Liquids	24	5									
	Zinc	WWTP Liquid Effluent	5	1									

1. The HBL for Arsenic corresponds to a 10-5 lifetime cancer risk.. The HBL for the other constituents correspond to a noncancer hazard quotient of 1.0.

4.2.5 Potential Health Benefits from Regulation of Storage of Recycled Materials: Non-Groundwater Pathways

Exhibit 4-12 summarizes the estimated numbers of facility-waste stream combinations which exceed HBLs for both surface water pathways under the modified prior treatment baseline. Under the ingestion pathway, the three facilities with HBL exceedances under HE assumptions drops to zero under CT assumptions, as do the two facilities storing zinc spent surface impoundment liquids. Similarly, when the fish ingestion pathway is considered, a large number of facilities storing six different waste streams show exceedances of the HBLs under HE assumptions, but only one facility (storing zinc spent surface impoundment liquids) exceeds an HBL under CT assumptions.

As was the case with the groundwater pathway, effective management of the recycled materials could reduce all of the estimated risks to below levels of concern. Again, however, there is no way to estimate how much risk reduction would be achieved without explicit modeling of the non-groundwater pathway releases from TCBs. Under Options 1 and 2, copper acid plant blowdown could no longer be recycled through a Bevill unit, and treatment of this stream as a Subtitle C waste would undoubtedly result in a high degree of risk reduction. Under Option 3, all of the streams could be managed in TCBs, and the degree of risk reduction and the magnitude of health benefits for storage are harder to estimate. Since the magnitude of exceedances of the HBLs for most waste stream-facility combinations are rather low for the surface water pathways, it is possible that most of these risks would, in fact, be reduced below levels of concern under Option 3. In terms of reduced risks from the storage of recycled materials, Option 4 provides no benefits over the modified prior treatment baseline.

4.3 Uncertainties and Limitations in the Risk and Benefits Assessment for the Modified Prior Treatment Baseline

As noted in section 4.1.1, the multipathway risk assessment for the storage of mineral processing recycled materials relies on relatively simple, generic models of contaminant releases, transport, exposures, and risks. Therefore, the risk assessment results cannot be used to estimate risk reduction benefits for actual exposed populations residing near the mineral processing facilities. Instead, they only provide plausible estimates of the potential health risks faced by hypothetical individuals under the defined exposure conditions.

The screening level analysis also shares the general limitations of all generic analyses in that high levels of uncertainty and variability may not be adequately treated, since only a limited number of generally applicable models and generally representative data are used to model risks from a wide range of units, wastes, and constituents. Many of these generic sources of uncertainty have been addressed in our previous work on mineral processing wastes, and the following discussion is focused on limitations specific to the multipathway analysis.

As noted previously, constituent concentration data are available for only 14 recycled waste streams, and for some wastes only small numbers of samples are available. It is interesting to note that two of the wastes for which estimated risks are the highest (copper acid plant blowdown and zinc spent surface impoundment liquids) also are those for which the largest number of samples are available. It is not possible to estimate which of the other wastes might also show risks above levels of concern if more data were available. As noted previously, the storage risk assessment covers waste streams representing about 40 percent of the total waste generated and about 65 percent of the recycled volume.

April 15, 1997

EXHIBIT 4-12 RISK SUMMARY FOR STORAGE OF RECYCLED MATERIALS

DISTRIBUTION OF WASTE-STREAM FACILITY COMBINATIONS BY DEGREE OF HBL EXCEEDENCE UNDER THE MODIFIED PRIOR TREATMENT BASELINE							
			Number of Waste Stream-Facility Combinations with High-End Exceedences of HBLs by:			Waste Stream-Facility Combinations with Central Tendency Exceedences of HBLs by:	
Commodity	Waste Stream	Sector Total Waste Stream-Facility Combinations	1-10X	10-100X	100-1000X	1-10X	10-100X
<u>1. Drinking Water</u>							
Copper	Acid Blowdown	10	1				
Zinc	Spent Surface Impoundment Liquids	3					
<u>2. Fish Ingestion</u>							
Copper	Acid Blowdown	10	2	1			
Rare Earths	Process Wastewater	1					
Titanium, TiO ₂	Leach Liquor and Sponge Wash Water	2					
Zinc	Process Wastewater	3					
Zinc	Spent Surface Impoundment Liquids	3	1	1			
Zinc	WWTP Liquid Effluent	3			1		1

Limited data also are available concerning waste characteristics, including constituent speciation, solubility, and bioavailability. Throughout this analysis, we have assumed that all constituents would behave in such a manner as to maximize exposure potential. For example, we have assumed that none of the constituents would leach from soils after their initial deposition, and that all of the constituents would be bioavailable in the water column. Generally these assumptions increase the level of conservatism of the risk assessment.

In evaluating potential risks to human health, exposure through multiple release pathways (leaching to groundwater, particulate suspension, surface runoff, inlet/outlet failure for surface impoundments) were considered. In this analysis, it was assumed that all of the constituent mass placed in the management units was available for release through all release pathways. This assumption may have resulted in the overestimation of risks for some pathways due to double counting of constituent mass. For example, if constituent mass is depleted over time due to leaching, then the mass of constituent available for release through other pathways (e.g. particulate suspension) is reduced.

Mass balance calculations were performed for the non-groundwater release pathways (see Appendix H.2.2.1), and it was found that the proportion of constituent mass released by all of these pathways was below one percent of the total mass present in the management units. Thus, the neglect of mass balance considerations for these pathways resulted in negligible bias in the risk assessment results. The mass balance calculations did not include the groundwater pathway, however, because the methodology used did not allow release masses (only release concentrations) to be calculated. It is therefore possible that substantial depletion of some soluble and mobile constituents could occur through groundwater leaching, and these constituents would not be available for release by other pathways. This possibility has little or no impact on the findings of the risk assessment for waste piles, since, even if it is assumed that all of the constituents are released through every pathway, all calculated risks are below levels of concern. While it is not possible to estimate the magnitude of the potential bias in the risk results for surface impoundments, it is likely to be low, because of the relatively high through-put which is assumed for the impoundments, relative to plausible leachate release volumes.

Releases to groundwater and groundwater fate and transport were evaluated using EPA's EPACMTP model. Leachate concentrations and constituent- and facility-specific DAFs were derived using the best available data, which, although limited, provided a reasonable basis for generic modeling of the representative facilities. High-end (95th percentile) and central tendency (75th percentile) DAFs were used to explore the levels of uncertainty and variability in groundwater fate and transport processes. Comparison of the HE and CT DAFs indicates that the probability distribution of the DAF values is quite broad, and that the level of uncertainty is quite high. As for the other pathways, exposure assumptions were used that provide a moderate degree of conservatism for the groundwater pathway risk estimates.

Release events and amounts for non-groundwater pathways were simulated mostly using the general methods adopted in HWIR-Waste. The one exception is air particulate generation, which was estimated using the SCREEN3 model, rather than the model recommended in HWIR-Waste. SCREEN3 is a widely-accepted screening level EPA model. We believe that it is appropriate for the types of release events that were modeled. The use of SCREEN3 is unlikely to have biased the results of the risk assessment significantly compared to other methods. However, no data were available concerning the particle size characteristics of the two wastes streams that were modeled, so EPA relied on data from an earlier study of mineral processing wastes stored in waste piles. Based on limited information, the Agency believes, for example, that the particle size distribution which was used may overstate the potential for particulate release of the more coarse-grained, high-density zinc waste ferrosilicon, while more accurately describing the potential for particulate releases of aluminum cast house dust.

Run-off releases were evaluated using the same model the Universal Soil Loss Equation, USLE, applied in HWIR-Waste, with input parameters varied slightly to reflect the operating characteristics of the waste piles being simulated and the likely geographic distribution of the recycling facilities. We also assumed that no runoff controls would be used. The risk results are not particularly sensitive to these assumptions, as exposure concentrations in soil and surface water due to run-off events are very far below the levels of concern for all exposure pathways.

The ISCST3 model used to predict particulate air concentrations and deposition rates is a state-of-the-art model that has been used in many regulatory proceedings by EPA. The input data that were used, the "worst-case" meteorological conditions, were somewhat more conservative than the meteorological data used in HWIR-Waste with a similar model. Thus, our estimates of air impacts are likely to be higher than those that would have been achieved had we replicated the HWIR-Waste approach. Again, however, all the estimated risks and exposure concentrations for air releases are far below levels of concern, despite this conservatism.

The modeling of releases from surface impoundments reproduced exactly the approach used in HWIR-Waste. This release model and its input parameters were derived based on data from management units in the pulp and paper industry, and just how reliably they predict releases from surface impoundments in the mineral processing industries is not known. This is clearly a major source of uncertainty in the risk assessment, as these release events are the only ones for which health risks are predicted to be above levels of concern.

Because of resource limitations and the specific characteristics of the facilities that we were evaluating, we developed simplified approaches to modeling the concentrations of waste constituents in surface soils and surface water to substitute for the much more elaborate methods used in HWIR-Waste. In the case of surface run-off, in the absence of site-specific data, we conservatively assumed that soil contamination would be limited to relatively small distances (50 or 100 meters) from the piles in arbitrarily defined circular plumes. This is only intended as a bounding analysis, and the finding that this pathway is not a major concern can be supported by the fact that, even with these relatively small exposure areas (and the resultant high soil concentrations), constituent concentrations due to run-off events were two or more orders of magnitude below levels of health concern.

Similarly, to be conservative, we assumed that all of the run-off and all of the particulate generated by the waste piles would be deposited on the watershed in such a way that all of these materials would rapidly find their way into surface water. This approach, while it resulted in surface water concentrations far below levels of health concern, may be less conservative than the approach taken for surface soils, because the CT and HE streams are both rather large, and the model does not take into account possible run-off or deposition into smaller streams, lakes, or ponds where constituents may accumulate in surface water or sediment.

The approach taken in evaluating fish tissue concentrations was also somewhat more conservative than that taken in HWIR-Waste, in that the highest available BCF or BAF values were used, rather than representative values, in our calculations. For some constituents (arsenic, cadmium, mercury, thallium), this approach resulted in considerably higher tissue concentrations than would have been calculated had we used the HWIR-Waste values. This may be a major source of uncertainty in this analysis, since the fish ingestion pathway resulted in the highest risks predicted for several of the constituents and waste streams.

5. Other Administrative Requirements

This section describes the Agency's response to other rulemaking requirements established by statute and executive order, within the context of today's proposed rule.

Environmental Justice

EPA is committed to addressing environmental justice concerns and is assuming a leadership role in environmental justice initiatives to enhance environmental quality for all residents of the United States. The Agency's goals are to ensure that no segment of the population, regardless of race, color, national origin, or income bears disproportionately high and adverse human health and environmental impacts as a result of EPA's policies, programs, and activities, and that all people live in clean and sustainable communities. In response to Executive Order 12898 and to concerns voiced by many groups outside the Agency, EPA's Office of Solid Waste and Emergency Response formed an Environmental Justice Task Force to analyze the array of environmental justice issues specific to waste programs and to develop an overall strategy to identify and address these issues (OSWER Directive No. 9200.3-17).

Today's proposal covers wastes from mineral processing operations. The environmental problems addressed by this proposed rulemaking could disproportionately affect minority or low income communities, due to the location of some mineral processing and waste disposal facilities. Mineral processing sites are distributed throughout the country and many are located within highly populated areas. Mineral processing wastes have been disposed of in various states throughout the U.S., representing all geographic and climatic regions. In some cases, mineral processing waste is generated in one state and disposed of in another. In addition, mineral processing wastes are occasionally disposed of in municipal solid waste landfills.

Today's proposed rule is intended to reduce risks from mineral processing wastes, and to benefit all populations. It is, therefore, not expected to result in any disproportionately negative impacts on minority or low income communities relative to affluent or non-minority communities.

Unfunded Mandates Reform Act

Under Section 202 of the Unfunded Mandates Reform Act of 1995, signed into law on March 22, 1995, EPA must prepare a statement to accompany any rule where the estimated costs to state, local, or tribal governments in the aggregate, or to the private sector, will be \$100 million or more in any one year. Under Section 205, EPA must select the most cost-effective and least burdensome alternative that achieves the objective of the rule and is consistent with statutory requirements. Section 203 requires EPA to establish a plan for informing and advising any small governments that may be significantly impacted by the rule.

EPA has completed an analysis of the costs and benefits from today's proposed rule and has determined that this proposed rule does not include a federal mandate that may result in estimated costs of \$100 million or more to either state, local or tribal governments in the aggregate. The private sector also will not incur costs exceeding \$100 million per year under any of the three costing scenarios described in Section 4.4, Cost and Economic Impacts of the Rule, above.

6. Conclusions

This section presents the Agency's preliminary conclusions regarding the regulatory impacts of implementing the options presented in today's notice. The chapter is organized around the central elements of the analyses provided in previous sections, namely characterizing the affected population of waste streams, facilities, and mineral industry sectors, analyzing the cost and economic impacts of implementing the options, and assessing the human health benefits of adopting these regulatory alternatives.

6.1 The Affected Universe

As described in depth in the RIA prepared in support of the January 1996 proposed rule, EPA conducted intensive research in an attempt to identify and characterize all of the waste streams that might be affected by imposition of LDR requirements on non-exempt hazardous mineral processing wastes. This research has yielded a group of 118 potentially hazardous mineral processing residues that may be subject to Subtitle C controls and accordingly, to new LDR treatment standards.

This number is far smaller than the total population of mineral industry wastes, and reflects EPA's step-wise process of eliminating from the analysis wastes that are: 1) generated by extraction and beneficiation operations (these are Bevill-exempt), 2) the 20 exempt special mineral processing wastes, and 3) wastes that are known or expected to be non-hazardous. The remaining waste streams have been included in the Agency's analyses, though in many cases substantial uncertainties regarding their generation rates, hazardous characteristics, and management practices have led EPA to develop several different estimates of these parameters, which in turn produce highly variable estimates of costs and benefits arising from new regulatory controls.

The Agency recognizes the limitations that these data gaps and simplifying assumptions impose on the accuracy of the analyses presented above. EPA has provided detailed analyses of the potential cost and benefit impacts of the LDR options in the interests of providing interested parties with as much pertinent information as possible.

EPA recognizes the limitations that these data gaps and simplifying assumptions impose on the accuracy of the analyses presented above. EPA has provided detailed analyses of the potential cost and benefit impacts of the LDR options in the interests of providing interested parties with as much pertinent information as possible.

6.2 Cost and Economic Impacts of the Rule

A summary of the projected costs of implementing the four options analyzed in this RIA is provided in Exhibit 4-13, below.

As can be seen in Exhibit 4-13, cost impacts are highest for Options 1 and 2, ranging between \$46 million and \$75 million annually for Option 1 and \$37 million and \$55 million annually for Option 2. Option 3 results in significantly lower cost impacts, with costs ranging only from \$5.2 million to \$13 million annually. Option 4 results in significantly lower cost impacts than the other three options, with impacts ranging only from \$71,000 to 190,000 annually.

Exhibit 6-1

**Summary of Cost Analysis Results
(Results in \$ Thousands per Year)**

Option^a	Costing Scenario	Modified Prior Treatment
Option 1	Minimum	46,000
	Expected	58,000
	Maximum	75,000
Option 2	Minimum	37,000
	Expected	45,000
	Maximum	55,000
Option 3	Minimum	5,200
	Expected	8,400
	Maximum	13,000
Option 4	Minimum	71
	Expected	190
	Maximum	190

^a Options are described in detail in Section 4.1.

The high costs associated with Option 1 are the result of additional requirements the option would impose on facility operator recycling secondary materials. Option 2 costs are slightly lower than Option 1 costs, and are driven primarily by the option's prohibition against recycling secondary materials to beneficiation or Bevill process units. The absence of a legitimacy test for recycling and the option's provisions that allow for storage of secondary materials in non-RCRA tanks, containers, and buildings prior to recycling account for Option 2's lower costs relative to Option 1.

Option 3 has the lowest costs of the non-land based storage options. The significantly lower costs associated with Option 3 result from the option's lack of prohibition in the recycling of secondary materials through beneficiation or Bevill process units. Option 4 results in relatively low net costs to industry because the option essentially allows facilities to continue operating as they currently operate. The Agency assumes that in some cases, facility owners and operators, out of misunderstanding of current requirements, handle spent materials improperly. Option 4 would allow these owners and operators to continue to handle spent materials in this manner. The only costs incurred by facility owners under this option are relatively insignificant recordkeeping and reporting requirements.

A brief summary of the projected economic impacts of the rule, assuming the modified prior treatment baseline, is summarized in Exhibit 4-14. Again, impact ratios are the annualized costs of compliance divided by annual value of shipments.

Exhibit 6-2

**Summary of Economic Impact Screening Results:
Modified Prior Treatment Baseline**

Option	Costing Scenario	Sectors with Impacts
Option 1	Minimum	1
	Expected	5
	Maximum	7
Option 2	Minimum	1
	Expected	5
	Maximum	6
Option 3	Minimum	0
	Expected	3
	Maximum	5
Option 4	Minimum	0
	Expected	0
	Maximum	0

Analysis of costs as a percentage of value added indicates that only Option 4 results in no significant impacts (defined as greater than 10 percent) to industry. Option 3 will significantly impact the cadmium and selenium sectors (13 percent of the sectors analyzed). Greater impacts are expected to result from Options 1 and 2. For Option 1, EPA anticipates that five of the 16 industry sectors (31 percent of the sectors included in this analysis) will be significantly affected (lead, cadmium, selenium, tellurium, and zinc). Under Option 2, three of the 16 sectors (19 percent of the sectors analyzed) are expected to be significantly affected (lead, cadmium and selenium).

None of the five industry sectors for which profits data were available are projected to have severe cost impacts (defined as costs greater than estimated industry profits) under any option. In fact, impacts exceed one percent in the expected value case only for the copper sector and only under Options 1 and 2.

6.3 Health Benefits of the Proposed LDRs

The benefits of the proposed LDRs for mineral processing wastes take the form of reduced risks to human health and the environment from improved management of the subject wastes. EPA has conducted analyses of the potential health risks associated with the disposal of mineral processing wastes and the storage of recycled streams under different sets of baseline assumptions, and of the potential reductions in health risks that may be achieved under the proposed regulatory options. Potential risks and benefits have been evaluated for potential groundwater exposures to toxic waste constituents arising from waste disposal, and for groundwater and non-groundwater pathway exposures to constituents released during the storage of recycled streams. Detailed descriptions of the methods used to evaluate risks and benefits for waste

disposal are found in Appendix A, and descriptions of the methods used for the risk assessment for waste storage are found in Appendix H of this RIA.

Under the modified prior treatment baseline, which EPA believes is the most realistic and representative characterization of current industry practice, it is assumed that the wasted (unrecycled) portion of all waste streams would be treated by stabilization to achieve compliance with the TC regulatory leachate levels prior to land disposal. Under this set of assumptions, the baseline groundwater pathway risks associated with the disposal of the wastes have been estimated to be quite low. As discussed in Section 4.2.1, disposal of the waste streams in compliance with the TC regulatory levels would result in groundwater risks below levels of concern (10^{-5} cancer risk or noncancer hazard quotient of 1.0) for all of the TC analytes except arsenic. For arsenic, disposal at the TC concentration would result in estimated cancer risks that just exceed 10^{-5} . EPA believes (although the issue has not been evaluated quantitatively) that stabilization to comply with the TC regulatory levels also will control the mobility of most toxic non-TC inorganic constituents to the extent that baseline groundwater risks for these constituents also will be below levels of concern.

For these reasons, EPA estimates that the health benefits from improved waste disposal practices under all of the regulatory options would be quite low compared to the modified prior treatment baseline, considering only groundwater pathway exposures. For arsenic, which is a major risk-driving constituent for many wastes, risk reduction would not occur, since the TC regulatory level and UTS leachate concentration are identical. For other constituents, some exposure reduction could occur under these options, since the UTS levels are lower than the TC leachate concentrations, and because some non-TC analytes may not be effectively immobilized by treatments designed to comply with the TC.

EPA's evaluation of the potential groundwater risks associated with the storage of recycled streams under the modified prior treatment baseline is described in Section 4.2.3. Estimated groundwater pathway cancer risks under high-end (HE) baseline assumptions exceeded 10^{-5} at 24 of 57 facilities storing recycled streams, while under central tendency (CT) assumptions, only 11 facilities exceed this level (Exhibit 4-8). The HE noncancer hazard quotients for groundwater exposures exceed 1.0 at 28 facilities storing recycled materials, and under CT assumptions baseline hazard quotients exceed 1.0 at 12 facilities (Exhibit 4-9). All of the facilities for which baseline cancer risks or noncancer hazard quotients exceed levels of concern manage wastewater and liquid nonwastewater streams in impoundments. Owing primarily to the low recycled volumes and small facility sizes, the baseline groundwater risks for the two nonwastewater streams managed in waste piles are below levels of concern under both CT and HE assumptions.

The analysis of non-groundwater pathway risks associated with waste storage under the modified prior treatment baseline indicated that, for the majority of the pathways evaluated, estimated risks were far below levels of concern. As was the case for the groundwater pathway risk assessment, risks from the storage of the two nonwastewater streams in waste piles were less than levels of concern for all release events and exposure pathways.

Baseline risks greater than levels of concern were found for exposures to surface water contaminated by releases from surface impoundment failures of some waste streams, however. In the case of the direct ingestion pathway, one facility storing copper acid plant blowdown had an HE cancer risk exceeding 10^{-5} . Under CT assumptions, the estimated cancer risk for this facility was below the level of concern. When exposure through fish consumption is considered, six facilities from three commodity sectors had HE risks from waste storage exceeding cancer or noncancer levels of concern. Under CT assumptions, risks from only two storage facilities exceeded levels of concern for the fish ingestion pathway. These results are summarized in Exhibit 4-12.

EPA did not quantitatively estimate the extent of risk reduction or the level of health benefits that could be brought about by the proposed LDRs' effects on recycled materials storage. This is because the available data and models do not allow the development of risk reduction estimates for tanks, containers, and buildings, which would be the required management units for most of the recycled streams under regulatory Options 1-3. If these options completely or substantially eliminate the release of recycled streams to groundwater and other media, the baseline risks discussed in the previous paragraphs could all be reduced to below levels of concern. Lesser degrees of control would result in less risk reduction and lower health benefits. Under Options 1 and 2, the risks for three of the streams managed through Bevill units (copper acid plant blowdown, and the two streams from elemental phosphorus production) would be greatly reduced by the requirement to manage them in Subtitle C units. Copper acid plant blowdown figures prominently as a contributor to storage risks through both the groundwater and non-groundwater pathways. Under Option 4, no health benefits associated with the storage of recycled materials would be realized, as there is no requirement for improved management of these streams.

ANALYSIS OF OPTIONS UNDER ALTERNATIVE BASELINES**APPENDIX A**

This appendix presents the estimated costs, economic impacts, and benefits of regulatory options under two alternative baselines, the "no prior treatment" baseline and the "prior treatment" baseline, for mineral processing wastes under Phase IV LDRs. Under the no prior treatment baseline, wastes are assumed to be managed, untreated, in unlined surface impoundments and waste piles, i.e., the practices that were generally in place prior to removal of these wastes from the Beville exclusion in 1989 and 1990. Under the prior treatment baseline, wastes are either treated to UTS levels and disposed in a Subtitle D unit or stored prior to recycling in tanks, containers, and buildings if they are spent materials or in unlined land based units if they are sludges or byproducts. The prior treatment baseline assumes facility operators clearly understand the Subtitle C regulations that apply to their secondary materials, i.e., that spent materials intended for recycling are not currently excluded from Subtitle C regulation.

Although the costs and economic impacts under the no prior treatment baseline were analyzed in the December 1995 RIA to the proposed rule, they are not analyzed in today's RIA because the costs of managing wastes with no prior treatment are not properly attributed to this rule. In addition, while the prior treatment baseline may more accurately assess the cost attributable to this rulemaking than the modified prior treatment baseline (i.e., the baseline used in the main analysis), EPA believes the modified prior treatment baseline more accurately reflects actual practice in the mineral processing industry. In both cases, however, EPA has elected to present the cost and benefits attributable to these other baselines in this Appendix.

The methodology for estimating the costs and economic impacts under these alternative baselines is the same as the methodology used in the primary analysis, which is discussed in Section 3.1. The estimated costs and economic impacts under these baselines are presented in Section A.1 of this Appendix. Section A.2 presents the results of the risk analysis for the no prior treatment baseline. Additional information supporting the risk analysis is included in Section A.3.

A.1 Costs and Impacts

In developing its estimates of the proposed rule's costs and economic impacts, EPA used a dynamic analysis to predict changes in the management of newly identified mineral processing wastes. The dynamic analysis accounts for a shift in the amount of material that is recycled rather than being treated and disposed due to incentives and disincentives for future recycling. EPA estimated the percentage of hazardous material sent to treatment and disposed for each baseline and option. The *remaining* hazardous material is considered to be recycled. The dynamic analysis reflects the shifts in management anticipated in each baseline/option combination.

Exhibit A.1-1 presents required changes in management practices as a result of the proposed Phase IV Land Disposal Restrictions for the wasted portion and the recycled portion of hazardous mineral processing secondary materials for the four regulatory options. Exhibit A.1-2 presents the predicted changes in recycling, given the required changes in management practices listed in Exhibit A.1-1. The information in Exhibit A.1-2 combines into an overall impact all incentives operating at a facility. For instance, under Option 3 assuming the modified prior treatment baseline, Exhibit A.1-1 suggested that there would be (1) no change in the amount recycled due to treatment requirements, and (2) a decrease in the amount recycled because of the stricter recycling unit standards. Because, however, the incremental cost of storing material in a tank, container, or building prior to recycling is usually less than the cost of moving that material to treatment and disposal, the overall predicted effect of this option-baseline

combination is a small decrease in the amount of material recycled. (That is, a facility operator in this option-baseline combination would usually pay the extra cost of storage rather than changing management practices.)

Exhibit A.1-1

Changes in Management of Hazardous Mineral Processing Waste

Baseline/Option	Affected Material	Required Change in Management	Implied Change In Recycling
NPT	Wasted Portion	Disposal to UTS and Disposal	Increase
MPT/PT		TC to UTS	No Change
NPT/MPT to Option 1	Non- Bevill	Unlined Units to RCRA TCBs Legitimacy Test, Sig. Aff.	Decrease
	Bevill	Unlined Units to No Recycling	Complete Halt
NPT/MPT to Option 2	Non-Bevill	Unlined Units toTCBs	Decrease
	Bevill	Unlined Units to No Recycling	Complete Halt
NPT/MPT to Option 3	All	Unlined Units to TCBs	Decrease
NPT/MPT to Option 4	All	Unlined Units to Unlined Units	No Change
PT (SL/BP) to Option 1	Non- Bevill	Unlined Units to RCRA TCBs Legitimacy Test, Sig. Aff.	Decrease
	Bevill	Unlined Units to No Recycling	Complete Halt
PT (SL/BP) to Option 2	Non-Bevill	Unlined Units toTCBs	Decrease
	Bevill	Unlined Units to No Recycling	Complete Halt
PT (SL/BP) to Option 3	All	Unlined Units to TCBs	Decrease
PT (SL/BP) to Option 4	All	Unlined Units to Unlined Units	No Change
PT (SM) to Option 1	Non- Bevill	TCBs to RCRA TCBs Legitimacy Test, Sig. Aff.	Decrease
	Bevill	TCBs to No Recycling	Complete Halt
PT (SM) to Option 2	Non-Bevill	TCBs toTCBs	No Change
	Bevill	TCBs to No Recycling	Complete Halt
PT (SM) to Option 3	All	TCBs to TCBs	No Change
PT (SM) to Option 4	All	TCBs to Unlined Units	No Change

Option 1 - Storage in RCRA Tanks, Containers, and Buildings Only, Recycling of Materials through Bevill Units Prohibited

Option 2 - No Land-based Storage Recycling of Materials through Bevill Units Prohibited

Option 3 - No Land-based Storage

Option 4 - Land-based Storage without restriction

Bevill means that secondary materials are recycled through beneficiation or Bevill process units

Non-Bevill means that secondary materials are not recycled through beneficiation or Bevill process units

Exhibit A.1-2

Overall Predicted Changes in Recycling

	Option 1*	Option 2 *	Option 3	Option 4
No Prior Treatment	Small Decrease	Increase	Increase	Big Increase
Modified Prior Treatment and Prior Treatment (SL/BP)	Moderate Decrease	Small Decrease	Small Decrease	No Change
Prior Treatment (SM)	Decrease	No Change	No Change	Increase

* For materials recycled through non-Bevill Units only. Materials recycled through Bevill units will completely cease to be recycled under Options 1 and 2.

Exhibit A.1-3 presents the percentages of the hazardous portion of mineral processing waste streams that are sent to treatment and disposal, in both the baseline and post-rule options, and Exhibit A.1-4 presents the percentages stored prior to recycling. Exhibits A.1-3 and A.1-4 are based on (1) the overall predicted changes in recycling listed in Exhibit A.1-2 and (2) empirical data, as described below. For option-baseline combinations that eliminate the differences in regulatory requirements for recycled sludges, by-products, and spent materials, the proportion of material recycled is the same for all three types of material after the rule goes into effect. Lastly, Exhibit A.1-5 shows the change in recycling percentage for each option-baseline combination. For option-baseline combinations that increase recycling, the largest shift is seen in Y? materials, and the smallest shift is seen in YS? materials. The opposite is true for option-baseline combinations that decrease recycling. Generally the largest shift should be seen in the YS? case. This trend is not always apparent, however, because the percentage recycled is limited to the range from 0 to 100 percent.

The limited available data on the recycling of two listed wastes, K061 (emission control dust from electric arc steel furnaces) and F006 (wastewater treatment sludge from electroplating operations) were used to quantify the expected shift in recycling. These data were used due to the fact that an increase in the amount of K061 and F006 being recycled was observed after Land Disposal Restrictions (LDRs) for K061 and F006 were promulgated.¹ A 75 percent increase in K061 recycling was observed after the LDR for K061 was implemented, from an average of 15 percent recycled pre-LDR to 90 percent recycled post-LDR. Similarly, a 15-20 percent increase in the amount of F006 recycling was observed as a result of the F006 LDR, from 0 percent recycled pre-LDR to 15-20 percent recycled post-LDR.² Therefore, in the December 1995 RIA, the Agency modeled the 75 percent shift for Y? materials from the No Prior Treatment Baseline to Option 2 on K061, and the 15 percent shift for YS? materials from the No Prior Treatment Baseline to Option 2 on F006. Because Option 2 in the December RIA is no longer modeled, and Options 2 and 3 of today's proposal require slightly more expensive storage units (tanks, containers, and buildings instead of lined land-based units, EPA adjusted these data slightly for use in Options 2 and 3 of today's RIA. The predicted shift in these two options for Y? material is 70 percent and the predicted

¹ 1990 Survey of Selected Firms in the Hazardous Waste Management Industry, Final Report, U.S. E.P.A. Office of Policy Analysis, (July 1992).

² Report to Congress on Metal Recovery, Environmental Regulation, & Hazardous Waste, U.S. E.P.A., Washington, D.C., (February 1994).

shift for YS? materials is 10 percent. EPA used best professional judgement to estimate the shifts in the other option-baseline combinations.

Exhibit A.1-3
Proportions of Waste Streams Treated and Disposed (in percent)

Baseline or Option	Affected Material	Percent Recycled				
		Certainty of Recycling				N
		Y	Y?	YS	YS?	
Prior Treatment	SL/BP	0	15	25	80	100
Prior Treatment	SM	0	25	35	85	100
Modified Prior Treatment	All	0	15	25	80	100
No Prior Treatment	All	0	100	60	100	100
Option 1 from PT	Bevill	100	100	100	100	100
	Non-Bevill	30	65	100	100	100
Option 2 from PT	Bevill	100	100	100	100	100
	Non-Bevill	0	25	35	85	100
Option 3 from PT	All	0	25	35	85	100
Option 4 from PT	All	0	15	25	80	100
Option 1 from MPT	Bevill	100	100	100	100	100
	Non-Bevill	30	65	100	100	100
Option 2 from MPT	Bevill	100	100	100	100	100
	Non-Bevill	0	25	35	85	100
Option 3 from MPT	All	0	25	35	85	100
Option 4 from MPT	All	0	15	25	80	100
Option 1 from NPT	Bevill	100	100	100	100	100
	Non-Bevill	20	100	90	100	100
Option 2 from NPT	Bevill	100	100	100	100	100
	Non-Bevill	0	30	40	85	100
Option 3 from NPT	All	0	30	40	85	100
Option 4 from NPT	All	0	15	25	80	100

Notes:

Y means that EPA has information indicating that the waste stream is fully recycled.

Y? means that EPA, based on professional judgment, believes that the waste stream could be fully recycled.

YS means that EPA has information indicating that a portion of the waste stream is fully recycled.

YS? means that EPA, based on professional judgment, believes that a portion of the waste stream could be fully recycled.

Bevill means that secondary materials are recycled through beneficiation or Bevill process units

Non-Bevill means that secondary materials are not recycled through beneficiation or Bevill process units

Exhibit A.1-4

**Proportions of Waste Streams Stored Prior to Recycling
(in percent)**

Baseline or Option	Affected Material	Percent Recycled				
		Certainty of Recycling				
		Y	Y?	YS	YS?	N
Prior Treatment	SL/BP	100	85	75	20	0
Prior Treatment	SM	100	75	65	15	0
Modified Prior Treatment	All	100	85	75	20	0
No Prior Treatment	All	100	0	40	0	0
Option 1 from PT	Bevill	0	0	0	0	0
	Non-Bevill	70	35	0	0	0
Option 2 from PT	Bevill	0	0	0	0	0
	Non-Bevill	100	75	65	15	0
Option 3 from PT	All	100	75	65	15	0
Option 4 from PT	All	100	85	75	20	0
Option 1 from MPT	Bevill	0	0	0	0	0
	Non-Bevill	70	35	0	0	0
Option 2 from MPT	Bevill	0	0	0	0	0
	Non-Bevill	100	75	65	15	0
Option 3 from MPT	All	100	75	65	15	0
Option 4 from MPT	All	100	85	75	20	0
Option 1 from NPT	Bevill	0	0	0	0	0
	Non-Bevill	80	0	10	0	0
Option 2 from NPT	Bevill	0	0	0	0	0
	Non-Bevill	100	70	60	15	0
Option 3 from NPT	All	100	70	60	15	0
Option 4 from NPT	All	100	85	75	20	0

Notes:

Y means that EPA has information indicating that the waste stream is fully recycled.

Y? means that EPA, based on professional judgment, believes that the waste stream could be fully recycled.

YS means that EPA has information indicating that a portion of the waste stream is fully recycled.

YS? means that EPA, based on professional judgment, believes that a portion of the waste stream could be fully recycled.

Bevill means that secondary materials are recycled through beneficiation or Bevill process units

Non-Bevill means that secondary materials are not recycled through beneficiation or Bevill process units

Exhibit A.1-5

Change in Recycling Percentage for Affected Option-Baseline Combinations

Baseline or Option	Affected Material	Increase in Recycling (percent)				
		Certainty of Recycling				
		Y	Y?	YS	YS?	N
Option 1 from NPT	Bevill	-100	0.00	-40	0.00	0
	Non-Bevill	-20	0.00	-30	0.00	0
Option 2 from NPT	Bevill	-100	0.00	-40	0.00	0
	Non-Bevill	0.00	70	20	10	0
Option 3 from NPT	All	0.00	70	20	10	0
Option 4 from NPT	All	0.00	85	35	20	0
Option 1 from MPT & PT (SL/BP)	Bevill	-100	-85	-75	-20	0
	Non-Bevill	-30	-50	-75	-20	0
Option 2 from MPT & PT (SL/BP)	Bevill	-100	-85	-75	-20	0
	Non-Bevill	0.00	25	35	85	0
Option 3 from MPT & PT (SL/BP)	All	0.00	-10	-10	-5	0
Option 4 from MPT & PT (SL/BP)	All	0.00	0.00	0.00	0.00	0
Option 1 from PT (SM)	Bevill	-100	-75	-65	-15	0
	Non-Bevill	-30	-40	-65	-15	0
Option 2 from PT (SM)	Bevill	-100	-75	-65	-15	0
	Non-Bevill	0.00	0.00	0.00	0.00	0
Option 3 from PT (SM)	All	0.00	0.00	0.00	0.00	0
Option 4 from PT (SM)	All	0.00	10	10	5	0.00

Notes:

Bold type indicates shifts derived from empirical data.

Gray shading indicates shifts that break expected pattern because 100 percent is sent to treatment or recycling.

Cost results for all three baselines are summarized in Exhibit A.1-6. In general, the costs for the no prior treatment baseline are greater than for the modified prior treatment baseline (the baseline used in the main analysis) because facilities incur the full cost of waste treatment when coming into compliance from the no prior treatment baseline. Conversely, the costs in the prior treatment baseline are lower than the modified prior treatment baseline because recycled spent material are assumed to be already managed in tanks, containers, and buildings. The savings in the prior treatment baseline attributed to baseline management practices is most clearly seen under Option 4, which yields an overall savings. Sector specific cost results for the no prior treatment baseline are presented in Exhibits A.1-7 through A.1-10, and cost results for the prior treatment baseline are presented in Exhibits A.1-11 through A.1-14. Value of shipment impact results for the no prior treatment baseline and the prior treatment baseline are shown in Exhibits A.1-15 through A.1-22.

Exhibit A.1-6**Summary of Cost Results for All Option-Baseline Combinations**

	Minimum	Expected	Maximum
Option 1 PT	43,000,000	53,000,000	66,000,000
Option 2 PT	33,000,000	40,000,000	48,000,000
Option 3 PT	2,000,000	3,000,000	5,000,000
Option 4 PT	(3,000,000)	(4,900,000)	(7,100,000)
Option 1 MPT	46,000,000	58,000,000	75,000,000
Option 2 MPT	37,000,000	45,000,000	55,000,000
Option 3 MPT	5,200,000	8,400,000	13,000,000
Option 4 MPT	71,000	190,000	190,000
Option 1 NPT	67,000,000	120,000,000	220,000,000
Option 2 NPT	54,000,000	110,000,000	200,000,000
Option 3 NPT	24,000,000	74,000,000	160,000,000
Option 4 NPT	17,000,000	63,000,000	140,000,000

Exhibit A.1-7

Option 1 Incremental Costs Assuming No Prior Treatment

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	3,000,000	130,000	4,800,000	210,000	6,400,000	280,000
Antimony	-	-	1,600,000	270,000	2,500,000	410,000
Beryllium	-	-	1,800,000	910,000	10,000,000	5,100,000
Bismuth	-	-	510,000	510,000	1,700,000	1,700,000
Cadmium	-	-	670,000	330,000	7,000,000	3,500,000
Calcium	-	-	4,300	4,300	7,300	7,300
Coal Gas	-	-	-	-	390,000	390,000
Copper	15,000,000	1,500,000	15,000,000	1,500,000	15,000,000	1,500,000
Elemental Phosphorus	3,500,000	1,700,000	3,500,000	1,700,000	3,500,000	1,700,000
Fluorspar and Hydrofluoric Acid	-	-	290,000	97,000	590,000	200,000
Germanium	-	-	220,000	54,000	500,000	120,000
Lead	21,000,000	5,200,000	32,000,000	7,900,000	43,000,000	11,000,000
Magnesium and Magnesia from Brines	1,600,000	820,000	1,700,000	830,000	2,100,000	1,000,000
Mercury	-	-	850,000	120,000	2,600,000	370,000
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	8,100,000	740,000	29,000,000	2,600,000
Platinum Group Metals	-	-	160,000	54,000	290,000	98,000
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	1,600,000	820,000	5,400,000	2,700,000
Rare Earths	220,000	220,000	1,600,000	1,600,000	5,600,000	5,600,000
Rhenium	-	-	2,600,000	1,300,000	5,100,000	2,500,000
Scandium	-	-	370,000	53,000	590,000	85,000
Selenium	580,000	290,000	830,000	280,000	1,900,000	640,000
Synthetic Rutile	-	-	1,600,000	1,600,000	3,000,000	3,000,000
Tantalum, Columbium, and Ferrocolumbium	810,000	410,000	870,000	440,000	960,000	480,000
Tellurium	-	-	510,000	250,000	1,600,000	780,000
Titanium and Titanium Dioxide	1,300,000	640,000	17,000,000	2,400,000	31,000,000	4,400,000
Tungsten	-	-	230,000	38,000	710,000	120,000
Uranium	-	-	980,000	58,000	2,400,000	140,000
Zinc	20,000,000	6,500,000	23,000,000	7,700,000	27,000,000	9,000,000
Zirconium and Hafnium	-	-	1,600,000	790,000	12,000,000	5,900,000
Total	67,000,000		120,000,000		220,000,000	

Exhibit A.1-8

Option 2 Incremental Costs Assuming No Prior Treatment

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	1,200,000	52,000	3,300,000	140,000	4,700,000	210,000
Antimony	-	-	1,600,000	270,000	2,500,000	410,000
Beryllium	-	-	1,800,000	910,000	10,000,000	5,000,000
Bismuth	-	-	490,000	490,000	1,700,000	1,700,000
Cadmium	-	-	620,000	310,000	4,400,000	2,200,000
Calcium	-	-	4,300	4,300	7,300	7,300
Coal Gas	-	-	-	-	390,000	390,000
Copper	15,000,000	1,500,000	15,000,000	1,500,000	15,000,000	1,500,000
Elemental Phosphorus	3,500,000	1,700,000	3,500,000	1,700,000	3,500,000	1,700,000
Fluorspar and Hydrofluoric Acid	-	-	180,000	60,000	370,000	120,000
Germanium	-	-	200,000	51,000	480,000	120,000
Lead	21,000,000	5,200,000	32,000,000	7,900,000	43,000,000	11,000,000
Magnesium and Magnesia from Brines	1,600,000	820,000	1,700,000	830,000	1,800,000	900,000
Mercury	-	-	850,000	120,000	2,600,000	370,000
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	8,100,000	740,000	29,000,000	2,600,000
Platinum Group Metals	-	-	160,000	53,000	250,000	83,000
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	1,500,000	770,000	5,300,000	2,700,000
Rare Earths	220,000	220,000	1,600,000	1,600,000	5,500,000	5,500,000
Rhenium	-	-	2,600,000	1,300,000	5,100,000	2,500,000
Scandium	-	-	260,000	38,000	470,000	67,000
Selenium	580,000	290,000	770,000	260,000	1,700,000	570,000
Synthetic Rutile	-	-	1,300,000	1,300,000	2,400,000	2,400,000
Tantalum, Columbium, and Ferrocolumbium	470,000	240,000	620,000	310,000	700,000	350,000
Tellurium	-	-	390,000	200,000	1,500,000	730,000
Titanium and Titanium Dioxide	1,200,000	610,000	16,000,000	2,300,000	29,000,000	4,100,000
Tungsten	-	-	230,000	38,000	710,000	120,000
Uranium	-	-	820,000	48,000	1,500,000	91,000
Zinc	9,600,000	3,200,000	13,000,000	4,300,000	17,000,000	5,600,000
Zirconium and Hafnium	-	-	1,500,000	750,000	11,000,000	5,600,000
Total	54,000,000		110,000,000		200,000,000	

Exhibit A.1-9

Option 3 Incremental Costs Assuming No Prior Treatment

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	1,200,000	52,000	3,300,000	140,000	4,700,000	210,000
Antimony	-	-	1,600,000	270,000	2,500,000	410,000
Beryllium	-	-	1,800,000	910,000	10,000,000	5,000,000
Bismuth	-	-	490,000	490,000	1,700,000	1,700,000
Cadmium	-	-	590,000	300,000	4,300,000	2,200,000
Calcium	-	-	1,400	1,400	1,400	1,400
Coal Gas	-	-	-	-	260,000	260,000
Copper	8,200,000	820,000	8,100,000	810,000	8,200,000	820,000
Elemental Phosphorus	540,000	270,000	540,000	270,000	540,000	270,000
Fluorspar and Hydrofluoric Acid	-	-	180,000	60,000	370,000	120,000
Germanium	-	-	200,000	51,000	480,000	120,000
Lead	120,000	30,000	6,100,000	1,500,000	13,000,000	3,200,000
Magnesium and Magnesia from Brines	1,600,000	820,000	1,700,000	830,000	1,800,000	900,000
Mercury	-	-	420,000	60,000	1,400,000	210,000
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	8,100,000	740,000	29,000,000	2,600,000
Platinum Group Metals	-	-	160,000	53,000	250,000	83,000
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	1,500,000	770,000	5,300,000	2,700,000
Rare Earths	220,000	220,000	1,500,000	1,500,000	5,000,000	5,000,000
Rhenium	-	-	2,600,000	1,300,000	5,100,000	2,500,000
Scandium	-	-	260,000	38,000	470,000	67,000
Selenium	550,000	270,000	730,000	240,000	1,700,000	570,000
Synthetic Rutile	-	-	1,300,000	1,300,000	2,400,000	2,400,000
Tantalum, Columbium, and Ferrocolumbium	470,000	240,000	620,000	310,000	700,000	350,000
Tellurium	-	-	390,000	200,000	1,500,000	730,000
Titanium and Titanium Dioxide	1,200,000	610,000	16,000,000	2,300,000	29,000,000	4,100,000
Tungsten	-	-	320,000	53,000	690,000	110,000
Uranium	-	-	820,000	48,000	1,500,000	91,000
Zinc	9,600,000	3,200,000	13,000,000	4,300,000	17,000,000	5,600,000
Zirconium and Hafnium	-	-	1,500,000	750,000	11,000,000	5,600,000
Total	24,000,000		74,000,000		160,000,000	

Exhibit A.1-10

Option 4 Incremental Costs Assuming No Prior Treatment

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	770,000	34,000	2,200,000	95,000	3,000,000	130,000
Antimony	-	-	1,600,000	260,000	2,400,000	400,000
Beryllium	-	-	1,800,000	900,000	9,500,000	4,700,000
Bismuth	-	-	480,000	480,000	1,700,000	1,700,000
Cadmium	-	-	560,000	280,000	3,600,000	1,800,000
Calcium	-	-	1,400	1,400	1,400	1,400
Coal Gas	-	-	-	-	180,000	180,000
Copper	5,200,000	520,000	5,200,000	520,000	5,200,000	520,000
Elemental Phosphorus	57,000	29,000	57,000	29,000	57,000	29,000
Fluorspar and Hydrofluoric Acid	-	-	120,000	39,000	270,000	89,000
Germanium	-	-	180,000	46,000	460,000	110,000
Lead	65,000	16,000	4,800,000	1,200,000	10,000,000	2,600,000
Magnesium and Magnesia from Brines	1,600,000	820,000	1,700,000	830,000	1,700,000	870,000
Mercury	-	-	190,000	27,000	810,000	120,000
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	8,100,000	740,000	29,000,000	2,600,000
Platinum Group Metals	-	-	160,000	53,000	240,000	79,000
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	1,500,000	740,000	5,200,000	2,600,000
Rare Earths	220,000	220,000	1,400,000	1,400,000	4,500,000	4,500,000
Rhenium	-	-	2,600,000	1,300,000	5,100,000	2,500,000
Scandium	-	-	360,000	51,000	430,000	61,000
Selenium	500,000	250,000	670,000	220,000	1,600,000	520,000
Synthetic Rutile	-	-	1,100,000	1,100,000	2,100,000	2,100,000
Tantalum, Columbium, and Ferrocolumbium	260,000	130,000	470,000	230,000	550,000	280,000
Tellurium	-	-	380,000	190,000	1,400,000	700,000
Titanium and Titanium Dioxide	1,100,000	560,000	15,000,000	2,200,000	28,000,000	4,100,000
Tungsten	-	-	280,000	47,000	650,000	110,000
Uranium	-	-	780,000	46,000	1,400,000	84,000
Zinc	7,600,000	2,500,000	9,800,000	3,300,000	13,000,000	4,200,000
Zirconium and Hafnium	-	-	1,400,000	690,000	11,000,000	5,300,000
Total	17,000,000		63,000,000		140,000,000	

Exhibit A.1-11

Option 1 Incremental Costs Assuming Prior Treatment

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	1,400,000	62,000	2,400,000	100,000	2,900,000	130,000
Antimony	-	-	40,000	6,700	52,000	8,600
Beryllium	-	-	24,000	12,000	440,000	220,000
Bismuth	-	-	30,000	30,000	53,000	53,000
Cadmium	-	-	56,000	28,000	2,400,000	1,200,000
Calcium	-	-	4,300	4,300	7,300	7,300
Coal Gas	-	-	-	-	220,000	220,000
Copper	10,000,000	1,000,000	10,000,000	1,000,000	10,000,000	1,000,000
Elemental Phosphorus	3,100,000	1,600,000	3,100,000	1,600,000	3,100,000	1,600,000
Fluorspar and Hydrofluoric Acid	-	-	190,000	63,000	330,000	110,000
Germanium	-	-	30,000	7,500	37,000	9,200
Lead	21,000,000	5,200,000	26,000,000	6,500,000	30,000,000	7,600,000
Magnesium and Magnesia from Brines	2,800	1,400	3,100	1,500	240,000	120,000
Mercury	-	-	500,000	72,000	1,300,000	190,000
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	16,000	1,400	16,000	1,400
Platinum Group Metals	-	-	5,900	2,000	38,000	13,000
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	93,000	46,000	110,000	56,000
Rare Earths	6,100	6,100	200,000	200,000	1,100,000	1,100,000
Rhenium	-	-	9,500	4,700	31,000	15,000
Scandium	-	-	82,000	12,000	140,000	20,000
Selenium	53,000	27,000	110,000	36,000	280,000	94,000
Synthetic Rutile	-	-	550,000	550,000	1,000,000	1,000,000
Tantalum, Columbium, and Ferrocolumbium	370,000	180,000	260,000	130,000	260,000	130,000
Tellurium	-	-	140,000	71,000	160,000	78,000
Titanium and Titanium Dioxide	93,000	46,000	810,000	120,000	1,300,000	190,000
Tungsten	-	-	(62,000)	(10,000)	45,000	7,500
Uranium	-	-	220,000	13,000	1,100,000	63,000
Zinc	7,100,000	2,400,000	7,600,000	2,500,000	8,800,000	2,900,000
Zirconium and Hafnium	-	-	110,000	57,000	900,000	450,000
Total	43,000,000		53,000,000		66,000,000	

Exhibit A.1-12

Option 2 Incremental Costs Assuming Prior Treatment

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	310,000	14,000	810,000	35,000	1,500,000	64,000
Antimony	-	-	8,500	1,400	8,500	1,400
Beryllium	-	-	2,800	1,400	2,800	1,400
Bismuth	-	-	1,400	1,400	2,100	2,100
Cadmium	-	-	47,000	23,000	530,000	270,000
Calcium	-	-	4,300	4,300	7,300	7,300
Coal Gas	-	-	-	-	220,000	220,000
Copper	10,000,000	1,000,000	10,000,000	1,000,000	10,000,000	1,000,000
Elemental Phosphorus	3,100,000	1,600,000	3,100,000	1,600,000	3,100,000	1,600,000
Fluorspar and Hydrofluoric Acid	-	-	52,000	17,000	84,000	28,000
Germanium	-	-	6,400	1,600	8,600	2,200
Lead	21,000,000	5,200,000	26,000,000	6,500,000	30,000,000	7,600,000
Magnesium and Magnesia from Brines	2,800	1,400	3,900	2,000	49,000	25,000
Mercury	-	-	500,000	72,000	1,300,000	190,000
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	16,000	1,400	16,000	1,400
Platinum Group Metals	-	-	4,600	1,500	11,000	3,700
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	2,800	1,400	2,800	1,400
Rare Earths	6,100	6,100	200,000	200,000	980,000	980,000
Rhenium	-	-	9,500	4,700	31,000	15,000
Scandium	-	-	9,900	1,400	9,900	1,400
Selenium	53,000	27,000	71,000	24,000	140,000	47,000
Synthetic Rutile	-	-	71,000	71,000	130,000	130,000
Tantalum, Columbium, and Ferrocolumbium	2,800	1,400	2,800	1,400	2,800	1,400
Tellurium	-	-	4,500	2,300	17,000	8,500
Titanium and Titanium Dioxide	3,200	1,600	130,000	19,000	260,000	37,000
Tungsten	-	-	(62,000)	(10,000)	45,000	7,500
Uranium	-	-	43,000	2,500	100,000	6,000
Zinc	(1,200,000)	(390,000)	(1,100,000)	(370,000)	(1,000,000)	(350,000)
Zirconium and Hafnium	-	-	2,800	1,400	2,800	1,400
Total	33,000,000		40,000,000		48,000,000	

Exhibit A.1-13

Option 3 Incremental Costs Assuming Prior Treatment

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	310,000	14,000	810,000	35,000	1,500,000	64,000
Antimony	-	-	8,500	1,400	8,500	1,400
Beryllium	-	-	2,800	1,400	2,800	1,400
Bismuth	-	-	1,400	1,400	2,100	2,100
Cadmium	-	-	18,000	8,800	460,000	230,000
Calcium	-	-	1,400	1,400	1,400	1,400
Coal Gas	-	-	-	-	68,000	68,000
Copper	2,600,000	260,000	2,500,000	250,000	2,600,000	260,000
Elemental Phosphorus	200,000	100,000	200,000	100,000	200,000	100,000
Fluorspar and Hydrofluoric Acid	-	-	52,000	17,000	84,000	28,000
Germanium	-	-	6,400	1,600	8,600	2,200
Lead	56,000	14,000	120,000	30,000	150,000	38,000
Magnesium and Magnesia from Brines	2,800	1,400	3,900	2,000	49,000	25,000
Mercury	-	-	9,900	1,400	9,900	1,400
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	16,000	1,400	16,000	1,400
Platinum Group Metals	-	-	4,600	1,500	11,000	3,700
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	2,800	1,400	2,800	1,400
Rare Earths	1,400	1,400	92,000	92,000	320,000	320,000
Rhenium	-	-	3,700	1,800	6,200	3,100
Scandium	-	-	9,900	1,400	9,900	1,400
Selenium	2,800	1,400	14,000	4,600	110,000	37,000
Synthetic Rutile	-	-	71,000	71,000	130,000	130,000
Tantalum, Columbium, and Ferrocolumbium	2,800	1,400	2,800	1,400	2,800	1,400
Tellurium	-	-	4,500	2,300	17,000	8,500
Titanium and Titanium Dioxide	3,200	1,600	130,000	19,000	260,000	37,000
Tungsten	-	-	8,500	1,400	8,500	1,400
Uranium	-	-	43,000	2,500	100,000	6,000
Zinc	(1,200,000)	(390,000)	(1,100,000)	(370,000)	(1,100,000)	(350,000)
Zirconium and Hafnium	-	-	2,800	1,400	2,800	1,400
Total	2,000,000		3,000,000		5,000,000	

Exhibit A.1-14

Option 4 Incremental Costs Assuming Prior Treatment

Commodity	Minimum Value Case		Expected Value Case		Maximum Value Case	
	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)	Total Incremental Cost (\$/yr)	Avg. Fac. Incremental Cost (\$/yr)
Alumina and Aluminum	32,000	1,400	32,000	1,400	32,000	1,400
Antimony	-	-	(6,900)	(1,100)	(17,000)	(2,900)
Beryllium	-	-	(11,000)	(5,700)	(330,000)	(160,000)
Bismuth	-	-	(5,900)	(5,900)	(16,000)	(16,000)
Cadmium	-	-	(3,600)	(1,800)	(26,000)	(13,000)
Calcium	-	-	1,400	1,400	1,400	1,400
Coal Gas	-	-	-	-	1,400	1,400
Copper	14,000	1,400	14,000	1,400	14,000	1,400
Elemental Phosphorus	(240,000)	(120,000)	(240,000)	(120,000)	(240,000)	(120,000)
Fluorspar and Hydrofluoric Acid	-	-	4,200	1,400	4,200	1,400
Germanium	-	-	(3,100)	(780)	(3,000)	(740)
Lead	2,700	660	(920,000)	(230,000)	(1,700,000)	(430,000)
Magnesium and Magnesia from Brines	2,800	1,400	2,800	1,400	2,800	1,400
Mercury	-	-	(160,000)	(23,000)	(480,000)	(68,000)
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	-	-	16,000	1,400	16,000	1,400
Platinum Group Metals	-	-	4,200	1,400	4,200	1,400
Pyrobitumens, Mineral Waxes, and Natural Asphalts	-	-	(39,000)	(20,000)	(49,000)	(25,000)
Rare Earths	(1,700)	(1,700)	(30)	(30)	18	18
Rhenium	-	-	2,800	1,400	2,800	1,400
Scandium	-	-	110,000	16,000	(20,000)	(2,900)
Selenium	(23,000)	(11,000)	(24,000)	(8,000)	(15,000)	(5,100)
Synthetic Rutile	-	-	(6,100)	(6,100)	(13,000)	(13,000)
Tantalum, Columbium, and Ferrocolumbium	(160,000)	(80,000)	(120,000)	(60,000)	(120,000)	(60,000)
Tellurium	-	-	(2,600)	(1,300)	(17,000)	(8,500)
Titanium and Titanium Dioxide	(65,000)	(32,000)	(85,000)	(12,000)	(110,000)	(15,000)
Tungsten	-	-	(9,800)	(1,600)	(16,000)	(2,600)
Uranium	-	-	20,000	1,200	22,000	1,300
Zinc	(2,600,000)	(870,000)	(3,400,000)	(1,100,000)	(3,700,000)	(1,200,000)
Zirconium and Hafnium	-	-	(87,000)	(44,000)	(300,000)	(150,000)
Total	(3,000,000)		(4,900,000)		(7,100,000)	

Exhibit A.1-15
Option 1 No Prior Treatment Baseline Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	3,000,000	4,800,000	6,400,000	0.07	0.11	0.15
Antimony	18,000	1,764	31,752,000	-	1,600,000	2,500,000	0.00	5.04	7.87
Beryllium	159	352,640	56,069,760	-	1,800,000	10,000,000	0.00	3.21	17.83
Bismuth	1,100	7,824	8,606,400	-	510,000	1,700,000	0.00	5.93	19.75
Cadmium	1,050	992	1,041,600	-	670,000	7,000,000	0.00	64.32	672.04
Calcium	1,200	4,605	5,526,000	-	4,300	7,300	0.00	0.08	0.13
Coal Gas			170,000,000	-	-	390,000	0.00	0.00	0.23
Copper	1,770,000	2,029	3,591,330,000	15,000,000	15,000,000	15,000,000	0.42	0.42	0.42
Elemental Phosphorus	311,000	1,833	570,063,000	3,500,000	3,500,000	3,500,000	0.61	0.61	0.61
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	290,000	590,000	0.00	2.50	5.09
Germanium	10	1,080,000	10,600,000	-	220,000	500,000	0.00	2.08	4.72
Lead	290,000	706	204,740,000	21,000,000	32,000,000	43,000,000	10.26	15.63	21.00
Magnesium and Magnesia from Brines	145,000	3,219	468,755,000	1,600,000	1,700,000	2,100,000	0.34	0.36	0.45
Mercury	70	5,512	385,840	-	850,000	2,600,000	0.00	220.30	673.85
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	8,100,000	29,000,000	0.00	3.38	12.09
Platinum Group Metals			53,203,971	-	160,000	290,000	0.00	0.30	0.55
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	1,600,000	5,400,000	0.00	640.00	2,160.00
Rare Earths			57,372,120	220,000	1,600,000	5,600,000	0.38	2.79	9.76
Rhenium	5	1,200,000	6,000,000	-	2,600,000	5,100,000	0.00	43.33	85.00
Scandium	25	1,500,000	37,500,000	-	370,000	590,000	0.00	0.89	1.57
Selenium	250	11,248	2,811,500	580,000	830,000	1,900,000	20.63	29.52	67.58
Synthetic Rutile	140,000	345	48,300,000	-	1,600,000	3,000,000	0.00	3.31	6.21
Tantalum, Columbium, and Ferrocolumbium			60,897,400	810,000	870,000	960,000	1.33	1.43	1.58
Tellurium	60	59,508	3,570,480	-	510,000	1,600,000	0.00	14.28	44.81
Titanium and Titanium Dioxide			2,516,300,000	1,300,000	17,000,000	31,000,000	0.05	0.68	1.23
Tungsten	9,406	40	376,240	-	230,000	710,000	0.00	61.13	188.71
Uranium			40,734,000	-	980,000	2,400,000	0.00	2.41	5.89
Zinc	505,000	1,014	512,070,000	20,000,000	23,000,000	27,000,000	3.91	4.49	5.27
Zirconium and Hafnium			379,899,000	-	1,600,000	12,000,000	0.00	0.42	3.16
Total				67,000,000	120,000,000	220,000,000			

Exhibit A.1-16
Option 2 No Prior Treatment Baseline Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	1,200,000	3,300,000	4,700,000	0.03	0.08	0.11
Antimony	18,000	1,764	31,752,000	-	1,600,000	2,500,000	0.00	5.04	7.87
Beryllium	159	352,640	56,069,760	-	1,800,000	10,000,000	0.00	3.21	17.83
Bismuth	1,100	7,824	8,606,400	-	490,000	1,700,000	0.00	5.69	19.75
Cadmium	1,050	992	1,041,600	-	620,000	4,400,000	0.00	59.52	422.43
Calcium	1,200	4,605	5,526,000	-	4,300	7,300	0.00	0.08	0.13
Coal Gas			170,000,000	-	-	390,000	0.00	0.00	0.23
Copper	1,770,000	2,029	3,591,330,000	15,000,000	15,000,000	15,000,000	0.42	0.42	0.42
Elemental Phosphorus	311,000	1,833	570,063,000	3,500,000	3,500,000	3,500,000	0.61	0.61	0.61
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	180,000	370,000	0.00	1.55	3.20
Germanium	10	1,060,000	10,600,000	-	200,000	480,000	0.00	1.89	4.53
Lead	290,000	706	204,740,000	21,000,000	32,000,000	43,000,000	10.26	15.63	21.00
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	1,600,000	1,700,000	1,800,000	0.34	0.36	0.39
Mercury	70	5,512	385,840	-	850,000	2,600,000	0.00	220.30	673.85
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	8,100,000	29,000,000	0.00	3.38	12.09
Platinum Group Metals			53,203,971	-	160,000	250,000	0.00	0.30	0.47
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	1,500,000	5,300,000	0.00	600.00	2,120.00
Rare Earths			57,372,120	220,000	1,600,000	5,500,000	0.38	2.79	9.59
Rhenium	5	1,200,000	6,000,000	-	2,600,000	5,100,000	0.00	43.33	85.00
Scandium	25	1,500,000	37,500,000	-	260,000	470,000	0.00	0.69	1.25
Selenium	250	11,246	2,811,500	580,000	770,000	1,700,000	20.63	27.39	60.47
Synthetic Rutile	140,000	345	48,300,000	-	1,300,000	2,400,000	0.00	2.69	4.97
Tantalum, Columbium, and Ferrocolumbium			60,897,400	470,000	620,000	700,000	0.77	1.02	1.15
Tellurium	60	59,508	3,570,480	-	390,000	1,500,000	0.00	10.92	42.01
Titanium and Titanium Dioxide			2,516,300,000	1,200,000	16,000,000	29,000,000	0.05	0.64	1.15
Tungsten	9,408	40	376,240	-	230,000	710,000	0.00	61.13	188.71
Uranium			40,734,000	-	820,000	1,500,000	0.00	2.01	3.68
Zinc	505,000	1,014	512,070,000	9,600,000	13,000,000	17,000,000	1.87	2.54	3.32
Zirconium and Hafnium			379,899,000	-	1,500,000	11,000,000	0.00	0.39	2.90
Total				54,000,000	110,000,000	200,000,000			

Exhibit A.1-17
Option 3 No Prior Treatment Baseline Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	1,200,000	3,300,000	4,700,000	0.03	0.08	0.11
Antimony	18,000	1,764	31,752,000	-	1,600,000	2,500,000	0.00	5.04	7.87
Beryllium	159	352,640	56,069,760	-	1,800,000	10,000,000	0.00	3.21	17.83
Bismuth	1,100	7,824	8,606,400	-	490,000	1,700,000	0.00	5.69	19.75
Cadmium	1,050	992	1,041,600	-	590,000	4,300,000	0.00	56.64	412.83
Calcium	1,200	4,605	5,526,000	-	1,400	1,400	0.00	0.03	0.03
Coal Gas			170,000,000	-	-	260,000	0.00	0.00	0.15
Copper	1,770,000	2,029	3,591,330,000	8,200,000	8,100,000	8,200,000	0.23	0.23	0.23
Elemental Phosphorus	311,000	1,833	570,063,000	540,000	540,000	540,000	0.09	0.09	0.09
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	180,000	370,000	0.00	1.55	3.20
Germanium	10	1,060,000	10,600,000	-	200,000	480,000	0.00	1.89	4.53
Lead	290,000	706	204,740,000	120,000	6,100,000	13,000,000	0.06	2.98	6.35
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	1,600,000	1,700,000	1,800,000	0.34	0.36	0.39
Mercury	70	5,512	385,840	-	420,000	1,400,000	0.00	108.85	362.84
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	8,100,000	29,000,000	0.00	3.38	12.09
Platinum Group Metals			53,203,971	-	160,000	250,000	0.00	0.30	0.47
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	1,500,000	5,300,000	0.00	600.00	2,120.00
Rare Earths			57,372,120	220,000	1,500,000	5,000,000	0.38	2.61	8.72
Rhenium	5	1,200,000	6,000,000	-	2,600,000	5,100,000	0.00	43.33	85.00
Scandium	25	1,500,000	37,500,000	-	260,000	470,000	0.00	0.69	1.25
Selenium	250	11,246	2,811,500	550,000	730,000	1,700,000	19.56	25.96	60.47
Synthetic Rutile	140,000	345	48,300,000	-	1,300,000	2,400,000	0.00	2.69	4.97
Tantalum, Columbium, and Ferrocolumbium			60,897,400	470,000	620,000	700,000	0.77	1.02	1.15
Tellurium	60	59,508	3,570,480	-	390,000	1,500,000	0.00	10.92	42.01
Titanium and Titanium Dioxide			2,516,300,000	1,200,000	16,000,000	29,000,000	0.05	0.64	1.15
Tungsten	9,406	40	376,240	-	320,000	690,000	0.00	85.05	183.39
Uranium			40,734,000	-	820,000	1,500,000	0.00	2.01	3.68
Zinc	505,000	1,014	512,070,000	9,600,000	13,000,000	17,000,000	1.87	2.54	3.32
Zirconium and Hafnium			379,899,000	-	1,500,000	11,000,000	0.00	0.39	2.90
Total				24,000,000	74,000,000	160,000,000			

Exhibit A.1-18
Option 4 No Prior Treatment Baseline Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	770,000	2,200,000	3,000,000	0.02	0.05	0.07
Antimony	18,000	1,764	31,752,000	-	1,600,000	2,400,000	0.00	5.04	7.56
Beryllium	159	352,640	56,069,760	-	1,800,000	9,500,000	0.00	3.21	16.94
Bismuth	1,100	7,824	8,606,400	-	480,000	1,700,000	0.00	5.58	19.75
Cadmium	1,050	992	1,041,600	-	560,000	3,600,000	0.00	53.76	345.62
Calcium	1,200	4,605	5,526,000	-	1,400	1,400	0.00	0.03	0.03
Coal Gas			170,000,000	-	-	180,000	0.00	0.00	0.11
Copper	1,770,000	2,029	3,591,330,000	5,200,000	5,200,000	5,200,000	0.14	0.14	0.14
Elemental Phosphorus	311,000	1,833	570,063,000	57,000	57,000	57,000	0.01	0.01	0.01
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	120,000	270,000	0.00	1.04	2.33
Germanium	10	1,060,000	10,600,000	-	180,000	460,000	0.00	1.70	4.34
Lead	290,000	706	204,740,000	65,000	4,800,000	10,000,000	0.03	2.34	4.88
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	1,600,000	1,700,000	1,700,000	0.34	0.36	0.36
Mercury	70	5,512	385,840	-	190,000	810,000	0.00	49.24	209.93
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	8,100,000	29,000,000	0.00	3.38	12.09
Platinum Group Metals			53,203,971	-	160,000	240,000	0.00	0.30	0.45
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	1,500,000	5,200,000	0.00	600.00	2,080.00
Rare Earths			57,372,120	220,000	1,400,000	4,500,000	0.38	2.44	7.84
Rhenium	5	1,200,000	6,000,000	-	2,600,000	5,100,000	0.00	43.33	85.00
Scandium	25	1,500,000	37,500,000	-	360,000	430,000	0.00	0.96	1.15
Selenium	250	11,246	2,811,500	500,000	670,000	1,600,000	17.78	23.83	56.91
Synthetic Rutile	140,000	345	48,300,000	-	1,100,000	2,100,000	0.00	2.28	4.35
Tantalum, Columbium, and Ferrocolumbium			60,897,400	260,000	470,000	550,000	0.43	0.77	0.90
Tellurium	60	59,508	3,570,480	-	380,000	1,400,000	0.00	10.64	39.21
Titanium and Titanium Dioxide			2,516,300,000	1,100,000	15,000,000	28,000,000	0.04	0.60	1.11
Tungsten	9,406	40	376,240	-	280,000	650,000	0.00	74.42	172.76
Uranium			40,734,000	-	780,000	1,400,000	0.00	1.91	3.44
Zinc	505,000	1,014	512,070,000	7,600,000	9,800,000	13,000,000	1.48	1.91	2.54
Zirconium and Hafnium			379,899,000	-	1,400,000	11,000,000	0.00	0.37	2.90
Total				17,000,000	63,000,000	140,000,000			

Exhibit A.1-19
Option 1 Prior Treatment Baseline Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	1,400,000	2,400,000	2,900,000	0.03	0.06	0.07
Antimony	18,000	1,764	31,752,000	-	40,000	52,000	0.00	0.13	0.16
Beryllium	159	352,640	56,069,760	-	24,000	440,000	0.00	0.04	0.78
Bismuth	1,100	7,824	8,606,400	-	30,000	53,000	0.00	0.35	0.62
Cadmium	1,050	992	1,041,600	-	56,000	2,400,000	0.00	5.38	230.41
Calcium	1,200	4,605	5,526,000	-	4,300	7,300	0.00	0.08	0.13
Coal Gas			170,000,000	-	-	220,000	0.00	0.00	0.13
Copper	1,770,000	2,029	3,591,330,000	10,000,000	10,000,000	10,000,000	0.28	0.28	0.28
Elemental Phosphorus	311,000	1,833	570,063,000	3,100,000	3,100,000	3,100,000	0.54	0.54	0.54
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	190,000	330,000	0.00	1.64	2.85
Germanium	10	1,080,000	10,800,000	-	30,000	37,000	0.00	0.28	0.35
Lead	290,000	706	204,740,000	21,000,000	26,000,000	30,000,000	10.26	12.70	14.65
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	2,800	3,100	240,000	0.00	0.00	0.05
Mercury	70	5,512	385,840	-	500,000	1,300,000	0.00	129.59	336.93
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	16,000	16,000	0.00	0.01	0.01
Platinum Group Metals			53,203,971	-	5,900	38,000	0.00	0.01	0.07
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	93,000	110,000	0.00	37.20	44.00
Rare Earths			57,372,120	6,100	200,000	1,100,000	0.01	0.35	1.92
Rhenium	5	1,200,000	6,000,000	-	9,500	31,000	0.00	0.16	0.52
Scandium	25	1,500,000	37,500,000	-	82,000	140,000	0.00	0.22	0.37
Selenium	250	11,246	2,811,500	53,000	110,000	280,000	1.89	3.91	9.96
Synthetic Rutile	140,000	345	48,300,000	-	550,000	1,000,000	0.00	1.14	2.07
Tantalum, Columbium, and Ferrocolumbium			60,897,400	370,000	260,000	260,000	0.61	0.43	0.43
Tellurium	60	59,508	3,570,480	-	140,000	160,000	0.00	3.92	4.48
Titanium and Titanium Dioxide			2,516,300,000	93,000	810,000	1,300,000	0.00	0.03	0.05
Tungsten	9,406	40	376,240	-	(62,000)	45,000	0.00	-16.48	11.96
Uranium			40,734,000	-	220,000	1,100,000	0.00	0.54	2.70
Zinc	505,000	1,014	512,070,000	7,100,000	7,600,000	8,800,000	1.39	1.48	1.72
Zirconium and Hafnium			379,899,000	-	110,000	900,000	0.00	0.03	0.24
Total				43,000,000	53,000,000	66,000,000			

Exhibit A.1-20
Option 2 Prior Treatment Baseline Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	310,000	810,000	1,500,000	0.01	0.02	0.03
Antimony	18,000	1,764	31,752,000	-	8,500	8,500	0.00	0.03	0.03
Beryllium	159	352,640	56,069,760	-	2,800	2,800	0.00	0.00	0.00
Bismuth	1,100	7,824	8,606,400	-	1,400	2,100	0.00	0.02	0.02
Cadmium	1,050	992	1,041,600	-	47,000	530,000	0.00	4.51	50.88
Calcium	1,200	4,605	5,526,000	-	4,300	7,300	0.00	0.08	0.13
Coal Gas			170,000,000	-	-	220,000	0.00	0.00	0.13
Copper	1,770,000	2,029	3,591,330,000	10,000,000	10,000,000	10,000,000	0.28	0.28	0.28
Elemental Phosphorus	311,000	1,833	570,063,000	3,100,000	3,100,000	3,100,000	0.54	0.54	0.54
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	52,000	84,000	0.00	0.45	0.73
Germanium	10	1,060,000	10,600,000	-	6,400	8,600	0.00	0.06	0.08
Lead	290,000	706	204,740,000	21,000,000	26,000,000	30,000,000	10.26	12.70	14.65
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	2,800	3,900	49,000	0.00	0.00	0.01
Mercury	70	5,512	385,840	-	500,000	1,300,000	0.00	129.59	336.93
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	16,000	16,000	0.00	0.01	0.01
Platinum Group Metals			53,203,971	-	4,600	11,000	0.00	0.01	0.02
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	2,800	2,800	0.00	1.12	1.12
Rare Earths			57,372,120	6,100	200,000	980,000	0.01	0.35	1.71
Rhenium	5	1,200,000	6,000,000	-	9,500	31,000	0.00	0.16	0.52
Scandium	25	1,500,000	37,500,000	-	9,900	9,900	0.00	0.03	0.03
Selenium	250	11,246	2,811,500	53,000	71,000	140,000	1.89	2.53	4.98
Synthetic Rutile	140,000	345	48,300,000	-	71,000	130,000	0.00	0.15	0.27
Tantalum, Columbium, and Ferrocolumbium			60,897,400	2,800	2,800	2,800	0.00	0.00	0.00
Tellurium	60	59,508	3,570,480	-	4,500	17,000	0.00	0.13	0.48
Titanium and Titanium Dioxide			2,516,300,000	3,200	130,000	260,000	0.00	0.01	0.01
Tungsten	9,406	40	376,240	-	(62,000)	45,000	0.00	-16.48	11.96
Uranium			40,734,000	-	43,000	100,000	0.00	0.11	0.25
Zinc	505,000	1,014	512,070,000	(1,200,000)	(1,100,000)	(1,000,000)	-0.23	-0.21	-0.20
Zirconium and Hafnium			379,899,000	-	2,800	2,800	0.00	0.00	0.00
Total				33,000,000	40,000,000	48,000,000			

Exhibit A.1-21
Option 3 Prior Treatment Baseline Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	310,000	810,000	1,500,000	0.01	0.02	0.03
Antimony	18,000	1,764	31,752,000	-	8,500	8,500	0.00	0.03	0.03
Beryllium	159	352,640	56,069,760	-	2,800	2,800	0.00	0.00	0.00
Bismuth	1,100	7,824	8,606,400	-	1,400	2,100	0.00	0.02	0.02
Cadmium	1,050	992	1,041,600	-	18,000	460,000	0.00	1.73	44.16
Calcium	1,200	4,605	5,526,000	-	1,400	1,400	0.00	0.03	0.03
Coal Gas			170,000,000	-	-	68,000	0.00	0.00	0.04
Copper	1,770,000	2,029	3,591,330,000	2,600,000	2,500,000	2,600,000	0.07	0.07	0.07
Elemental Phosphorus	311,000	1,833	570,063,000	200,000	200,000	200,000	0.04	0.04	0.04
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	52,000	84,000	0.00	0.45	0.73
Germanium	10	1,060,000	10,600,000	-	6,400	8,600	0.00	0.06	0.08
Lead	290,000	706	204,740,000	56,000	120,000	150,000	0.03	0.06	0.07
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	2,800	3,900	49,000	0.00	0.00	0.01
Mercury	70	5,512	385,840	-	9,900	9,900	0.00	2.57	2.57
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	16,000	16,000	0.00	0.01	0.01
Platinum Group Metals			53,203,971	-	4,600	11,000	0.00	0.01	0.02
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	2,800	2,800	0.00	1.12	1.12
Rare Earths			57,372,120	1,400	92,000	320,000	0.00	0.16	0.56
Rhenium	5	1,200,000	6,000,000	-	3,700	6,200	0.00	0.06	0.10
Scandium	25	1,500,000	37,500,000	-	9,900	9,900	0.00	0.03	0.03
Selenium	250	11,246	2,811,500	2,800	14,000	110,000	0.10	0.50	3.91
Synthetic Rutile	140,000	345	48,300,000	-	71,000	130,000	0.00	0.15	0.27
Tantalum, Columbium, and Ferrocolumbium			60,897,400	2,800	2,800	2,800	0.00	0.00	0.00
Tellurium	60	59,508	3,570,480	-	4,500	17,000	0.00	0.13	0.48
Titanium and Titanium Dioxide			2,516,300,000	3,200	130,000	260,000	0.00	0.01	0.01
Tungsten	9,406	40	376,240	-	8,500	8,500	0.00	2.26	2.26
Uranium			40,734,000	-	43,000	100,000	0.00	0.11	0.25
Zinc	505,000	1,014	512,070,000	(1,200,000)	(1,100,000)	(1,100,000)	-0.23	-0.21	-0.21
Zirconium and Hafnium			379,899,000	-	2,800	2,800	0.00	0.00	0.00
Total				2,000,000	3,000,000	5,000,000			

Exhibit A.1-22
Option 4 Prior Treatment Baseline Impacts

Sector	Production MT	Price \$/MT	Value of Shipments \$	Incremental Sector Cost \$			Economic Impact (percent of Value of Shipments)		
				Minimum	Expected	Maximum	Minimum	Expected	Maximum
Alumina and Aluminum	3,700,000	1,168	4,321,600,000	32,000	32,000	32,000	0.00	0.00	0.00
Antimony	18,000	1,764	31,752,000	-	(6,900)	(17,000)	0.00	-0.02	-0.05
Beryllium	159	352,640	56,069,760	-	(11,000)	(330,000)	0.00	-0.02	-0.59
Bismuth	1,100	7,824	8,606,400	-	(5,900)	(16,000)	0.00	-0.07	-0.19
Cadmium	1,050	992	1,041,600	-	(3,600)	(26,000)	0.00	-0.35	-2.50
Calcium	1,200	4,605	5,526,000	-	1,400	1,400	0.00	0.03	0.03
Coal Gas			170,000,000	-	-	1,400	0.00	0.00	0.00
Copper	1,770,000	2,029	3,591,330,000	14,000	14,000	14,000	0.00	0.00	0.00
Elemental Phosphorus	311,000	1,833	570,063,000	(240,000)	(240,000)	(240,000)	-0.04	-0.04	-0.04
Fluorspar and Hydrofluoric Acid	60,000	193	11,580,000	-	4,200	4,200	0.00	0.04	0.04
Germanium	10	1,080,000	10,800,000	-	(3,100)	(3,000)	0.00	-0.03	-0.03
Lead	290,000	706	204,740,000	2,700	(920,000)	(1,700,000)	0.00	-0.45	-0.83
Magnesium and Magnesia from Brines	145,000	3,219	466,755,000	2,800	2,800	2,800	0.00	0.00	0.00
Mercury	70	5,512	385,840	-	(160,000)	(480,000)	0.00	-41.47	-124.40
Molybdenum, Ferromolybdenum and Ammonium Molybdate			239,864,579	-	16,000	16,000	0.00	0.01	0.01
Platinum Group Metals			53,203,971	-	4,200	4,200	0.00	0.01	0.01
Pyrobitumens, Mineral Waxes, and Natural Asphalt	10,000	25	250,000	-	(39,000)	(49,000)	0.00	-15.60	-19.60
Rare Earths			57,372,120	(1,700)	(30)	18	0.00	0.00	0.00
Rhenium	5	1,200,000	6,000,000	-	2,800	2,800	0.00	0.05	0.05
Scandium	25	1,500,000	37,500,000	-	110,000	(20,000)	0.00	0.29	-0.05
Selenium	250	11,248	2,811,500	(23,000)	(24,000)	(15,000)	-0.82	-0.85	-0.53
Synthetic Rutile	140,000	345	48,300,000	-	(6,100)	(13,000)	0.00	-0.01	-0.03
Tantalum, Columbium, and Ferrocolumbium			60,897,400	(160,000)	(120,000)	(120,000)	-0.26	-0.20	-0.20
Tellurium	60	59,508	3,570,480	-	(2,600)	(17,000)	0.00	-0.07	-0.48
Titanium and Titanium Dioxide			2,516,300,000	(65,000)	(85,000)	(110,000)	0.00	0.00	0.00
Tungsten	9,408	40	376,240	-	(9,800)	(16,000)	0.00	-2.60	-4.25
Uranium			40,734,000	-	20,000	22,000	0.00	0.05	0.05
Zinc	505,000	1,014	512,070,000	(2,600,000)	(3,400,000)	(3,700,000)	-0.51	-0.66	-0.72
Zirconium and Hafnium			379,899,000	-	(87,000)	(300,000)	0.00	-0.02	-0.08
Total				(3,000,000)	(4,900,000)	(7,100,000)			

A.2 Risk and Benefits Assessment Assumptions, Methods, and Results

A.2.1. Introduction

As discussed in Section 4.1, while EPA's current judgement is that the modified prior treatment baseline best represents current industry practice, the Agency has conducted a substantial amount of risk and benefits assessment work for the alternative baseline scenarios. This is particularly true for the no prior treatment baseline, which was regarded early in the regulatory development process as a prudently conservative characterization of current practice. EPA has also evaluated some potential risks and benefits for the prior treatment baseline as well. As will be discussed further below, some of the risk and benefits assessment for the activities evaluated (disposal or storage) are applicable to more than one baseline, and to more than one regulatory option, because the behavioral assumptions made for that activity are the same under the various baselines and options. Thus they can be used to infer baseline risks and risk reduction benefits for other sets of baseline assumptions.

This appendix describes in detail the risk and benefits assessments that have been performed for the alternative baselines. The primary focus is on the work that EPA has done to evaluate groundwater pathway risks associated with waste disposal under the no prior treatment baseline. In addition, it discusses in less detail aspects of the risk and benefits assessments for the storage of recycled materials compared to the modified prior treatment baseline that are relevant to the alternative baselines.

A.2.1.1 Groundwater Risk and Benefits Assessment for Waste Disposal

The bulk of this appendix is devoted to a description of the risk and benefits analysis for mineral processing waste disposal. As discussed in Section 4.1, EPA has performed quantitative risk and benefits analysis for the groundwater pathway risks associated with the disposal of these wastes. EPA analyzed risks for all 42 (later reduced to 34) of the spent materials, sludges, and byproduct streams from the mineral processing industry for which constituent concentration data were available. Pre-regulatory risks were analyzed under the no prior treatment baseline, which assumed final disposal of untreated materials in land units (waste piles and surface impoundment). Benefits were estimated for the three regulatory options under consideration at the time of the analysis. For all three options, it was assumed that the wastes would be treated to meet UTS levels for all constituents prior to disposal.

Since the modified prior treatment baseline assumes that all wastes would be treated to meet TC regulatory levels, the no prior treatment and modified prior treatment baseline risks are not the same, and the health benefits of moving from the baseline to the regulated environment are not equivalent. On the other hand, the post-regulatory requirements for treatment of all wastes to meet the UTS requirements remains a feature of the current regulatory options. Thus, the post-regulatory risks calculated for waste disposal are still relevant to the current options, as was discussed in Section 4.2.

A.2.1.2 Groundwater and Multipathway Risk Assessment for Recycled Materials

The methods used to evaluate risks associated with the storage of recycled materials are described in detail in Appendix H, and will not be discussed in detail here. Risks were assessed for waste storage under the modified prior treatment baseline, which assumes that the recycled materials would be stored in unlined land-based units (waste piles and surface impoundments). This assumption is the same as that made in the no prior treatment baseline. Therefore the risks associated with these two baselines are the same, and this provides the rationale for including a discussion of these results in this appendix.

Because suitable models and data are not available that would allow risk estimation for tanks, containers, and buildings, the risks associated with the storage of recycled materials under the prior treatment baseline and under regulatory Options 1-3 have not been evaluated quantitatively. In section 4.2, the potential degrees of risk reduction associated with the various regulatory options are discussed qualitatively.

A.2.2 RISK AND BENEFITS ASSESSMENT METHODS

A.2.2.1 Risk Assessment Methods for Waste Disposal

A.2.1.1 Identification of Waste Streams for Quantitative Risk and Benefits Analysis

The procedures used to identify waste streams for inclusion in the risk and benefits assessments in the December 1995 RIA are described in Section 5.1.1.1 of that RIA.³ The number of waste streams that could be evaluated with regard to risks and benefits was limited by the lack of constituent concentration data to a small fraction of the wastes that were evaluated in the cost and economic analysis. To evaluate pre-LDR constituent concentrations, bulk concentration data were used for wastewaters (WW), and EP leachate data were used to estimate release concentrations for liquid nonwastewaters (LNWW) and nonwastewaters (NWW). Wastes for which these types of data were not available were excluded from the quantitative risk and benefits assessments.

The procedures used to identify waste streams for inclusion in the sample-specific risk and benefits were slightly different, as described in Section 5.5.1.1 of the December RIA. First, the data requirements for including a waste in the quantitative risk assessment were relaxed somewhat, allowing inclusion of LNWW and NWW wastes for which only bulk concentration data were available. Second, the assumed proportion of high-probability ("Y") recycled materials that would be disposed was reduced from 20 percent to zero. This resulted in the removal of the two recycled materials for which constituent concentration data were available from the quantitative risk assessment, making the risk and benefits analysis for Regulatory Options 1 and 2 the same, in terms of the waste streams that were included.

A total of 42 waste streams ultimately met the criteria for inclusion in the sample-specific risk and benefits assessments for changes in waste disposal practices under the proposed LDRs. These waste streams represent a relatively small proportion, in terms of numbers, of the waste streams included in the cost and economic analysis. However, as discussed in the December RIA Appendix J, the wastes that are included in the risk and benefits analysis for waste disposal account for between 71 and 92 percent of the estimated total waste volume covered by the cost and economic analysis, depending on which volume estimates are used.

These same 42 wastes were included in the preliminary risk and benefits calculations (ICF Incorporated 1996a). Since that time, as discussed above, a number of waste streams have been eliminated from the risk and benefits assessments, as summarized in Exhibit A.2-1. Two beryllium sector waste streams were removed because they are beneficiation wastes, and would not be addressed by LDRs. One waste stream in the copper commodity sector was removed from the waste disposal risk and benefits assessment because EPA believes that it is fully recycled. Another copper waste stream was removed because it appears to be redundant with another stream. Two waste streams from lead production were

³ *Regulatory Impact Analysis of the Supplemental Proposed Rule Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes, December 1995.*

Exhibit A.2-1
Commodity Waste Streams Included in Revised Benefits Analysis

Commodity	Waste Stream
Aluminum and Alumina	Cast house dust
Antimony	Autoclave filtrate
Beryllium	Spent barren filtrate streams
Beryllium	Bertrandite thickener slurry
Beryllium	Chip treatment wastewater
Beryllium	Spent raffinate
Copper	Acid plant blowdown (1)
Copper	Scrubber blowdown
Copper	Spent bleed electrolyte
Copper	Surface impoundment waste liquids
Elemental Phosphorous	AFM rinse
Elemental Phosphorous	Furnace offgas solids
Elemental Phosphorous	Furnace scrubber blowdown
Elemental Phosphorous	Slag quenchwater
Germanium	Waste acid wash/rinse water
Germanium	Chlorinator wet air pollution control sludge
Germanium	Hydrolysis filtrate
Germanium	Waste still liquor
Lead	Process wastewater
Lead	Surface impoundment waste liquids
Magnesium and Magnesia (brine)	Smut
Molybdenum, Ferromolybdenum, Ammonium Molybdate	Liquid residues
Rare Earths	Spent ammonium nitrate processing solution (2)
Rare Earths	Process wastewater (2)
Selenium	Plant process wastewater
Tantalum, Columbium, and Ferrocolumbium.	Process wastewater
Titanium and Titanium Dioxide	Pickle liquor & wash water
Titanium and Titanium Dioxide	Leach liquor & sponge wash water
Titanium and Titanium Dioxide	Scrap milling scrubber water
Titanium and Titanium Dioxide	Spent surface impoundment liquids
Titanium and Titanium Dioxide	Spent surface impoundment solids
Titanium and Titanium Dioxide	Waste acids (Chloride process)
Titanium and Titanium Dioxide	Waste acids (Sulfate process)
Titanium and Titanium Dioxide	Wastewater treatment plant sludge/solids
Tungsten	Spent acid & rinse water
Zinc	Waste ferrosilicon
Zinc	Process wastewater
Zinc	Spent surface impoundment liquids (3)
Zinc	Spent surface impoundment solids (4)
Zinc	Spent synthetic gypsum (3)
Zinc	Wastewater treatment plant liquid effluent (3)
Zinc	Zinc lean slag

removed, one because it is fully recycled, and another because it is no longer generated. Acid waste from titanium chloride production was removed from the analysis because EPA received information indicating that it is currently deep-well injected, and not land disposed. One waste stream from zinc production was removed because it is either recycled or not stored in land-based units. After removing these streams, 34 were left in the risk and benefits analysis for waste disposal. A zinc waste stream, "spent surface impoundment solids," was renamed to "waste water treatment plant solids," but remained in the analysis.

A.2.2.1.2 Waste Characterization Data and Release Concentration Estimates

The source of the mineral processing waste constituent concentration data used in the pre-LDR risk estimates is the same source as that used in the December 1995 RIA sample-specific risk assessment. These data are summarized in Appendix K of the December RIA. In this analysis a slightly different approach from that used in the RIA was adopted to enumerate samples of each waste type. In the December RIA, when both bulk analyses and EP leachate sample results were available for a LNWW or NWW stream, only the leachate data were used to estimate release concentrations. In the revised risk assessment presented below, both types of samples, when available, were used in the risk assessment to develop separate risk estimates. This approach makes the best possible use of the available data, and takes into account that, in many cases, it was not clear that the EP and bulk analyses for a given waste stream were from the same samples or batch of waste.

In adopting this approach, it was assumed that the observed differences in the release concentrations calculated from the two types of samples of the same wastes reflect real variability in waste stream constituent concentrations and in the leaching characteristics of the various constituents. In the December RIA, a total of 126 waste samples were evaluated for carcinogenic risks, and 217 samples were evaluated for noncarcinogenic risks. Using all of the available data in the revised risk assessment and excluding the wastes as described above, EPA calculated carcinogenic risks and noncarcinogenic hazard quotients for 115 samples and 190 samples, respectively. The number of samples evaluated for carcinogenicity was also reduced because EPA no longer calculated carcinogenic risks for beryllium (see below), and thus only streams containing arsenic were assumed to be carcinogenic.

For WW streams, the bulk concentration sample results were used directly as release concentration estimates. For LNWW and NWW streams, EP leachate concentrations were also used directly as release concentrations. For LNWW and WW bulk samples, release concentrations (mg/l) were conservatively estimated as being equal to the bulk constituent concentrations (mg/kg) divided by 20. This approach conservatively assumes that all waste constituents are completely leachable into the EP leachant.

For the post-LDR scenario, release concentrations for all constituents were estimated to be equal to one-half the landfill UTS concentrations for each constituent, or they were to be as being equal to the sample concentration, if that value was less than one-half the UTS concentration. The decision to use one-half the UTS concentration, instead of the UTS concentration itself, was based on EPA's assumption that waste managers required to comply with UTS would give themselves a conservative margin of safety and assume that all of the constituents are completely leachable. The basis for this judgment is discussed in Section 5.5.1.3 of the December RIA.

A.2.2.1.3 Exposure Assessment

Exposure concentrations of the waste constituents in ground water were estimated by dividing the release concentrations by the recently-developed constituent-specific DAF values derived for mineral

processing wastes. Under the no-treatment baseline scenario, all NWW streams were assumed to be disposed in waste piles. Therefore, the 75th and 95th percentile wastepile DAF values were used to evaluate central tendency (CT) and high end (HE) exposure concentrations, respectively. All WW and LNWW wastes were assumed to be disposed in surface impoundments, and the 75th and 95th percentile impoundment DAFs were therefore used to calculate the CT and HE exposure concentrations for these wastes.

In evaluating risks, the 75th percentile constituent-specific DAFs were used to estimate central tendency (CT) groundwater concentrations. The rationale for using the 75th percentile DAFs rather than, for example, the 50th percentile value was that the EPACMTP model used to derive DAFs does not consider fractured or channeled flow or other facilitated transport mechanisms which may occur at some sites, resulting in higher groundwater concentrations than those predicted for homogeneous flow processes modeled by EPACMTP. The 95th percentile constituent-specific DAF values were used to estimate high-end (HE) groundwater concentrations, in keeping with the definition of a high-end receptor as someone exposed at levels between the 90th and 99th percentiles of all exposed individuals.

In the post-LDR case, all wastes (WW, LNWW, NWW) were assumed to be treated and disposed of in landfills. Since no data related to mineral processing waste disposal in landfills were available, DAFs values derived for waste piles were used for estimating all of the exposure concentrations in the post-LDR scenario.

As noted above, the DAF values used in this analysis differed from those used previously. The DAF values used here were derived based on data on constituent concentrations, facility and waste volumes, and locational data specifically for mineral processing wastes, rather than on generic values. In addition, the DAF values used in this assessments were calculated separately for pre- and post-LDR release concentration distributions. Thus, these values better reflect the expected fate and transport characteristics of the mineral processing industry waste constituents than did the values used previously. In particular, the revised DAFs account for the concentration-dependence of groundwater transport for each constituent and regional variations in precipitation and groundwater transport. These variations were not taken into account in the previous DAF derivations.

The constituent-specific DAF values used in this risk assessment are provided in Exhibit A.2-2. The surface impoundment DAFs, which are used in this analysis only for evaluating pre-LDR risks for liquid wastes, are summarized in the second and third columns of the Exhibit A.2-2. Most of the 75th percentile DAF (CT) values are lower than the CT value of 500 used in the RIA risk analysis. The values for antimony, arsenic, chromium, mercury, and thallium are only slightly lower (within about a factor of ten), while the values for barium, beryllium, cadmium, nickel, selenium, silver, and zinc are much lower (greater than a factor of ten) than the CT DAF values used in the December RIA. For these liquid waste stream constituents, the estimated pre-LDR constituent groundwater concentrations were greater than those estimated in the RIA. In contrast, the 75th percentile surface impoundment DAF value for lead and cyanide used in this analysis increased by several orders of magnitude over the CT DAFs used in the RIA, and thus the pre-LDR groundwater concentration estimates are lower for lead- and cyanide-containing liquid waste streams than they were in previous analyses.

The 95th percentile surface impoundment DAF values derived for this analysis are generally similar to the HE DAF values used in the RIA. The HE DAF values in the December RIA risk analysis ranged between 6 and 100. The constituent-specific DAFs used in this analysis range between 1.3 and 200 for all but one constituent. The sole outlier is the DAF for cyanide, which is 4200. For all constituents except cyanide, the 95th percentile surface impoundment DAFs used in this assessment result

Exhibit A.2-2
Revised Constituent-Specific DAFs for the Mineral Processing Industry

Constituent	Surface Impoundments (1)		Waste Piles			
	Central Tendency (75th percentile) Pre- LDR	High End (95th percentile) Pre-LDR	Central Tendency (75th percentile) Pre-LDR	High End (95th percentile) Pre-LDR	Central Tendency (75th percentile) Post-LDR	High End (95th percentile) Post- LDR
Antimony	1.93E+02	2.28E+01	>10 ⁹	8.36E+03	>10 ⁹	8.36E+03
Arsenic	1.66E+02	1.71E+01	>10 ⁹	2.56E+03	4.37E+09	2.56E+03
Barium	5.81E+00	1.17E+00	2.22E+03	1.38E+01	2.33E+03	1.46E+01
Beryllium	8.47E+00	1.24E+00	>10 ⁹	4.87E+02	>10 ⁹	5.54E+02
Cadmium	2.49E+01	1.40E+00	>10 ⁹	2.67E+03	>10 ⁹	3.26E+03
Chromium	9.82E+01	1.15E+01	2.21E+04	1.60E+02	2.21E+04	1.60E+02
Cyanide	2.81E+10	4.20E+03	-- (2)	--(2)	--(2)	--(2)
Lead	7.11E+05	4.98E+00	>10 ⁹	2.27E+05	>10 ⁹	8.93E+08
Mercury	1.97E+02	8.05E+00	>10 ⁹	4.29E+03	>10 ⁹	4.29E+03
Nickel	2.23E+01	1.51E+00	1.54E+06	1.41E+02	1.97E+06	1.46E+02
Selenium	2.70E+01	3.38E+00	1.18E+08	4.28E+02	1.19E+08	4.28E+02
Silver	1.11E+01	1.23E+00	>10 ⁹	4.96E+02	>10 ⁹	4.87E+02
Thallium	2.97E+02	4.15E+01	>10 ⁹	9.63E+04	>10 ⁹	9.63E+04
Vanadium	5.67E+00	2.03E+00	>10 ⁹	>10 ⁹	>10 ⁹	>10 ⁹
Zinc	1.23E+01	1.35E+00	>10 ⁹	>10 ⁹	>10 ⁹	>10 ⁹

Source: U.S. EPA (1996)

Notes:

- (1) Post LDR DAFs for surface impoundments were not used in the risk calculations because it was assumed that all liquid wastes would be dewatered under LDRs.
- (2) No DAFs were derived for cyanide disposed in waste piles because cyanide concentration data for non-liquid wastes were not available.

in pre-LDR estimated groundwater concentrations and health risks for liquid waste streams of generally similar magnitude to those calculated in the December RIA.

The constituent-specific waste pile DAF values derived for mineral processing wastes are shown in the last four columns of Exhibit A.2-2. These values were derived for both pre-LDR and post-LDR constituent concentrations. The former values were used to evaluate risks for all non-liquid waste streams pre-LDR, and the latter were used to evaluate risks post-LDR for all wastes, as explained above. The 75th percentile waste pile DAFs used in this analysis are, with few exceptions, many orders of magnitude greater than the CT DAF value (50) used in the December RIA. Thus, the predicted pre- and post-LDR risks for non-liquid waste streams containing these constituents are much lower than in the RIA. The lowest CT waste pile DAF value (about 2200), which was estimated for barium, is still about 40 times greater than the CT DAF value used in the RIA.

In comparison, most of the 95th percentile constituent-specific DAFs for the mineral processing wastes are somewhat closer to the range of HE values (12 to 100) used in the RIA. The pre-LDR HE waste pile DAFs are less than 10,000 for all but two contaminants, which are within two to three orders of magnitude of the RIA HE DAF range. Lead, vanadium, and thallium have HE DAFs that are higher than the values used in previous assessments. Post-LDR, the situation is similar. Most of the constituent-specific post-LDR DAF values for waste piles are less than 10,000, with the outliers again being lead and vanadium for which the DAF values are much higher. As with the 75th percentile DAFs, these revised 95th percentile DAF values result in the prediction of lower groundwater concentrations than those predicted in the previous assessments.

A.2.2.1.4 Risk Characterization

Lifetime cancer risks for the hypothetical receptor are calculated using the following equation:

$$CancerRisk = \frac{EC * IR * EF * ED * CSF}{BW * 365 * AT} \quad (1)$$

Where:

- EC = Exposure concentration of constituent in groundwater, mg/l
- IR = Water ingestion rate (1.4 l/day)
- EF = Exposure frequency (350 days/year)
- ED = Exposure duration (9 years)
- CSF = Ingestion pathway Cancer Slope Factor (mg/kg-day)⁻¹
- BW = Adult body weight (70 kg)
- AT = Averaging time for dose estimation (70 years)

Chronic noncancer hazard quotients for exposure to waste constituents in groundwater are calculated as follows:

$$HazardQuotient = \frac{EC * IR * EF}{BW * 365 * RfD} \quad (2)$$

where the RfD is the EPA chronic ingestion pathway Reference Dose for the constituent,⁴ and the other variables have the same meaning as in Equation (1). The rationale for selecting the exposure factor values used in Equations (1) and (2) is discussed in Section 5.2.1.2 of the December RIA.

Two changes were made in the toxicological parameter values which were used to calculate risk results in this analysis. First, beryllium was no longer treated as an ingestion pathway carcinogen. While EPA has published an ingestion pathway cancer slope factor for beryllium, the Agency has not applied this value in several recent rulemakings, citing the great uncertainty surrounding the data supporting the cancer-causing potential of beryllium by the oral route. Thus, cancer risks are no longer calculated for beryllium-containing wastes, and arsenic is the sole carcinogenic constituent by the ingestion route included in the risk assessment. The other change in the toxicological parameter values was to use an updated IRIS RfD value for manganese, which had a very limited effect on the risk and benefits results.

A.2.2.2 Risk Assessment Methods for Storage of Recycled Materials

Risks associated with the storage recycled streams were assessed both for groundwater and non-groundwater pathways, as described in Appendix H. These methods will not be discussed in detail here.

A.2.2.3 Benefits Assessment Methods for Waste Disposal

A.2.2.3.1 Unit of Analysis for Benefits Assessment

Consistent with the December RIA, the unit of analysis of the benefits assessment is the "waste stream-facility combination." To calculate the benefits of improved management for a given waste stream, the number of facilities is first estimated, as described in Section A.2.2.3.2 of the RIA. Then, the numbers of facilities the imposition of the LDRs would result in changes in risk are calculated and categorized based on the order-of-magnitude change in risks pre- and post-LDR. The benefit measure is the number of facilities generating the waste (i.e., waste stream-facility combinations) that move from high-risk categories pre-LDR to lower-risk categories post-LDR. One feature of this approach is that a single facility that disposes of more than one waste stream will be counted in the benefits assessment as more than one waste stream-facility combination. Thus, the total number of waste stream-facility combinations in the benefits assessment exceeds the total number of facilities affected by the LDRs.

Another feature of this approach is that, as will be seen in Appendix A.2.2.3.3, not every exceedence of risk levels of concern pre-LDR results in an estimated benefit post-LDR. This is because if only a small number of samples from a given waste stream (one of 20, for example) give risk results above the level of concern, this may not translate into even one facility waste-stream combination if the number of facilities managing the waste is small (two or three). In this case, the estimated number of facilities with pre-LDR risks at levels of concern is zero. (Or more properly, it is less than one.)

This approach does not provide an estimate of risk reduction for identifiable exposed individuals, nor does it allow calculations of population risk reduction. As explained in the December RIA, the lack of data regarding the number of individuals exposed to groundwater around mineral processing facilities precludes the development of population risk and benefit estimates.

⁴ Since there is currently no RfD value for lead, EPA calculated the hazard quotient for lead as the ratio of the exposure concentration to the MCL of 15 ug/l.

A.2.2.3.2 Estimation of Numbers of Facilities Managing Mining Wastes

The total number of facilities managing specific wastes were estimated as described in Chapter 4 of the December 1995 RIA. For the HE benefits estimates, the total estimated numbers of facilities generating the various waste streams nation-wide were used in the benefits estimation. For the CT benefits estimates, a reduced number of facilities managing some of the waste streams was used. For all of the waste streams categorized "Y?" (i.e., low likelihood of being TC hazardous), the CT number of facilities was estimated as the total facilities generating the waste stream divided by two. Odd numbers of facilities were rounded up by one to generate an even number (e.g., an HE estimate of seven facilities resulted in a CT estimate of four facilities).

A.2.2.3.3 Attribution of Risks to Facility-Waste Stream Combinations

If there were always one and only one sample result per waste stream per facility, then the attribution of risks across waste streams and facilities would have been simple. (Each sample risk result would correspond to one facility-waste stream combination in the benefits analysis.) Unfortunately, the number of samples per waste stream and per facility varied considerably, necessitating the development of a method for distributing risk results from single samples and groups of samples across multiple facility-waste stream combinations. The approach used to distribute risks across facilities used in the revised benefits assessment is essentially identical to that described in detail in Section 5.5.2.4 of the December RIA, and can be summarized as follows:

- Where there is only one sample result for a waste stream, all of the facilities managing that waste are assigned the risk value associated with the pre- or post-LDR disposal of a waste having the same composition as the sample;
- Where there are multiple samples from a waste stream, the facilities disposing of that waste are assigned risk values in the same proportion as the risks are distributed across the samples. For example, if there are four waste samples and eight facilities disposing of the wastes, the risk results from each of the four waste samples are assigned to two facility-waste stream combinations;
- Where there are multiple samples from a single facility, the risk results for each sample at the facility are counted as separate risk estimates only if they are significantly different from one another.⁵ However, if multiple samples from a single facility result in risks that are very similar, the risks for all of those samples are averaged and counted as a single sample for purposes of the benefits analysis. The facility-waste stream combinations for a waste stream are then assigned to risk categories according the risk results from the individual samples from that waste stream, and from the combined samples counted as a single sample. This approach avoids giving too great a weight to multiple samples from the same facility and the same batch of wastes.

The approach described above is rather complex, and requires a certain amount of professional

⁵ Risk from multiple samples are considered to be similar (homogeneous) if the same constituents account for the bulk of the risks, and if all of the sample-specific cancer risks or hazard quotients are within one to two orders of magnitude. (See the December RIA, p. 5-37.)

judgment. However, as was the case for the sample-specific risk analysis in the December RIA, decisions about whether to combine samples within facilities had relatively little impact on either the pre-LDR or post LDR risk distributions, and the distribution of facility-wastes stream combinations across risk categories followed the distribution of the individual samples risk results quite closely.

A.2.2.4 Benefits Assessment Methods for Storage or Recycled Materials

As discussed in Section 4.2, a quantitative benefits assessment was not performed for recycled materials storage. Instead, the baseline risks are identified as an upper bound estimate of the risk reduction that could occur if all releases of toxic constituents were eliminated by storage in tanks containers, and buildings. This assumption also holds true for the no treatment baseline, since no treatment of stored materials is assumed under that baseline. The risk assessment for storage does not provide an estimate of the magnitude of the potential benefits associated with the prior treatment baseline. Analogous to the case for the disposal of treated wastes, it is likely that the benefits of improved storage under any of the regulatory options over the prior treatment baseline would be minimal.

A.2.3 RESULTS OF RISK AND BENEFITS ASSESSMENT FOR THE NO TREATMENT BASELINE

This section summarizes the results of the revised screening risk and benefits calculations that were completed using the constituent-specific DAFs, as described in Section A.2.2.1.

A.2.3.1 Risk and Benefits Assessment Results for Waste Disposal

The results of the risk assessment for mineral processing wastes are summarized in Exhibits A.2-3 and A.2-4. Exhibit A.2-3 provides the results of the pre- and post-LDR assessments of the individual cancer risks calculated for each sample, and Exhibit A.2-4 provides the results of the noncancer hazard quotient calculations for the samples.

The general pattern of waste disposal risks calculated in the December RIA is replicated in the risk calculations that use the newly-revised constituent-specific DAFs are used, but in a more extreme fashion. Waste streams move from higher risk categories pre-LDR to lower risk categories post-LDR. The most striking difference between the risk results presented here and those in the RIA is that all of the wastes with estimated health risks (both CT and HE) above levels of concern pre-LDR (greater than 10^{-5} cancer risk or hazard quotient > 1.0) move to below the levels of concern post-LDR.

Pre-LDR, CT cancer risks greater than 10^{-5} are predicted for 58 of 115 samples, with risk results distributed through all of the categories up to $>10^{-1}$. The pre-LDR HE cancer risks for 80 of 115 samples were greater than 10^{-5} , with the highest risks again reaching the highest risk category. These proportions are not very different from those seen pre-LDR in both the December RIA. As noted above, estimated cancer risks for all of the waste samples post-LDR are below 10^{-5} .

EXHIBIT A.2-3

Distribution of Samples by Groundwater Risk Category: Cancer Risks

Commodity	Waste Stream	Number of Samples with Cancer Risk	Central Tendency												High End													
			Pre-LDR						Post-LDR						Pre-LDR						Post-LDR							
			10-5 to	10-4 to	10-3 to	10-2 to			10-5 to	10-4 to	10-3 to	10-2 to			10-5 to	10-4 to	10-3 to	10-2 to			10-5 to	10-4 to	10-3 to	10-2 to				
			<10-5	10-4	10-3	10-2	10-1	>10-1	<10-5	10-4	10-3	10-2	10-1	>10-1	<10-5	10-4	10-3	10-2	10-1	>10-1	<10-5	10-4	10-3	10-2	10-1	>10-1		
Al and Alumina	Cast house dust	2	2	0	0	0	0	0					2	0	0	0	0	0					2	0	0	0	0	0
Sb	Autoclave filtrate	8	0	0	0	2	6	0					8	0	0	0	0	0					8	0	0	0	0	0
Be	Spent barren filtrate streams	2	1	0	1	0	0	0					2	0	0	0	0	0					2	0	0	0	0	0
Be	Chip treatment WW	1	1	0	0	0	0	0					1	0	0	0	0	0					1	0	0	0	0	0
Cu	Acid plant blowdown	30	7	4	10	4	3	2					30	0	0	0	0	0					1	6	4	10	4	5
Cu	Scrubber blowdown	3	1	0	2	0	0	0					3	0	0	0	0	0					0	1	0	2	0	0
Elemental Phosphorous	AFM rinsate	2	1	1	0	0	0	0					2	0	0	0	0	0					0	1	1	0	0	0
Elemental Phosphorous	Furnace offgas solids	9	9	0	0	0	0	0					9	0	0	0	0	0					9	0	0	0	0	0
Elemental Phosphorous	Furnace scrubber blowdown	8	4	3	1	0	0	0					8	0	0	0	0	0					1	3	3	1	0	0
Elemental Phosphorous	Slag quenchwater	1	0	1	0	0	0	0					1	0	0	0	0	0					0	0	1	0	0	0
Ge	Waste acid wash/rinse water	1	1	0	0	0	0	0					1	0	0	0	0	0					0	1	0	0	0	0
Ge	Chlorinator wet air poll. ctrl. sludge	1	1	0	0	0	0	0					1	0	0	0	0	0					1	0	0	0	0	0
Ge	Hydrolysis filtrate	1	1	0	0	0	0	0					1	0	0	0	0	0					1	0	0	0	0	0
Ge	Waste still liquor	1	1	0	0	0	0	0					1	0	0	0	0	0					1	0	0	0	0	0
Mg and Magnesia (brine)	Smut	2	2	0	0	0	0	0					2	0	0	0	0	0					2	0	0	0	0	0
Mo, FeMo, Anm. Mo	Liquid residues	1	0	0	0	1	0	0					1	0	0	0	0	0					0	0	0	0	1	0
Rare Earths	Spent ammon. nitrate proc. sol.	5	5	0	0	0	0	0					5	0	0	0	0	0					5	0	0	0	0	0
Rare Earths	PWW	2	0	2	0	0	0	0					2	0	0	0	0	0					0	0	2	0	0	0
Se	Plant PWW	2	0	2	0	0	0	0					2	0	0	0	0	0					0	0	2	0	0	0
Ta, Columbium, and FeCoI.	PWW	13	8	2	2	1	0	0					13	0	0	0	0	0					6	3	1	3	0	0
Titanium and TiO2	Pickle liquor & wash water	3	2	1	0	0	0	0					3	0	0	0	0	0					0	2	1	0	0	0
Titanium and TiO2	Leach liquor & sponge wash water	2	1	1	0	0	0	0					2	0	0	0	0	0					0	1	1	0	0	0
Titanium and TiO2	Scrap milling scrubber water	1	0	1	0	0	0	0					1	0	0	0	0	0					0	0	1	0	0	0
Titanium and TiO2	Spent s.i. liquids	0	0	0	0	0	0	0					0	0	0	0	0	0					0	0	0	0	0	0
Titanium and TiO2	Spent s.i. solids	0	0	0	0	0	0	0					0	0	0	0	0	0					0	0	0	0	0	0
Titanium and TiO2	Waste acids (Sulfate process)	4	1	3	0	0	0	0					4	0	0	0	0	0					1	0	3	0	0	0
Titanium and TiO2	WWTP sludge/solids	0	0	0	0	0	0	0					0	0	0	0	0	0					0	0	0	0	0	0
W	Spent acid & rinse water	2	1	0	1	0	0	0					2	0	0	0	0	0					0	1	0	1	0	0
Zn	Waste ferrosilicon	0	0	0	0	0	0	0					0	0	0	0	0	0					0	0	0	0	0	0
Zn	Spent s.i. liquids	1	0	0	0	1	0	0					1	0	0	0	0	0					0	0	0	0	1	0
Zn	WWTP solids	1	1	0	0	0	0	0					1	0	0	0	0	0					0	1	0	0	0	0
Zn	Spent synthetic gypsum	4	4	0	0	0	0	0					4	0	0	0	0	0					2	0	2	0	0	0
Zn	WWTP liquid effluent	0	0	0	0	0	0	0					0	0	0	0	0	0					0	0	0	0	0	0
Zn	Zinc lean slag	2	2	0	0	0	0	0					2	0	0	0	0	0					2	0	0	0	0	0
Totals		115	57	21	17	9	9	2					115	0	0	0	0	0					35	21	22	18	8	11

EXHIBIT A.2-4
Distribution of Samples by Groundwater Hazard Category: Non-Cancer Hazards

Commodity	Waste Stream	Number of Samples with Non-cancer Hazard	Central Tendency												High End											
			Pre-LDR						Post-LDR						Pre-LDR						Post-LDR					
			1	10	100	1k			1	10	100	1k			1	10	100	1k			1	10	100	1k		
			to	to	to	to			to	to	to	to			to	to	to	to			to	to	to	to		
			<1	10	100	1k	10k	>10k	<1	10	100	1k	10k	>10k	<1	10	100	1k	10k	>10k	<1	10	100	1k	10k	>10k
Al and Alumina	Cast house dust	2	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0
Sb	Autoclave filtrate	8	0	0	0	4	4	0	8	0	0	0	0	0	0	0	0	2	2	4	8	0	0	0	0	0
Be	Spent barren filtrate streams	5	0	1	4	0	0	0	5	0	0	0	0	0	0	0	1	4	0	0	5	0	0	0	0	0
Be	Chip treatment WW	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	
Cu	Acid plant blowdown	35	6	8	13	5	3	0	35	0	0	0	0	0	0	3	8	14	5	5	35	0	0	0	0	0
Cu	Scrubber blowdown	3	0	1	2	0	0	0	3	0	0	0	0	0	0	0	0	3	0	0	3	0	0	0	0	0
Elemental Phosphorous	AFM rinsate	2	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0
Elemental Phosphorous	Furnace offgas solids	14	14	0	0	0	0	0	14	0	0	0	0	0	14	0	0	0	0	0	14	0	0	0	0	0
Elemental Phosphorous	Furnace scrubber blowdown	14	5	6	2	1	0	0	14	0	0	0	0	0	1	1	6	5	1	0	14	0	0	0	0	0
Elemental Phosphorous	Slag quenchwater	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
Ge	Waste acid wash/rinse water	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Ge	Chlorinator wet air poll. ctrl. sludge	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Ge	Hydrolysis filtrate	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Ge	Waste still liquor	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Mg and Magnesia (brine)	Smut	2	2	0	0	0	0	0	2	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0
Mo, FeMo, Amm. Mo	Liquid residues	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
Rare Earths	Spent ammon. nitrate proc. sol.	6	5	1	0	0	0	0	6	0	0	0	0	0	4	1	1	0	0	0	6	0	0	0	0	0
Rare Earths	PWW	4	2	2	0	0	0	0	4	0	0	0	0	0	1	1	1	1	0	0	4	0	0	0	0	0
Se	Plant PWW	2	1	1	0	0	0	0	2	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0
Ta, Columbium, and FeCol.	PWW	21	13	2	5	0	1	0	21	0	0	0	0	0	8	2	3	2	2	4	21	0	0	0	0	0
Titanium and TiO2	Pickle liquor & wash water	3	0	3	0	0	0	0	3	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0
Titanium and TiO2	Leach liquor & sponge wash water	2	0	1	1	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0
Titanium and TiO2	Scrap milling scrubber water	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Titanium and TiO2	Spent s.i. liquids	10	10	0	0	0	0	0	10	0	0	0	0	0	10	0	0	0	0	0	10	0	0	0	0	0
Titanium and TiO2	Spent s.i. solids	6	6	0	0	0	0	0	6	0	0	0	0	0	3	3	0	0	0	0	6	0	0	0	0	0
Titanium and TiO2	Waste acids (Sulfate process)	4	0	0	4	0	0	0	4	0	0	0	0	0	0	0	2	2	0	0	4	0	0	0	0	0
Titanium and TiO2	WWTP sludge/solids	2	2	0	0	0	0	0	2	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0
W	Spent acid & rinse water	4	3	1	0	0	0	0	4	0	0	0	0	0	2	1	0	1	0	0	4	0	0	0	0	0
Zn	Waste ferrosilicon	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Zn	Spent s.i. liquids	22	4	4	3	6	4	1	22	0	0	0	0	0	0	5	2	3	6	6	22	0	0	0	0	0
Zn	WWTP solids	7	7	0	0	0	0	0	7	0	0	0	0	0	2	4	1	0	0	0	7	0	0	0	0	0
Zn	Spent synthetic gypsum	4	4	0	0	0	0	0	4	0	0	0	0	0	2	2	0	0	0	0	4	0	0	0	0	0
Zn	WWTP liquid effluent	3	0	1	1	0	0	1	3	0	0	0	0	0	0	0	2	0	0	1	3	0	0	0	0	0
Zn	Zinc lean slag	3	3	0	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0	0
Totals		197	95	35	36	16	13	2	197	0	0	0	0	0	58	26	35	41	16	21	197	0	0	0	0	0

The distribution of pre-LDR cancer risks across waste streams is generally the same as that seen in the previous risk assessments, with exception that several of the high-risk waste streams have been eliminated from the analysis, as described above. The majority of samples with risks above 10^{-5} pre-LDR were from antimony autoclave filtrate, copper acid plant blowdown, elemental phosphorous furnace scrubber blowdown, tantalum, columbium and ferrocolumbium process wastewater, and titanium/titanium oxide waste acids from the sulfate process. High-risk streams from the previous analysis which were eliminated in this analysis include beryllium spent raffinate, lead process wastewater, and zinc process wastewater.

As was the case for cancer risks, all of the wastes with pre-LDR noncancer hazard quotients above the level of concern drop below this level post-LDR, under both CT and HE assumptions (Exhibit A.2-4). Pre-LDR, the CT hazard quotients for 102 of 197 waste samples are above 1.0, while 139 of 197 samples had HE pre-LDR hazard quotients above 1.0. All of the same wastes having high pre-LDR cancer risks also had high pre-LDR hazard quotients. In addition, a substantial number of samples from zinc spent surface impoundment liquids and waste water treatment plant solids both had high noncancer hazard quotients pre-LDR. As was the case for cancer risks, the reduction in hazard quotients below the level of concern post-LDR is the result of the higher post-LDR DAF values that were derived using data for the mineral processing waste constituents.

The results of the benefits analysis for cancer risks and noncancer risks under the no prior treatment baseline are summarized in Exhibits A.2-5 and A.2-6, respectively. As discussed previously, the distribution of risks across facility-waste stream combinations closely follows that seen for the individual samples.

In the CT case, the number of facility-waste stream combinations with pre-LDR cancer risks greater than 10^{-5} is 33 out of an estimated 108 facilities.⁶ Post-LDR, all of the facility-waste stream combinations fall below the 10^{-5} CT risk level. In the HE case, 62 out of 133 facility-waste stream combination have pre-LDR cancer greater than 10^{-5} . All of these waste stream-facility combinations fall into the risk category less than 10^{-5} post-LDR.

The number of facility-waste stream combinations with pre-LDR CT hazard quotients greater than 1.0 is 39 out of 108. In the HE case, 70 of 133 facilities have pre-LDR hazard quotients greater than 1.0. Post-LDR, all of the waste stream-facility combinations fall below the level of concern. The changes in the distributions of facility-waste stream combinations across cancer risk and hazard quotient categories associated with the LDRs for mineral processing wastes are shown graphically in Exhibit A.2-7.

A.2.3.2 Risk and Benefits Assessment Results for Storage of Recycled Materials

EPA's evaluation of the potential groundwater risks associated with the storage of recycled streams under the modified prior treatment baseline is described in Section 4.2.1 of this RIA. Estimated

⁶ In reviewing Exhibits 5, the reader will note that the sums of the waste-stream-facility combinations in each risk category do not add up to the total number of facilities. This is because some of the facilities do not produce wastes with carcinogenic constituents (e.g., arsenic).

EXHIBIT A.2-5
Distribution of Waste Stream/Facility Combinations by Groundwater Risk Category: Cancer Risks

Commodity	Waste Stream	Number of Waste Stream/ Facility Combinations* #		Central Tendency												High End											
				Pre-LDR						Post-LDR						Pre-LDR						Post-LDR					
		Central Tendency	High End	10-5	10-4	10-3	10-2	10-5	10-4	10-3	10-2	10-5	10-4	10-3	10-2	10-5	10-4	10-3	10-2	10-5	10-4	10-3	10-2	10-5	10-4	10-3	10-2
				to	to	to	to		to	to	to		to	to	to		to	to	to		to	to	to		to	to	to
				<10-5	10-4	10-3	10-2	10-1	>10-1	<10-5	10-4	10-3	10-2	10-1	>10-1	<10-5	10-4	10-3	10-2	10-1	>10-1	<10-5	10-4	10-3	10-2	10-1	>10-1
Al and Alumina	Cast house dust	23	23	23	0	0	0	0	0	23	0	0	0	0	0	23	0	0	0	0	0	23	0	0	0	0	0
Sb	Autoclave filtrate	4	7	0	0	0	2	2	0	4	0	0	0	0	0	0	0	0	0	4	4	7	0	0	0	0	0
Be	Spent barren filtrate streams	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0
Be	Chip treatment WW	1	2	1	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0
Cu	Acid plant blowdown	7	7	2	0	2	1	0	1	7	0	0	0	0	0	0	1	0	2	1	1	7	0	0	0	0	0
Cu	Scrubber blowdown	10	10	3	0	7	0	0	0	10	0	0	0	0	0	0	3	0	7	0	0	10	0	0	0	0	0
Elemental Phosphorous	AFM rinsate	2	2	1	1	0	0	0	0	2	0	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0	0
Elemental Phosphorous	Furnace offgas solids	2	2	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0
Elemental Phosphorous	Furnace scrubber blowdown	2	2	1	1	0	0	0	0	2	0	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0	0
Elemental Phosphorous	Slag quenchwater	2	2	0	2	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0
Ge	Waste acid wash/rinse water	2	4	2	0	0	0	0	0	2	0	0	0	0	0	0	4	0	0	0	0	4	0	0	0	0	0
Ge	Chlorinator wet air poll. ctrl. sludge	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0
Ge	Hydrolysis filtrate	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0
Ge	Waste still liquor	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0
Mg and Magnesia (brine)	Smut	2	2	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0
Mo, FeMo, Amm. Mo	Liquid residues	1	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0
Rare Earths	Spent ammon. nitrate proc. sol.	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Rare Earths	PWW	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Se	Plant PWW	2	2	0	2	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0
Ta, Columbium, and FeCoI.	PWW	2	2	1	0	0	0	0	0	2	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0
Titanium and TiO2	Pickle liquor & wash water	2	3	1	1	0	0	0	0	2	0	0	0	0	0	0	2	2	0	0	0	3	0	0	0	0	0
Titanium and TiO2	Leach liquor & sponge wash water	1	2	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0	0
Titanium and TiO2	Scrap milling scrubber water	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Titanium and TiO2	Spent s.i. liquids	4	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Titanium and TiO2	Spent s.i. solids	4	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Titanium and TiO2	Waste acids (Sulfate process)	1	2	0	1	0	0	0	0	1	0	0	0	0	0	1	0	2	0	0	0	2	0	0	0	0	0
Titanium and TiO2	WWTP sludge/solids	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
W	Spent acid & rinse water	3	6	2	0	2	0	0	0	3	0	0	0	0	0	0	3	0	3	0	0	6	0	0	0	0	0
Zn	Waste ferrosilicon	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zn	Spent s.i. liquids	3	3	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0
Zn	WWTP solids	3	3	3	0	0	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0
Zn	Spent synthetic gypsum	3	3	3	0	0	0	0	0	3	0	0	0	0	0	2	0	2	0	0	0	3	0	0	0	0	0
Zn	WWTP liquid effluent	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zn	Zinc lean slag	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
TOTALS*		108	133	56	11	11	8	2	1	89	0	0	0	0	0	46	20	14	13	10	5	108	0	0	0	0	0

* Some by risk category may not add to the number of central or high-end waste stream/facility combinations due to rounding.

Includes waste stream/facility combinations with no cancer risk (but with an associated non-cancer hazard)

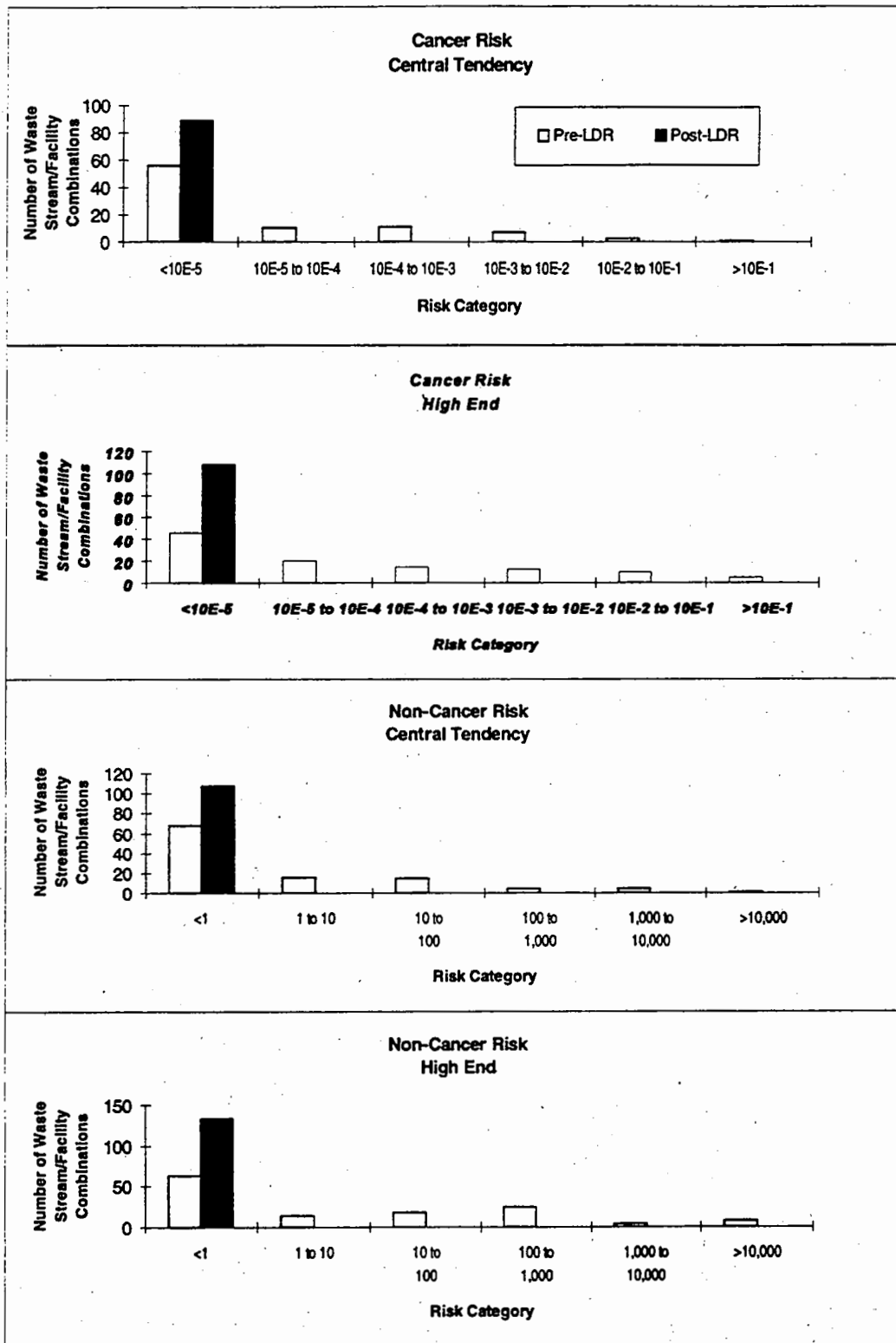
EXHIBIT A.2-6

Distribution of Waste Stream/Facility Combinations by Groundwater Hazard Category: Non-Cancer Hazards

Commodity	Waste Stream	Number of Waste Stream/ Facility Combinations*		Central Tendency												High End											
				Pre-LDR						Post-LDR						Pre-LDR						Post-LDR					
				1	10	100	1k			1	10	100	1k			1	10	100	1k			1	10	100	1k		
		Central Tendency	High End	to <1	to 10	to 100	to 1k	to 10k	to >10k	to <1	to 10	to 100	to 1k	to 10k	to >10k	to <1	to 10	to 100	to 1k	to 10k	to >10k	to <1	to 10	to 100	to 1k	to 10k	to >10k
Al and Alumina	Cast house dust	23	23	23	0	0	0	0	0	23	0	0	0	0	0	23	0	0	0	0	0	23	0	0	0	0	0
Sb	Autoclave filtrate	4	7	0	0	0	3	1	0	4	0	0	0	0	0	0	0	0	2	2	2	7	0	0	0	0	0
Be	Spent barren filtrate streams	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
Be	Chip treatment WW	1	2	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0
Cu	Acid plant blowdown	7	7	1	2	2	1	1	0	7	0	0	0	0	0	0	1	1	2	1	1	7	0	0	0	0	0
Cu	Scrubber blowdown	10	10	0	3	7	0	0	0	10	0	0	0	0	0	0	0	0	10	0	0	10	0	0	0	0	0
Elemental Phosphorous	AFM rinsate	2	2	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0
Elemental Phosphorous	Furnace offgas solids	2	2	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0
Elemental Phosphorous	Furnace scrubber blowdown	2	2	1	1	0	0	0	0	2	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0
Elemental Phosphorous	Slag quenchwater	2	2	2	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0
Ge	Waste acid wash/rinse water	2	4	2	0	0	0	0	0	2	0	0	0	0	0	0	0	4	0	0	0	4	0	0	0	0	0
Ge	Chlorinator wet air poll. ctrl. sludge	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0
Ge	Hydrolysis filtrate	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0
Ge	Waste still liquor	2	4	2	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	4	0	0	0	0	0
Mg and Magnesia (brine)	Smelt	2	2	2	0	0	0	0	0	2	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	0
Mo, FeMo, Amm. Mo	Liquid residues	1	2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0
Rare Earths	Spent ammon. nitrate proc. sol.	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Rare Earths	PWW	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Se	Plant PWW	2	2	1	1	0	0	0	0	2	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0
Ta, Columbium, and FeCol.	PWW	2	2	1	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0
Titanium and TiO2	Pickle liquor & wash water	2	3	0	2	0	0	0	0	2	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0
Titanium and TiO2	Leach liquor & sponge wash water	1	2	0	1	1	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0
Titanium and TiO2	Scrap milling scrubber water	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Titanium and TiO2	Spent s.i. liquids	4	7	4	0	0	0	0	0	4	0	0	0	0	0	7	0	0	0	0	0	7	0	0	0	0	0
Titanium and TiO2	Spent s.i. solids	4	7	4	0	0	0	0	0	4	0	0	0	0	0	5	2	0	0	0	0	7	0	0	0	0	0
Titanium and TiO2	Waste acids (Sulfate process)	1	2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0
Titanium and TiO2	WWTP sludge/solids	7	7	7	0	0	0	0	0	7	0	0	0	0	0	4	4	0	0	0	0	7	0	0	0	0	0
W	Spent acid & rinse water	3	6	2	1	0	0	0	0	3	0	0	0	0	0	3	2	0	2	0	0	6	0	0	0	0	0
Zn	Waste ferrosilicon	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Zn	Spent s.i. liquids	3	3	0	1	1	0	1	0	3	0	0	0	0	0	0	1	0	1	0	1	3	0	0	0	0	0
Zn	WWTP solids	3	3	3	0	0	0	0	0	3	0	0	0	0	0	1	1	1	0	0	0	3	0	0	0	0	0
Zn	Spent synthetic gypsum	3	3	3	0	0	0	0	0	3	0	0	0	0	0	2	2	0	0	0	0	3	0	0	0	0	0
Zn	WWTP liquid effluent	3	3	0	1	1	0	0	1	3	0	0	0	0	0	0	0	2	0	0	1	3	0	0	0	0	0
Zn	Zinc lean slag	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
TOTALS*		108	133	68	16	14	4	4	1	108	0	0	0	0	0	63	15	19	24	4	8	133	0	0	0	0	0

* Sums by hazard category may not add to the number of central or high-end waste stream/facility combinations due to rounding.

Exhibit A.2-7
Distribution of Waste Stream/Facility Combinations by Groundwater Risk
and Hazard Categories



groundwater pathway cancer risks under high-end (HE) baseline assumptions exceeded 10^{-5} at 24 of 57 facilities storing recycled streams, while under central tendency (CT) assumptions, only 11 facilities exceed this level (Exhibit 4-8). The HE noncancer hazard quotients for groundwater exposures exceed 1.0 at 28 facilities storing recycled materials, and under CT assumptions baseline hazard quotients exceed 1.0 at 12 facilities. All of the facilities for which baseline cancer risks or noncancer hazard quotients exceed levels of concern manage wastewater and liquid nonwastewater streams in impoundments. Owing primarily to the low recycled volumes and small facility sizes, the baseline groundwater risks for the two nonwastewater streams managed in waste piles are below levels of concern under both CT and HE assumptions.

The analysis of non-groundwater pathway risks associated with waste storage under the modified prior treatment baseline indicated that, for the majority of the pathways evaluated, estimated risks were far below levels of concern. As was the case for the groundwater pathway risk assessment, risks from the storage of the two nonwastewater streams in waste piles were all less than levels of concern for all release events and exposure pathways.

Baseline risks greater than levels of concern were found for exposures to surface water contaminated by releases from surface impoundment failures for some waste streams, however. In the case of the direct ingestion pathway, one facility storing copper acid plant blowdown had an HE cancer risk exceeding 10^{-5} . Under CT assumptions, the estimated cancer risk for this facility was below the level of concern. When exposure through fish consumption is considered, six facilities from three commodity sectors had HE risks from waste storage exceeding cancer or noncancer levels of concern. Under CT assumptions, risks from only two storage facilities exceeded levels of concern for the fish ingestion pathway. These results are summarized in Exhibit 4-12.

As noted above, the EPA did not quantitatively estimate the extent of risk reduction or the level of health benefits that could be brought about by the proposed LDRs' effects on recycled materials storage. This is because the available data and models do not allow the development of risk reduction estimates for tanks, containers, and buildings, which would be required management units for most of the recycled streams under regulatory Options 1-3. If these options completely or substantially abolish the release of recycled streams to groundwater and other media, the baseline risks discussed in the previous paragraphs could all be reduced to below levels of concern. Lesser degrees of control would result in less risk reduction and lower health benefits. Under options 1 and 2, it is clear that risks for three of the streams currently managed through Beville units (copper acid plant blowdown, and the two streams from elemental phosphorous production) would be greatly reduced by the requirement to manage these wastes in Subtitle C units. Copper acid plant blowdown figures prominently as a contributor to storage risks through both the groundwater and non-groundwater pathways. Under Option 4, no health benefits associated with the storage of recycled streams would be realized, as there is no requirement for improved management of these streams.

A.2.4.0 LIMITATIONS AND UNCERTAINTIES OF RISK AND BENEFITS ASSESSMENT

The section presents a brief discussion of the major uncertainties and limitations in the risk and benefits assessment for the no prior treatment baseline scenario. As stated in A.2.1, the discussion will be limited primarily to the sources of uncertainty specific to the revised analysis, and issues associated with previous risk and benefits work will only be mentioned briefly.

A.2.4.1 Major Uncertainties in the Risk Assessment for Waste Disposal

The major uncertainties associated with the risk assessment for mineral processing wastes are discussed in detail in Section 5.3.4 of December RIA, the major factors limiting the ability to quantify risks associated with the pre- and post-LDR disposal of mineral processing wastes include:

- Uncertainty about the identities, amounts, toxicity characteristics, elemental composition, and leaching behavior of wastes;
- Uncertainty about pre- and post-LDR waste amounts, waste management, recycling, and disposal practices;
- The use of the generic chemical release, groundwater transport, and exposure models instead of facility-specific data;
- The use of toxicity criteria derived primarily from animal studies; and
- The use of simplified models for predicting cancer risks and the potential for adverse noncancer affects.

This analysis represents EPA's an attempt to address some of these uncertainties, continuing the process of refinement which began with the sensitivity analysis performed as part of the December RIA. In addition, EPA has incorporated information received from commenters on the RIA to further assure that the risk assessment is consistent with the most recent information available. The efforts taken to incorporate new data, and their affect on the risk results, are discussed below.

EPA has received no substantial new information regarding the identities of additional waste streams or constituent concentrations that could be incorporated into the risk analysis. Based on public comments on the December RIA, a number of waste streams were removed from the risk and benefits analysis, either because they are no longer generated, or because EPA has determined that they are fully recycled and not disposed in land units. Removing these wastes from the analysis resulted in a reduction in the number of samples for which risks were calculated and in the number of facilities in the benefits analysis. The analysis is more accurate than the previous risk and benefits assessment in that it no longer includes waste streams that would not be covered by the LDRs. It should be remembered, however, that the risk and benefits assessment, while it still covers the majority of the estimated mineral processing waste volume, does not address the majority of waste streams that are included in the cost and economic impact analysis. Thus, it is likely that benefits from controls on waste disposal are underestimated, given that the risks for many wastes streams could not be calculated.

Several commenters on the December RIA noted the relatively limited amount of constituent concentration data that was used for the risk and benefits analysis, and criticized the assumptions used to characterize the leaching characteristics of wastes for which only bulk concentration data were used. In order to help address the shortage of data and to evaluate the impact of the leaching assumption, the both the EP and bulk analysis data were used in this analysis to develop separate risk estimates for NWW and LNWW waste streams when both are available, instead of using only the leachate data. This expansion of the analysis resulted in increases in the numbers of samples for which risk estimates were developed, as discussed in Section 2.1.2. This change in approach, which was adopted to make the fullest possible use of the available data, did not result in significant changes in the distribution of risks for the mineral

processing waste samples as a whole, or for any of the individual waste streams. This also suggests that the particular leaching assumption that was used did not result in any significant bias in the risk assessment results.

The major change in the risk results from previous analyses of waste management practices is the dramatic reduction in estimated post-LDR risks, to the extent that no waste samples had CT or HE post-LDR cancer risk or hazard quotients above levels of concern. This change is due to the changes in the method used to estimate groundwater concentrations. Like the previous analyses, the results presented in this assessment were derived using DAF values instead of site-specific modeling. In the original risk modeling, the DAFs were specific to the type of management unit, but were not constituent-specific, and they were derived for a nationally representative set of hydrogeological conditions. They, therefore, did not reflect (1) the inherent geochemical properties of the waste constituents, (2) the variations in transport that could be expected to occur as release concentrations varied, or (3) the specific hydrogeologic regimes at mineral processing facilities. In contrast, the DAF values used in this analysis take into account all of these factors. They were derived using constituent-specific geochemical characteristics, waste management unit sizes, waste volumes, and constituent concentrations from mineral processing industries, as well as hydrogeological variable values typical of the regional distribution of mineral processing facilities (e.g., primarily western, with low rainfall and high depth to groundwater).

Thus, while the approach to groundwater transport modeling taken in this analysis is still not site-specific, it has been carefully adjusted to incorporate all of the available data affecting potential releases and transport of waste constituents in groundwater. The degree of uncertainty associated with groundwater transport modeling, while still large, has thus been reduced substantially from previous analysis, and biases in the modeling resulting from failure to incorporate key variables has been greatly reduced.

The only major change in the toxicological parameter values that has been made since the previous risk analyses has been to eliminate consideration of beryllium as an ingestion pathway carcinogen. This change resulted in minimal impacts on the risk or benefits analysis, because beryllium was a risk driver for only a few waste streams. The impact of this change was reduced further because two of the waste streams from the beryllium industry were removed from the analysis for other reasons, as discussed in Section A.2.2.1.2.

A.2.4.2 Major Uncertainties in the Risk Assessment for Storage of Recycled Materials

The major limitations and sources of uncertainty in the multipathway risk assessment for the storage of recycled materials are discussed in detail in Appendix H, and will not be further addressed here.

A.2.5 REFERENCES CITED

ICF Incorporated (1996a), "Preliminary Results of Mineral Processing Wastes Risk and Benefits Assessments Using Constituent-Specific DAFs" technical memorandum submitted to the USEPA Office of Solid Waste, May 8, 1996.

ICF Incorporated (1996b), "Revised Results of Mineral Processing Wastes Risk and Benefits Assessments Using Constituent-Specific DAFs Derived for Mineral Processing Waste" technical memorandum submitted to the USEPA Office of Solid Waste, July 2, 1996.

ICF Incorporated (1995), "Regulatory Impact Analysis of the Supplemental Proposed Rules Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes", submitted to the USEPA Office of Solid Waste, December 1995.

USEPA, Office of Solid Waste (1996), "Groundwater Pathway Analysis for Mineral Processing Wastes Background Document (Draft), July 1996.

A.3 Risk Characterization Spreadsheets

This section of Appendix A presents the data and calculations that were used to characterize risk changes for waste disposal pre- and post-LDR under the no prior treatment baseline scenario. Exhibit A.3-1 presents the list of wastes for which constituent-specific data were available. Exhibit A.3-2 presents the constituent-specific DAFs used to evaluate groundwater exposures. Exhibit A.3-3 presents the toxicity parameter values used in the risk analysis. Finally, Exhibit A.3-4 presents an example risk calculation for a single waste sample from concentration data to risk results.

Exhibit A.3-1
List of Wastes for Which Constituent-Specific Data were Available

Commodity	Waste Stream
Aluminum and Alumina	Cast house dust
Antimony	Autoclave filtrate
Beryllium	Spent barren filtrate streams
Beryllium	Chip treatment wastewater
Copper	Acid plant blowdown
Copper	Scrubber blowdown
Elemental Phosphorous	AFM rinsate
Elemental Phosphorous	Furnace offgas solids
Elemental Phosphorous	Furnace scrubber blowdown
Elemental Phosphorous	Slag quenchwater
Germanium	Waste acid wash/rinse water
Germanium	Chlorinator wet air pollution control sludge
Germanium	Hydrolysis filtrate
Germanium	Waste still liquor
Magnesium and Magnesia (brine)	Smut
Molybdenum, Ferromolybdenum, Ammonium Molybdate	Liquid residues
Rare Earths	Spent ammonium nitrate processing solution
Rare Earths	Process wastewater
Selenium	Plant process wastewater
Tantalum, Columbium, and Ferrocolumbium	Process wastewater
Titanium and Titanium Dioxide	Pickle liquor & wash water
Titanium and Titanium Dioxide	Leach liquor & sponge wash water
Titanium and Titanium Dioxide	Scrap milling scrubber water
Titanium and Titanium Dioxide	Spent surface impoundment liquids
Titanium and Titanium Dioxide	Spent surface impoundment solids
Titanium and Titanium Dioxide	Waste acids (Sulfate process)
Titanium and Titanium Dioxide	Wastewater treatment plant sludge/solids
Tungsten	Spent acid & rinse water
Zinc	Waste ferrosilicon
Zinc	Spent surface impoundment liquids
Zinc	Wastewater treatment plant solids
Zinc	Spent synthetic gypsum
Zinc	Wastewater treatment plant liquid effluent
Zinc	Zinc lean slag

Exhibit A.3-2

Constituent-Specific DAFs Used to Evaluate Groundwater Exposures

Constituent	Surface Impoundments		Waste Piles			
	Central Tendency (75th percentile) Pre-LDR	High End (95th percentile) Pre-LDR	Central Tendency (75th percentile) Pre-LDR	High End (95th percentile) Pre-LDR	Central Tendency (75th percentile) Post-LDR	High End (95th percentile) Post-LDR
Antimony	1.93E+02	2.28E+01	>10 ⁹	8.36E+03	>10 ⁹	8.36E+03
Arsenic	1.66E+02	1.71E+01	>10 ⁹	2.56E+03	4.37E+09	2.56E+03
Barium	5.81E+00	1.17E+00	2.22E+03	1.38E+01	2.33E+03	1.46E+01
Beryllium	8.47E+00	1.24E+00	>10 ⁹	4.87E+02	>10 ⁹	5.54E+02
Cadmium	2.49E+01	1.40E+00	>10 ⁹	2.67E+03	>10 ⁹	3.26E+03
Chromium	9.82E+01	1.15E+01	2.21E+04	1.60E+02	2.21E+04	1.60E+02
Cyanide	2.81E+10	4.20E+03	--	--	--	--
Lead	7.11E+05	4.98E+00	>10 ⁹	2.27E+05	>10 ⁹	8.93E+08
Mercury	1.97E+02	8.05E+00	>10 ⁹	4.29E+03	>10 ⁹	4.29E+03
Nickel	2.23E+01	1.51E+00	1.54E+06	1.41E+02	1.97E+06	1.46E+02
Selenium	2.70E+01	3.38E+00	1.18E+08	4.28E+02	1.19E+08	4.28E+02
Silver	1.11E+01	1.23E+00	>10 ⁹	4.96E+02	>10 ⁹	4.87E+02
Thallium	2.97E+02	4.15E+01	>10 ⁹	9.63E+04	>10 ⁹	9.63E+04
Vanadium	5.67E+00	2.03E+00	>10 ⁹	>10 ⁹	>10 ⁹	>10 ⁹
Zinc	1.23E+01	1.35E+00	>10 ⁹	>10 ⁹	>10 ⁹	>10 ⁹

Note: Central Tendency values are the 75th percentile of the distribution of DAF values and the High End values are the 95th percentile.

Exhibit A.3-3
Toxicity Parameter Values Used in the Risk Analysis

Constituent	Oral Cancer Slope Factor (CSF) 1/(mg/kg-day)	Oral Reference Dose (RfD) mg/kg-day
Antimony	----	0.0004
Arsenic	1.5	0.0003
Barium	----	0.07
Beryllium	----	0.005
Boron	----	0.09
Cadmium	----	0.0005
Chromium	----	0.005
Lead	----	0.0003
Manganese	----	0.047
Mercury	----	0.0003
Molybdenum	----	0.005
Nickel	----	0.02
Selenium	----	0.005
Silver	----	0.005
Thallium	----	0.00008
Vanadium	----	0.007
Zinc	----	0.3
Cyanide	----	0.02
Fluoride	----	0.06
Source: EPA IRIS (1996) and HEAST (1995)		
The Lead RfD is derived from the EPA action level of 0.015 mg/L.		
The RfD for Chromium is from Cr+6.		
The RfD for Thallium is from Thallium sulfate.		
There were no toxicity values for the following constituents: Aluminum, Cobalt, Copper, Iron, Magnesium, Phosphate, Silica, Chloride, TSS, pH, Organics (TOC), Sulfide, or Sulfate.		

Exhibit A.3-4 - Example Risk Calculation for a Single Waste Sample from Concentration Data to Risk Results

Waste Stream Data & Calculations				Cancer				Non-Cancer			
Commodity Waste Stream		Sample Number		Central Tendency		High End		Central Tendency		High End	
				Pre-LDR	Post-LDR	Pre-LDR	Post-LDR	Pre-LDR	Post-LDR	Pre-LDR	Post-LDR
Rare Earths	Spent ammonium nitrate processing solution	7		5.57E-08	2.12E-12	5.41E-07	5.41E-07	3.85E-03	4.47E-04	1.41E-01	1.17E-02
Facility Identifier = Res. Chem, Phoenix State = AZ				<p>The cancer risk values are the sum of risks from each constituent in a sample. The non-cancer hazard values represent the highest hazard quotient for a constituent in a sample.</p>							
Treatment Type				Total		Pre-LDR DAFS		Post-LDR DAFS			
Waste	10%	Solids	Solid	Constituents	Constituent Analysis (ppm)	EP Toxicity Analysis (ppm)	Central Tendency	High End	Central Tendency	High End	
1	0	0	0	Aluminum							
1	0	0	0	Antimony			1.93E+02	2.28E+01	3.00E+13	8.36E+03	
1	0	0	0	Arsenic	0.0025		1.66E+02	1.71E+01	4.37E+09	2.56E+03	
1	0	0	0	Barium	0.05		5.81E+00	1.17E+00	2.33E+03	1.46E+01	
1	0	0	0	Beryllium			8.47E+00	1.24E+00	2.13E+15	5.54E+02	
1	0	0	0	Boron	0.12						
1	0	0	0	Cadmium	0.0025		2.49E+01	1.40E+00	6.12E+16	3.26E+03	
1	0	0	0	Chromium	0.01		9.82E+01	1.15E+01	2.21E+04	1.60E+02	
1	0	0	0	Copper	0.005						
1	0	0	0	Iron							
1	0	0	0	Lead	0.011		7.11E+05	4.98E+00	1.00E+30	8.93E+08	
1	0	0	0	Magnesium							
1	0	0	0	Manganese	0.005						
1	0	0	0	Mercury	0.0001		1.97E+02	8.05E+00	6.37E+12	4.29E+03	
1	0	0	0	Molybdenum							
1	0	0	0	Nickel			2.23E+01	1.51E+00	1.97E+06	1.46E+02	
1	0	0	0	Selenium	0.0025		2.70E+01	3.38E+00	1.19E+08	4.28E+02	
1	0	0	0	Silver	0.005		1.11E+01	1.23E+00	1.33E+10	4.87E+02	
1	0	0	0	Thallium			2.97E+02	4.15E+01	1.23E+28	9.63E+04	
1	0	0	0	Vanadium			5.67E+00	2.03E+00	1.00E+30	1.00E+30	
1	0	0	0	Zinc	0.005		1.23E+01	1.35E+00	1.34E+16	1.77E+03	
1	0	0	0	Cyanide	0.005		2.81E+10	4.20E+03			
1	0	0	0	Sulfide	0.025						
1	0	0	0	Fluoride							

For constituents with a DAF, if the treatment type is solid (the solid column has a 1), the DAF value returned is for waste piles; otherwise, the DAF value returned is for surface impoundments. See Exhibit A.3-2 for the DAF values.

Exhibit A.3-4 (Continued) - Example Risk Calculation for a Single Waste Sample from Concentration Data to Risk Results

Constituents	Pre-LDRs - Central Tendency					Pre-LDRs - High End				
	Groundwater	Cancer	Noncancer	Lifetime	Hazard	Groundwater	Cancer	Noncancer	Lifetime	Hazard
	Conc (ppm=mg/L)	Dose (mg/kg-d)	Dose (mg/kg-d)	Excess Cancer Risk		Conc (ppm=mg/L)	Dose (mg/kg-d)	Dose (mg/kg-d)	Excess Cancer Risk	
Aluminum										
Antimony										
Arsenic	1.51E-05	3.71E-08	2.89E-07	5.57E-08	9.63E-04	1.46E-04	3.60E-07	2.80E-06	5.41E-07	9.35E-03
Barium	8.61E-03	2.12E-05	1.65E-04		2.36E-03	4.27E-02	1.05E-04	8.20E-04		1.17E-02
Beryllium										
Boron										
Cadmium	1.00E-04	2.48E-07	1.93E-06		3.85E-03	1.79E-03	4.40E-06	3.42E-05		6.85E-02
Chromium	1.02E-04	2.51E-07	1.95E-06		3.91E-04	8.70E-04	2.14E-06	1.67E-05		3.34E-03
Copper										
Iron										
Lead	1.55E-08	3.81E-11	2.97E-10		9.89E-07	2.21E-03	5.45E-06	4.24E-05		1.41E-01
Magnesium										
Manganese										
Mercury	5.08E-07	1.25E-09	9.74E-09		3.25E-05	1.24E-05	3.06E-08	2.38E-07		7.94E-04
Molybdenum										
Nickel										
Selenium	9.26E-05	2.28E-07	1.78E-06		3.55E-04	7.40E-04	1.82E-06	1.42E-05		2.84E-03
Silver	4.50E-04	1.11E-06	8.64E-06		1.73E-03	4.07E-03	1.00E-05	7.80E-05		1.56E-02
Thallium										
Vanadium										
Zinc	4.07E-04	1.00E-06	7.80E-06		2.60E-05	3.70E-03	9.13E-06	7.10E-05		2.37E-04
Cyanide	1.78E-13	4.39E-16	3.41E-15		1.71E-13	1.19E-06	2.94E-09	2.28E-08		1.14E-06
Sulfide										
Fluoride										

Groundwater (gw) concentration = total constituent analysis concentration / DAF (for waste waters with a total constituent analysis concentration)
 gw concentration = EP toxicity analysis concentration / DAF (for non-waste waters with an EP toxicity analysis concentration)
 gw concentration = total constituent analysis concentration / 20 / DAF (for solids with a total constituent analysis concentration and no EP toxicity analysis concentration)
 gw concentration = total constituent analysis concentration / DAF (for 10% solids with a total constituent analysis concentration and no EP toxicity analysis concentration)
 No gw values are returned for constituents with no DAF or total constituent analysis concentration.

Cancer dose = gw concentration x cancer gw intake Noncancer dose = gw concentration x noncancer gw intake.
 Cancer gw intake = (gw intake*exposure duration*exposure frequency)/(cancer averaging time*365*body weight) = 0.00247 L/kg-day.
 Noncancer gw intake = (gw intake*exposure duration*exposure frequency)/(noncancer averaging time*365*body weight) = 0.01918 L/kg-day.
 Cancer risk = slope factor x cancer dose. Hazard quotient (hq) = noncancer dose / RfD. See Exhibit A.3-3 for slope factors and RfDs.
 Body Weight = 70 kg Exposure Duration = 9 years Non-cancer Averaging Time = 9 years
 Exposure Frequency = 350 days/year Cancer Averaging Time = 70 years Groundwater Ingestion Rate = 1.4 L/day

No cancer risk values are returned for constituents with no slope factor; no hq values are returned for constituents with no RfD.

Exhibit A.3-4 (Continued) - Example Risk Calculation for a Single Waste Sample from Concentration Data to Risk Results

Constituents	Post-LDRs (UTS) - Central Tendency					Post-LDRs (UTS) - High End				
	Groundwater	Cancer	Noncancer	Lifetime	Hazard	Groundwater	Cancer	Noncancer	Lifetime	Hazard
	Conc (ppm=mg/L)	Dose (mg/kg-d)	Dose (mg/kg-d)	Excess Cancer Risk		Conc (ppm=mg/L)	Dose (mg/kg-d)	Dose (mg/kg-d)	Excess Cancer Risk	
Aluminum										
Antimony										
Arsenic	5.72E-10	1.41E-12	1.10E-11	2.12E-12	3.66E-08	1.46E-04	3.60E-07	2.80E-06	5.41E-07	9.35E-03
Barium	1.63E-03	4.02E-06	3.13E-05		4.47E-04	4.27E-02	1.05E-04	8.20E-04		1.17E-02
Beryllium										
Boron										
Cadmium	1.55E-18	3.83E-21	2.98E-20		5.95E-17	2.91E-05	7.19E-08	5.59E-07		1.12E-03
Chromium	1.95E-05	4.80E-08	3.73E-07		7.46E-05	8.70E-04	2.14E-06	1.67E-05		3.34E-03
Copper										
Iron										
Lead	1.85E-31	4.56E-34	3.55E-33		1.18E-29	2.07E-10	5.11E-13	3.97E-12		1.32E-08
Magnesium										
Manganese										
Mercury	1.96E-15	4.84E-18	3.76E-17		1.25E-13	2.91E-06	7.18E-09	5.59E-08		1.86E-04
Molybdenum										
Nickel										
Selenium	6.72E-10	1.66E-12	1.29E-11		2.58E-09	1.87E-04	4.61E-07	3.58E-06		7.17E-04
Silver	1.13E-11	2.78E-14	2.16E-13		4.33E-11	3.08E-04	7.59E-07	5.91E-06		1.18E-03
Thallium										
Vanadium										
Zinc	1.98E-16	4.88E-19	3.79E-18		1.26E-17	1.50E-03	3.69E-06	2.87E-05		9.57E-05
Cyanide										
Sulfide										
Fluoride										

Groundwater (gw) concentration = treatment level / DAF (if pre-LDR gw concentration is greater than the treatment level / DAF); otherwise gw concentration = pre-LDR gw concentration

No gw values are returned for constituents with no DAF or treatment level.
See the previous page for an explanation of the dose, risk, and hazard calculations.

**SUMMARY OF MINERAL PROCESSING FACILITIES
PRODUCING HAZARDOUS WASTE STREAMS**

APPENDIX B

Mineral (Commodity)	Facility Name	Facility Location	Mining and MP Facility Collocated	Comments	Generates one of the Special 20 Wastes
Alumina & Aluminum	Alcan Aluminum Corp.	Henderson, KY	no	Processing	No
	ALCOA	Newburgh, IN	no	Processing	No
	ALCOA	Massena, NY	no	Processing	No
	ALCOA	Badin, NC	no	Processing	No
	ALCOA	Alcoa, TN	no	Processing	No
	ALCOA	Rockdale, TX	no	Processing	No
	ALCOA	Wenatchee, WA	no	Processing	No
	ALUMAX	Mt. Holly, SC	no	Processing	No
	Columbia Aluminum Corp.	Goldendale, WA	no	Processing	No
	Columbia Falls Aluminum Corp.	Columbia Falls, MT	no	Processing	No
	Eastco	Frederick, MD	no	Processing	No
	Intalco Aluminum Corp.	Ferndale, WA	no	Processing	No
	Kaiser Aluminum Corp.	Spokane, WA	no	Processing	No
	Kaiser Aluminum Corp.	Tacoma, WA	no	Processing	No
	National South Wire	Hawesville, KY	no	Processing	No
	Noranda Aluminum	New Madrid, MO	no	Processing	No
	Northwest Alloys Inc.	The Dalles, OR	no	Processing	No
	Ormet	Hannibal, OH	no	Processing	No

April 15, 1997

Mineral Commodity	Facility Names	Facility Locations	Mining and MP Facility Collocated	Comments	Generates one of the Special 20 Wastes
Aluminum (continued)	Ravenswood Aluminum Corp.	Ravenswood, WV	no	Processing	No
	Reynolds	Massena, NY	no	Processing	No
	Reynolds	Troutdale, OR	no	Processing	No
	Reynolds	Longview, WA	no	Processing	No
	Venalco	Vancouver, WA	no	Processing	No
Antimony	Amspec Chemical Corp	Gloucester, NJ	no	Processing	No
	Anzon, Inc.	Laredo, TX	no	Processing	No
	ASARCO Inc.	Omaha, NE	no	Processing	No
	Laurel Ind.	LaPorte, TX	no	Processing	No
	Sunshine Mining Company	Kellogg, ID	yes	Processing	no
	US Antimony Corp.	Thompson Falls, MT	no	Processing	no
Beryllium	Brush Wellman	Delta, UT	yes	mining, produces Be(OH) ₂	no
	Brush Wellman	Elmore, OH	no	Secondary ore processing of Be Metal and Alloys	no
	NGK Metals	Revere, PA	no	Secondary ore processing of Be Metal	no
Bismuth	ASARCO	Omaha, NE	no	Processing	yes
Cadmium	ASARCO	Denver, CO	no	Processing	no
	Big River Zinc Corp.	Sauget, IL	no	Processing	no
	Jersey Miniere Zinc Corp	Clarksville, TN	yes (Gordonsville)	Processing	no
	ZCA	Bartlesville, OK	no	Processing	no
Calcium Metal	Pfizer Chem (Quigley Company)	Canaan, CT	no	Processing	no

Mineral Commodity	Facility Names	Facility Locations	Mining and MP Facility Collocated	Comments	Generates one of the Special 20 Wastes
Coal gas	Great Plains Coal Gasification Plant, Dakota Gasification Co.	Beulah, ND	yes	Synthetic Gas produced	yes Gasifier Ash, Process Wastewater
Copper	ASARCO	El Paso, TX	no	Smelting	Yes. Slag, slag tailings and/or calcium sulfate sludge
	ASARCO	Amarillo, TX	no	Electrolytic Refining	Yes. Slag, slag tailings and/or calcium sulfate sludge
	ASARCO	Hayden, AZ	yes	Mining, Smelting and Electrowinning	Yes. Slag, slag tailings and/or calcium sulfate sludge
	Copper Range	White Pine, MI	yes	Mining, Smelting & Refining	Yes. Slag, slag tailings and/or calcium sulfate sludge
	Cyprus	Claypool, AZ	yes	Mining, Smelting, Refining, & Electrowinning	Yes. Slag, slag tailings and/or calcium sulfate sludge
	Kennecott	Garfield, UT	yes	Mining, Smelting and Refining	Yes. Slag, slag tailings and/or calcium sulfate sludge
	Magma (BHP)	San Manuel, AZ	yes	Mining, Smelting, Refining, and Electrowinning	Yes. Slag, slag tailings and/or calcium sulfate sludge
	Phelps Dodge	Playas, NM	no	Smelting only	Yes. Slag, slag tailings and/or calcium sulfate sludge
	Phelps Dodge	El Paso, TX	no	Refining only	Yes. Slag, slag tailings and/or calcium sulfate sludge
	Phelps Dodge	Hurley, NM	yes	Mining, Smelting and Electrowinning (same as Chino Mines)	Yes. Slag, slag tailings and/or calcium sulfate sludge
Elemental Phosphorous	FMC	Pocatello, ID	yes	Processing	Yes. Slag
	Monsanto	Soda Springs, ID	yes	Processing	Yes. Slag
Germanium	Atomergic Chem	Plainview, NY	no	Processing	no
	Cabot	Revere, PA	no	Processing	no
	Eagle-Picher	Quapaw, OK	no	Processing	no

Mineral Commodities	Facility Name	Facility Location	Mining and MP Facility Collocated	Comments	Generates one of the Special 20 Wastes
Germanium (continued)	Musto Exploration (inactive)	St. George, UT	yes	Mining and Refining	no
Fluorospar and Hydrofluoric Acid	Allied Signal	Geismar, LA	no	Processing	Yes. Fluorogypsum and process wastewater
	E.I. duPont	La Port, TX	no	Processing	Yes. Fluorogypsum and process wastewater
	Attochemical, N.A.	Calvert City, KY	no	Processing	Yes. Fluorogypsum and process wastewater
Lead	ASARCO	East Helena, MT	yes	Smelter	Yes. Slag
	ASARCO	Glover, MO	yes	Smelter/Refinery	Yes. Slag
	ASARCO	Omaha, NE	no	Refinery	Yes. Slag
	Doe Run Co.	Herculaneum, MO	yes	Smelter/Refinery	Yes. Slag
Magnesium	Dow Chemical Co.	Freeport, TX	yes	MgCl from seawater, Mg metal processing, magnesia processing	no
	Magnesium Corp. of America	Salt Lake City, UT	yes	Mg metal processing from lake brines	Yes. Process wastewater
	Northwest Alloys Inc.	Addy, WA	no	Mg metal processing	no
Mercury	Barrick Meur Gold Mines, Inc.	Toole, UT	yes	Mining and Retorting	no
	FMC Gold Co.	Humboldt, NV	yes	Mining	no
	FMC Gold Co.	Gabbs, NV	yes	Mining	no
	Homestake Mining Co.	Napa, CA	yes	Mining, leaching	no
	Independence Mining Co. Inc.	Elko, NV	yes	Mining	no
	Newmont Gold Co.	Eureka, NV	yes	Mining	no
	Placer Dome U.S.	East Ely, NV	yes	Mining	no

Mineral Commodity	Facility Names	Facility Locations	Mining and MP Facility Collocated	Comments	Generates one of the Special 20 Wastes
Molybdenum, Ferro molybdenum and Ammonium Molybdate	Cyprus-Climax- Henderson	Empire, CO	yes	Mining and Processing	no
	Cyprus-Climax	Fort Madison, IA	no	Processing	no
	Cyprus-Climax	Cold Water, MI	no	Processing, possibly phased out	no
	Cyprus-Climax- Green Valley	Tucson, AZ	no	Processing	no
	Kennecott	Bingham Canyon, UT	yes	Processing	copper slag, slag tailings, WWTP sludge
	Montana Resources Inc.	Butte, MT	yes	Processing	no
	Phelps Dodge	Hurley, NM	yes	Processing	no
	San Manuel	San Manuel, AZ	yes	Processing	no
	San Manuel	Morenci, AZ	yes	Processing	no
	Thompson Creek	Challis, ID	yes	Processing	no
	Thompson Creek	Langeloth, PA	no	Processing	no
Platinum Group Metals	ASARCO Inc.	Amarillo, TX	no	Processing	
	Kennecott Corp.	Salt Lake City, UT	yes	Processing	
	Stillwater Mine	Nye, MT	yes	Mining and Smelting	no
Pyrobitumens, Mineral Waxes, and Natural Asphalts	American Gilsonite	Bonanza, UT Uintah County	yes	Production of gilsonite (natural asphalt)	no
	Ziegler Chemical and Mineral Corp.	Vernal, UT Uintah County,	yes	Production of gilsonite (natural asphalt)	no
Rare Earths	Molycorp	Mountain Pass, CA	yes	Mining of Bastnasite	no
Rhenium	Cyprus-Climax	Green Valley, AZ	yes	Recovers and refines rhenium	no
	Cyprus-Climax	Fort Madison, IA	no	Rhenium recovery	no

Mineral Commodity	Facility Name	Facility Location	Mining and MP Facility Collocated	Comments	Generates one of the Special 20 Wastes
Scandium	Baldwin Metals Processing Co.	Phoenix, AZ	no	Processing	no
	Boulder Scientific Co.	Mead, CO	no	Refining	no
	Interpro (subsidiary of Concord Trading Corp.)	Golden, CO	no	Refining	no
	Materials Preparation Center	Ames, IA	no	Processing	no
	Rhone-Poulenc, Inc.	Phoenix, AZ	no	Processing	no
	APL Engineered Materials	Urbana, IL	no	Refining	no
	Sausville Chemical Co.	Garfield, NJ	no	Refining	no
Selenium	ASARCO	Amarillo, TX	no	Processing	no
	Kennecott	Garfield, UT	yes	Processing	yes
	Phelps Dodge	El Paso, TX	no	Processing	no
Synthetic Rutile	Kerr-McGee Chemical Corp.	Mobile, AL	no	Processing	no
Tantalum, Columbium and Ferrocolumbium	Cabot Corp.	Boyertown, PA	no	Cb and Ta pentoxide/metal, FeCb, Ta capacitor powder	no
	Shieldalloy Metallurgical Corp.	Newfield, NJ	no	FeCb	no
Tellurium	ASARCO	Amarillo, TX	no	Processing	no
	Kennecott Corp.	Garfield, UT	yes	Mining, Smelting and Refining	Yes. Slag, slag tailings and/or calcium sulfate sludge

Mineral Commodity	Facility Name	Facility Location	Mining and MP Facility Collocated	Comments	Generates one of the Special 20 Wastes
Titanium and Titanium Dioxide	E.I. duPont de Nemours & Co. Inc.	Antioch, CA	no	TiO ₂ Production	Yes. Chloride process waste solids
	E.I. duPont	Edgemoor, DE	no	TiO ₂ Production	Yes. Chloride process waste solids
	E.I. duPont	New Johnsonville, TN	no	TiO ₂ Production	Yes. Chloride process waste solids
	E.I. duPont	Pass Christian, MS	no	TiO ₂ Production	Yes. Chloride process waste solids
	Kemira, Inc.	Savannah, GA	no	TiO ₂ Production	Yes. Chloride process waste solids
	Kerr-McGee Chemical Corp.	Hamilton, MS	no	TiO ₂ Production	Yes. Chloride process waste solids
	Kronos, Inc.	Lake Charles, LA	no	TiO ₂ Production	Yes. Chloride process waste solids
	SCM Chemicals, Inc.	Ashtabula, OH	no	TiO ₂ Production	Yes. Chloride process waste solids
	SCM Chemicals, Inc.	Baltimore, MD	no	TiO ₂ Production	Yes. Chloride process waste solids
Tungsten	Buffalo Tungsten	Depew, NY	no	Processing	no
	General Electric	Euclid, OH	no	Processing	no
	OSRAM Sylvania, Inc.	Towanda, PA	no	Processing	no
	Kennametal	Fallon, NV	100-150 miles to Humboldt and Starlight mine	Processing	no
	Kennametal	LaTrobe, PA	no	Processing	no
	Teledyne Advance Materials	Huntsville, AL	no	Processing	no
Uranium	no facilities listed				

Mineral Commodities	Facility Names	Facility Locations	Mining and MP Facility Collocated	Comments	Generates one of the Special 20 Wastes
Zinc	Big River Zinc Corp.	Sauget, IL	no	Smelter (electrolytic)	no
	Jersey Miniere Zinc Co.	Clarksville, TN	yes	Smelter (electrolytic)	no
	Zinc Corp. of America	Monaco, PA	no	Smelter (pyrometallurgical)	Yes. Slag
Zirconium and Hafnium	Teledyne	Albany, OR	no	Processing	no
	Western Zirconium	Ogden, UT	no	Processing	no

MINERAL PROCESSING WASTE TREATMENT AND DISPOSAL COSTS: LOW-COST ANALYSIS

APPENDIX C

This appendix comprises an analysis of the treatment and disposal options available to owners and/or operators of mineral processing facilities. The appendix presents the available technically feasible treatment and disposal options, a comparison of those options, and a determination of the lowest-cost alternative.

Under the current regulations governing the disposal of hazardous mineral processing waste, owners and/or operators of mineral processing facilities have several disposal options available, depending on the type of waste that is generated:

- Solid wastes may be:
 - Disposed of in a Subtitle C landfill; or
 - Treated and disposed of in a Subtitle C landfill; or
 - Treated and disposed of in a Subtitle D landfill.
- Liquid wastes may be:
 - Treated, with solid wastes disposed in a Subtitle C landfill; or
 - Treated, with solid wastes disposed in a Subtitle D landfill.

Upon completion of this rulemaking, owners and/or operators of mineral processing facilities that generate hazardous waste must choose between two treatment and disposal options. Both solid and liquid wastes may be:

- Treated and disposed of in a Subtitle D landfill; or
- Treated and disposed of in a Subtitle C landfill.

Depending on the quantity of waste generated, owners and/or operators of mineral processing facilities may choose to send the waste off-site for treatment and disposal, or build a treatment system on-site.

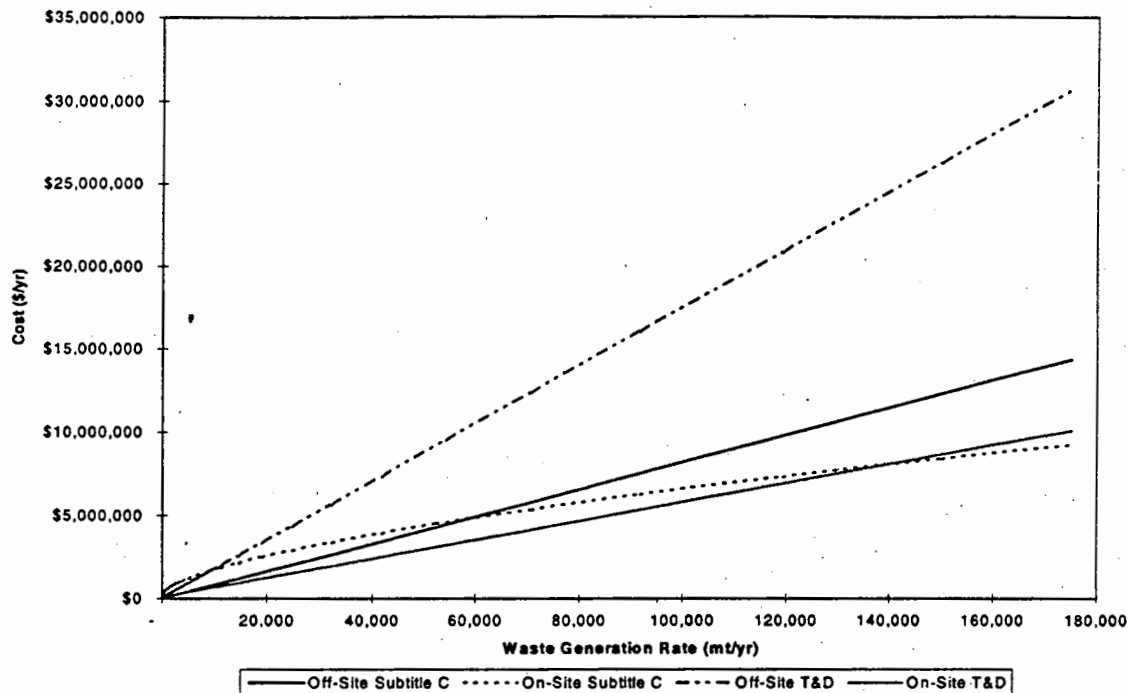
C.1 Pre-Rule Lowest Cost Option

C.1.1 Analysis of Treatment and Disposal Costs

Using on-site cost functions and off-site unit prices from Appendix D, EPA has calculated pre-rule (or baseline) treatment and disposal costs over a range of waste generation rates (100 mt/yr - 175,000 mt/yr) for on- and off-site Subtitle C landfill disposal, and on- and off-site treatment followed by Subtitle D landfill disposal. Exhibit C-1 shows the total treatment and/or disposal cost plotted against a range of waste generation rates. The total cost of disposing mineral processing wastes increases as the quantity of waste increases using all four alternatives.

Total treatment and/or disposal costs were divided by the waste generation rate to obtain unit costs. Exhibit C-2 shows the unit treatment and/or disposal cost plotted against a range of waste generation rates. Note that the unit cost of off-site treatment and disposal is constant, while the unit cost of Subtitle C landfilling and on-site treatment and disposal decreases as waste quantity increases.

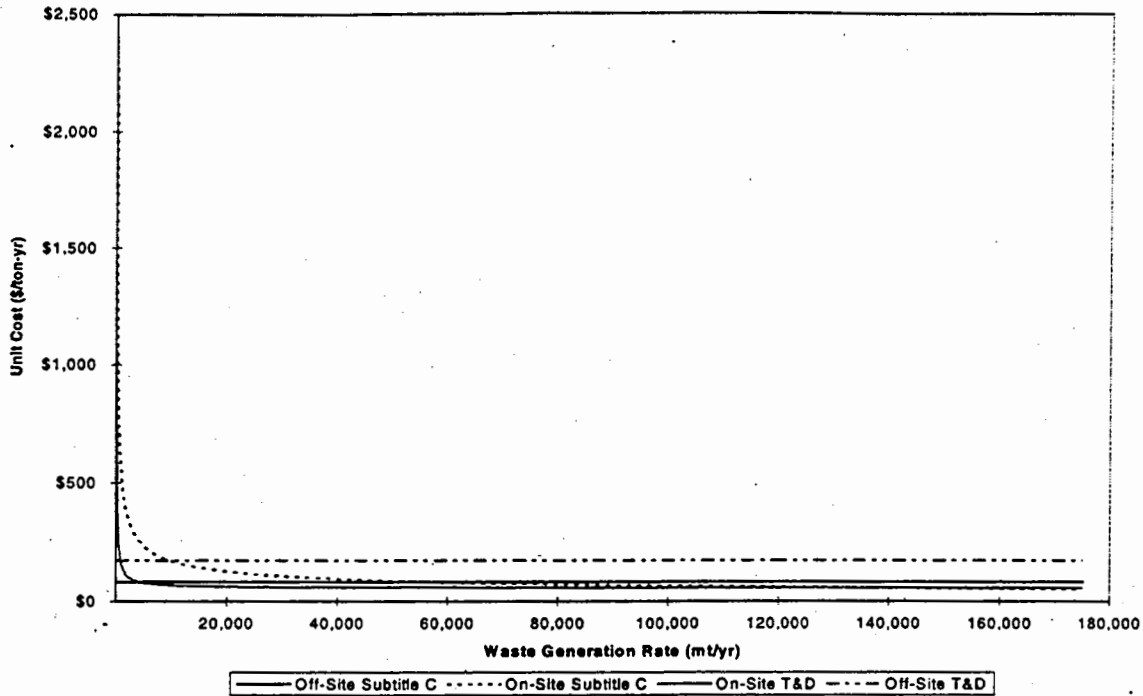
Exhibit C-1
Total Cost of Treatment and/or Disposal Alternatives



C.1.2 Subtitle C Disposal vs. Treatment and Subtitle D Disposal

Exhibits 1 and 2 show that treatment followed by disposal in a Subtitle D landfill is less costly than Subtitle C landfilling for virtually the entire range of solid waste generation rates under consideration in this rulemaking. For very small waste generation rates, however, off-site Subtitle C landfilling is actually a lower cost option than treatment and Subtitle D disposal. Likewise, for waste generated in excess of approximately 150,000 mt/yr, on-site Subtitle C landfilling is a lower cost option than treatment and Subtitle D disposal. However, liability costs (from corrective action requirements) of Subtitle C landfills are not accounted for in the on-site Subtitle C cost functions or the off-site Subtitle C unit disposal price described in Appendix D. It is EPA's assertion that owners and/or operators of mineral processing facilities generating very small quantities of waste or facilities generating waste in excess of 150,000 mt/yr will treat and dispose the waste in a Subtitle D landfill due to the potentially high liability cost associated with Subtitle C landfilling. Therefore, EPA considers on- and off-site treatment and Subtitle D disposal to be the lowest-cost disposal options for mineral processing hazardous wastes.

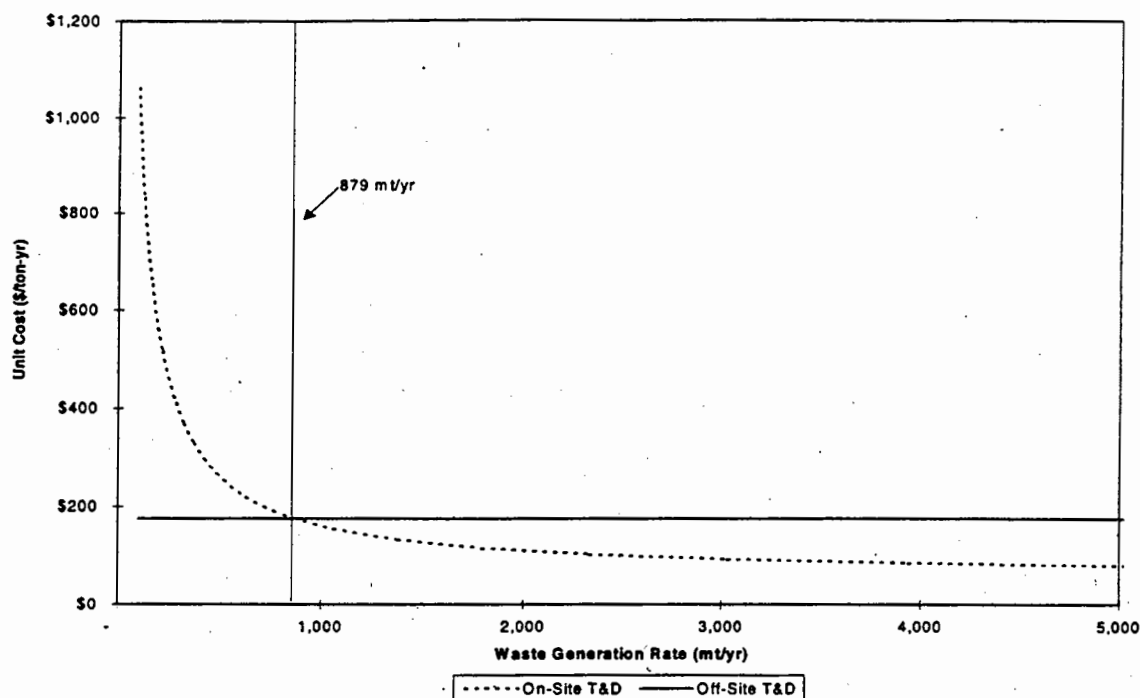
Exhibit C-2
Unit Cost of Treatment and/or Disposal Alternatives



C.1.3 On-Site vs. Off-Site Treatment and Subtitle D Disposal

In addition to determining that treatment and disposal is the lowest cost disposal option, EPA has identified a "break-even" point at which it is more economical to send waste off-site for treatment and disposal rather than treat and dispose of waste on-site. Exhibit C-3 (an enlargement of Exhibit C-2) shows the "break-even" point between off-site treatment and disposal and on-site treatment and disposal. This "break-even" point occurs at approximately 879 mt/yr, and therefore waste that is generated in small quantities (0 mt/yr - 879 mt/yr) will be sent off-site for treatment and disposal rather than be treated and disposed on-site. Waste generated in excess of 879 mt/yr, however, will be treated and disposed on-site.

Exhibit C-3 Treatment and Subtitle D Disposal Unit Costs



C.2 Post-Rule Lowest Cost Option

Based on the above analysis that shows that disposal of waste in a Subtitle C landfill alone is almost always more expensive than treatment and disposal of waste in a Subtitle D landfill, EPA asserts that treatment and disposal of waste in a Subtitle C landfill is clearly more expensive than treatment and disposal of waste in a Subtitle D landfill. Therefore, EPA assumes that the post-rule lowest-cost option is treatment followed by Subtitle D disposal.

C.3 Conclusion

EPA believes that Subtitle C disposal is generally more expensive than treatment followed by Subtitle D disposal. This assertion, coupled with potentially high Subtitle C liability costs, has led EPA to assume that owners and/or operators of mineral processing facilities will choose to treat waste to UTS levels and dispose of the treated waste in a Subtitle D landfill. Therefore, in both the pre-rule (baseline) and post-rule (option) scenarios, the mineral processing cost model assumes that for waste generated in quantities below 879 mt/yr, owners and/or operators will send the waste off-site for treatment and disposal, while owners/operators will build an on-site treatment system for waste generated in excess of 879 mt/yr.

EPA's cost analysis is based on costing functions and/or unit costs for on- and off-site treatment and disposal costs and for on-site storage of recyclable materials. To develop the cost functions, EPA identified all of the treatment and disposal permutations that are available in the various baseline-Option scenarios. Similarly, EPA identified all of the possible storage practices available under any of the assumed baseline practices and regulatory options considered. The costing functions were developed by estimating costs for facilities of different sizes and curve-fitting these individual facility costs. For some equipment associated with disposal and storage practices, the Agency has used rental costs rather than purchase costs, irrespective of the quantities of material involved. EPA recognizes the likelihood that mineral processing facilities actually own this equipment, such as front end loaders and dump trucks. To be conservative, however, the Agency included rental costs as a simple way to account for the use of this equipment.

The cost functions and associated assumptions are presented in the following seven sections:

- a. Annualization of Before-Tax Compliance Costs
- b. On-site Treatment and Disposal Costs
- c. Off-site Treatment and Disposal Costs
- d. Storage of Solid Materials
- e. Storage Of Liquid Materials
- f. Curve-fit Cost functions
- g. Costs of Groundwater Monitoring

D.1 Annualization of Before-Tax Compliance Costs

Under Executive Order 12866, EPA must determine whether a regulation constitutes a "significant regulatory action." One criterion 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 a rule is a significant regulatory action under this criterion, all costs are annualized on a before-tax basis assuming a seven percent real rate of return and a 20-year operating life. The savings attributable to corporate tax deductions or depreciation on capital expenditures for pollution control equipment are not considered in calculating before-tax costs.

Annual before-tax compliance costs were determined for on-site treatment, disposal, and storage. Before-tax compliance costs were used because they represent a resource cost of the rule, measured before any business expense tax deductions available to affected companies. Also, as described in section 3.2.2 of this RIA, screening level economic impacts are computed based upon other pre-tax indications or financial wherewithal, such as value of shipments and value added. Accordingly, computing management and compliance costs on a pre-tax basis provides a consistent measure of impacts on all affected facilities, and is the method used throughout this RIA. In reformulating the costs of compliance, EPA used a public sector discount rate of seven percent and assumed a 20-year operating life for annualizing capital costs.

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

$$\text{Before-Tax Costs} = (\text{Capital Costs})(\text{CRF}) + (\text{Annual Capital} + \text{O\&M Costs}) + (\text{Closure Costs}) * (\text{CRF}) / (1.07^{21})$$

Where: CRF = Capital recovery factor based on a 7 percent real rate of return (i) as follows:

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

D.2 On-site Treatment and Disposal

Neutralization and Precipitation of Acidic and Caustic Liquid Wastes

Neutralization is the process of adjusting either acidic or caustic liquid waste streams to a pH of approximately seven. Many manufacturing and processing operations produce effluents that are acidic or alkaline (caustic) in nature. Neutralization of acidic or caustic waste streams is necessary in a variety of situations: (1) to prevent metal corrosion and/or damage to other construction materials; (2) as a preliminary treatment for optimum operation of subsequent waste treatment processes; and (3) to provide neutral water for recycling, either as process water or as boiler feed. Treatment to adjust pH also may be desirable to break emulsions, to precipitate certain chemical species, or to control chemical reaction rates (e.g., chlorination). Precipitation, which may occur as a result of the addition of neutralization reagents, or which may require additional reagents, is necessary to remove dissolved solids, such as toxicity characteristic metals from solutions. Corrosive waste streams are neutralized by the addition of an alkaline material, such as lime. Caustic waste streams are neutralized by the addition of an acidic material, such as sulfuric acid. Additional reagent will cause precipitation of dissolved metals. The assumptions described in the following subsections were used in preparing cost estimates, with one exception: batch runs were assumed for 3,510 metric tons per year (mt/yr) and 350 mt/yr, adjusting the operating hours per year to 876 and 88, respectively, while 1,752 hours per year was assumed for waste flow rates of 35,130 mt/yr to 350,000 mt/yr.

Capital Costs - Neutralization

The following assumptions were used in developing the direct capital cost equations for neutralization in Exhibit D-1:

- Stainless steel neutralization reactor (1) - ½-hour retention time, 5% over design (based on waste and calcium hydroxide or sulfuric acid solution flows);
- Stainless steel mix tank (1) - two-hour retention time, 5% over design (based on 10% calcium hydroxide or 20% sulfuric acid solution flows);
- Piping, electrical, and instrumentation; and

- Neutralization is performed in <90 day accumulation treatment tanks (40 CFR 262.34); therefore, a RCRA permit is not required.

Acidic Waste Only

- Carbon steel holding tank (1) - two-hour retention time, 5% over design (based on 10% calcium hydroxide solution flow);
- Carbon steel centrifugal pumps (3) - for the calcium hydroxide solution out of the mix tank and out of the holding tank, and for the waste flow into the reactor;
- Stainless steel centrifugal pump (1) - for the waste flow into the reactor;
- Cast iron agitators (2) - for the mix tank and the holding tank; and
- Stainless steel agitator (1) - for the reactor.

Caustic Waste Only

- Stainless steel pump (1) - for sulfuric acid flow out of the mix tank;
- Carbon steel pumps (2) - for the waste flow into and out of the neutralization reactor; and
- Stainless steel agitators (2) - for the sulfuric acid mix tank and the neutralization reactor.

Capital costs are similar for either type of waste due to the use of a high cost stainless steel reactor in both designs.

Operation and Maintenance Costs - Neutralization

The following assumptions were used in development of the O&M cost equations for neutralization in Exhibit D-1:

- Operating hours - 90 percent operating factor (i.e., 330 days/year);
- Labor - one operator at 20 percent time for continuous systems, or ½ hour of labor per batch;
- Power - electricity for pumps and agitators; and
- Materials - waste pH was assumed to be 1.0 (acidic wastes) and 13.0 (caustic wastes) and waste specific gravity was assumed to be 1.03. Material quantities calculated from the stoichiometric addition of 0.033 gallon of 10% calcium hydroxide or 0.022 gallon of 20% sulfuric acid solution needed per gallon of waste.

O&M costs are similar for either acidic or alkaline waste due to roughly equal neutralizing material costs.

EXHIBIT D-1**COST EQUATIONS FOR ON-SITE NEUTRALIZATION
AND PRECIPITATION OF PHASE IV WASTES (1995 \$)**Neutralization

Capital Costs ($350 \leq Q \leq 370,000$ mt/yr) ¹	Cost(\$) = $36,131 + 151.95 Q^{-5}$
O&M Costs / Yr ($350 \leq Q \leq 370,000$ mt/yr)	Cost(\$) = $-206,719 + 36,594 \ln Q$

Precipitation

Capital Costs ($350 \leq Q \leq 370,000$ mt/yr) ²	Cost(\$) = $3,613 + 15.195 Q^{-5}$
O&M Costs / Yr ($350 \leq Q \leq 370,000$ mt/yr)	Cost(\$) = $0.3465 Q + 826.48$

Closure

Closure Costs ($Q < 37,910$ mt/yr)	Cost(\$) = 6,493
Closure Costs ($37,910 \leq Q \leq 370,000$ mt/yr)	Cost(\$) = $6,361 + 3.0 \times 10^{-3} Q$

Note:

For quantities above the upper limit of the cost equations, a second system is required.

¹ Q = Annual quantity of acidic or caustic waste managed (mt/yr). Capital and O&M equations apply to either type of waste (similar costs due to use of high cost stainless steel reactor in both designs and roughly equal neutralizing material costs). Fifteen percent of the waste stream neutralized and precipitated will need to be treated by stabilization due to sludge formation (see cost equations for Case A in Exhibit D-2 and use $0.15 * Q$).

Performance Assumptions

The following performance goals were assumed for neutralization:

- Neutralized waste exits with a pH of approximately seven;
 - Solid residuals are generated, with half of inlet total suspended solids (TSS) level of 3.0% assumed to settle and form a sludge with 10% solids content. Therefore, 15% of the original waste stream will leave the neutralization step as hazardous sludge, due to
-

precipitation of a portion of the 500 ppm TC-metals assumed to be in the inlet waste stream--this sludge will require dewatering, stabilization, and disposal; and

- The quantity of calcium hydroxide or sulfuric acid solutions added to the waste streams results in minimal flow changes.

Closure Costs

Cost equations for closure of the neutralization tanks and associated equipment are listed in Exhibit D-1 and include the following components:

- Decontamination of tank interiors, pumps, and liners;
- Management and off-site disposal of decontamination residuals as hazardous waste;
- Testing rinsate to demonstrate tanks and equipment are successfully decontaminated; and
- Certification of closure by a professional engineer.

Precipitation

EPA has assumed that in some cases, precipitation will require more reagent than used for neutralization, though these reagents will be added to the same reactor vessel. To account for this possibility, the Agency has determined that the capital cost for precipitation will consist of the cost of a small reagent holding tank, assumed to be 10 percent of the capital cost equation. O & M costs will consist of doubling the original reagent cost.

Surge Capacity

EPA also has assumed that a seven day surge tank is needed. The cost of this tank was developed along with that of other storage tanks, and is presented below in section 5.

On-Site Dewatering and Stabilization

Chemical stabilization/fixation, which consists of cement solidification and pozzolonic (lime-fly ash) solidification, is used to solidify organic and inorganic sludges. It also may be used to reduce the leachability of solid residues by first dissolving the materials and subsequently precipitating and fixing the dissolved solids. This technology adds cement and water to hazardous sludges to form a rock-like material that binds waste constituents in a solidified matrix. The process improves the physical characteristics of the waste by increasing its strength and reducing the leachability of contaminants after the solidified waste is land disposed. Cement solidification is particularly successful with sludges generated by the precipitation of heavy metals because the high pH of the cement mixture tends to keep the metals in the form of insoluble hydrated oxides, hydroxides, or carbonates. There is probably no lower limit on the solids content of sludges handled by cement solidification, although dewatering is advantageous as a volume reduction measure.

The stabilization process requires storage tanks and weighing equipment for both cement and the hazardous waste, a concrete mixer, and a loading hopper. Waste streams and cement are pumped from storage tanks to their respective weigh batchers, where the proper ratio for cement fixation is obtained. The two materials are then discharged from the weigh batchers to a concrete mixer. The proper amount of water is added to the two materials in the mixer, which then produces a homogeneous mixture. The mixture is discharged into a loading hopper, which may be transported by truck to a landfill site for disposal.

The assumptions described in the following subsections were used in generating cost equations for on-site dewatering and stabilization.

Capital Costs

The following assumptions were used in development of the direct capital cost equations for dewatering and stabilization presented in Exhibit D-2:

- Stabilization direct capital costs include the purchase costs for storage bins, weigh batchers, a concrete mixer, a loading hopper, instruments, controls, and pumps;
- The dewatering direct capital cost includes a scroll centrifuge;
- Installation charges were estimated at 15% of the equipment purchase costs;
- Storage tanks have a maximum capacity to store waste and cement for five days. The system is run as a batch processing operation. Waste rates considered range from 350 mt/yr to 370,000 mt/yr; and
- Stabilization is performed in a <90 day accumulation treatment tank (40 CFR 262.34); therefore, a RCRA permit is not required.

Operation and Maintenance Costs

The following assumptions were used in the development of the O&M cost equations for stabilization in Exhibit D-2:

- Direct operation and maintenance costs consist of operating labor, electricity, and cement and water consumption;
- The cement mixer has a minimum retention time of 15 minutes;
- Operating hours--90% operating factor (i.e., 330 days/year);

EXHIBIT D-2
COST EQUATIONS FOR ON-SITE DEWATERING AND
STABILIZATION OF PHASE IV WASTES (1995 \$)

Case A - Dewatering of 1-10% Solids-Containing Wastes

Capital Costs ($350 \leq Q \leq 370,000$ mt/yr)¹ Cost(\$) = $95,354 + 664.48 Q^5$

O&M Costs / Yr ($350 \leq Q \leq 370,000$ mt/yr) Cost(\$) = $12,219 + 286.86 Q^5$

Case B - Stabilization Only of >10% (35% average) Solids-Containing Wastes

Capital Costs ($425 \leq Q \leq 200,000$ mt/yr) Cost(\$) = $207.93 Q^{.78}$

O&M Costs / Yr ($425 \leq Q \leq 200,000$ mt/yr) Cost(\$) = $87,839 + 52.16 Q$

Closure Costs

Closure Costs ($350 \leq Q \leq 200,000$ mt/yr) Cost(\$) = $9,806 + 0.19 Q$

¹ Q = Annual quantity of waste managed (mt/yr)

- The dewatered sludge (Case A) has a specific gravity of 1.03, while wastes with greater than 10 percent solids (Case B) have a specific gravity of 1.25;
- The Case A mixing ratio for fixation is 0.05 : 0.50 : 1.00 (water : cement : waste) by weight. The mixing ratio assumes that the stabilized waste quantity is approximately equal to 9% of the initial sludge amount prior to being dewatered to a sludge consisting of 60% solids and specific gravity of 1.56; and
- The Case B mixing ratio for fixation is 0.05 : 0.70 : 1.00 (water : cement : waste) by weight. The mixing ratio assumes that the stabilized waste quantity is equal to 100% of the initial sludge amount with a solids content of 35% and sludge specific gravity of 1.25.

Performance Assumptions

The following performance goals were assumed for stabilization:

- The subsequent leaching of hazardous constituents from land disposal of a stabilized waste is reduced by approximately two orders of magnitude; and
-

- The amount of solidified waste disposed of in a landfill is 1.55 (Case A) and 1.75 (Case B) times the quantity, on a weight basis, of the waste generated.

Closure Costs

Cost equations for closure of the stabilization tanks and associated equipment are listed in Exhibit D-2 and include the following components:

- Decontamination of tank interiors, pumps, and lines;
- Management and off-site disposal of decontamination residuals as hazardous waste;
- Testing rinsate to demonstrate tanks and equipment are successfully decontaminated; and
- Certification of closure by a professional engineer.

On-site Subtitle C Landfill

Initial Capital Costs and Assumptions

The landfill design assumes a 20-year operating life with one new cell opened per year (20 cells for 20-year operating life). The following assumptions were used in the development of the initial capital cost equation for landfill operations in Exhibit D-3:

- Land, which includes 5 meters between cells, 15 meters between the cells and the edge of the active area, and a 46-meter buffer around the 20 cell area;
- Site preparation, which includes clearing the 20-cell area and the 21 meters around the 20-cell area of vegetation;
- Gravel roads within the active area;
- A 50-foot x 35-foot concrete pad for unloading waste and truck cleaning;
- Warning, stop, and directional signs;
- A maintenance building for equipment repair;
- Utilities site work that includes the installation of electricity, a septic system, a domestic well, a gas line to propane tank, and a telephone at the site;
- An earthen berm around the 20-cell active area for surface water control;
- A package leachate treatment system;

EXHIBIT D-3

COST EQUATIONS FOR ON-SITE SUBTITLE C LANDFILLS
PHASE IV WASTES (1995 \$)

Capital Costs ($Q \geq 1,000$ mt/yr)	$\text{Cost}(\$) = 83,378 + 23,422 Q^{0.5}$
Annual Capital Costs ($Q \geq 1,000$ mt/yr)	$\text{Cost}(\$) = 3,137 Q^{0.64}$
O&M Costs / Yr ($Q \geq 1,000$ mt/yr)	$\text{Cost}(\$) = 114,223 + 1,737 Q^{0.5}$
Closure Costs ($Q \geq 1,000$ mt/yr)	$\text{Cost}(\$) = 1,829 Q^{0.57}$
Post-Closure Costs / Yr ($Q \geq 1,000$ mt/yr)	$\text{Cost}(\$) = 1,523 Q^{0.50}$
Cover Replacement Costs / Yr ($Q \geq 1,000$ mt/yr)	$\text{Cost}(\$) = 3,502 Q^{0.59}$

Note: Q = Annual quantity of waste managed (mt/yr) ranging from 1,000 to 150,000 MT/yr.

- A groundwater monitoring system that includes six upgradient wells (three shallow wells to provide a horizontal profile of groundwater composition and one cluster of three wells at different depths near one another to provide a vertical profile of groundwater composition) and a minimum of nine downgradient wells (three three-well clusters with the wells in each cluster at different depths). For facilities with an active area side dimension greater than 300 ft, the unit would have the minimum three three-well cluster for the first 300 ft, plus one cluster of three wells for every additional 150 ft.;
- Portable submersible pumps for cell dewatering and leachate removal if sump pump fails;
- Heavy equipment, which includes dozers, landfill compactors, scrapers, and utility trucks;
- Construction of the first cell with the following containment system design in descending order starting with the layer closest to the waste:
 - 0.3 meter protective soil layer;

- geotextile filter fabric;
- 0.3 meter sand layer (LCS);
- 30 mil HDPE liner;
- 0.3 meter sand layer (LDS);
- 30 mil HDPE liner; and
- 0.91 meter clay layer;
- Wet wells and pumps for the leachate collection system and the leachate detection system;
- RCRA initial costs, which include the following items:
 - ID number;
 - waste analysis;
 - waste analysis plan;
 - inspection schedule;
 - personnel training;
 - alarm and spill equipment;
 - arrangement with local land authority;
 - contingency plan;
 - operating record;
 - groundwater monitoring plan;
 - background groundwater monitoring;
 - closure plan, closure cost estimate, post-closure plan, post-closure cost estimate;
 - closure/post-closure financial assurance (obtain mechanism - excludes payments to mechanism);
 - liability insurance (obtain mechanism - excludes payments to mechanism);
 - Part A permit application; and
 - Part B permit application; and
- Fees, which include construction quality assurance (CQA), engineering, construction and inspection, construction and field expenses, contractor's overhead and profit, spare parts inventory, and contingency.

Annual Capital Costs and Assumptions

Annual capital costs include the construction of one new cell and closure (i.e., final cover) of the previously used cell each year for the operating life (i.e., 19 years). The following assumptions were used in the development of the annual capital cost equation for landfill operations in Exhibit D-3:

- Cell construction consisting of the same containment design as described in the initial capital cost assumptions;
- Construction of each cell's cover with the following cover system design in ascending order starting with the layer closest to the waste:
 - 0.6 meter clay layer;
 - 30 mil PVC liner;
 - 0.3 meter sand layer;
 - geotextile filter fabric;
 - 0.6 meter topsoil layer; and
 - vegetation; and
- Fees which include CQA, engineering, construction and inspection, contractor's overhead and profit, and contingency.

Operation and Maintenance Costs and Assumptions

The following assumptions were used in the development of the O&M cost equation for landfill operations in Exhibit D-3:

- Labor for personnel to operate the landfill, which includes equipment operators, laborers, clerical, a technician, a manager, and an engineer;
- RCRA administrative costs, which include the following items:
 - review waste analysis and plan;
 - conduct and record inspections;
 - training program review for facility personnel;
 - review contingency plan;
 - maintain operating record;
 - review closure/post-closure plan;
 - update closure/post-closure cost estimate;
 - review closure/post-closure financial assurance mechanism;
 - review third party liability mechanism;
 - review corrective action schedule; and
 - permit renewal (Assumed the Part B permit is renewed every five years. Averaged the periodic costs out on an annual basis.);

- Maintenance labor and supplies;
- Leachate treatment;
- Groundwater monitoring semi-annually for the following parameters: pH; specific conductance; total organic carbon; total organic halogens; metals; and VOC's; and
- Utilities, which include fuel for heavy equipment, electricity for maintenance building and pumps, and heat for maintenance building.

Closure Costs and Assumptions

The following assumptions were used in the development of the closure cost equation for landfill operations in Exhibit D-3:

- Construction of the final cell's (cell 20) cover consisting of the same cover design described in the annual capital cost assumptions;
- Decontamination by steam cleaning of heavy equipment (dozers, scrapers, compactors, and trucks). Assumed residuals generated at 100 gal/hr and managed off-site as a hazardous waste (transportation 100 miles one-way and commercial hazardous waste treatment);
- Pumps and lines decontaminated with an alkaline solution. Assumed residuals generated at 500 gal/pump and managed off-site as a hazardous waste (transportation 100 miles one-way and commercial hazardous waste treatment);
- Certification of closure by an independent registered professional engineer; and
- Fees, which include CQA, engineering, construction and inspection, contractor's overhead and profit, and contingency.

Post-Closure Costs and Assumptions

The following assumptions were used in the development of the post-closure and cover replacement cost equations for landfill operations in Exhibit D-3:

- Survey plat indicating location and dimension of cells to permanently surveyed benchmarks;
- Waste record submitted to local land authority;
- Note added to property deed stating previous land use;
- Final cover inspected semi-annually;
- Maintenance of final cover (i.e., mow semi-annually and fertilize annually);

- Reseed, fertilize, mulch, and water 1/6 of entire 20-cell area every five years;
- Conduct routine erosion damage repair of cover and ditch every five years;
- Exterminate for burrowing rodents every two years;
- Replace the cover on the first five cells during the last five years of post-closure;
- Leachate managed off-site as a hazardous waste (transportation 100 miles one-way and commercial hazardous waste treatment) for all landfill sizes;
- Pumps replaced annually;
- Groundwater monitoring semi-annually for the following parameters: pH; specific conductance; total organic carbon; total organic halogens; metals; and VOC's;
- Certification of post-closure by an independent registered professional engineer; and
- Fees, which include administration, CQA, engineering, construction inspection testing, construction and field expenses, contractor's overhead and profit on the cover replacement cost, and contingency.

Disposal of Solid Materials in On-site Subtitle D Piles

The waste pile disposal cost function includes land, a compacted soil base, and the costs of a dump truck to move the material to the pile.

EPA made the following assumptions in assembling these cost functions:

- The purchase cost of land is \$2500/acre (from CKD Monofill Model Cost Documentation, 1995);
- The unit does not require a formal liner, though it is assumed that it will need at least a foot of compacted soil as a base;
- The cost of compacted soil is \$0.2325/ft³ (from CKD Monofill Model Cost Documentation, 1995);
- The unit must be sized for 20 years' accumulation of waste;
- The necessary land area is determined by assuming the material is stored in a conical pile with a maximum height of 100 ft, where the height of the pile is 1/2 the radius and the volume of the pile is calculated using the following formula: $V = 1/3\pi r^2 h$;
- The length of a side of the square plot for a single pile is the twice the radius plus a ten foot buffer zone around the edge of the pile to move equipment; therefore, the area of the pile is $[2*(r+10)]^2$;
- The area of the square plot for multiple piles is calculated by assuming that the volume to be stored is equally divided by the number of piles, then adding the area of each individual pile with its buffer zone (to allow equipment to move between the piles);

- The density of solid materials is the same as crushed furnace slag (85 lb/ft³);
- The cost of purchasing a 25 short ton capacity dump truck is \$275,000 (vendor quote, 1996);
- The cost of renting a 25 short ton capacity dump truck is \$775/day (from Means, 1995);
- The fuel and maintenance cost of the truck is \$18.85/hr (from Means, 1995);
- The cost of labor to operate the truck is \$22.80/hr (Engineering News Record, 10/31/94, p. 49);
- It would take 1/2 hour to drive the dump truck to the waste pile, empty it, and return to the point of generation;
- There is no cost associated with a conveying system at the waste pile; and
- Below 50 mt/yr, facilities would not use a pile for disposal as it would be more economically attractive to send the material off-site for disposal, even for Subtitle C treatment and disposal.

The costs of disposing solid materials in on-site subtitle D piles are shown in Exhibit D-4.

Disposal of Liquid Materials in Surface Impoundments (on-site Subtitle D)

On-site disposal of liquids (for the no prior treatment baseline) poses some interesting problems, in that release of wastewater is regulated under the NPDES programs, which places limits on what "pollutants" can be released into the environment, including heat, turbidity, and percent solids, to name a few. Because EPA has assumed simple release of materials (for this baseline) under the RCRA program, but some treatment or settling is required under the NPDES programs, EPA has assumed that a facility operator will "treat" liquid waste in surface impoundments, by adding reagent in a tank basin before the waste enters the surface impoundment. Further EPA has assumed that the facility will then hold the material in the surface impoundment for 15 days before release. Because, however, facility operators will have to treat these waste liquids to UTS levels in a tank system before release, EPA believes the cost of constructing the surface impoundment is a sunk cost, and should not be counted towards calculating the baseline cost.¹

Equations were developed for the capital and O & M costs for on-site neutralization of acidic and caustic wastewaters subject to federal NPDES standards. The cost functions were developed by estimating the costs for different size facilities and curve fitting the results. These equations are presented in Exhibit D-5. Because the capital costs for acidic and caustic wastes are very close, EPA used the costs for acidic wastes for all waste streams in the cost model. The Agency based this decision on the assumption that the majority of corrosive mineral processing wastestreams were acidic rather than caustic.

¹EPA believes it is inappropriate to include sunk capital costs in the baseline, because the incremental costs of this rule are calculated as the difference between the post rule costs and the baseline costs. If EPA included these non-recoverable costs in the baseline, the incremental cost of the rule would be understated.

Exhibit D-4

Annual Disposal Cost of Solids in Waste Piles

Waste Pile - Disposal	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		50	500	5,000	50,000	75,000	100,000	250,000	500,000
Waste Quantity (ft3/yr)		1,297	12,968	129,682	1,296,824	1,945,235	2,593,647	6,484,118	12,968,235
Total Unit Waste Quantity (ft3)		25,936	259,365	2,593,647	25,936,471	38,904,706	51,872,941	129,682,353	259,364,706
Unit Construction									
Number of Piles		1	1	1	7	10	13	31	62
Radius of Pile (ft)		47	89	180	202	205	207	210	210
Height of Pile (ft)		18	40	85	96	98	98	100	100
Unit size (ft2)		8,733	31,772	130,272	1,142,363	1,683,210	2,223,596	5,463,850	10,927,699
Unit size (acres)		0.20	1	3	26	39	51	125	251
Annualized Land (\$/yr)	\$2500/acre	47	172	706	6,188	9,118	12,046	29,599	59,198
Unit base (compacted soil)	\$0.2325/ft3	192	697	2,859	25,070	36,939	48,798	119,908	239,816
Dump Truck									
Number of trips - Annual		3	23	221	2,205	3,307	4,410	11,023	22,046
Number of hours - annual		1.5	12	111	1,103	1,654	2,205	5,512	11,023
Annual Rental Cost	\$775/day	2,325	17,825	-	-	-	-	-	-
Number of Original Trucks Needed		1	1	1	1	1	1	3	5
Lifetime of Truck(s)		20	20	20	20	16	12	14	12
Total Number of Trucks Needed		1	1	1	1	2	2	6	10
Annualized Purchase cost	\$275,000	-	-	25,957	25,957	34,915	37,646	107,762	188,224
Annualized Labor Cost	\$22.80/hr	34	262	2,519	25,137	37,700	50,274	125,662	251,324
Ann. Fuel and Maintenance Cost	\$18.85/hr	28	217	2,083	20,782	31,168	41,564	103,892	207,784
Total Annual Cost (\$/yr)									
Unit Cost (\$/mt)		52.53	38.35	6.82	2.06	2.00	1.90	1.95	1.89

April 15, 1997

Exhibit D-5
COST EQUATIONS FOR ON-SITE DISPOSAL OF WASTEWATERS
(TO MEET NPDES STANDARDS ONLY - 1995 \$)

Capital Costs ($350 \leq Q \leq 350,000$ mt/yr)¹ Cost(\$) = $16,777 + 75.08 Q^5$

O&M Costs / Yr ($350 \leq Q \leq 350,000$ mt/yr) Cost(\$) = $-113,989 + 19,114 \ln Q$

¹ Q = Annual quantity of waste managed (mt/yr)

D.3 Off-site Treatment and Disposal

The cost of sending liquids off-site for treatment and disposal of residues is \$175/mt, which includes a cost of \$25/mt for transportation and a cost of \$150/mt for treatment. The cost of sending solid waste off-site for treatment is \$175/mt, which includes \$25/mt for transportation, \$88/mt for stabilization, and \$35/mt for disposal (which is adjusted to \$61/mt because stabilization increases the mass of waste to be disposed to 175 percent of the original mass). The price of off-site treatment of liquids was taken from the September 1994 document Estimating Costs for the Economic Benefit of RCRA Noncompliance. The cost of off-site Subtitle D disposal is taken from the Technical Background Document: Data and Analyses Addressing the Costs of CKD Management Alternatives. The commercial price for stabilization is estimated at \$88/mt, based on an \$80/short ton difference between off-site landfill and stabilization (\$170/short ton) and off-site landfill alone (\$90/short ton) reported in *EI Digest*, November 1994.

D.4 Storage of Solid Materials

Storage of Solid Materials in Drums

The drum storage cost function for solids includes the capital cost of the drums, labor to open and close drums, and labor to move the drums either manually (using a handtruck) or using a pallet truck. The drum(s) would be filled by placing them under a hopper or chute, and would then be closed by a laborer. The drum would be moved to a storage area within the same area of the facility either on a handtruck (using manual labor) or on a pallet truck. Later, the drum would be moved to the point of reentry and opened. The normal feed handling equipment would be used to reinsert the material back into the process.

The Agency made the following assumptions in assembling these cost functions:

D-17

- The capital cost of a carbon steel drum is \$52 (from Non-RCRA Tanks, Containers, and Buildings, December 1996, p. 17. This price includes \$2 per drum for freight);
- 55 gallon drums have 50 gallons of usable capacity;
- The density of solid materials is the same as crushed furnace slag (85 lb/ft³);
- A laborer could close (or open) drums at the rate of 12 drums per hour;
- A laborer could move a drum from the point of generation to the storage area (or back from the storage area to the point of reentry) using a handtruck at a rate of 8 drums per hour;
- A laborer could move drums from point of generation to the storage area (or back from the storage area to the point of reentry) using a pallet truck at a rate of 32 drums per hour;
- The material to be stored is generated continuously, therefore, unless more than 90 drums are generated, the efficiencies of using a pallet truck would be lost and facilities would use manual labor to move drums rather than use the pallet truck;
- The cost of unskilled labor is \$19/hr (from CKD Monofill Model Cost Documentation, 1995);
- The cost of a small equipment operator is \$24.60/hr (Engineering News Record, 10/31/94, p. 49);
- The cost of a handtruck is \$209, and the cost of a pallet truck is \$3,020 (from Peters and Timmerhaus, 1990, updated to 1995 dollars);
- The cost of fuel and maintenance for the pallet truck is \$1.50/hr, which is estimated to be the same as the fuel and maintenance cost of a gasoline powered cart (from Means Building Construction Cost Data, 1995, p. 18);
- Once a drum had been returned to the point of reentry it would be handled by the normal processing equipment, and would not incur any further "storage" costs; and
- The upper limit of material being stored in drums is 200 mt/yr, because having more than 200 drums would both be impractical and impose opportunity costs that have not been fully accounted for (there is likely to be both a practical limit on the floor space available to store the drums, and a cost associated with using additional floor space).

The costs of storing solid materials in drums are shown in Exhibit D-6.

Exhibit D-6

Annual Storage Cost Assuming Quarterly Storage of Solids in Drums

Drum Storage Cost (Solids)	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		0.5	4	10	50	75	100	150	200
Waste Quantities (mt/qtr)		0.125	1	2.5	12.5	18.75	25	37.5	50
Waste Quantity (gal/qtr)		24.25	194.02	485.04	2425.22	3637.83	4850.44	7275.67	9700.89
Purchase of Drums									
Number of Drums per quarter		1	4	10	49	73	98	146	195
Annualized Cost of Drums	\$52/drum	4.91	19.63	49.08	240.51	358.30	481.01	716.61	957.11
Labor to Open/Close Drums									
Number of Hours per year		0.67	2.67	6.67	32.67	48.67	65.33	97.33	130.00
Annual Labor Cost	\$19/hr	12.67	50.67	126.67	620.67	924.67	1241.33	1849.33	2470.00
Move Drums									
Ann. Handtruck Capital. Cost	\$209	19.73	19.73	19.73	0.00	0.00	0.00	0.00	0.00
Ann. pallet truck Cap. Cost	\$3020	0.00	0.00	0.00	285.06	285.06	285.06	285.06	285.06
Number of Hours - Annual		1	4	10	12.25	18.25	24.5	36.5	48.75
Annual Labor Cost	see notes	19	76	190	301.35	448.95	602.7	897.9	1199.25
Annual Fuel and O & M Cost	\$1.50/hr	0	0	0	18.38	27.38	36.75	54.75	73.13
Total Annual Cost (\$/yr)		56.30	166.03	385.48	1465.96	2044.35	2646.85	3803.65	4984.55
Unit Cost (\$/mt)		112.60	41.51	38.55	29.32	27.26	26.47	25.36	24.92

April 15, 1997

Storage of Solid Materials in Roll-off Containers

The roll-off container storage cost function includes the capital cost of the containers, and the rental of a truck to move full roll-offs first to the storage area and then to the point of re-entry. It also includes labor, fuel, and maintenance to operate the truck.

A roll-off container would be filled by parking it beneath a hopper or chute. It would then be driven across the site to a storage area by a truck designed to move roll-off containers. The container would be "rolled off" the truck and set on the ground. Later the container would be picked up by the truck and driven back across the site to the point of re-entry and the contents dumped into a pile beside the normal feed materials, where the material would be picked up by the normal feed handling equipment.

The Agency made the following assumptions in assembling these cost functions:

- The purchase price of a 20 yd³ roll-off container is \$2670, a 30 yd³ container is \$3,045 and a 40 yd³ container is \$3,510 (from Non-RCRA Tanks, Containers, and Buildings, December, 1996, p.27);
- The cost of shipping is \$320 per container, based on a shipping cost of \$1.60 per mile and an assumed distance of 200 miles (from Non-RCRA Tanks, Containers, and Buildings, December, 1996, p.27);
- The cost of a tarp is \$425 (from Non-RCRA Tanks, Containers, and Buildings, December, 1996, p.25);
- The density of solid materials is the same as crushed furnace slag (85 lb/ft³);
- It would take 2 hours to move a roll-off container from the point of generation to the storage area (or back from the storage area to the point of reentry);
- The roll-off truck must be rented in full day increments each time it is necessary to move a roll-off container;
- The cost of renting the roll-off truck is \$500/day or \$4,500/month (based on a vendor quote of \$4,500/month, and standard construction estimating practices that daily rental is a third of weekly rental, which is a third of monthly rental);
- The cost of labor to operate the roll-off truck is \$22.80/hr (Engineering News Record, 10/31/94, p. 49);
- The fuel and maintenance cost of the roll-off truck is \$18.85/hr (which is the fuel and maintenance cost of a 25 ton off-road dump truck from Means, 1995); and
- Once the contents of a roll-off container had been emptied into a pile at the point of reentry they would be handled by the normal processing equipment, and would not incur any further "storage" costs.

The costs of storing solid materials in roll-off containers are shown in Exhibit D-7.

Storage of Solid Materials in Buildings

The building storage cost function includes the capital cost of constructing a dome style building, such as those used by regional highway departments to store road chemicals. This cost function also includes rental of a dump truck to move material from the point of generation to the storage area and later to the point of re-entry, labor to operate the truck, truck fuel, and maintenance as well as the capital, operating, and maintenance costs of a front end loader to fill the truck at the storage building. The following is a brief description of how materials would be stored in buildings.

The dump truck would be filled by parking it under a hopper or chute, and would then be driven across the site to a storage building where it would dump the material onto the pad outside the entrance to the building. The front end loader would then push the material into a pile in the dome. Later the material would be picked up by a front end loader and put back into the dump truck, be driven across the site to the point of re-entry and dumped into a pile beside the normal feed materials, where it would be picked up by the normal feed handling equipment.

The Agency made the following assumptions in assembling these cost functions:

- The capital cost of a building is based on the average price for dome buildings (see Tables 14, 15, and 16 of Non-RCRA Tanks, Containers, and Buildings, December, 1996, pp. 32-33);
- The capacity utilization of these buildings is assumed to be 80 percent, since a conveying system is not used;
- The dome will be built on an asphalt base pad that is a square with sides equal in length to the diameter of the building plus 20 feet.
- The cost of the asphalt pad is \$6.50/yd² (from Means Site Work 1994, p. 59)
- The density of solid materials is the same as crushed furnace slag (85 lb/ft³);
- The cost of purchasing a 25 short ton capacity dump truck is \$275,000. The expected lifetime of this equipment is 26,000 operating hours (vendor quote, 1996);
- The fuel and maintenance cost of the truck is \$18.85/hr (from Means, 1995);
- The cost of labor to operate the truck is \$22.80/hr (Engineering News Record, 10/31/94, p. 49);
- It would take 1/2 hour to drive the dump truck to the building, empty it, and return to the point of generation;
- It would take 1/2 hour to drive the truck back from the storage area to the point of reentry, and dump the contents on the ground;

Exhibit D-7

Annual Storage Cost Assuming Quarterly Storage of Solids in Roll-Off Containers

Roll-off Storage Cost	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		50	75	100	500	1,000	2,500	5,000	7,500
Waste Quantities (mt/qtr)		12.5	19	25	125	250	625	1,250	1,875
Waste Quantity (yd3/qtr)		12.0	18	24	120	240	600	1,201	1,801
Purchase of Roll-offs									
Number of 20 yd3 Roll-offs		1	1	-	-	-	-	-	-
Cost of Roll-offs	\$2670/R-off	2,670	2,670	-	-	-	-	-	-
Number of 30 yd3 Roll-offs		-	-	1	-	-	-	-	-
Cost of Roll-offs	\$3045/r-off	-	-	3,045	-	-	-	-	-
Number of 30 yd3 Roll-offs		-	-	-	4	7	16	31	46
Cost of Roll-offs	\$3510/r-off	-	-	-	14,040	24,570	56,160	108,810	161,460
Tarp	\$425 each	425	425	425	1,700	2,975	6,800	13,175	19,550
Shipping	\$320 Each	320	320	320	1,280	2,240	5,120	9,920	14,720
Annualized Cost of Roll-offs		322	322	358	1,607	2,811	6,426	12,451	18,475
Roll-off Truck									
Number of Trips - Annual		8	8	8	32	56	128	248	368
Number of Rental days		8	8	8	32	56	128	248	365
Annual Rental of Roll-off Truck	\$500/day	4,000	4,000	4,000	16,000	28,000	-	-	-
Annual Rental of Roll-off Truck	\$4500/mo	0	0	0	0	0	54000	54000	54000
Number of Hours - Annual		16	16	16	64	112	256	496	736
Annual Labor Cost	\$22.80/hr	365	365	365	1,459	2,554	5,837	11,309	16,781
Ann.Fuel and Maintenance Cost	\$18.85/hr	302	302	302	1,206	2,111	4,826	9,350	13,874
Total Annual Cost (\$/yr)		4,989	4,989	5,024	20,272	35,476	71,088	87,109	103,129
Unit Cost (\$/mt)		99.77	66.52	50.24	40.54	35.48	28.44	17.42	13.75

April 15, 1997

- The cost of renting a 7.5 yd³ capacity 375 hp front end loader is \$1,400/day (from Means, 1995);
- The fuel and maintenance cost of the front end loader is \$56.15/hr (from Means, 1995);
- The cost of labor to operate the front end loader is \$26.90/hr (Engineering News Record, 10/31/94, p. 49);
- The front end loader can move 20 shovelfuls per hour;
- The front end loader must be rented for full days; and
- Once the contents of the dump truck had been emptied into a pile at the point of reentry they would be handled by the normal processing equipment, and would not incur any further "storage" costs.

The costs of storing solid materials in buildings are shown in Exhibit D-8.

Storage of Solid Materials in RCRA Containment Buildings

The RCRA containment building storage cost function is similar to the regular building cost functions, with two exceptions: 1) the RCRA building is assumed to be rectangular rather than round, and 2) the building itself must meet the standards outlined in 40 CFR 264 Subpart DD. EPA used containment building costs from the Cost and Economic Impact Analysis of Land Disposal Restrictions for Newly Listed Wastes and Contaminated Debris (Phase 1 LDRs) Final Rule, EPA Office of Solid Waste, June 10, 1992. The annualized capital cost listed on Page 3-17 of that document includes the capital cost of the building (annualized using a 3 percent social discount rate over 20 years) as well as an O & M cost (equivalent to 10 percent of the initial capital). Because EPA has used a 7 percent discount rate in other parts of this analysis, the Agency backed out the original capital costs and re-annualized them using a seven percent discount rate. The Agency then used these annualized costs in the building cost calculations to compute the cost of storage in RCRA containment buildings.

The Agency made the following assumptions in assembling these cost functions:

- The necessary building area is determined by assuming the material is stored in a conical pile with a maximum height of 18 ft, (or for smaller piles the height of the pile is equal to the radius) where the volume of the pile is calculated using the following formula: $V = 1/3\pi r^2 h$;
- The length of a side of the building is the twice the pile radius plus a ten foot buffer zone around the edge of the pile to move equipment; therefore, the area of the building is $[2*(r+10)]^2$;

Exhibit D-8

Annual Storage Cost Assuming Quarterly Storage of Solids in Dome Buildings

Building Storage Cost	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		1,380	2,048	2,660	15,800	17,952	28,448	42,072	50,764
Waste Quantities (mt/qtr)		345	512	665	3,950	4,488	7,112	10,518	12,691
Waste Quantity (ft3/qtr)		8,948	13,279	17,248	102,449	116,403	184,460	272,800	329,160
Waste Quantity (yd3/qtr)		331	492	639	3,794	4,311	6,832	10,104	12,191
Capital Cost									
Number of Buildings		1	1	1	1	1	1	1	1
Diameter of Building (ft)		40	40	50	100	100	124	150	150
size of base pad (yd2)		400	400	544	1,600	1,600	2,304	3,211	3,211
Asphalt Pad	6.50/yd2	2,600	2,600	3,539	10,400	10,400	14,976	20,872	20,872
Total Cost of Building		50,500	62,500	72,000	121,000	134,000	190,000	343,000	381,500
Annualized Cost of Building		5,012	6,145	7,130	12,403	13,630	19,348	34,346	37,980
Dump Truck									
Number of trips - quarter		32	46	60	350	396	628	928	1,120
Number of trips - annual		128	184	240	1,400	1,584	2,512	3,712	4,480
Number of hours - annual		64	92	120	700	792	1,256	1,856	2,240
Lifetime of Truck		20	20	20	20	20	20	14	12
Annualized Purchase cost	\$275,000	25,957	25,957	25,957	25,957	25,957	25,957	36,018	37,793
Annual Labor Cost	\$22.80/hr	1,459	2,098	2,736	15,960	18,058	28,637	42,317	51,072
Ann. Fuel and Maintenance Cost	\$18.85/hr	1,206	1,734	2,262	13,195	14,929	23,676	34,986	42,224
Front End Loader									
Number of Hours (annual)		9	13	17	101	115	182	269	325
Number of Days (annual)		4	4	4	12	12	20	28	36
Annual Rental	\$1,400/day	5,600	5,600	5,600	16,800	16,800	28,000	39,200	50,400
Annual Labor Cost	\$26.90/hr	238	353	458	2,722	3,093	4,901	7,248	8,745
Ann. Fuel and Maintenance Cost	\$ 56.15/hr	496	736	957	5,681	6,455	10,230	15,129	18,254
Total Annual Cost (\$/yr)		39,969	42,623	45,100	92,718	98,922	140,748	209,243	246,468
Unit Cost (\$/mt)		28.96	20.81	16.95	5.87	5.51	4.95	4.97	4.86

- If the volume to be stored exceeds 290,600 ft³, more than one building must be constructed;
- The costs of the dump truck and front end loader are based on the same assumptions used in calculating the dome building cost function.

The costs of storing solid material in RCRA containment buildings are shown in Exhibit D-9.

Storage of Solid Materials in Lined Waste Piles (Assuming No Free Liquids)

The waste pile storage cost function includes land, a liner base, a liner, liner protections, the costs of a dump truck to move the material to the storage site and back, and a front end loader to move the material at the pile. The following is a brief description of how solid materials would be stored in waste piles.

A dump truck would be filled by parking it under a hopper or chute, and would then be driven across the site to a waste pile where it would dump the material (either on the lined site directly, or onto a conveyer system). The waste pile is lined with a foot of compacted soil under 3 feet of compacted clay. Later, the material is picked up by a front end loader, put back into the dump truck, driven across the site to the point of re-entry, and dumped into a pile beside the normal feed materials, where it would be picked up by the normal feed handling equipment.

EPA made the following assumptions in assembling these cost functions:

- The purchase cost of land is \$2500/acre (from CKD Monofill Model Cost Documentation, 1995);
- The cost of compacted soil is \$0.2325/ft³ (from CKD Monofill Model Cost Documentation, 1995);
- The cost of compacted clay is \$0.3667/ft³ (from CKD Monofill Model Cost Documentation, 1995); The necessary land area is determined by assuming the material is stored in a conical pile with a maximum height of 100 ft, where the height of the pile is 1/2 the radius and the volume of the pile is calculated using the following formula: $V = \frac{1}{3}\pi r^2 h$;
- The length of a side of the square plot for a single pile is the twice the radius plus a ten foot buffer zone around the edge of the pile to move equipment; therefore, the area of the pile is $[2*(r+10)]^2$;
- The area of the square plot for multiple piles is calculated by assuming that the volume to be stored is equally divided by the number of piles, then adding the area of each individual pile with its buffer zone (to allow equipment to move between the piles);

Exhibit D-9

Annual Storage Cost Assuming Quarterly Storage of Solids in RCRA Containment Buildings

Building Storage Cost	Unit Cost	A	B	C	D	E
Waste Quantities (mt/yr)		135	600	2,400	8,245	42,130
Waste Quantities (mt/qtr)		34	150	600	2,061	10,533
Waste Quantity (ft3/qtr)		875	3,890	15,562	53,462	273,176
Waste Quantity (yd3/qtr)		32	144	576	1,980	10,118
Capital Cost						
Fixed height pile		0	0	1	1	1
Number of Buildings		1	1	1	1	1
Average sq ft of building		1,509	2,599	6,001	16,005	68,000
Capital Cost of building		400,679	514,305	777,438	1,375,466	4,784,231
Maintenance cost of building		40,068	51,430	77,744	137,547	478,423
Annualized Cost of Building		77,888	99,976	151,126	267,377	930,007
Dump Truck						
Number of trips - quarter		4	14	54	182	930
Number of trips - annual		16	56	216	728	3,720
Number of hours - annual		8	28	108	364	1,860
Lifetime of Truck		20	20	20	20	14
Annualized Purchase cost	\$275,000	25,957	25,957	25,957	25,957	36,039
Annual Labor Cost	\$22.80/hr	182	638	2,462	8,299	42,408
Ann. Fuel and Maintenance Cost	\$18.85/hr	151	528	2,036	6,861	35,061
Front End Loader						
Number of Hours (annual)		1	4	15	53	270
Number of Days (annual)		4	4	4	8	28
Annual Rental	\$1,400/day	5,600	5,600	5,600	11,200	39,200
Annual Labor Cost	\$26.90/hr	23	103	413	1,420	7,258
Ann. Fuel and Maintenance Cost	\$ 56.15/hr	49	216	863	2,965	15,149
Total Annual Cost (\$/yr)		109,850	133,018	188,458	324,080	1,105,121
Unit Cost (\$/mt)		813.71	221.70	78.52	39.31	26.23

- The density of solid materials is the same as crushed furnace slag (85 lb/ft³);
- The cost of purchasing a 25 short ton capacity dump truck is \$275,000. The expected lifetime of this equipment is 26,000 operating hours (vendor quote, 1996);
- The fuel and maintenance cost of the truck is \$18.85/hr (from Means, 1995);
- The cost of labor to operate the truck is \$22.80/hr (Engineering News Record, 10/31/94, p. 49);
- It would take 1/2 hour to drive the dump truck to the waste pile, empty it, and return to the point of generation;
- There is no cost associated with a conveying system at the waste pile;
- It would take 1/2 hour to drive the truck back from the storage area to the point of reentry, and dump the contents on the ground;
- The cost of renting a 7.5 yd³ capacity 375 hp front end loader is \$1,400/day (from Means, 1995);
- The fuel and maintenance cost of the front end loader is \$56.15/hr (from Means, 1995);
- The cost of labor to operate the front end loader is \$26.90/hr (Engineering News Record, 10/31/94, p. 49);
- The front end loader can move 20 shovelfuls per hour;
- The front end loader must be rented for full days; and
- Once the contents of the dump truck had been emptied into a pile at the point of reentry they would be handled by the normal processing equipment, and would not incur any further "storage" costs.

The costs of storing solid materials with no free liquids in waste piles are shown in Exhibit

D-10.

Storage of Solid Materials in Unlined Waste Piles (with Groundwater Monitoring)

The costs of storing materials in unlined waste piles are very similar to the costs of storing materials in lined waste piles, with two notable exceptions: The costs of the liner and liner protection are not used, and costs of groundwater monitoring have been added. (The development of groundwater monitoring costs is described later in this Appendix.) One of the stipulations of using these units is that if monitoring reveals contamination, the facility is responsible for the costs of corrective action. However, even without adding the potential costs of corrective action, these costs of regular monitoring are higher than the costs of liners. Therefore, EPA considered this option to be economically inferior to storage in waste piles with liners, and did not attempt to add corrective action costs to the costs shown in Exhibit D-11.

Exhibit D-10

Annual Storage Cost Assuming Quarterly Storage of Solids with No Free Liquids in Lined Waste Piles

Waste Pile - No Free Liquids	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		500	5,000	15,000	25,000	40,000	70,000	90,000	120,000
Waste Quantities (mt/qtr)		125	1,250	3,750	6,250	10,000	17,500	22,500	30,000
Waste Quantity (ft ³ /qtr)		3,242	32,421	97,262	162,103	259,365	453,888	583,571	778,094
Waste Quantity (yd ³ /qtr)		120	1,201	3,602	6,004	9,606	16,811	21,614	28,818
Unit Construction									
Unit size (ft ²)		3,218	9,825	17,987	24,118	31,772	44,394	51,693	61,619
Annualized Land (\$/yr)	\$2500/acre	17	53	97	131	172	240	280	334
Ann. Liner base (compacted soil)	\$0.2325/ft ³	71	216	395	529	697	974	1,134	1,352
Annualized Liner (3 ft of clay)	\$0.3867/ft ³	334	1,020	1,868	2,504	3,299	4,610	5,368	6,398
Ann. Liner Protection (cmpct. soil)	\$0.2325/ft ³	71	216	395	529	697	974	1,134	1,352
Dump Truck									
Number of trips - quarter		12	112	332	552	882	1,544	1,986	2,646
Number of trips - annual		48	448	1,328	2,208	3,528	6,176	7,944	10,584
Number of hours - annual		24	224	664	1,104	1,764	3,088	3,972	5,292
Number of Original Trucks Needed		1	1	1	1	1	2	2	2
Lifetime of Truck(s)		20	20	20	20	15	17	13	10
Total Number of Trucks Needed		1	1	1	1	2	4	4	4
Annualized Purchase cost	\$275,000	25,957	25,957	25,957	25,957	35,533	68,529	73,324	78,617
Annualized Labor Cost	\$22.80/hr	547	5,107	15,139	25,171	40,219	70,406	90,562	120,658
Ann. Fuel and Maintenance Cost	\$18.85/hr	452	4,222	12,516	20,810	33,251	58,209	74,872	99,754
Front End Loader									
Number of Hours (annual)		3.20	32.02	96.06	160.10	256.16	448.28	576.37	768.49
Number of Days (annual)		4	8	16	24	36	60	76	100
Annual Rental	\$1,400/day	5,600	11,200	22,400	33,600	50,400	84,000	106,400	140,000
Annual Labor Cost	\$26.90/hr	86	861	2,584	4,307	6,891	12,059	15,504	20,672
Ann. Fuel and Maintenance Cost	\$56.15/hr	180	1,798	5,394	8,990	14,384	25,171	32,363	43,151
Total Annual Cost (\$/yr)									
		33,316	50,651	86,745	122,529	185,543	325,173	400,942	512,289
Unit Cost (\$/mt)									
		66.63	10.13	5.78	4.90	4.64	4.65	4.45	4.27

April 15, 1997

Exhibit D-11

Annual Storage Cost Assuming Quarterly Storage of Solids in Unlined Waste Piles with Groundwater Monitoring

Waste Pile - Free Liquids	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		500	5,000	15,000	25,000	40,000	70,000	90,000	120,000
Waste Quantities (mt/qr)		125	1,250	3,750	6,250	10,000	17,500	22,500	30,000
Waste Quantity (ft3/qr)		3,242	32,421	97,262	162,103	259,365	453,888	583,571	778,094
Waste Quantity (yd3/qr)		120	1,201	3,602	6,004	9,606	16,811	21,614	28,818
Unit Construction									
Unit size (ft2)		3,218	9,825	17,987	24,118	31,772	44,394	51,693	61,619
Annualized Land (\$/yr)	\$2500/acre	17	53	97	131	172	240	280	334
Unit base (compacted soil)	\$0.2325/ft3	71	216	395	529	697	974	1,134	1,352
Groundwater Monitoring									
Number of Downgradient Wells		3	3	3	3	3	3	3	3
Annualized Capital Cost		6,722	6,722	6,722	6,722	6,722	6,722	6,722	6,722
Annual O & M Cost		7,290	7,290	7,290	7,290	7,290	7,290	7,290	7,290
Dump Truck									
Number of trips - quarter		12	112	332	552	882	1,544	1,986	2,646
Number of trips - annual		48	448	1,328	2,208	3,528	6,176	7,944	10,584
Number of hours - annual		24	224	664	1,104	1,764	3,088	3,972	5,292
Number of Original Trucks Needed		1	1	1	1	1	2	2	2
Lifetime of Truck(s)		20	20	20	20	15	17	13	10
Total Number of Trucks Needed		1	1	1	1	2	4	4	4
Annualized Purchase cost	\$275,000	25,957	25,957	25,957	25,957	35,533	68,529	73,324	78,617
Annualized Labor Cost	\$22.80/hr	547	5,107	15,139	25,171	40,219	70,406	90,562	120,658
Ann. Fuel and Maintenance Cost	\$18.85/hr	452	4,222	12,518	20,810	33,251	58,209	74,872	99,754
Front End Loader									
Number of Hours (annual)		3.20	32.02	96.06	160.10	256.16	448.28	576.37	768.49
Number of Days (annual)		4	8	16	24	36	60	76	100
Annual Rental	\$1,400/day	5,600	11,200	22,400	33,600	50,400	84,000	106,400	140,000
Annual Labor Cost	\$26.90/hr	86	861	2,584	4,307	6,891	12,059	15,504	20,872
Ann. Fuel and Maintenance Cost	\$56.15/hr	180	1,798	5,394	8,990	14,384	25,171	32,363	43,151
Total Annual Cost (\$/yr)		46,923	63,427	98,495	133,508	195,560	333,601	408,452	518,551
Unit Cost (\$/mt)		93.85	12.69	6.57	5.34	4.89	4.77	4.54	4.32

April 15, 1997

Storage of Solid Materials in Unlined, Unmonitored Waste Piles

The costs of storing materials in unlined, unmonitored waste piles are similar to the costs of storing wastes in lined piles. The notable exception is the cost of the liner and liner protection. These costs are listed in Exhibit D-12. In addition, EPA developed the costs of just the operation and maintenance costs of storing materials in unlined, unmonitored units for baseline-option combinations that induce a change of storage units from land based to non-land based units (i.e., storing sludges in the prior treatment baseline and in RCRA containment buildings in Option 1). The O & M costs of storing materials in unlined, unmonitored piles are shown in Exhibit D-13.

D.5 Storage of Liquid Materials

Storage of Liquid Materials in Drums or Mobile Mini-Bulk Tanks

Low volumes of liquid materials can be stored in either drums or mobile mini-bulk containers, which are small tanks that are designed to be moved by a pallet truck. The costs associated with storing liquid materials in drums are calculated in same manner as storing solid materials in drums, with the following exceptions:

- Liquid materials are stored for 30 days, while solid materials are stored for 90 days. Therefore, fewer drums are required;
- Because liquid materials are often corrosive, polyethylene drums and mini-bulk containers are used;
- The density of liquid materials is the same as water (62.4 lb/ft³);
- The capital cost of a 55-gallon polyethylene drum is \$127 (from Non-RCRA Tanks, Containers, and Building, December 1996, p. 17. This price includes \$2 per drum for freight);
- The capital cost of a 220-gallon polyethylene mini-bulk tank is \$285 (from Non-RCRA Tanks, Containers, and Building, December 1996, Appendix D); and
- A laborer could move mini-bulks from point of generation to the storage area (or back from the storage area to the point of reentry) using a pallet truck at a rate of 4 tanks per hour;

The costs of storing liquid materials in drums and mobile mini-bulk tanks are shown in Exhibit D-14.

Exhibit D-12

Annual Storage Cost Assuming Quarterly Storage of Solids in Unlined, Unmonitored Waste Piles

Waste Pile - Free Liquids	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (ml/yr)		500	5,000	15,000	25,000	40,000	70,000	90,000	120,000
Waste Quantities (ml/qtr)		125	1,250	3,750	6,250	10,000	17,500	22,500	30,000
Waste Quantity (ft3/qtr)		3,242	32,421	97,262	162,103	259,365	453,888	583,571	778,094
Waste Quantity (yd3/qtr)		120	1,201	3,602	6,004	9,606	16,811	21,614	28,818
Unit Construction									
Unit size (ft2)		3,218	9,825	17,987	24,118	31,772	44,394	51,693	61,619
Annualized Land (\$/yr)	\$2500/acre	17	53	97	131	172	240	280	334
Unit base (compacted soil)	\$0.2325/ft3	71	216	395	529	697	974	1,134	1,352
Dump Truck									
Number of trips - quarter		12	112	332	552	882	1,544	1,986	2,646
Number of trips - annual		48	448	1,328	2,208	3,528	6,176	7,944	10,584
Number of hours - annual		24	224	664	1,104	1,764	3,088	3,972	5,292
Number of Original Trucks Needed		1	1	1	1	1	2	2	2
Lifetime of Truck(s)		20	20	20	20	15	17	13	10
Total Number of Trucks Needed		1	1	1	1	2	4	4	4
Annualized Purchase cost	\$275,000	25,957	25,957	25,957	25,957	35,533	68,529	73,324	78,617
Annualized Labor Cost	\$22.80/hr	547	5,107	15,139	25,171	40,219	70,406	90,562	120,658
Ann. Fuel and Maintenance Cost	\$18.85/hr	452	4,222	12,516	20,810	33,251	58,209	74,872	99,754
Front End Loader									
Number of Hours (annual)		3.20	32.02	96.06	160.10	256.16	448.28	576.37	768.49
Number of Days (annual)		4	8	16	24	36	60	76	100
Annual Rental	\$1,400/day	5,600	11,200	22,400	33,600	50,400	84,000	106,400	140,000
Annual Labor Cost	\$26.90/hr	86	861	2,584	4,307	6,891	12,059	15,504	20,672
Ann. Fuel and Maintenance Cost	\$56.15/hr	180	1,798	5,394	8,990	14,384	25,171	32,363	43,151
Total Annual Cost (\$/yr)		32,911	49,415	84,483	119,495	181,547	319,589	394,439	504,538
Unit Cost (\$/mt)		65.82	9.88	5.63	4.78	4.54	4.57	4.38	4.20

April 15, 1997

Exhibit D-13

Annual Storage Cost (O & M only) Assuming Quarterly Storage of Solids in Unlined, Unmonitored Waste Piles

Waste Pile - Free Liquids	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		500	5,000	15,000	25,000	40,000	70,000	90,000	120,000
Waste Quantities (mt/qtr)		125	1,250	3,750	6,250	10,000	17,500	22,500	30,000
Waste Quantity (ft3/qtr)		3,242	32,421	97,262	162,103	259,365	453,888	583,571	778,094
Waste Quantity (yd3/qtr)		120	1,201	3,602	6,004	9,606	16,811	21,614	28,818
Unit Construction									
Unit size (ft2)		3,218	9,825	17,987	24,118	31,772	44,394	51,693	61,619
Annualized Land (\$/yr)	\$2500/acre								
Unit base (compacted soil)	\$0.2325/ft3								
Dump Truck									
Number of trips - quarter		12	112	332	552	882	1,544	1,986	2,646
Number of trips - annual		48	448	1,328	2,208	3,528	6,176	7,944	10,584
Number of hours - annual		24	224	664	1,104	1,764	3,088	3,972	5,292
Number of Original Trucks Needed		1	1	1	1	1	2	2	2
Lifetime of Truck(s)		20	20	20	20	15	17	13	10
Total Number of Trucks Needed		1	1	1	1	2	4	4	4
Annualized Purchase cost	\$275,000	25,957	25,957	25,957	25,957	35,533	68,529	73,324	78,617
Annualized Labor Cost	\$22.80/hr	547	5,107	15,139	25,171	40,219	70,406	90,562	120,658
Ann. Fuel and Maintenance Cost	\$18.85/hr	452	4,222	12,516	20,810	33,251	58,209	74,872	99,754
Front End Loader									
Number of Hours (annual)		3.20	32.02	96.06	160.10	256.16	448.28	576.37	768.49
Number of Days (annual)		4	8	16	24	36	60	76	100
Annual Rental	\$1,400/day	5,600	11,200	22,400	33,600	50,400	84,000	106,400	140,000
Annual Labor Cost	\$26.90/hr	86	861	2,584	4,307	6,891	12,059	15,504	20,672
Ann. Fuel and Maintenance Cost	\$56.15/hr	180	1,798	5,394	8,990	14,384	25,171	32,363	43,151
Total Annual Cost (\$/yr)									
		32,823	49,146	83,991	118,835	180,678	318,374	393,025	502,852
Unit Cost (\$/mt)									
		65.65	9.83	5.60	4.75	4.52	4.55	4.37	4.19

April 15, 1997

Exhibit D-14

Annual Storage Cost Assuming 30 Day Storage of Liquids in Drum and Mini-Bulks

Drum Storage Cost (liquids)	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		0.5	10	50	75	100	150	200	250
Waste Quantities (mt/mo)		0.042	0.833	4.167	6.250	8.333	12.500	16.667	20.833
Waste Quantity (gal/mo)		11.01	220.24	1101.20	1651.79	2202.39	3303.59	4404.78	5505.98
Purchase of Drums									
Number of Drums		1	5	0	0	0	0	0	0
Annualized Cost of Drums	\$127/drum	127.00	635.00	0.00	0.00	0.00	0.00	0.00	0.00
Number of 220-gallon Mini-bulks		0	0	6	8	11	16	21	26
Cost of Mini-bulk	\$285/tank	0.00	0.00	1881.00	2508.00	3448.50	5016.00	6583.50	8151.00
Annualized Capital Cost		11.99	59.94	177.55	236.73	325.50	473.46	621.42	769.37
Labor to Open/Close Drums									
Number of Hours per year		2	10	-	-	-	-	-	-
Annual Labor Cost	\$19/hr	38	190	-	-	-	-	-	-
Move Drums									
Ann. Handtruck Capital. Cost	\$209	19.73	19.73	0.00	0.00	0.00	0.00	0.00	0.00
Ann. Pallet Truck Cap. Cost	\$3020	0	0	285	285	285	285	285	285
Number of Hours - Annual		1	5	12	16	22	32	42	52
Annual Labor Cost	\$19/hr	19	95	228	304	418	608	798	988
Ann. Fuel and Maintenance Cost	\$1.5/hr	0	0	18	24	33	48	63	78
Total Annual Cost (\$/yr)		88.72	364.67	708.61	849.79	1061.56	1414.52	1767.47	2120.43
Unit Cost (\$/mt)		177.43	36.47	14.17	11.33	10.62	9.43	8.84	8.48

April 15, 1997

Storage of Liquid Materials in Tanks

The tank storage cost function includes the capital cost of the tanks, as well as piping to move the liquids from the point of generation to the storage area and then back to the point of re-entry. Liquid materials would be piped from the point of generation to storage tanks. When these materials are going to be reused they would be piped back through the same pipes to the point of re-entry, where they would be handled by the normal feed dispersing equipment.

The Agency made the following assumptions in assembling the tank storage cost function:

- Liquids are stored for a maximum of 30 days;
- The density of liquid materials is the same as water (62.4 lb/ft³);
- Tank capital and O & M costs were developed following the method used by DPRA for the "Organic Dyes and Pigments Waste Listings," 1995, and include the minimal plumbing associated with the tank only;
- For tanks with a capacity of or less than 25,000 gallons, the base capital cost was updated using the price of a single walled vertical tank (from Non-RCRA Tanks, Containers, and Building, December 1996, p. 22.)
- For tanks greater than 25,000 gallons EPA used the cost from the "Organic Dyes and Pigments Waste Listings document" (these costs were adjusted to use the correct discount rate and retention time);
- The distance from the point of generation to the storage tank, and from the storage tank back to the point of reentry are a function of the amount of material to be stored. Small volumes of liquid material to be stored do not require additional piping, while large volumes of material to be stored will need to be piped to storage areas further away;
- There is no cost associated with pumping the material to and from the tank; and
- Once the liquid has been returned to the point of reentry it will be handled by the normal processing equipment, and would not incur any further "storage" costs.

The costs of storing liquid materials in tanks are shown in Exhibit D-15.

Storage of Liquid Materials in RCRA Tanks

The RCRA storage tank cost function is similar to the regular storage tank cost functions, with the exception that the tank must have secondary containment, and be inspected daily. (See 40 CFR 264 Subpart J.) EPA assumed double walled tanks to meet the secondary containment requirement. EPA used the prices from Non-RCRA Tanks, Containers, and Building, December 1996, p. 22 for tanks with a capacity of 25,000 gallons or less, and vendor quotes for large field erected double walled tanks.

Exhibit D-15

Annual Storage Cost Assuming 30 Day Storage of Liquids in Tanks

Tank Storage Cost (Liquids)	Unit Cost	A	B	C	D	E	F
Waste Quantities (mt/yr)		45.4	227.0	1,135.1	22,702.6	90,810.4	181,620.7
Waste Quantity (gal/yr)		12,000	60,000	300,000	6,000,000	24,000,000	48,000,000
Waste Quantity (gal/mo)		1,000	5,000	25,000	500,000	2,000,000	4,000,000
Waste Flow rate (gal/day)		33	167	833	16,667	66,667	133,333
Purchase of Tanks							
Number of Tanks		1	1	1	1	1	1
Cap. Cost of Double Walled Tanks		1,246	3,466	9,405			
Freight and Installation		374	1,040	2,822			
Indirect Capital		518	1,442	3,912			
Annualized Cost of Tanks		202	561	1,523	9,318	23,897	40,604
Annual O & M		141	393	1,065	6,515	16,710	28,392
Piping							
Length of additional pipe (ft)		-	-	-	500	1,000	1,000
Piping - Annualized Capital		-	-	-	425	821	821
Piping - Annual O & M		-	-	-	1,000	1,000	1,000
Total Annual Cost (\$/yr)		343	954	2,589	17,258	42,428	70,817
Unit Cost (\$/mt)		7.55	4.20	2.28	0.76	0.47	0.39

April 15, 1997

EPA also assumed that it would take a skilled laborer (\$39.50/hr, from CKD Monofill Model Cost Documentation, 1995) a half hour per day to inspect a tank and file any necessary paperwork. The cost of storage in RCRA storage tanks are shown in Exhibit D-16.

Storage of Liquid Materials in Lined Surface Impoundments

The surface impoundment storage cost function includes the capital cost of land, site preparation, a liner, and piping of liquids to the surface impoundment. Liquid materials would be piped from the point of generation to the surface impoundment. When these materials are going to be reused they would be piped back through the same pipes to the point of reentry, where they would be handled by the normal feed equipment.

The Agency made the following assumptions in assembling the surface impoundment storage cost function:

- Liquid materials are stored for a maximum of 30 days;
- The density of liquid materials is the same as water (62.4 lb/ft³);
- The purchase cost of land is \$2500/acre (from CKD Monofill Model Cost Documentation, 1995);
- The cost of excavation is \$0.1077/ft³ (from CKD Monofill Model Cost Documentation, 1995); The cost of a 40 mil HDPE geomembrane liner is 0.5602/ft² (from CKD Monofill Model Cost Documentation, 1995);
- The area of the surface impoundment is calculated using the formulas described in section D.7;
- The distance from the point of generation to the surface impoundment, and from the surface impoundment back to the point of reentry, are a function of the amount of material to be stored, but the minimum distance is 500 feet. Larger quantities of material to be stored will need to be piped 1000 feet away;
- There is no cost associated with pumping the material to and from the surface impoundment; and
- Once the liquid has been returned to the point of reentry it will be handled by the normal processing equipment, and would not incur any further "storage" costs.

Exhibit D-16

Annual Storage Cost Assuming 30 Day Storage of Liquids in RCRA Tanks

Tank Storage Cost (Liquids)	Unit Cost	A	B	C	D	E	F	G
Waste Quantities (mt/yr)		45.4	227.0	1,135.1	5,221.6	21,340.4	52,261.4	184,390.4
Waste Quantity (gal/yr)		12,000	60,000	300,000	1,380,000	5,640,000	13,812,000	48,732,000
Waste Quantity (gal/mo)		1,000	5,000	25,000	115,000	470,000	1,151,000	4,061,000
Waste Flow rate (gal/day)		33	167	833	3,833	15,667	38,367	135,367
Purchase of Tanks								
Number of Tanks		1	1	1	1	1	1	1
Cap. Cost of Double Walled Tanks		1,619	6,164	17,417	110,000	200,000	350,000	900,000
Freight and Installation		486	1,849	5,225	33,000	60,000	105,000	270,000
Indirect Capital	32% of cap	674	2,564	7,245	45,760	83,200	145,600	374,400
Annualized Cost of Tanks		262	998	2,821	17,817	32,395	56,691	145,776
Annual O & M		183	698	1,973	12,458	22,651	39,640	101,930
Annual Inspection Cost (Labor)	\$39.5/hr	7,209	7,209	7,209	7,209	7,209	7,209	7,209
Piping								
Length of additional pipe (ft)		-	-	-	1,000	1,000	1,000	1,000
Piping - Annualized Capital		-	-	-	821	821	821	821
Piping - Annual O & M		-	-	-	1,000	1,000	1,000	1,000
Total Annual Cost (\$/yr)		446	1,697	4,794	32,096	56,867	98,151	249,528
Unit Cost (\$/mt)		9.81	7.47	4.22	6.15	2.66	1.88	1.35

April 15, 1997

The costs of storing liquid materials in lined surface impoundments are shown in Exhibit D-17.

Storage of Liquid Materials in Unlined Surface Impoundments with Groundwater Monitoring

The costs of storing materials in unlined surface impoundments are very similar to the costs of storing materials in lined surface impoundments, with two notable exceptions: The cost of the liner is not used, and costs of groundwater monitoring have been added. (The development of groundwater monitoring costs are described later in this Appendix.) One of the stipulations of using these units is that if monitoring reveals contamination, the facility is responsible for the costs of corrective action. However, even without adding the potential costs of corrective action, these costs of regular monitoring are higher than the costs of liners. Therefore, EPA considered this option to be economically inferior to storage in surface impoundments with liners, and did not attempt to add corrective action costs to the costs shown in Exhibit D-18.

Storage of Liquid Materials in Unlined, Unmonitored Surface Impoundments

The costs of storing materials in unlined, unmonitored surface impoundments are similar to the costs of storing wastes in lined surface impoundments. The notable exception is the cost of the liner. The costs of storing liquid materials in unlined surface impoundments without groundwater monitoring are shown in Exhibit D-19. In addition, EPA developed the costs of just the operation and maintenance costs of storing materials in unlined, unmonitored units for baseline-option combinations that induce a change of storage units from land based to non-land based units (i.e., storing by-products in the prior treatment baseline and in RCRA tanks in Option 1). The O & M costs of storing materials in unlined, unmonitored surface impoundments are shown in Exhibit D-20.

D.6 Curve Fit Cost Functions

The Agency plotted and curve fit each set of cost results (from Exhibits D-4, and D-6 through D-20) to transform the costs into cost functions. Exhibit D-21 presents these curve fit storage and disposal cost functions, along with the range for which these cost equations are valid. EPA determined the break-even points between the relevant storage methods for each Baseline or Option. Exhibit D-21 also presents the optimum management ranges allowed under each baseline and option. Cells in this exhibit which have been blacked out under a particular option or baseline are unallowable management methods. Finally, Exhibits D-22 through D-38 present graphs of the individual cost for our sample waste generation rates along with the resulting curve fit cost functions.

Exhibit D-17

Annual Storage Cost Assuming Quarterly Storage of Solids in Unlined, Unmonitored Waste Piles

Waste Quantities (mt/yr)		500	5,000	25,000	50,000	100,000	200,000	1,000,000	2,000,000
Waste Quantities (mt/mo)		42	417	2,083	4,167	8,333	16,667	83,333	166,667
Waste Quantity (ft3/mo)		1,472	14,721	73,604	147,209	294,418	588,835	2,944,177	5,888,355
Waste Quantity (gal/mo)		11,012	110,120	550,598	1,101,196	2,202,392	4,404,784	22,023,919	44,047,837
Waste Quantity (gal/day)		367	3,671	18,353	36,707	73,413	146,826	734,131	1,468,261
Unit Construction									
Unit size (ft2)		4,061	6,410	15,688	26,478	47,192	87,314	395,890	774,557
Unit size (acres)		0.09	0.15	0.36	0.61	1.08	2.00	9.09	17.78
Annualized Land (\$/yr)	\$2500/acre	22	35	85	143	256	473	2,145	4,196
Annualized Excavation	\$0.17077/ft3	24	237	1,186	2,373	4,746	9,491	47,457	94,914
Ann. Liner (40 mil geomembrane)	\$0.5602/ft2	215	339	830	1,400	2,495	4,617	20,934	40,956
Material Handling									
Distance to Unit (ft)		500	500	500	500	1,000	1,000	1,000	1,000
Piping - annualized capital		425	425	425	425	821	904	1,120	1,390
Piping - annual O & M		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total Annual Cost (\$/yr)		1,685	2,036	3,526	5,341	9,318	16,485	72,655	142,457
Unit Cost (\$/mt)		3.37	0.41	0.14	0.11	0.09	0.08	0.07	0.07

April 15, 1997

Exhibit D-18

Annual Storage Cost Assuming 30 Day Storage of Liquids in Unlined Surface Impoundments with Groundwater Monitoring

Surface Impoundment	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		500	5,000	25,000	50,000	100,000	500,000	1,000,000	2,000,000
Waste Quantities (mt/mo)		42	417	2,083	4,167	8,333	41,667	83,333	166,667
Waste Quantity (ft3/mo)		1,472	14,721	73,604	147,209	294,418	1,472,089	2,944,177	5,888,355
Waste Quantity (gal/mo)		11,012	110,120	550,598	1,101,196	2,202,392	11,011,959	22,023,919	44,047,837
Waste Quantity (gal/day)		367	3,671	18,353	36,707	73,413	367,065	734,131	1,468,261
Unit Construction									
Unit size (ft2)		4,061	6,410	15,688	26,478	47,192	204,364	395,890	774,557
Unit size (acres)		0.09	0.15	0.36	0.61	1.08	4.69	9.09	17.78
Annualized Land (\$/yr)	\$2500/acre	22	35	85	143	256	1,107	2,145	4,196
Annualized Excavation	\$0.17077/ft3	24	237	1,186	2,373	4,746	23,729	47,457	94,914
Groundwater Monitoring									
Number of Downgradient Wells		3	3	3	3	4	7	10	13
Annualized Capital Cost		6,722	6,722	6,722	6,722	7,840	11,193	14,545	17,898
Annual O & M Cost		7,290	7,290	7,290	7,290	8,760	13,170	17,580	21,990
Material Handling									
Distance to Unit (ft)		500	500	500	500	1,000	1,000	1,000	1,000
Piping - annualized capital		425	425	425	425	821	985	1,120	1,390
Piping - annual O & M		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total Annual Cost (\$/yr)		15,483	15,709	16,709	17,954	23,423	51,183	83,847	141,388
Unit Cost (\$/mt)		30.97	3.14	0.67	0.36	0.23	0.10	0.08	0.07

April 15, 1997

Exhibit D-19

Annual Storage Cost Assuming 30 Day Storage of Liquids in Unlined, Unmonitored Surface Impoundments

Surface Impoundment	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		500	5,000	25,000	50,000	100,000	500,000	1,000,000	2,000,000
Waste Quantities (mt/mo)		42	417	2,083	4,167	8,333	41,667	83,333	166,667
Waste Quantity (ft3/mo)		1,472	14,721	73,604	147,209	294,418	1,472,089	2,944,177	5,888,355
Waste Quantity (gal/mo)		11,012	110,120	550,598	1,101,196	2,202,392	11,011,959	22,023,919	44,047,837
Waste Quantity (gal/day)		367	3,671	18,353	36,707	73,413	367,065	734,131	1,468,261
Unit Construction									
Unit size (ft2)		4,061	6,410	15,688	26,478	47,192	204,364	395,890	774,557
Unit size (acres)		0.09	0.15	0.36	0.61	1.08	4.69	9.09	17.78
Annualized Land (\$/yr)	\$2500/acre	22	35	85	143	256	1,107	2,145	4,196
Annualized Excavation	\$0.17077/ft3	24	237	1,186	2,373	4,746	23,729	47,457	94,914
Material Handling									
Distance to Unit (ft)		500	500	500	500	1,000	1,000	1,000	1,000
Piping - annualized capital		425	425	425	425	821	985	1,120	1,390
Piping - annual O & M		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total Annual Cost (\$/yr)		1,470	1,697	2,696	3,941	6,823	26,820	51,722	101,500
Unit Cost (\$/mt)		2.94	0.34	0.11	0.08	0.07	0.05	0.05	0.05

Exhibit D-20

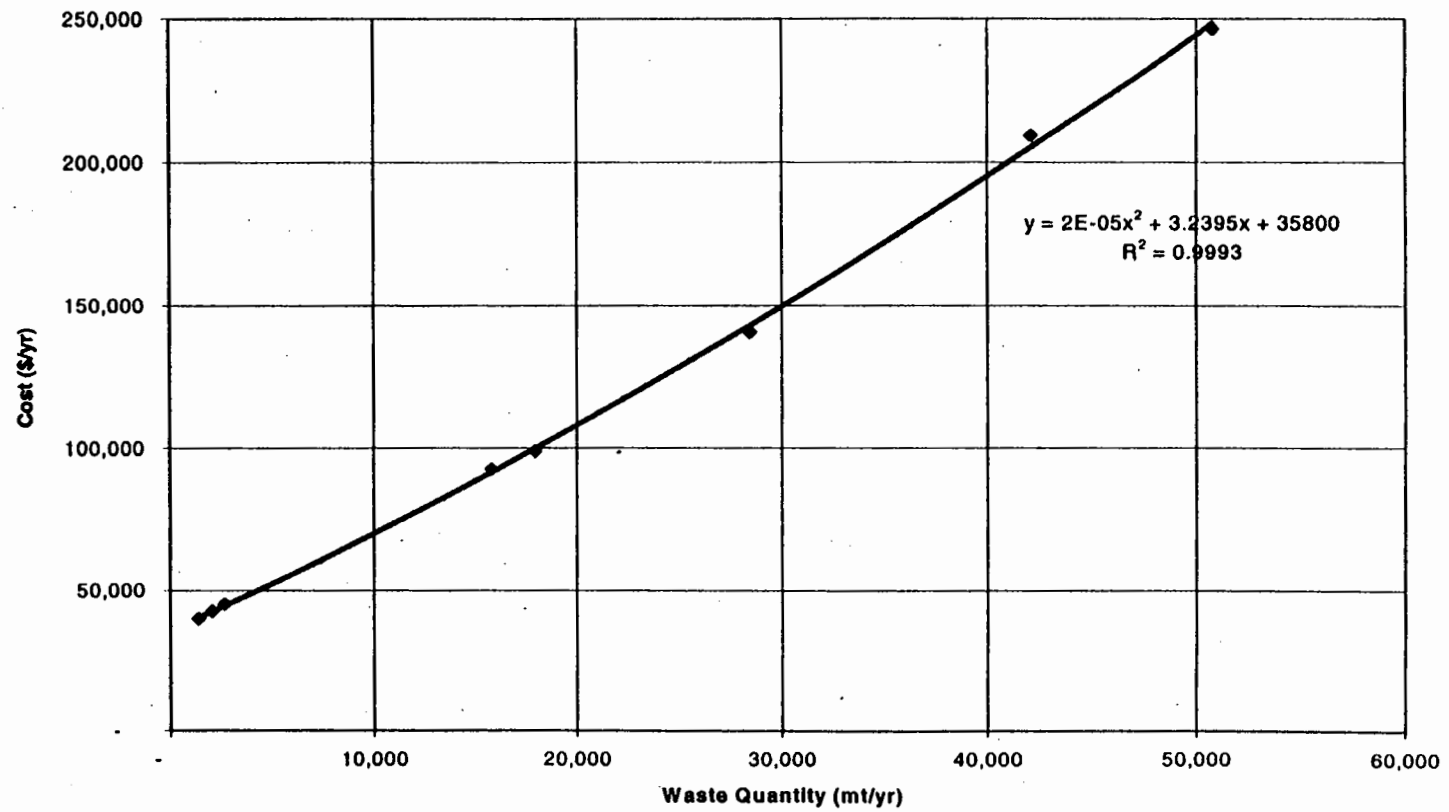
Annual Storage Cost (O & M only) Assuming 30 Day Storage of Liquids in Unlined, Unmonitored Waste Piles

Surface Impoundment	Unit Cost	A	B	C	D	E	F	G	H
Waste Quantities (mt/yr)		500	5,000	25,000	50,000	100,000	500,000	1,000,000	2,000,000
Waste Quantities (mt/mo)		42	417	2,083	4,167	8,333	41,667	83,333	166,667
Waste Quantity (ft3/mo)		1,472	14,721	73,604	147,209	294,418	1,472,089	2,944,177	5,888,355
Waste Quantity (gal/mo)		11,012	110,120	550,598	1,101,196	2,202,392	11,011,959	22,023,919	44,047,837
Waste Quantity (gal/day)		367	3,671	18,353	36,707	73,413	367,065	734,131	1,468,261
Unit Construction									
Unit size (ft2)		4,061	6,410	15,688	26,478	47,192	204,364	395,890	774,557
Unit size (acres)		0.09	0.15	0.36	0.61	1.08	4.69	9.09	17.78
Annualized Land (\$/yr)	\$2500/acre								
Annualized Excavation	\$0.17077/ft3								
Material Handling									
Distance to Unit (ft)		500	500	500	500	1,000	1,000	1,000	1,000
Piping - annualized capital									
Piping - annual O & M		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total Annual Cost (\$/yr)		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Unit Cost (\$/mt)		2.00	0.20	0.04	0.02	0.01	0.00	0.00	0.00

Exhibit D-21
Relevant Ranges of Use for Curve Fit Cost Functions

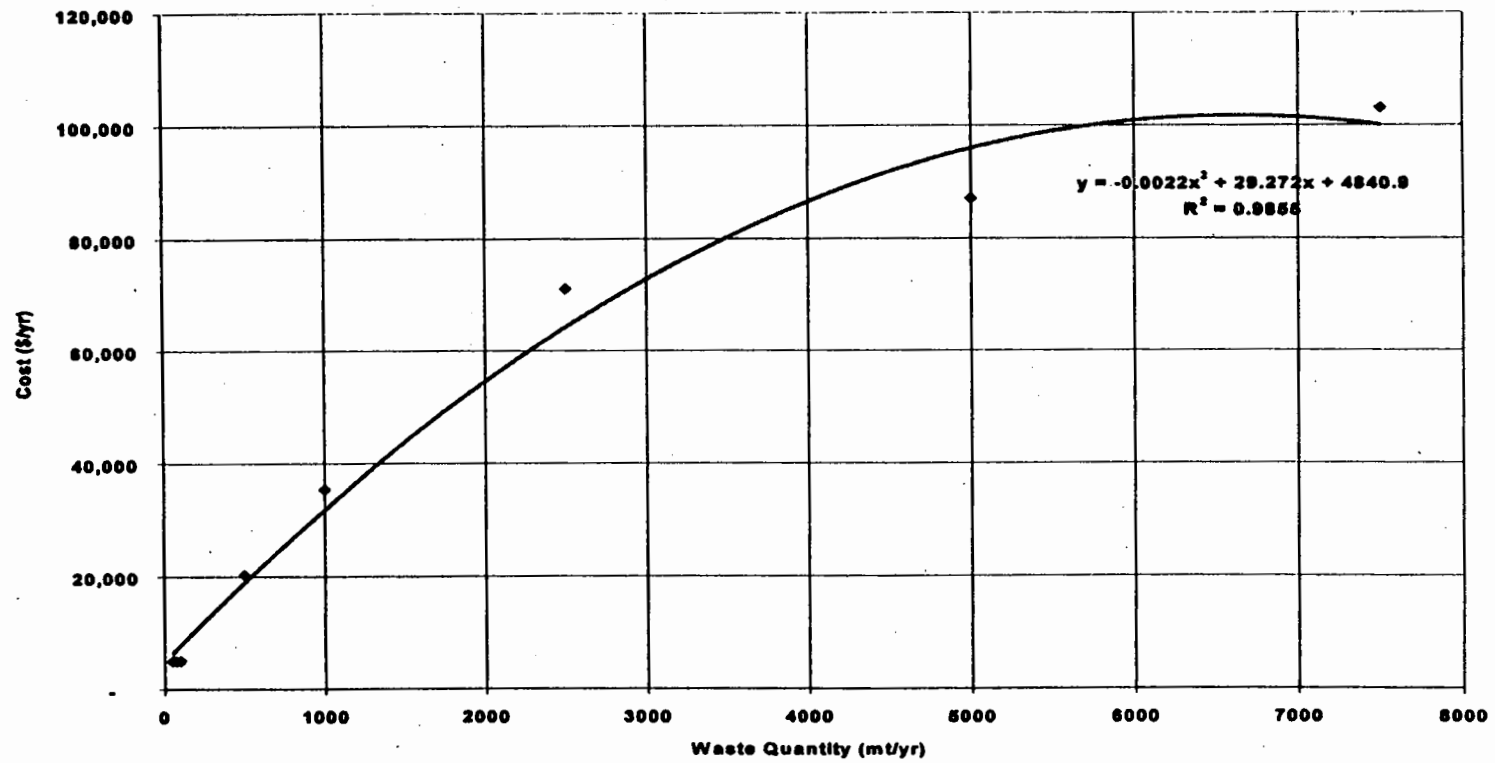
Solids	Equation	Range	NPT, MPT	PT SL/BP	PT SM	Opt. 1	Opt. 2	Opt. 3	Opt. 4
Drums - solid	$y = 24.589x + 132.23$	0.5 - 200	0 - 200	0 - 200	0 - 200	0 - 200	0 - 200	0 - 200	0 - 200
Roll-off	$y = -0.0022x^2 + 29.272x + 4840.9$	50-7500	200 - 935	200 - 935	200 - 1343.1	200-7500	200 - 1343.1	200 - 1343.1	200 - 935
Building	$y = 0.00002x^2 + 3.2395x + 35800$	1300 - 51000			1343.1 ++		1343.1 ++	1343.1 ++	
RCRA Building	$y = 23.399x + 121689$	120 - 45000				7500-45000			
Line Pile	$y = 4.0924x + 27676$	500 - 120,000				45000++	45000++	45000++	
Unlined Pile	$y = 4.0335x + 26522$	500 - 120,000	935 ++	935 ++					935 ++
Unlined Pile - O & M	$y = 4.0207x + 26271$	500 - 120,000	935 ++	935 ++					
Disposal Pile	$y = 1.8703x + 12308$	50 - 500000							
Liquids									
Drum	$y = -0.0074x^2 + 9.4798x + 189.34$	0.5 - 250	0-220	0-220	0-220	0-250	0-220	0-220	0-220
Tanks	$y = -9e-7x^2 + 0.55x + 1795.7$	45 - 200000	220-500	220-500	220++		220-1 million	220 - 1 million	220-500
RCRA Tanks	$y = -4e-6x^2 + 2.0665x + 6953.8$	45 - 200000				250 - 1 million			
Lined SI	$y = 0.0704x + 1955.1$	500 - 2000000				1 million ++	1 million ++	1 million ++	
Unlined SI	$y = 0.05x + 1565.9$	500 - 2000000	500++	500++					500++
Unlined SI (O & M)	$y = 1000$	500 - 2000000	500++	500++					500++
Disposal SI	$y = 0.025x + 1491.4$	500 - 2000000							

Exhibit D-22
Storage of Solids in Drums



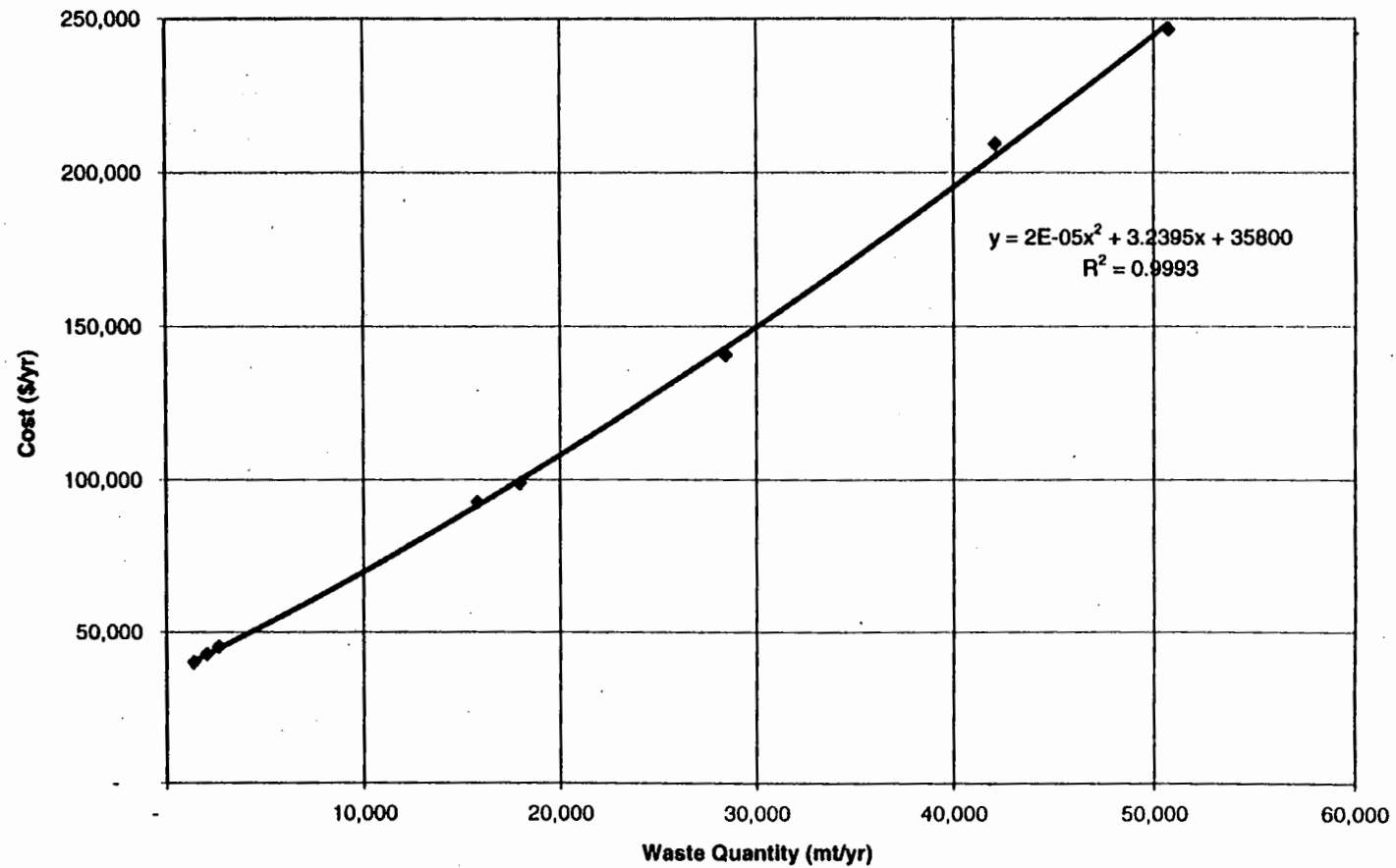
April 15, 1997

Exhibit D-23
Storage of Solids in Roll-off



April 15, 1997

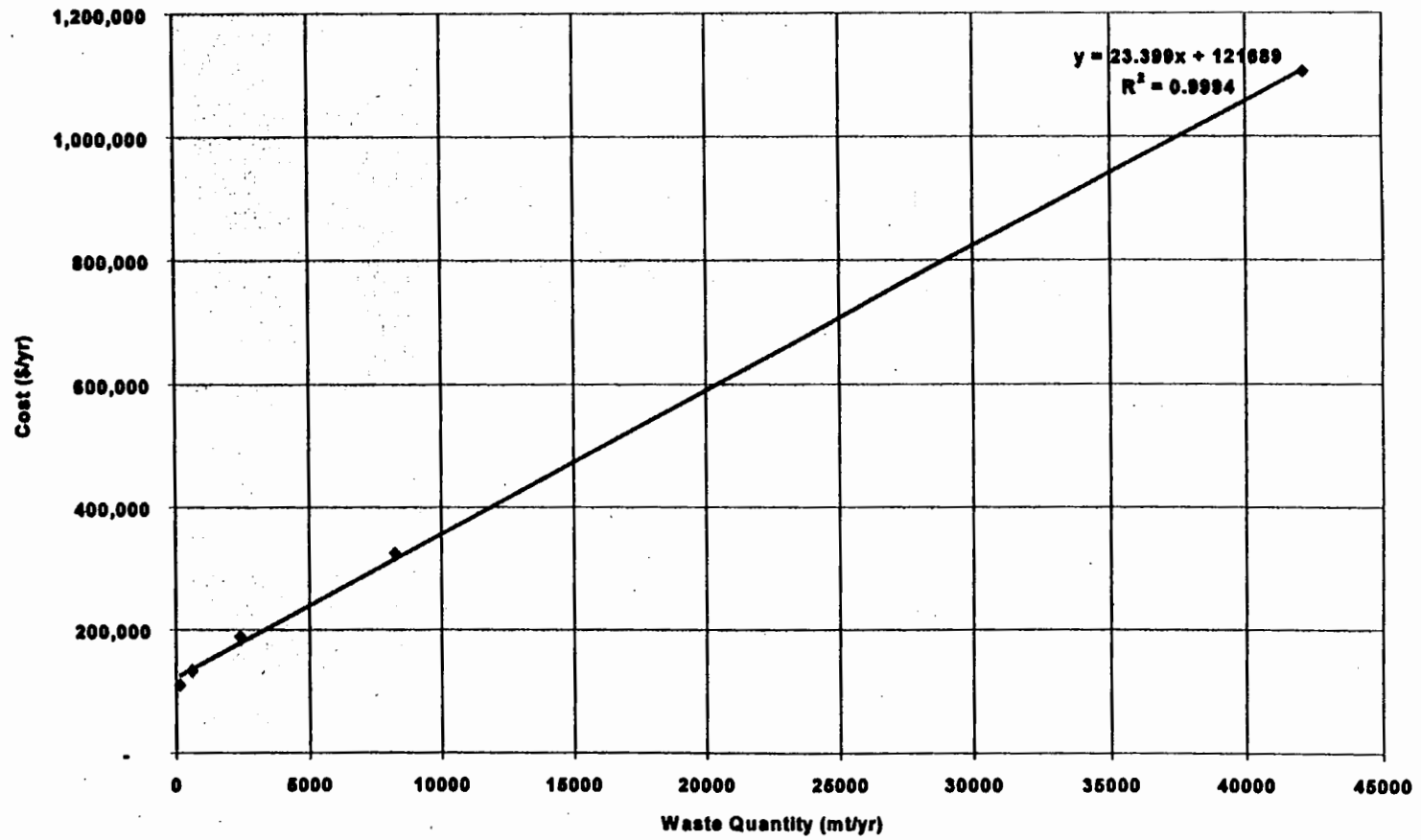
Exhibit D-24
Storage of Solids in Dome Buildings



April 15, 1997

Exhibit D-25

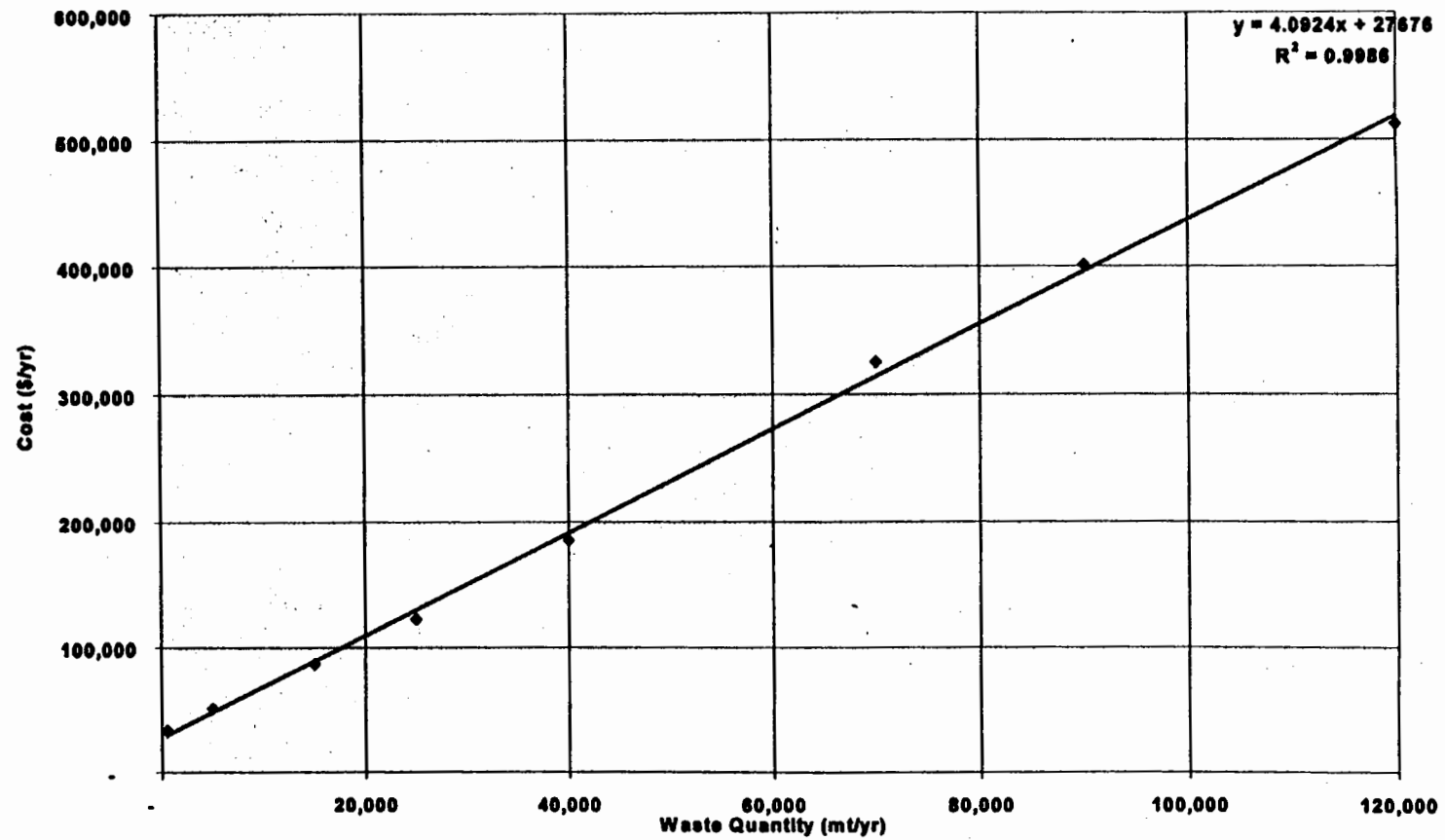
Storage of Solids in RCRA Containment Building



April 15, 1997

Exhibit D-26

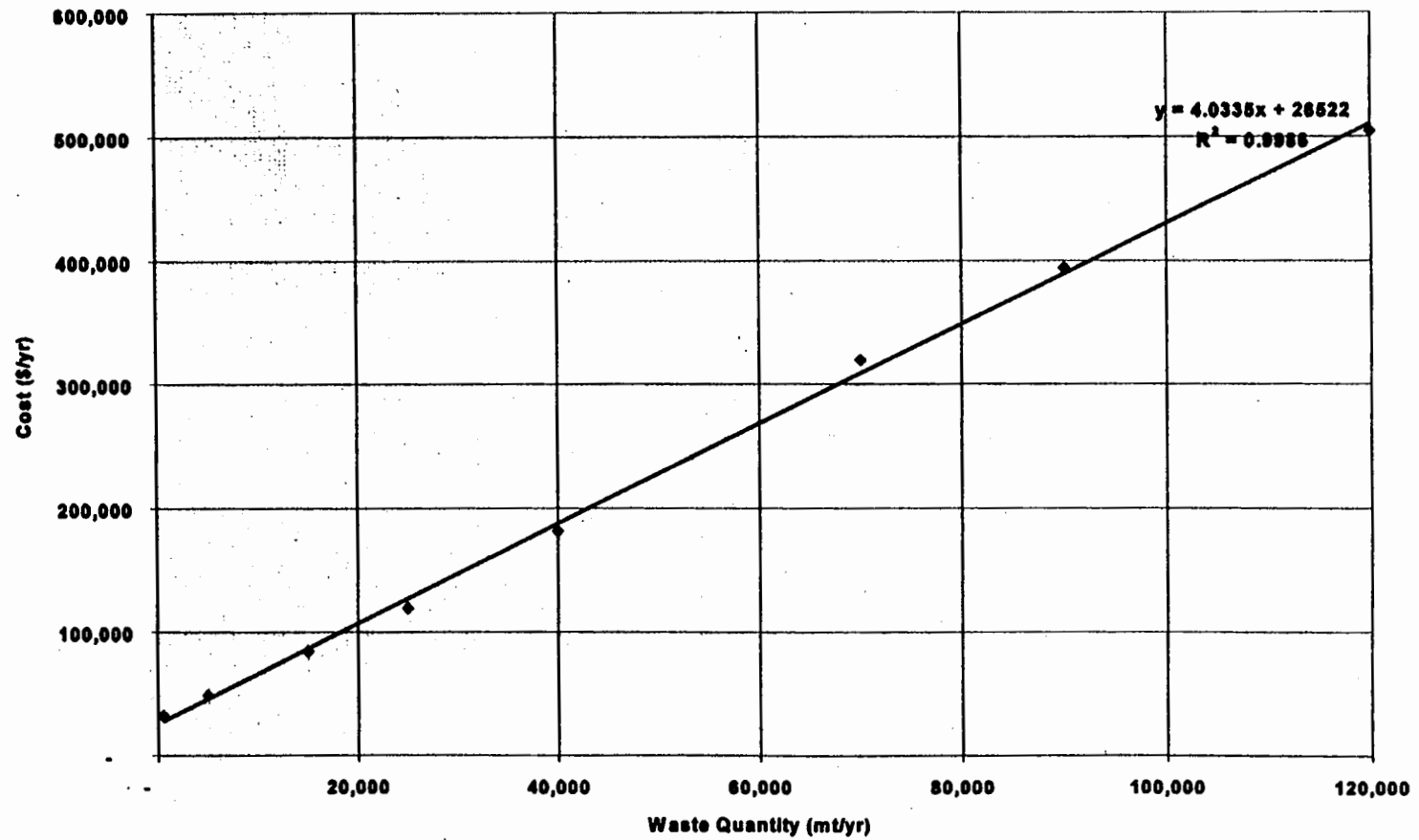
Storage Cost of Solids in Lined Piles



April 15, 1997

Exhibit D-27

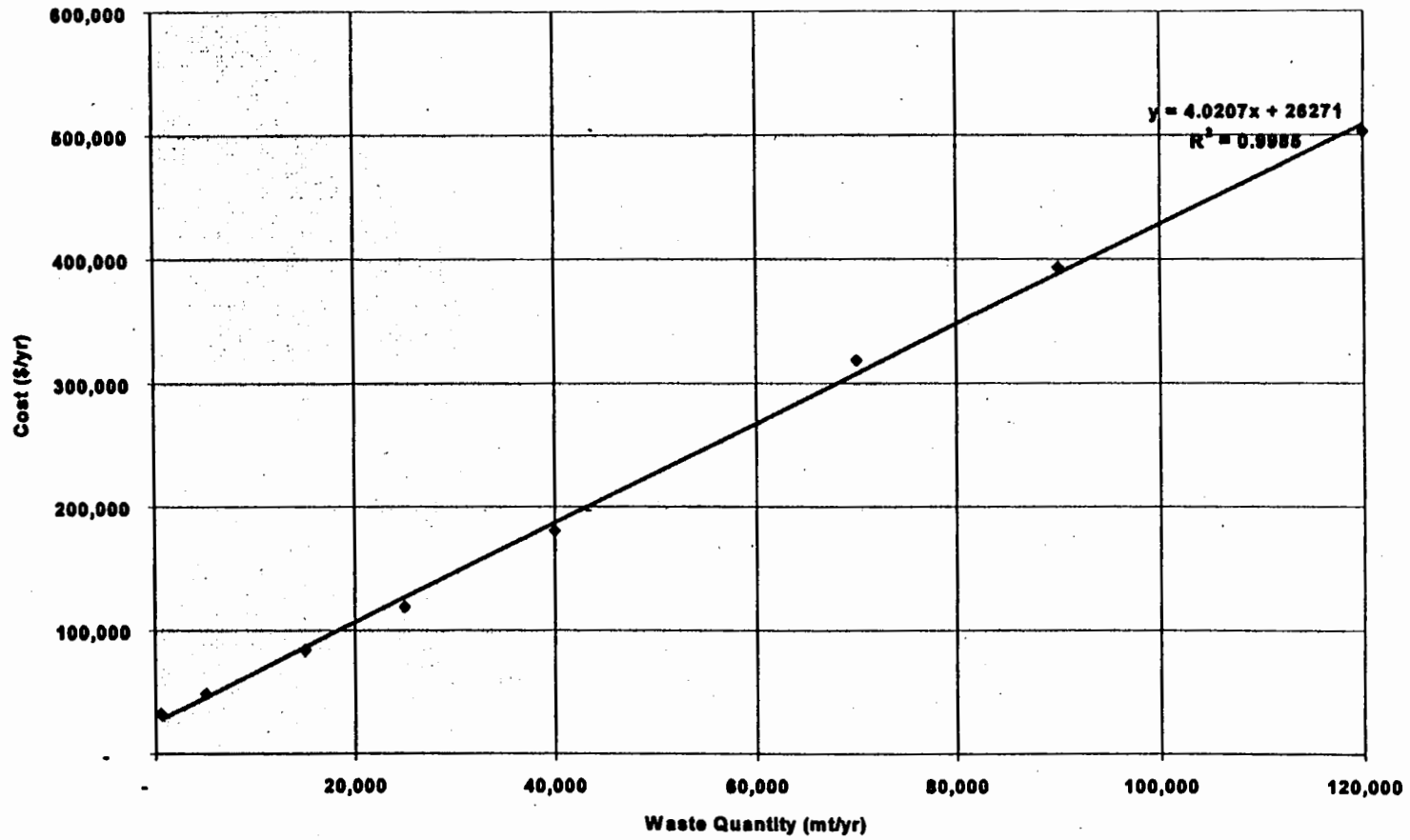
Storage of Solids in Unlined Piles



April 15, 1997

Exhibit D-28

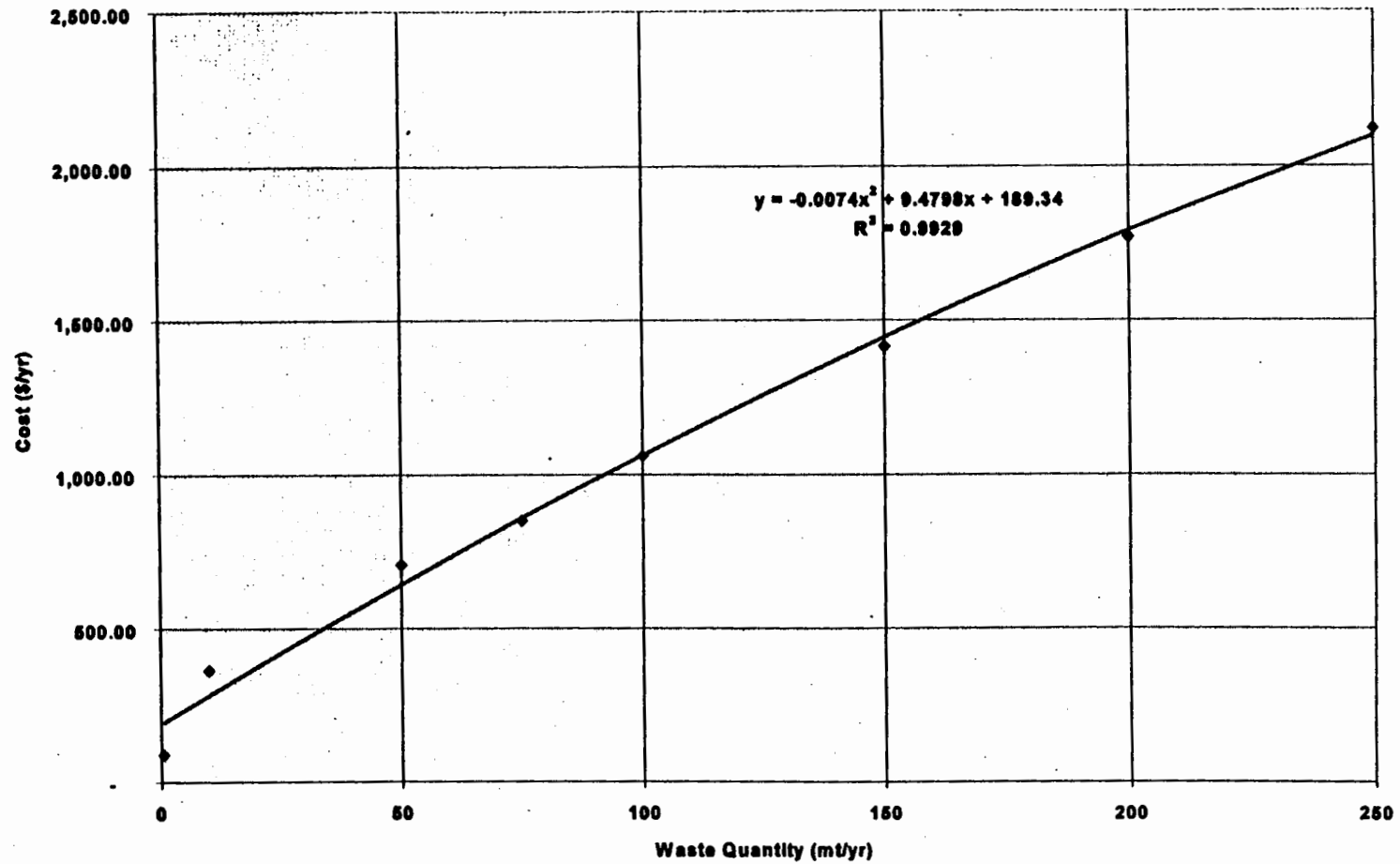
Storage of Solids in Unlined Pile (O & M only)



April 15, 1997

Exhibit D-29

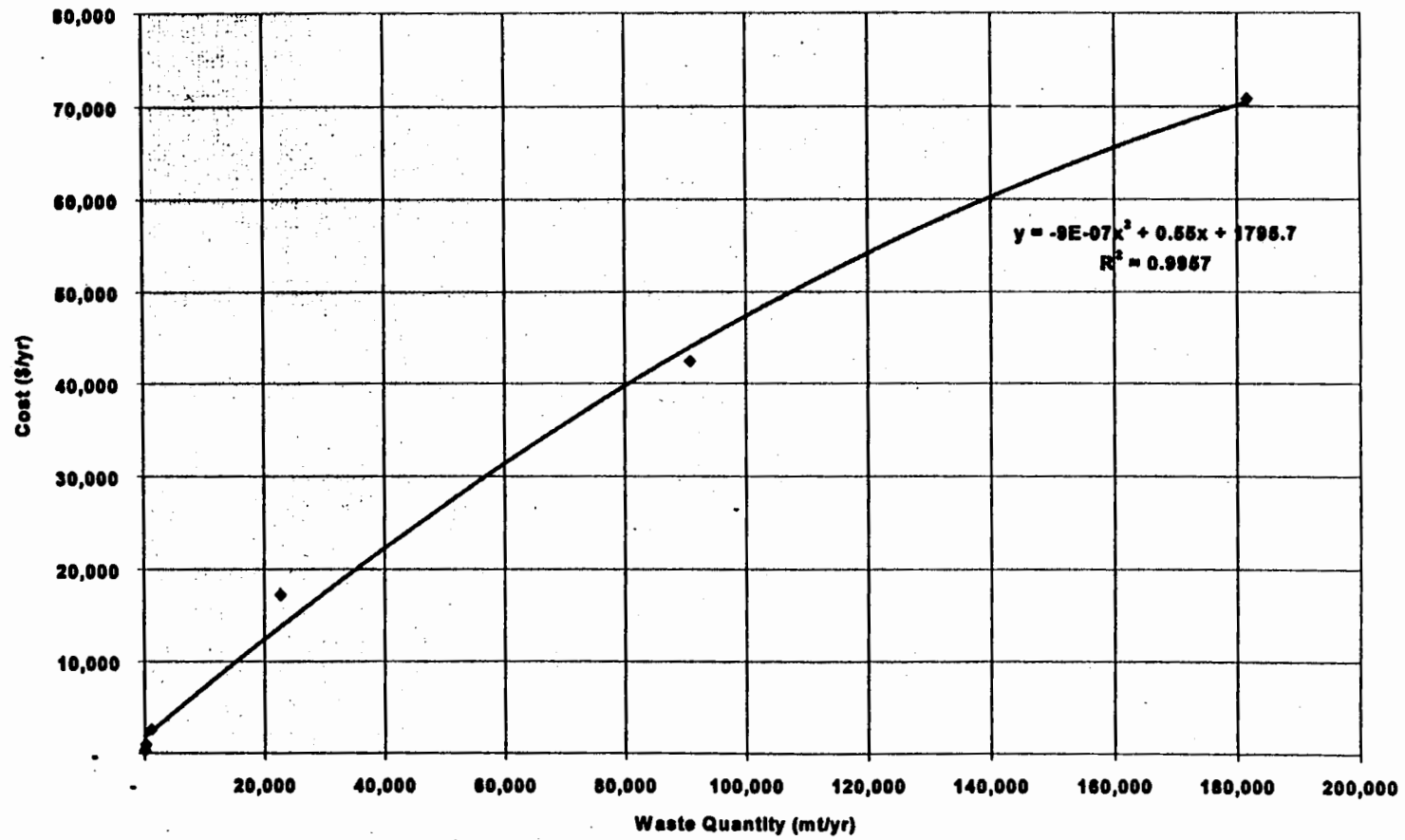
Storage of Liquids in Drums/Mini-Bulks



April 15, 1997

Exhibit D-30

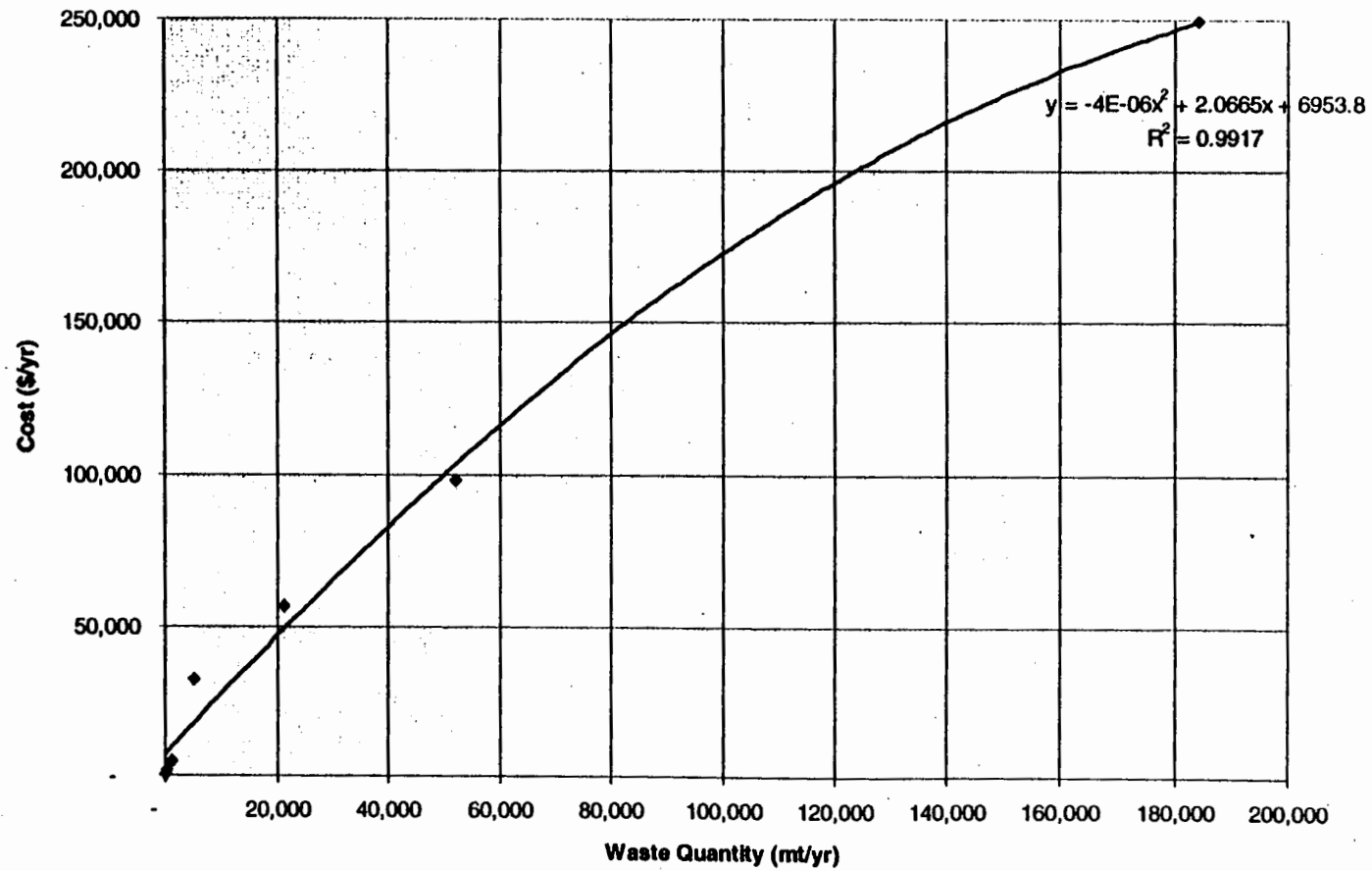
Storage in Tanks



April 15, 1997

Exhibit D-31

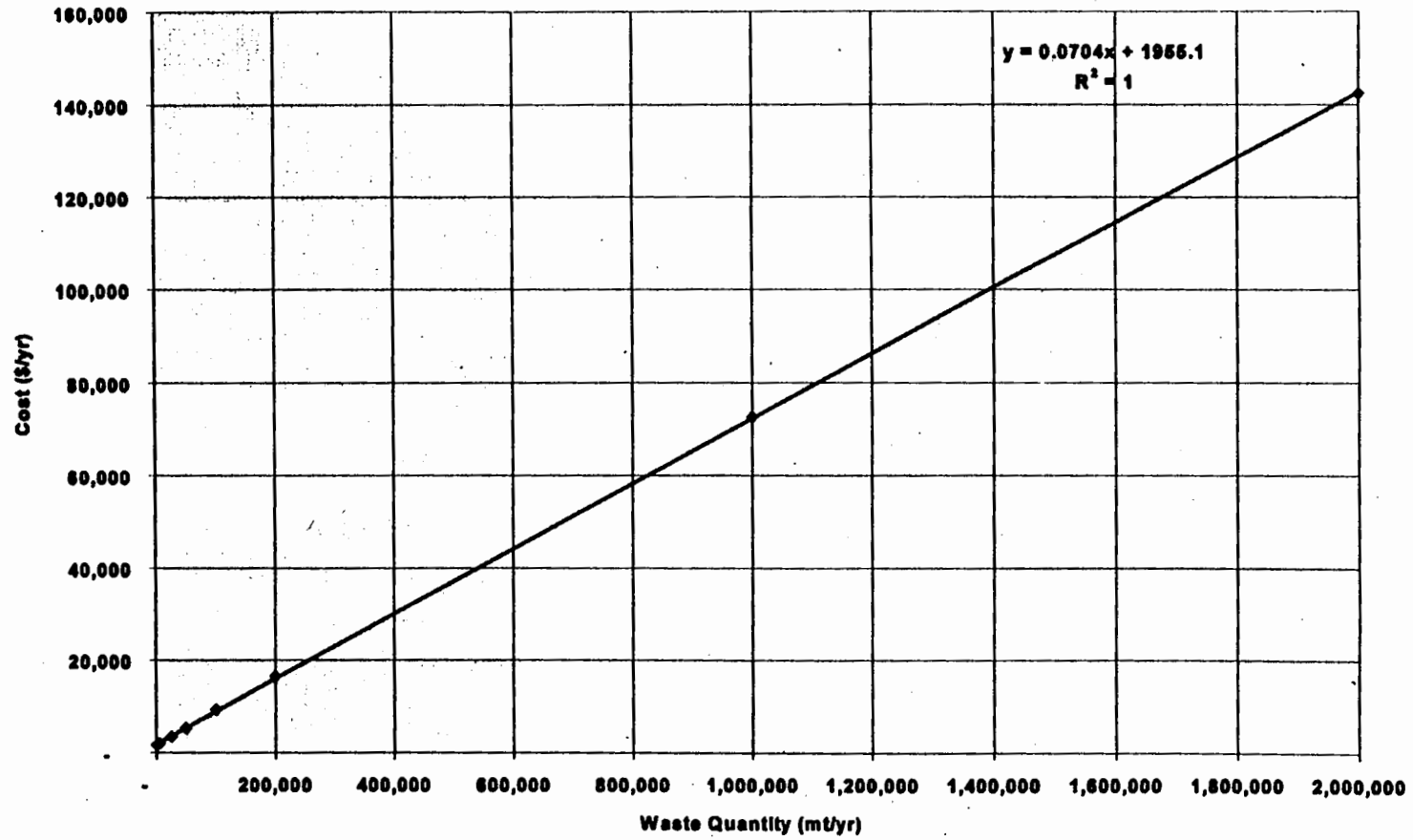
Storage of Liquids in RCRA Tanks



April 15, 1997

Exhibit D-32

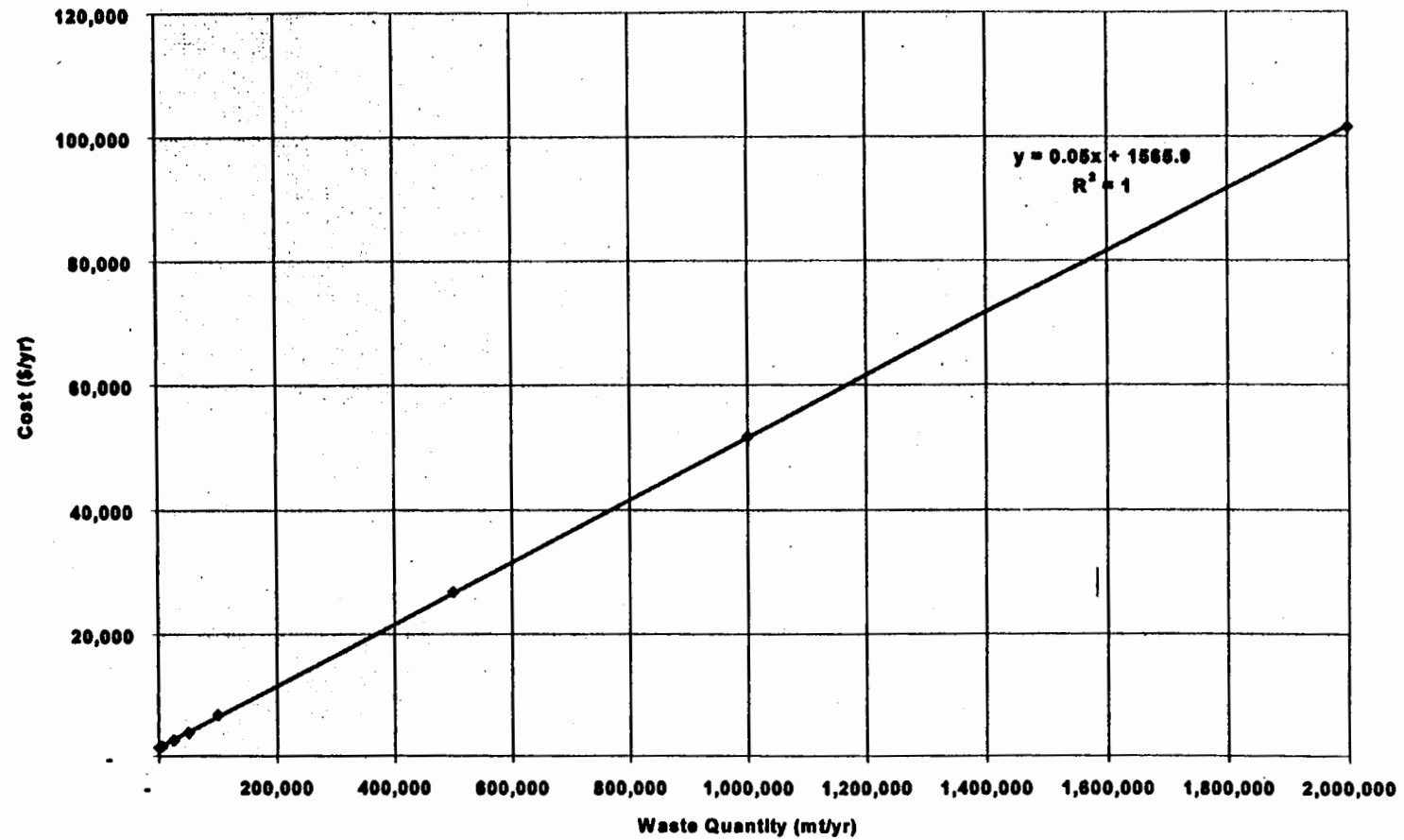
Storage of Liquids in Lined Impoundments



April 15, 1997

Exhibit D-33

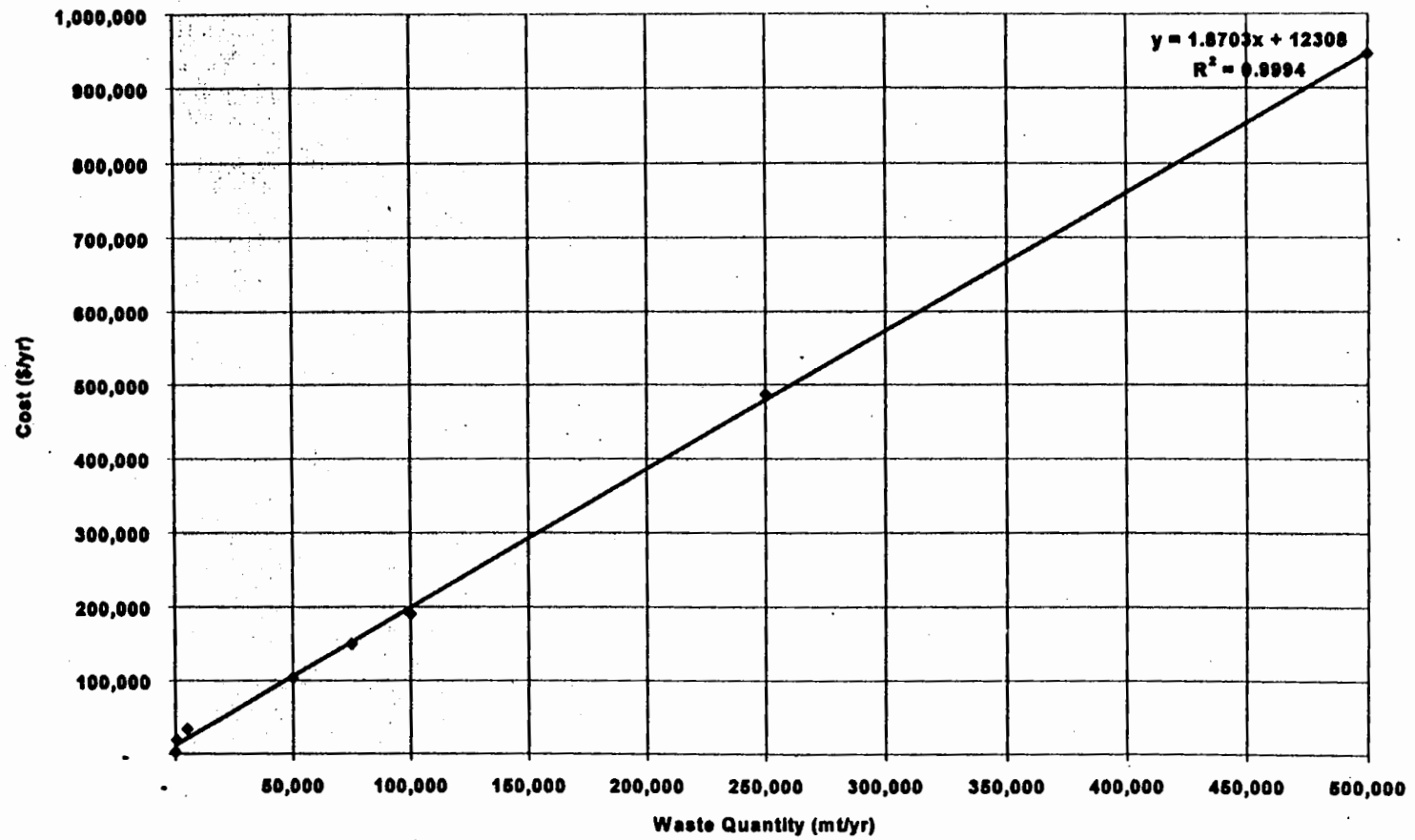
Storage of Liquids in Unlined Impoundments



April 15, 1997

Exhibit D-34

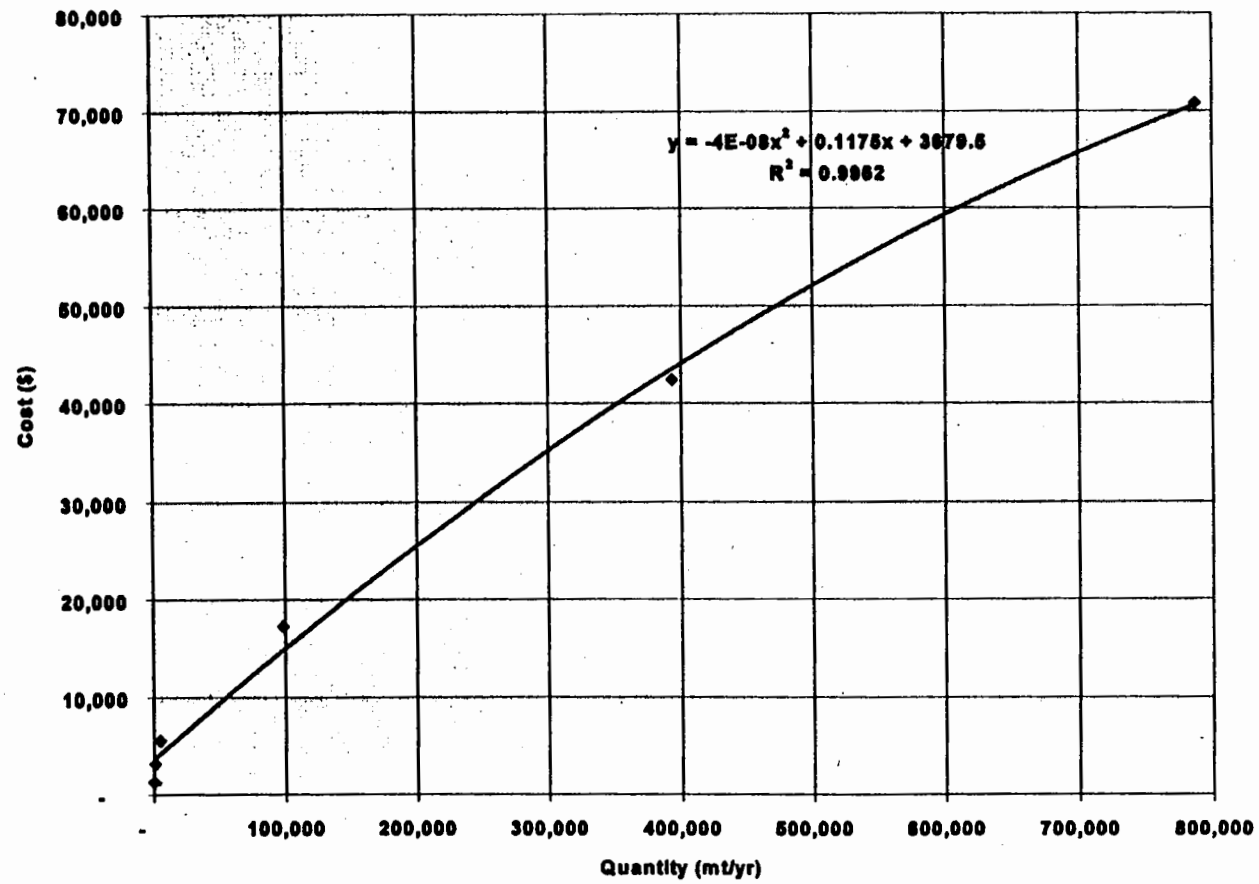
Disposal of Solids in Unlined Waste Pile



April 15, 1997

Exhibit D-35

7 day storage Tanks



April 15, 1997

D.7 Costs Associated with Groundwater Monitoring**Background and Requirements**

Several options allow for storage of high volume material in land based units prior to reclamation, if several conditions are met. One of these conditions includes a groundwater monitoring requirement if unlined piles or surface impoundments are being used. The minimum requirements for establishing a ground water monitoring program include:

At least three downgradient and one upgradient ground water monitoring wells,
6 test borings (4 of which are converted into the wells), and
Sampling to indicate if hazardous contaminants are migrating out of the unit.

The specific costs associated with groundwater monitoring include the following.

Capital and Initial Costs

Installation of wells:	\$5,600 / well (2 inch diameter, 50 feet deep)
Facility monitoring equipment:	\$5,500 / facility
Administrative time	\$15,360 / facility
- engineering study	
- soil borings	
- report preparation	
- sampling and analysis plan	
Establish Background Concentrations:	\$600 / facility
	\$6240 / well
Assess groundwater quality:	\$1,860 / facility
Report Results:	\$540 / facility
TOTAL FACILITY CAPITAL COST	\$11,840(N+1) + \$23,860

Operating and Annual Costs

Administrative Costs:	\$930 / facility
- Evaluate groundwater elevation	
- Report results	
Sampling and Analysis:	\$480 / facility
	\$1,470 / well
TOTAL FACILITY OPERATING COST	\$1,470(N+1) + \$1,410

where N is the number of groundwater monitoring wells.

While the minimum number of wells is four (three down gradient and one up gradient), the Agency assumed that more downgradient wells may be necessary for large units. The procedure for determining the number of downgradient wells (N) is presented below. If N is calculated to be less than three, N is assumed to be three.

Number of Ground Water Monitoring Wells for Waste Piles

The waste is assumed to be stored in a conical pile. The number of downgradient wells (N) will be half the perimeter (P) of the waste management area divided by 150 ft. The waste management area is a circle surrounding the waste pile, with a radius of 30 feet plus the radius of the actual pile. Therefore, there will be one well every 150 feet around the 10 foot downgradient buffer of the pile, or

$$N = \frac{P}{2 \times 150}$$

where

$$P = 2\pi(r+30)$$

where r can be determined from the volume of the pile (V)

$$V = \frac{\pi r^2 h}{3}$$

If we assume $h = r$, this formula becomes:

$$V = \frac{\pi r^3}{3}$$

Solving for r,

$$r = \sqrt[3]{\frac{3V}{\pi}}$$

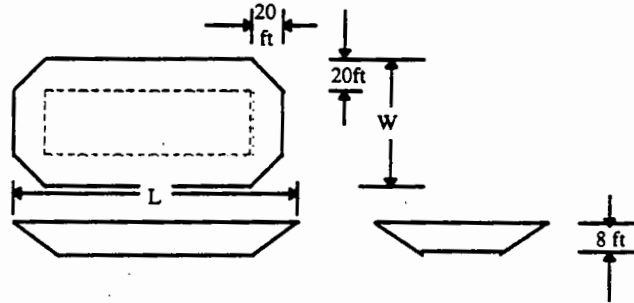
Therefore, the number of downgradient wells, by substitution is:

$$N = \frac{\pi \left(\sqrt[3]{\frac{3V}{\pi}} + 30 \right)}{150}$$

Where V is in ft³.

Number of Groundwater Monitoring Wells for Surface Impoundment

Shape of surface impoundment as follows:



The number of wells (N) will be the half of the perimeter (P) of the waste management area, divided by 150 feet. That is, one well every 150 feet on the downgradient half of the perimeter of the 10 foot buffer zone surrounding the unit.

$$N = \frac{P}{2 \times 150}$$

where

$$P = 2(L + 20) + 2(W + 20)$$

The length and width of the unit can be determined from the volume. The volume of the unit in cubic feet can be calculated by breaking the unit into the center rectangular (swimming pool shaped) section, the four triangular (prism) shaped sides, and the four corner sections, or

$$V = V_r + V_s + V_c$$

Assuming a depth of 8 ft, and a side slope of 2.5 horizontally for every vertical foot (resulting in the outside 20 feet of the unit being part of the triangular sides), the volume of the center section (V_r) is

$$V_r = (L - 40) \times (W - 40) \times 8$$

The volume of the sides is calculated:

$$V_s = \left(2 \times \frac{1}{2} \times 20 \times 8 \times (W - 40) \right) + \left(2 \times \frac{1}{2} \times 20 \times 8 \times (L - 40) \right)$$

Finally, the volume of the corners is calculated by putting all four corners together to form a four sided

pyramid, with diagonals of 40 ft. and sides of $20\sqrt{2}$. Therefore, V_c is:

$$V_c = \frac{20\sqrt{2} \times 20\sqrt{2} \times 8}{3}$$

Therefore,

$$V = (L-40) \times (W-40) \times 8 + \left(2 \times \frac{1}{2} \times 20 \times 8 \times (W-40) \right) + \left(2 \times \frac{1}{2} \times 20 \times 8 \times (L-40) \right) + \frac{20\sqrt{2} \times 20\sqrt{2} \times 8}{3}$$

By assuming $L = 2W$, this equation can be rewritten,

$$V = 16W^2 - 480W - 9387$$

Or, using the quadratic formula,

$$W = \frac{480 - \sqrt{(-480)^2 + 4(16)(9387 + V)}}{2(16)}$$

Therefore, substituting this back into the number of wells equation,

$$N = \frac{L+W+40}{150} = \frac{3W+40}{150} = \frac{\left[3 \times \left(\frac{480 - \sqrt{(-480)^2 + 4(16)(9387 + V)}}{2(16)} \right) \right] + 40}{150}$$

TYPE OF UNIT RECEIVING RECYCLED MATERIAL

APPENDIX E

Sector and Wastestream	Recycling Status	Bevill Special 20 Processing Unit/ Beneficiation Unit/ Processing Unit/ Both/Neither	Notes
<u>Alumina & Aluminum</u>			
Casthouse Dust	Y?	Process unit	Close to final unit
Electrolysis	Y?	Process unit	Appears to be mainly recycled to unit generating it
<u>Antimony</u>			
Autoclave Filtrate	Y?	Process unit	Water reuse (may require treatment)
Stripped Analytic Solids	Y	Process unit	Goes back to leach circuit (may be in-process material)
<u>Beryllium</u>			
Chip treatment wastewater	YS?	Process unit	Water reuse (may require treatment; generated at facilities without beneficiation Unit)
<u>Bismuth</u>			
Spent Caustic Soda	Y?	Process unit	Generated near end of processing, may require treatment
Electrolyte Slimes	Y?	Process unit	Recoverable products
Spent Soda Solution	Y?	Process unit	Generated new and of processing may require treatment
Waste Acids	YS?	Process Unit	Acid reuse, many parts of process used acid (may require treatment)
<u>Cadmium</u>			
Caustic Wastewater	Y?	Process Unit	Reuse for caustic value; may require treatment
Copper and land sulfate filter cakes	Y?	Process Unit	These would likely be sent to processing operations in copper and lead sectors for metal recovery
Copper removal filter cake	Y?	Process Unit	Would likely be sent to processing operations in copper and lead sectors for recovery
Spent leach solution	Y?	Both	Reuse for acid value, may require treatment
Lead sulfate waste	Y?	Process Unit	Would likely be sent to processing operations in lead sector
Scrubber wastewater	Y?	Both	Reuse for water/acid value, may require treatment
Zinc Precipitates	Y?	Process Unit	Would likely be sent to processing operations in zinc sector
<u>Calcium</u>			
Dust with quicklime	Y	Beneficiation Unit	Dust may be recycled to mixer and briquettes, prior to retorting

Sector and Wastestream	Recycling Status	Bevill Special 20 Processing Unit/ Beneficiation Unit/ Processing Unit/ Both/Neither	Notes
<u>Copper</u>			
Acid Plant Blowdown	YS	Both	Usually separated - liquids to beneficiation processes, solids to smelter (may be treated before separation)
WWTP Sludge	YS	Process unit	Appears to go to flush furnace or filter plant
<u>Coal Gas</u>			
MEE concentrate	YS	Process unit (gasifier)	Either recycled to gasifier or sent to incinerator
<u>Elemental Phosphorous</u>			
AFM Rinsate	Y	Both	Water is usually recycled in process after furnace, but sometimes to calcining unit (special waste unit)
Furnace Scrubber Blowdown	Y	Both	
Furnace Building Washdown	Y	Both	
<u>Fluorspar</u>			
Off-spec fluosilicic acid	YS	Off-site	Water fluoridation
<u>Germanium</u>			
Waste acid wash and rinse water	YS?	Process unit	Recycled for acid and/or water reuse within processing steps
Chlorinator wet air pollution control sludge	YS?	Process unit	Recycled to chlorinator for further removal of Ge
Spent acid/leachate	YS?	Process unit	Recycled to leaching unit for reuse as leaching agent to remove Ge from zinc sintering fumes
<u>Lead</u>			
Acid plant sludge	Y?	Beneficiation Unit	Recycled to sintering machine
Slurried APC dust	Y	Beneficiation Unit	Recycled to sintering machine (sinter feed preposition step)
Solid residues	Y?	Beneficiation Unit	Recycled to sintering machine
Spent furnace brick	Y	Bevill Proc. Unit	Recycled to blast furnace
Stockpiled miscellaneous plant waste	YS?	Bevill Proc. Unit	Recycled to blast furnace
WWTP liquid effluent	Y	Beneficiation Unit	Recycled to sintering machine
WWTP sludges/solids	Y	Beneficiation Unit	Recycled to sintering machine
<u>Magnesium</u>			
Cast House Dust	Y	Process unit	Close to final unit
Smut	N	Not recycled	Low grade Na/Ca/Mg sludge
<u>Mercury</u>			
Dust	N	Not recycled	Dust usually recycled for metal value - because of Hg low boiling point likely will not contain metal
Quench Water	Y?	Beneficiation Unit	Recycled to CIL circuit
<u>Molybdenum</u>			
Flue Dust/gases	N	Neither	No evidence that it could be recycled, text states it is not recycled and appendix says not recyclable
<u>Platinum Group Metals</u>			
Slag	Y?	Process Unit	Recycled to electric furnace

Sector and Wastestream	Recycling Status	Bevill Special 20 Processing Unit/ Beneficiation Unit/ Processing Unit/ Both/Neither	Notes
<u>Pyrobitumens, et al.</u> Waste catalysts	Y?	Process/Off-site	Either reused in cracking operation or sent off-site for reclamation
<u>Rare Earths</u> Electrolytic cell caustic wet APC sludge	Y	Process Unit	Aqueous streams can be used in numerous leaching, washing, and other operations
Process wastewater	YS?	Beneficiation Unit	
Spent scrubber liquor	YS?	Beneficiation Unit	
Solvent extraction crud	N	Not Recycled	
Wastewater from caustic cost APC	YS?	Beneficiation Unit	
<u>Rhenium</u> Spent barren scrubber liquor	Y?	Both	Water-reuse, both beneficiation, and Processing units on-site
<u>Scandium</u> Spent solvents from solvent extraction	Y?	Process Unit	Probably recycled directly to process (may require treatment) or sent off-site to solvent recovery
<u>Selenium</u> Spent filter cake	Y?	Process Unit	Recovery of other precious metals
Plant Process wastewater	YS?	Both	Water/acid reuse (may require treatment)
Slag	YS?	Process Unit	Copper Smelting
Tellurium slime wastes	Y?	Process Unit	Tellurium Recovery
<u>Synthetic Rutile</u> Spent Iron Oxide Slurry	YS?	Process Unit/off-site	Would be recycled for iron value, possibly at iron facilities
APC dust/sludge	Y	Process Unit	Recycled to process, pass roaster
Spent acid solution	Y	Process Unit	Recycled to digester
<u>Tellurium</u> Slag	YS?	Process Unit	May be returned to copper anode for further processing
Wastewater	Y	Process Unit	Sent to selenium recovery (which is processing operation)
<u>Titanium and TiO2</u> Pickle liquor washwater	YS?	Process Unit	Recycled to acid pickling step
Scrap milling scrubber water	YS?	Process Unit	Recycled to Ti scrap washing step after treatment to remove oil and grease and suspended solids
Smut from Mg recovery	Y	Process Unit	Recycled to reduction reactor in Knoll process
Leach liquor and sponge wash	YS?	Process Unit	Either reused after treatment as dust suppressant on needs, or recycled to acid leaching step
Spent furnace impoundment liquids	Y?	Process Unit	May be recycled to the finishing step in the chloride-ilmenite process

Sector and Wastestream	Recycling Status	Bevill Special 20 Processing Unit/ Beneficiation Unit/ Processing Unit/ Both/Neither	Notes
<u>Tantalum, Columbium, FeCb</u> Process Wastewater	Y?	Process Unit	Water Reuse - may require treatment - only processing on-site
<u>Tungsten</u> Spent acid and rinsewater	YS?	Both	Water and acid reuse - may require (to be getting) treatment - some facilities
Process wastewater	YS?	Both	Water reuse, see above
<u>Uranium</u> Waste nitric acid rinse from UOs prod	YS?	Process Unit	May require treatment, possible reuse in yellowcake and dissolution other acid uses
Slag	Y	Process Unit	Recycled to process
Uranium chips from ingot prod	Y?	Process Unit	May be recycled to reduction furnaces
<u>Zinc</u> Acid plant blowdown	Y	Process Unit	Recycled to hot tower
Waste ferrosilicon	Y?	Process Unit	Sold off-site
Process wastewater	Y?	Process Unit	Recycled to process units (e.g., casting)
Spent cloths, bags, and filters	Y	Neither/off-site	Bags/filters recycled to manufacturer
Spent goethite and leach cake residues	N	Process Unit	Not recycled in our opinion
Spent surface impoundment liquids	YS?	Process Unit	To various process units
WWTP solids	YS	Bevill process	Recycled to zinc ore roaster
TCA tower blowdown	YS	Process Unit	Recycled to zinc acid plant
WWTP liquid effluent	YS?	Process Unit	To various process units
<u>Zirconium and Hafnium</u> Leaching rinsewater from Zr alloy prod.	YS?	Process Unit	Water reuse
Leaching rinsewater from Zr metal prod.	YS?	Process Unit	Water reuse

This appendix describes the cost modeling assumptions and procedure used by EPA in developing cost estimates supporting the proposed RCRA Phase IV Land Disposal Restrictions (LDR) cost and economic impact analyses for mineral processing wastes. In general, the cost modeling was performed by manipulating the input data to determine portions of material sent to treatment and disposal, as well as storage prior to recycling. These portions of material were then used to determine the average facility and total sector costs associated with treatment and disposal, and storage prior to recycling for each baseline and option considered. The costs attributable to this rule were calculated by subtracting the cost of the baseline from the cost of each regulatory option. Appendix G presents a detailed example of the cost model calculations for the titanium and titanium dioxide sector.

Determine Portion of Waste Stream Considered to Be Hazardous

To account for the uncertainty in the data caused by the lack of documented information on both waste characteristics and recyclability, EPA developed a range consisting of minimum, expected, and maximum estimates of waste volumes potentially affected by the various options. Then EPA weighted these volume estimates for each waste stream to account for the degree of certainty in whether the particular waste stream exhibited one or more of the RCRA hazardous waste characteristics.

As shown below in Exhibit F-1, EPA used a matrix to account for the uncertainty in waste characterization. Each waste stream was assigned a multiplier in each costing scenario (i.e., minimum, expected, and maximum) based on the whether the waste stream was known to be hazardous (Y) or only suspected to be hazardous (Y?). Therefore, in the expected value case, if a waste stream was only suspected to be hazardous, only half of it was counted in the analysis and the rest was assumed to be non-hazardous. In the minimum value scenario, the stream would drop out of the analysis, and in the maximum value case the entire stream would be counted as if it was known to be hazardous.

Exhibit F-1
Portion of Waste Stream Considered to Be Hazardous (Percent)

Costing Scenario	Hazard Characteristic(s)	
	Y	Y?
Minimum	100	0
Expected	100	50
Maximum	100	100

where:

Y means that EPA has data **demonstrating** that the waste exhibits one or more of the RCRA hazardous waste characteristics; and

Y? means that EPA, based on professional judgment, believes that the waste may exhibit one or more of the RCRA hazardous waste characteristics.

Determine Portion of Waste Stream Sent to Treatment and Disposal and the Amount Recycled

EPA also used a set of matrices to divide the hazardous portion of each waste stream sent into a

component sent to treatment and disposal and a component stored prior to recycling. EPA used the tables in Exhibits F-2 and F-3 to determine each of these portions for the appropriate baseline or option. For example, in the modified prior treatment baseline, 15 percent of the hazardous portion of a waste believed to be fully recyclable (Y?) is assumed to be sent to treatment and disposal while 85 percent of the hazardous portion is assumed to require storage prior to recycling.

Exhibit F-2
Proportions of Waste Streams Treated and Disposed (in percent)

Baseline or Option	Affected Material	Percent Recycled				
		Certainty of Recycling				
		Y	Y?	YS	YS?	N
Prior Treatment	SL/BP	0	15	25	80	100
Prior Treatment	SM	0	25	35	85	100
Modified Prior Treatment	All	0	15	25	80	100
No Prior Treatment	All	0	100	60	100	100
Option 1 from PT	Bevill	100	100	100	100	100
	Non-Bevill	30	65	100	100	100
Option 2 from PT	Bevill	100	100	100	100	100
	Non-Bevill	0	25	35	85	100
Option 3 from PT	All	0	25	35	85	100
Option 4 from PT	All	0	15	25	80	100
Option 1 from MPT	Bevill	100	100	100	100	100
	Non-Bevill	30	65	100	100	100
Option 2 from MPT	Bevill	100	100	100	100	100
	Non-Bevill	0	25	35	85	100
Option 3 from MPT	All	0	25	35	85	100
Option 4 from MPT	All	0	15	25	80	100
Option 1 from NPT	Bevill	100	100	100	100	100
	Non-Bevill	20	100	90	100	100
Option 2 from NPT	Bevill	100	100	100	100	100
	Non-Bevill	0	30	40	85	100
Option 3 from NPT	All	0	30	40	85	100
Option 4 from NPT	All	0	15	25	80	100

Notes:

Y means that EPA has information indicating that the waste stream is fully recycled.

Y? means that EPA, based on professional judgment, believes that the waste stream could be fully recycled.

YS means that EPA has information indicating that a portion of the waste stream is fully recycled.

YS? means that EPA, based on professional judgment, believes that a portion of the waste stream could be fully recycled.

Bevill means that secondary materials are recycled through beneficiation or Bevill process units

Non-Bevill means that secondary materials are not recycled through beneficiation or Bevill process units

Exhibit F-3
Proportions of Waste Streams Stored Prior to Recycling (in percent)

Baseline or Option	Affected Material	Percent Recycled				
		Certainty of Recycling				
		Y	Y?	YS	YS?	N
Prior Treatment	SL/BP	100	85	75	20	0
Prior Treatment	SM	100	75	65	15	0
Modified Prior Treatment	All	100	85	75	20	0
No Prior Treatment	All	100	0	40	0	0
Option 1 from PT	Bevill	0	0	0	0	0
	Non-Bevill	70	35	0	0	0
Option 2 from PT	Bevill	0	0	0	0	0
	Non-Bevill	100	75	65	15	0
Option 3 from PT	All	100	75	65	15	0
Option 4 from PT	All	100	85	75	20	0
Option 1 from MPT	Bevill	0	0	0	0	0
	Non-Bevill	70	35	0	0	0
Option 2 from MPT	Bevill	0	0	0	0	0
	Non-Bevill	100	75	65	15	0
Option 3 from MPT	All	100	75	65	15	0
Option 4 from MPT	All	100	85	75	20	0
Option 1 from NPT	Bevill	0	0	0	0	0
	Non-Bevill	80	0	10	0	0
Option 2 from NPT	Bevill	0	0	0	0	0
	Non-Bevill	100	70	60	15	0
Option 3 from NPT	All	100	70	60	15	0
Option 4 from NPT	All	100	85	75	20	0

Notes:

Y means that EPA has information indicating that the waste stream is fully recycled.

Y? means that EPA, based on professional judgment, believes that the waste stream could be fully recycled.

YS means that EPA has information indicating that a portion of the waste stream is fully recycled.

YS? means that EPA, based on professional judgment, believes that a portion of the waste stream could be fully recycled.

Bevill means that secondary materials are recycled through beneficiation or Bevill process units

Non-Bevill means that secondary materials are not recycled through beneficiation or Bevill process units

Calculate Treatment Cost

"Model facility" generation rates of each type of waste sent to treatment (i.e., wastewaters, wastes with 1 to 10 percent solids, and wastes with more than 10 percent solids) were computed in each sector by summing the total sector quantities of each waste type sent to treatment and dividing by the maximum number of affected facilities in each costing scenario. These data can be found in the input data tables of the Cost Model Appendix (bound separately). These "model facility" generation rates of each type of

waste were used to first determine whether wastes would be treated on- or off-site and then to determine the cost associated with their being sent to treatment. EPA assumed that the most efficient means of treating a number of waste streams was to commingle these streams and build a single treatment facility on-site. This treatment system would sequentially treat each type of waste by first neutralizing liquid streams (wastewaters and wastes with 1 to 10 percent solids), precipitating the metals in these liquid streams, dewatering the residue from precipitation, stabilizing both the residue from dewatering and any solid wastes, and disposing of the stabilized mass. As indicated, each step in the process would generate a residue requiring further treatment or disposal. Therefore, EPA calculated the total quantity requiring neutralization and precipitation (100 percent of the liquid streams), the quantity being dewatered (15 percent of liquid streams), the quantity being stabilized (2.25 percent of liquid streams plus 100 percent of solid streams), and the quantity being disposed (3.49 percent of liquid streams, and 175 percent of solid streams). If the quantity requiring neutralization was below 350 mt/yr, EPA assumed that this waste would be sent off-site for treatment. If the quantity requiring stabilization was below 870 mt/yr, EPA assumed this waste would be sent off-site for treatment and disposal.

EPA then applied these estimated quantities to the treatment and disposal costing functions described in Appendix E to estimate "model facility" treatment costs for each baseline and option. The model facility cost was then multiplied by the maximum number of affected facilities in each sector, to determine the total sector cost.

Calculate Recycling Costs

Recycling costs are specific to each waste stream, based on the assumption that it is important not to commingle materials prior to reclamation. Quantities of individual streams destined for recovery were therefore not totaled.

EPA assumed that the only costs associated with recycling wastes are the costs of constructing and operating storage units. For each waste stream, EPA used the quantity of each waste stream that is recycled to calculate storage costs for the three baselines and three options. EPA then multiplied the average facility recycling cost by the number of facilities generating that waste stream to calculate the total sector cost for each waste stream. The total sector costs were then added for each waste stream to determine the total sector recycling cost in each baseline and post-rule option. EPA then calculated the incremental total sector storage costs by subtracting the total sector baseline recycling storage costs from the total sector post-rule option recycling storage costs.

Calculate Total Sector Costs and Impacts

Finally, EPA calculated the total sector costs by adding the total sector incremental treatment costs to the total sector incremental recycling costs. EPA divided this total sector cost by the number of facilities to determine the average facility cost. EPA then divided the total sector costs by the value of shipments (and multiplied by 100) to determine the percentage impacts in each sector.

MINERAL PROCESSING COST MODEL EXAMPLE CALCULATION: TITANIUM AND TITANIUM DIOXIDE SECTOR

APPENDIX G

This appendix presents a stepwise example of how the mineral processing cost model calculates the cost of this rulemaking for Option 3 assuming the Modified Prior Treatment baseline for the sector producing titanium and titanium dioxide.¹ The intermediate quantities and cost results presented in this appendix are calculated using the same methodology as used by the cost model. *These quantities and results differ slightly from those found in the cost model printouts due to rounding.*

The appendix is divided into five sections, each of which describes one important facet of the data or calculations used in the cost model. The first section reviews the input data required for cost calculations. The second section shows how the input data are manipulated for use in later cost calculations. The third section presents calculations of treatment costs. The fourth section presents calculations of storage costs. Finally, in the fifth section, the incremental treatment and storage costs are combined, along with recordkeeping costs, to obtain the total incremental sector cost.

G.1. Review of Input Data

This section reviews the five types of input data used to calculate the cost of this rulemaking to the titanium and titanium dioxide mineral processing sector:

1. Waste stream generation rates;
2. Hazardous characteristics;
3. Certainty of recycling;
4. Physical form (i.e. wastewater, waste with 1 to 10 percent solids, solid); and
5. Regulatory classification (i.e. by-product, spent material, sludge).

These data are used to calculate sector costs as described in later sections of this appendix.

G.1.1 Waste Stream Generation Rate and Number of Waste-Producing Facilities

The titanium and titanium dioxide mineral processing sector generates eight waste streams. Exhibit G-1 shows the number of waste producing facilities and the total sector waste stream generation rates for each of these eight waste streams. The number of facilities generating each waste stream varies, ranging from one facility producing scrap milling scrubber water to seven facilities generating waste water treatment plant (WWTP) sludges or solids. EPA obtained data on the generation rate for two of the eight streams (spent surface impoundment solids and WWTP sludges or solids). For the six waste streams for which data were unavailable, EPA estimated a minimum generation rate, an expected generation rate, and a maximum generation rate.

¹ For the purpose of simplicity, this section only describes calculations for the Modified Prior Treatment baseline and Option 3. Calculations for all of the other baselines and options follow the same pattern as described below.

Exhibit G-1
Waste Stream Generation Rates

Titanium Waste Stream	Number of Facilities	Estimated or Reported Generation (mt/yr)		
		Minimum	Expected	Maximum
Pickle Liquor and Wash Water	3	2,200	2,700	3,200
Scrap Milling Scrubber Water	1	4,000	5,000	6,000
Smut from Mg Recovery	2	100	22,000	45,000
Leach Liquor and Sponge Wash Water	2	380,000	480,000	580,000
Spent Surface Impoundment Liquids	7	630	3,400	6,700
Spent Surface Impoundment Solids	7	36,000	36,000	36,000
Waste Acids (Sulfate Process)	2	200	39,000	77,000
WWTP Sludges/Solids	7	420,000	420,000	420,000

G.1.2 Hazardous Characteristics

Each waste stream in the data set is known or suspected to be hazardous for at least one of the four hazardous characteristics:

- Toxicity (i.e., containing on or more of the eight TC Metals);
- Corrosivity;
- Ignitability; and
- Reactivity.

Exhibit G-2 summarizes the status of each of the eight waste streams for the four hazardous characteristic categories, as well as each stream's overall hazard certainty. Four of the waste streams in the sector are known to be hazardous for at least one of the characteristics, as indicated in the far right column by a "Y" (yes) overall hazard certainty classification. The other four streams in the sector are only suspected to be hazardous and are assigned a "Y?" hazard certainty classification in the far right column. For example, leach liquor and sponge wash water is known to be hazardous because it is corrosive, even though the stream is only suspected to be hazardous for chromium and lead, and is not believed to be ignitable or reactive.

Exhibit G-2
Hazardous Characteristics

Titanium Waste Stream	TC Metals								Corr	Ignit	Rctv	Overall Haz?
	As	Ba	Cd	Cr	Pb	Hg	Se	Ag				
Pickle Liquor and Wash Water			Y?	Y?	Y?				Y?	N?	N?	Y?
Scrap Milling Scrubber Water			Y?	Y?	Y?		Y?		N?	N?	N?	Y?
Smut from Mg Recovery									N?	N?	Y	Y
Leach Liquor and Sponge Wash Water				Y?	Y?				Y	N?	N?	Y
Spent Surface Impoundment Liquids				Y?	Y?				N?	N?	N?	Y?
Spent Surface Impoundment Solids				Y?	Y?				N?	N?	N?	Y?
Waste Acids (Sulfate Process)	Y			Y			Y	Y	Y	N	N	Y
WWTP Sludges/Solids				Y					N	N	N	Y

Y = Known to be hazardous, Y? = suspected to be hazardous

G.1.3 Recycling Status, RCRA Waste Type, and Waste Treatment Type

Exhibit G-3 depicts the recycling status, RCRA waste type, and physical form of each of the waste streams in the titanium sector. Of the eight waste streams in the sector, none are assigned a "Y" (yes) in Exhibit G-3 because none are known to be fully recycled. Two are believed to be fully recycled (Y?). None are assigned a "YS" (yes sometimes) because none are known to be partially recycled, but three are believed to be partially recycled (YS?). Three are assigned "N" (no) because they are known not to be recycled at all (N). Of the five streams that are recycled in some capacity, three are spent materials, one is a by-product, and one is a sludge. Five of the waste streams in the sector are wastewaters, and three waste streams are solids.

Exhibit G-3
Recycling Status

Titanium Waste Stream	Recycling Status	RCRA Waste Type	Physical Form
Pickle Liquor and Wash Water	YS?	Spent Mat'l	Wastewater
Scrap Milling Scrubber Water	YS?	Sludge	Wastewater
Smut from Mg Recovery	Y?	By-Product	Solid
Leach Liquor and Sponge Wash Water	YS?	Spent Mat'l	Wastewater
Spent Surface Impoundment Liquids	Y?	Spent Mat'l	Wastewater
Spent Surface Impoundment Solids	N	NA	Solid
Waste Acids (Sulfate Process)	N	NA	Wastewater
WWTP Sludges/Solids	N	NA	Solid

G.2. Manipulation of Input Data

This section shows how input data described in the previous section are manipulated so that treatment and storage costs can be calculated. The model combines uncertainty about hazard characteristics with uncertainty in generation rates to create a bounded cost analysis, i.e., an expected value case with minimum and maximum value cases providing estimated lower- and upper-bound costs. This section of the appendix helps set the stage for later calculation of expected value costs, upper bound costs, and lower bound costs by calculating the quantity of each waste stream that must be treated and disposed versus recycled in the expected value case, the upper bound case, and the lower bound case.

Manipulation of input data occurs in four steps which are listed here and described in detail later in this section:

- 1) The estimated or reported generation rate for each of the eight waste streams (from Exhibit G- 1) is divided into a hazardous component and a non-hazardous component;
- 2) The hazardous portion of each waste stream is divided into a component that is treated and disposed, and a component that is stored prior to recycling;
- 3) "Model facility" totals are calculated for the treated and disposed waste; and
- 4) Average facility quantities are calculated for waste stored prior to recycling.

There is a critical difference between "model facility" totals for treated and disposed waste and average facility quantities for waste stored prior to recycling. "Model facility" totals, which are used to model treatment of all waste streams in a sector in a single treatment system at each facility, are calculated on a sector basis while average facility quantities, which are used to calculate storage costs of individual waste streams that must not be commingled, are calculated on an individual waste stream basis.

G.2.1 Estimate Waste Stream Portion Assumed to be Hazardous

As indicated in Exhibit G-2 above, four of the waste streams in the titanium and titanium dioxide mineral processing sector are only suspected to be hazardous (Y?). To apportion this uncertainty over the minimum, expected, and maximum value cases, we multiply the overall waste stream generation rates (minimum, expected, and maximum) for each of the eight waste streams from Exhibit G-1 by the following percentages in Exhibit G-4, to calculate the minimum, expected, and maximum quantities of the waste stream estimated to be both generated and hazardous:

**Exhibit G-4
Hazard Certainty Multipliers**

Costing Scenario	Hazard Certainty	
	Y?	Y
Minimum	0%	100%
Expected	50%	100%
Maximum	100%	100%

The resulting quantities of waste estimated to be hazardous for each waste stream in the titanium and titanium dioxide sector are shown in Exhibit G-5. The effect of this procedure is to bound the analysis, which is especially important for the four streams that are only suspected to be hazardous. For example, the quantity of pickle liquor and wash water (Y? hazard certainty) assumed to be hazardous in the minimum value case would be 0 mt/yr [i.e., 22,000 mt/yr generated (from Exhibit G-1) x 0% (from Exhibit G-4) = 0 mt/yr], while the expected value case hazardous portion would be 13,500 mt/yr [27,000 mt/yr generated (from Exhibit G-1) x 50% (from Exhibit G-4) = 13,500 mt/yr].² In the maximum value case, the entire quantity (32,000 mt/yr) is assumed to be hazardous. For the four titanium waste streams known to be hazardous, the entire generated quantity of those wastes is included in the analysis.

² Conversely, note that 22,000 mt/yr of the waste is considered non-hazardous in the minimum value case, while 13,500 mt/yr is considered non-hazardous in the expected value case. The portion of waste that is assumed non-hazardous drops out of the analysis from this point on.

Exhibit G-5
Portion of Waste Assumed to be Hazardous

Titanium Waste Stream	Hazard Certainty	Portion of Waste that is Hazardous (mt/yr)		
		Minimum	Expected	Maximum
Pickle Liquor and Wash Water	Y?	0	1,350	3,200
Scrap Milling Scrubber Water	Y?	0	2,500	6,000
Smut from Mg Recovery	Y	100	22,000	45,000
Leach Liquor and Sponge Wash Water	Y	380,000	480,000	580,000
Spent Surface Impoundment Liquids	Y?	0	1,700	6,700
Spent Surface Impoundment Solids	Y?	0	18,000	36,000
Waste Acids (Sulfate Process)	Y	200	39,000	77,000
WWTP Sludges/Solids	Y?	0	210,000	420,000

**G.2.2 Divide Hazardous Quantities Into Portion Treated/Disposed and Portion
Stored Prior to Recycling**

The hazardous portion of each waste stream (from Exhibit G-5) is then divided into a component of waste that is treated/disposed, and a component that is stored for recycling. To determine these portions, the model applies an appropriate multiplier, depending on its particular recycling status (as indicated in Exhibit G-3 above). The treatment/disposal multipliers are shown in Exhibit G-6, and the recycling multipliers are shown in Exhibit G-7. Note that in all cases the treatment and disposal multiplier in Exhibit G-6 and the recycling multiplier in Exhibit G-7 sum to 100 percent (i.e., all waste is assumed to be handled in accordance with EPA regulations and either treated and disposed, or stored prior to recycling). The multipliers are applied to the portion of material considered to be hazardous in the minimum, expected, and maximum value cases.

Exhibit G-6
Proportions of Waste Streams Treated and Disposed (in percent)

Baseline or Option	Affected Material	Percent Disposed				
		Recycling Status				
		Y	Y?	YS	YS?	N
No Modified Prior Treatment	All	0	100	60	100	100
Modified Prior Treatment (SL/BP) & MPT	All	0	15	25	80	100
Modified Prior Treatment (SM)	All	0	25	35	85	100
Option 1 from NPT	All	20	100	90	100	100
Option 2 from NPT	Bevill*	100	100	100	100	100
Option 3 from NPT	All	0	30	40	90	100
Option 4 from NPT	All	0	15	25	80	100
Option 1 from MPT & PT (SL/BP)	All	30	65	100	100	100
Option 2 from MPT & PT (SL/BP)	Bevill*	100	100	100	100	100
Option 3 from MPT & PT (SL/BP)	All	0	25	35	85	100
Option 4 from MPT & PT (SL/BP)	All	0	15	25	80	100
Option 1 from PT (SM)	All	30	65	100	100	100
Option 2 from PT (SM)	Bevill*	100	100	100	100	100
Option 3 from PT (SM)	All	0	25	35	85	100
Option 4 from PT (SM)	All	0	15	25	80	100

* For materials recycled through Bevill Units only -- Materials not recycled through Bevill Units are treated and disposed according to Option 3 multipliers.

SL = Sludge, BP = By-Product, SM = Spent Material

Exhibit G-7
Proportions of Waste Streams Stored Prior to Recycling (in percent)

Baseline or Option	Affected Material	Percent Recycled				
		Recycling Status				
		Y	Y?	YS	YS?	N
No Modified Prior Treatment	All	100	0	40	0	0
Modified Prior Treatment (SL/BP) & MPT	All	100	85	75	20	0
Modified Prior Treatment (SM)	All	100	75	65	15	0
Option 1 from NPT	All	80	0	10	0	0
Option 2 from NPT	Bevill*	0	0	0	0	0
Option 3 from NPT	All	100	70	60	10	0
Option 4 from NPT	All	100	85	75	20	0
Option 1 from MPT & PT (SL/BP)	All	70	35	0	0	0
Option 2 from MPT & PT (SL/BP)	Bevill*	0	0	0	0	0
Option 3 from MPT & PT (SL/BP)	All	100	75	65	15	0
Option 4 from MPT & PT (SL/BP)	All	100	85	75	20	0
Option 1 from PT (SM)	All	70	35	0	0	0
Option 2 from PT (SM)	Bevill*	0	0	0	0	0
Option 3 from PT (SM)	All	100	75	65	15	0
Option 4 from PT (SM)	All	100	85	75	20	0

* For materials recycled through Bevill Units only -- Materials not recycled through Bevill Units are stored prior to recycling according to Option 3 multipliers.

SL = Sludge, BP = By-Product, SM = Spent Material

The quantities of waste treated/disposed and the quantities of waste stored prior to recycling for each waste stream in the sector are shown in Exhibit G-8 and G-9, respectively. Quantities reported in Exhibit G-8 and G-9 are calculated by multiplying the portion of waste that is hazardous (Exhibit G-5) by the appropriate treatment/disposal or recycling multipliers (from Exhibit G-6 and G-7). For example, of the 1,350 mt/yr of pickle liquor and wash water assumed to be hazardous in the expected value case of the Modified Prior Treatment baseline, 85 percent of the waste, or approximately 1,150 mt/yr ($1,350 \text{ mt/yr} \times 0.85$), is sent to treatment/disposal, while 15 percent of the waste, or approximately 200 mt/yr ($1,350 \text{ mt/yr} \times 0.15$), is stored prior to recycling.

G.2.3 Calculate Total Quantity Treated and Disposed at a "Model Facility"

The cost model assumes that each facility generating waste in the titanium sector builds a single treatment plant to treat all wastes rather than building a separate treatment plant for each waste stream. Therefore to obtain the quantity of waste treated and disposed at a "model facility," the model sums the treated and disposed portion of all eight waste streams by physical form (i.e., wastewaters, wastes with one to ten percent solids, and wastes with more than ten percent solids) and divides by the maximum number of facilities generating waste in the sector, which is two in the minimum value case, and seven in the expected and maximum value cases. The reason why there are only two facilities generating waste in the minimum value case is that there is uncertainty about the hazard characteristics (Y?) of several of the titanium waste streams (see Exhibit G-5). Recall that waste streams that have a Y? hazard certainty classification are considered not hazardous in the minimum value case, 50% hazardous in the expected value case, and 100% hazardous in the maximum value case (see Exhibit G-4). Therefore, the maximum number of facilities generating at least one titanium waste drops to two in the minimum value case, because all of the titanium waste streams generated by more than two facilities have a Y? hazard certainty

classification (see Exhibit G-1). For purposes of calculations, it does not matter whether some types of waste are generated at fewer facilities, because the model assumes a single treatment system for all types of waste generated at all facilities. For example, the total wastewater treated/disposed for the pre-rule expected value case is 450,573 mt/yr (which is the sum of the wastewater streams in Exhibit G-10). Dividing by seven, the model facility wastewater treated/disposed for the expected value case is 64,368 mt/yr. Exhibit G-10 presents the model facility waste treated/disposed for the minimum, expected, and maximum value scenarios.

Exhibit G-8
Portion of Hazardous Wastes Generated Treated and Disposed

Waste Stream	Multiplier	Portion of Waste Treated/Disposed (mt/yr)		
		Minimum	Expected	Maximum
Pre-Rule				
Pickle Liquor and Wash Water	0.80	0	1,080	2,560
Scrap Milling Scrubber Water	0.80	0	2,000	4,800
Smut from Mg Recovery	0.15	15	3,300	6,750
Leach Liquor and Sponge Wash Water	0.80	304,000	384,000	464,000
Spent Surface Impoundment Liquids	0.15	0	255	1,005
Spent Surface Impoundment Solids	1	0	18,000	36,000
Waste Acids (Sulfate Process)	1	200	39,000	77,000
WWTP Sludges/Solids	1	0	210,000	420,000
Post-Rule				
Pickle Liquor and Wash Water	0.85	0	1,148	2,720
Scrap Milling Scrubber Water	0.85	0	2,125	5,100
Smut from Mg Recovery	0.25	25	5,500	11,250
Leach Liquor and Sponge Wash Water	0.85	323,000	408,000	493,000
Spent Surface Impoundment Liquids	0.25	0	425	1,675
Spent Surface Impoundment Solids	1	0	18,000	36,000
Waste Acids (Sulfate Process)	1	200	39,000	77,000
WWTP Sludges/Solids	1	0	210,000	420,000

Exhibit G-9
Portion of Hazardous Wastes Generated that is Stored Prior to Recycling

Waste Stream	Multiplier	Portion of Waste Stored Prior to Recycling (mt/yr)		
		Minimum	Expected	Maximum
Pre-Rule				
Pickle Liquor and Wash Water	0.20	0	270	640
Scrap Milling Scrubber Water	0.20	0	500	1,200
Smut from Mg Recovery	0.85	85	18,700	38,250
Leach Liquor and Sponge Wash Water	0.20	76,000	96,000	116,000
Spent Surface Impoundment Liquids	0.85	0	1,445	5,695
Spent Surface Impoundment Solids	0	0	0	0
Waste Acids (Sulfate Process)	0	0	0	0
WWTP Sludges/Solids	0	0	0	0
Post-Rule				
Pickle Liquor and Wash Water	0.15	0	203	480
Scrap Milling Scrubber Water	0.15	0	375	900
Smut from Mg Recovery	0.75	75	16,500	33,750
Leach Liquor and Sponge Wash Water	0.15	57,000	72,000	87,000
Spent Surface Impoundment Liquids	0.75	0	1,275	5,025
Spent Surface Impoundment Solids	0	0	0	0
Waste Acids (Sulfate Process)	0	0	0	0
WWTP Sludges/Solids	0	0	0	0

Exhibit G-10
Model Facility Quantity of Waste Treated/Disposed

Baseline/Option	Model Facility Waste Treated/Disposed (mt/yr)								
	Minimum			Expected			Maximum		
	Waste-waters	1-10% Solids	Solids	Waste-waters	1-10% Solids	Solids	Waste-waters	1-10% Solids	Solids
Pre-Rule	152,100	0	8	60,905	0	33,043	78,481	0	66,107
Post-Rule	161,100	0	13	64,385	0	33,357	82,785	0	66,750

G.2.4 Calculation of Average Quantity Recycled

Since recycling costs are specific to each waste stream in the sector, the cost model does not calculate model facility totals for recycling. Rather, it calculates an average facility total by dividing the portion of each waste stream that is stored prior to recycling (from Exhibit G-9) by the number of facilities that generate each waste (from Exhibit G-1). Exhibit G-11 shows the results of this calculation.

Exhibit G-11
Average Facility Quantities Stored Prior to Recycling

Waste Stream	Number of Facilities	Average Facility Waste Stored Prior to Recycling (mt/yr)		
		Minimum	Expected	Maximum
Pre-Rule				
Pickle Liquor and Wash Water	3	0	90	213
Scrap Milling Scrubber Water	1	0	500	1,200
Smut from Mg Recovery	2	43	9,350	19,125
Leach Liquor and Sponge Wash Water	2	38,000	48,000	58,000
Spent Surface Impoundment Liquids	7	0	206	814
Spent Surface Impoundment Solids	7	0	0	0
Waste Acids (Sulfate Process)	2	0	0	0
WWTP Sludges/Solids	7	0	0	0
Post-Rule				
Pickle Liquor and Wash Water	3	0	68	160
Scrap Milling Scrubber Water	1	0	375	900
Smut from Mg Recovery	2	38	8,250	16,875
Leach Liquor and Sponge Wash Water	2	28,500	36,000	43,500
Spent Surface Impoundment Liquids	7	0	182	718
Spent Surface Impoundment Solids	7	0	0	0
Waste Acids (Sulfate Process)	2	0	0	0
WWTP Sludges/Solids	7	0	0	0

G.3. Treatment Cost Calculations

This section of the appendix explains how the cost model calculates the total incremental treatment cost incurred by the titanium and titanium dioxide mineral processing sector.

The model first determines if the treated and disposed waste quantities from Exhibit G-10 are large enough to warrant on-site treatment. Next the model calculates neutralization, dewatering, stabilization, and disposal costs. The model then annualizes capital and closure costs and calculates a total sector treatment cost. Finally, the model calculates the total titanium sector incremental treatment cost. All treatment and disposal calculations are performed using the "model facility" quantities calculated in the last section of this document.

G.3.1 Determination of On-Site versus Off-Site Treatment

The model assumes that low-volume wastes (≤ 879 mt/yr solids or ≤ 350 mt/yr liquids) will be sent off-site for treatment and disposal. All wastes generated in the titanium sector are assumed to be treated on-site, because both wastewaters and solids are generated in quantities above the low-volume threshold in all three costing scenarios (see Exhibit G-10).

G.3.2 Neutralization and Precipitation Costs

Five of the eight titanium waste streams are wastewaters and therefore require neutralization, precipitation, dewatering, and stabilization prior to disposal. (The other three streams are solids and do not require neutralization, precipitation, and dewatering.) The model uses four equations to determine the neutralization cost for wastewaters:³

- Surge Tank Costs (\$/yr) = $4 \times 10^{-8} Q_n^2 + 0.1175 Q_n + 3,680$
- Capital Costs (\$) = $36,131 + 151.95 Q_n^{0.5}$
- O&M Costs (\$/yr) = $-206,719 + 36,594 \ln Q_n$
- Closure Costs (\$) = $6,361 + 10^{-3} Q_n$

In all four of the above equations, Q_n (the amount of waste requiring neutralization) equals the sum of wastewaters and waste streams with one to ten percent solids requiring treatment. Using the pre-rule expected value case as an example, the model facility quantity of wastewater requiring treatment is 60,905 mt/yr, and the quantity of wastes with one to ten percent solids content is 0 mt/yr (see Exhibit G-10). Therefore, neutralization surge tank storage costs equal \$10,985, neutralization capital costs equal \$73,631, neutralization O&M costs equal \$196,440 per year, and neutralization closure costs equal \$6,422. Exhibit G-12 shows the neutralization costs for the titanium and titanium dioxide sector.

Exhibit G-12
Neutralization Costs

Baseline/Option Costs	Neutralization Costs		
	Minimum	Expected	Maximum
Pre-Rule			
- Surge (\$/yr)	22,477	10,985	13,148
- Capital (\$)	95,392	73,631	78,699
- O&M (\$/yr)	229,931	196,440	205,718
- Closure (\$)	6,513	6,422	6,439
Post-Rule			
- Surge (\$/yr)	23,713	11,411	13,681
- Capital (\$)	97,214	74,687	79,851
- O&M (\$/yr)	232,148	198,473	207,672
- Closure (\$)	6,523	6,425	6,444

The model uses two equations to determine the precipitation cost for wastewaters:⁴

- Capital Costs (\$) = $3,613 + 15.195 Q_p^{0.5}$
- O&M Costs (\$/yr) = $826.48 + 0.3465 Q_p$

In the above equations, Q_p (the amount of waste requiring precipitation) equals the sum of wastewaters and waste streams with one to ten percent solids requiring treatment. Using the pre-rule expected value case as an example, the model facility quantity of wastewater requiring treatment is 60,905 mt/yr, and the quantity of wastes with one to ten percent solids content is 0 mt/yr (see Exhibit G-

³ Equations from Exhibit D-1, Appendix D.

⁴ EPA assumes that neutralization and precipitation occur within the same unit, therefore, precipitation closure costs are included in the neutralization closure cost equation.

10). Therefore, precipitation capital costs equal \$7,363, and precipitation O&M costs equal \$21,930 per year. Exhibit G-13 shows the precipitation costs for the titanium and titanium dioxide sector.

Exhibit G-13
Precipitation Costs

Baseline/Option Costs	Precipitation Costs		
	Minimum	Expected	Maximum
Pre-Rule			
- Capital (\$)	9,539	7,363	7,870
- O&M (\$/yr)	53,529	21,930	28,020
Post-Rule			
- Capital (\$)	9,721	7,469	7,985
- O&M (\$/yr)	56,821	23,136	29,511

G.3.3 Dewatering and Stabilization Costs

Neutralization operations produce a slurry which must be dewatered, stabilized, and disposed. About 15 percent of the quantity introduced into the neutralization operation leaves as this slurry. Therefore, in the following equations, Q_{dw} , the amount of material requiring dewatering, is 15 percent of the sum of the quantity of wastewaters and wastes with a solids content of 1 to 10 percent requiring treatment:⁵

- Capital Costs (\$) = $95,354 + 664.48 Q_{dw}^{0.5}$
- O&M Costs (\$/yr) = $12,219 + 286.86 Q_{dw}^{0.5}$

For example, in the post-rule expected value case, Q_{dw} is equal to 9,658 mt/yr [(64,385 mt/yr wastewaters plus 0 mt/yr wastes with a solids content of 1 to 10 percent (from Exhibit G-10)) x 0.15]. Therefore, the capital cost associated with dewatering 9,658 mt/yr waste is \$160,655, and the O&M cost is \$40,410 per year.

Dewatering produces a sludge which needs to be stabilized and disposed. The dewatered sludge, equal to about 15 percent of the mass entering dewatering, is combined with the solid waste streams requiring stabilization and disposal in the following equations:⁶

- Capital Costs (\$) = $207.93 Q_s^{0.78}$
- O&M Costs (\$/yr) = $87,839 + 52.16 Q_s$
- Closure Costs (\$) = $9,806 + 0.19 Q_s$

In these equations therefore, the quantity requiring stabilization, Q_s , is 2.25 percent⁷ of the sum of the original quantity of wastewaters and wastes with a solids content of 1 to 10 percent requiring treatment, added to the entire quantity of solid waste requiring treatment. For example, in the post-rule expected value case, Q_s is equal to 34,806 mt/yr [1,449 mt/yr wastewaters and wastes with 1 to 10 percent solids ((64,385 mt/yr + 0 mt/yr, from Exhibit G-10, * 0.0225) plus 33,357 mt/yr solids (from Exhibit G-10)]. Therefore, the capital cost associated with stabilizing 34,806 mt/yr waste is \$725,110, the O&M

⁵ Equations obtained from Case A, Exhibit D-2, Appendix D.

⁶ Equations obtained from Case B, Exhibit D-2, Appendix D.

⁷ This is equal to 15 percent of the quantity entering dewatering, which is 15 percent of the original quantity requiring treatment.

cost is \$1,903,302 per year, and the closure cost is \$16,419. Exhibit G-14 shows the dewatering and stabilization costs for the titanium and titanium dioxide sector.

Exhibit G-14
Dewatering and Stabilization Costs

Baseline/Option Costs	Dewatering and Stabilization Costs					
	Minimum		Expected		Maximum	
	Dewatering	Stabilization	Dewatering	Stabilization	Dewatering	Stabilization
Pre-Rule						
- Capital (\$)	195,721	118,979	158,866	718,728	167,450	1,220,787
- O&M (\$/yr)	55,548	266,761	39,637	1,882,840	43,343	3,628,085
- Closure (\$)	NA	10,458	NA	16,345	NA	22,702
Post-Rule						
- Capital (\$)	198,808	124,857	160,655	725,110	169,400	1,231,154
- O&M (\$/yr)	56,881	278,171	40,410	1,903,302	44,185	3,666,676
- Closure (\$)	NA	10,499	NA	16,419	NA	22,842

G.3.4 Disposal Costs

After neutralization, precipitation, dewatering, and/or stabilization, stabilized residues from titanium sector wastes are disposed of in a pile. The cost of disposal in a pile is described by the following equation:⁸

- $\text{Pile Costs (\$/yr)} = 1.8703 Q_{ds} + 12,308$

In the above equation, Q_{ds} , the quantity being disposed, is equal to 155 percent of the mass entering stabilization from dewatering added to 175 percent of the solid wastes entering stabilization. Alternatively Q_{ds} is the sum of $[1.55 \times (0.0225 \times (\text{quantity of wastewaters and wastes with a 1 to 10 percent solids content requiring treatment}))]$ and $[1.75 \times (\text{quantity of solids requiring treatment})]$. For example, in the expected value case of Option 3, Q_{ds} is equal to 60,621 mt/yr $[(1,449 \text{ mt/yr} \times 1.55) \text{ plus } (33,357 \text{ mt/yr} \times 1.75)]$. Therefore, the cost of disposal in a pile is equal to \$130,717. Exhibit G-15 depicts the disposal costs for the sector.

Exhibit G-15
Disposal Costs

Baseline/Option Costs	Disposal Costs		
	Minimum	Expected	Maximum
Pre-Rule	22,255	124,431	233,797
Post-Rule	22,859	125,686	236,182

⁸ Equation obtained from Exhibit D-21.

G.3.5 Annualization of Costs and Calculation of Total Sector Treatment Costs

Because capital and closure costs are one-time costs, they are annualized so that total annualized titanium sector incremental treatment costs may be calculated. The model annualizes the titanium sector capital costs by multiplying them by a capital recovery factor (CRF) of 0.09439.⁹ Closure costs, which are assumed to be incurred after 20 years of operation (i.e., in year 21), are reduced to present value and then annualized using the CRF. The annualization process and the calculation of total neutralization, precipitation, dewatering, and stabilization costs are accomplished using the following formula:¹⁰

$$\bullet \quad \text{Annualized Cost} = \frac{(\text{Capital Costs})(\text{CRF}) + \text{O\&M Costs} + (\text{Closure Costs})(\text{CRF})}{(1.07^{21})}$$

Using the above formula, the model combines the capital, O&M, and closure costs to obtain total annualized neutralization, precipitation, dewatering, and stabilization costs for the titanium sector.¹¹ For example, the pre-rule annualized stabilization cost in the titanium and titanium dioxide sector equals $(\$718,728 \times 0.09439) + \$1,882,840 + ((\$16,345 \times 0.09439) / 1.07^{21})$, or \$1,951,053. The disposal cost function is already annualized. Exhibit G-16 presents the total annualized neutralization, precipitation, dewatering, stabilization, and disposal costs for the titanium sector.

Exhibit G-16
Annualized Neutralization, Precipitation, Dewatering, Stabilization, and Disposal Costs
(Modified Prior Treatment Baseline and Option 3)

Baseline/Option Costs (\$)	Costing Scenario		
	Minimum	Expected	Maximum
Pre-Rule			
- Neutralization	261,531	214,521	226,441
- Precipitation	54,429	22,625	28,763
- Dewatering	74,022	54,632	59,149
- Stabilization	278,230	1,951,053	3,743,833
- Disposal	22,255	124,431	233,797
Total	690,467	2,367,262	4,291,983
Post-Rule			
- Neutralization	265,186	217,080	229,012
- Precipitation	57,739	23,841	30,265
- Dewatering	75,646	55,574	60,175
- Stabilization	290,196	1,972,119	3,783,405
- Disposal	22,859	125,686	236,182
Total	711,626	2,394,300	4,339,039

Total titanium sector pre- and post-rule treatment costs are calculated by summing the annualized neutralization, precipitation, dewatering, stabilization, and disposal costs from Exhibit G-16 and multiplying the sum by the maximum number of facilities in the titanium sector (two in the minimum value case, seven in the expected and maximum value cases). Therefore, the total titanium sector

⁹ Derivation of the CRF may be found on page D-2 of Appendix D.

¹⁰ For more information, see pages D-1 and D-2 of Appendix D.

¹¹ Surge tank costs are also added to the annualized capital, O&M, and annualized closure costs in the calculation of the total annualized neutralization cost.

expected value case pre-rule treatment cost in this example is equal to $((\$214,521 + \$22,625 + \$54,632 + \$1,951,053 + \$124,431 = \$2,372,235) \times 7)$, or **\$16,570,834**. Similarly, the total titanium sector expected value case post-rule treatment cost in this example is equal to $((\$217,080 + \$23,841 + \$55,574 + \$1,972,119 + \$125,686 = \$2,399,311) \times 7)$, or **\$16,760,100**.

G.3.6 Total Sector Incremental Treatment Cost

The total titanium sector incremental treatment cost is calculated by subtracting the pre-rule total sector treatment cost from the post-rule total sector treatment cost. In this example, the total titanium sector incremental treatment cost is **\$42,318** in the minimum value case, **\$189,266** in the expected value case, and **\$329,392** in the maximum value case.

G.4. Storage Cost Calculations

This section of the appendix calculates the total sector incremental storage cost incurred by the titanium and titanium dioxide mineral processing sector. This process involves four steps: (1) the appropriate storage unit for each waste stream is selected; (2) the average facility storage cost is calculated for each waste stream; (3) a total sector storage cost is calculated; and (4) a total sector incremental storage cost is calculated. Note that until the total sector storage cost is calculated at the end of this section, all calculations in this section are performed on an average facility basis.

G.4.1 Storage Unit and Cost Equation Determination

Depending on the quantity of recyclable waste generated and the physical form of the waste (liquid or solid), wastes that require storage prior to recycling can be stored in a variety of storage units. EPA developed individual cost equations for each type of storage unit and used these cost equations to determine the range of quantities over which each type of unit is the least costly storage unit available. Exhibit G-17 shows these cost functions for the various storage units available for use in the Modified Prior Treatment baseline and Option 3, as well as the range of quantities for which that unit would be employed.¹² In each of these equations, Q is the annual quantity requiring storage prior to recycling.

¹² For a full list of storage unit functions, refer to Exhibit D-21.

Exhibit G-17
Storage Cost Equations

Modified Prior Treatment Baseline			
Waste Type	Storage Unit	Quantity Range (mt/yr)	Cost Equation
Liquid	Drum	0 - 220	$Y = -0.0074 Q^2 + 9.4798 Q + 189.34$
	Tank	220 - 500	$Y = -9 \times 10^{-7} Q^2 + 0.55 Q + 1,795.7$
	Unlined S.I.	≥ 500	$Y = 1,000$
Solid	Drum	0 - 200	$Y = 24.589 Q + 132.23$
	Roll-Off	200 - 935	$Y = -0.0022 Q^2 + 29.272 Q + 4,840.9$
	Unlined Pile	≥ 935	$Y = 4.0207 Q + 26,271$
Option 3 (PT)			
Waste Type	Storage Unit	Quantity Range (mt/yr)	Cost Equation
Liquid	Drum	0 - 220	$Y = -0.0074 Q^2 + 9.4798 Q + 189.34$
	Tank	220 - 1 million	$Y = -9 \times 10^{-7} Q^2 + 0.55 Q + 1,795.7$
	Lined S.I.	> 1 million	$Y = 0.0704 Q + 1,955.1$
Solid	Drum	0 - 200	$Y = 24.589 Q + 132.23$
	Roll-Off	200 - 1343.1	$Y = -0.0022 Q^2 + 29.272 Q + 4,840.9$
	Building	1343.1 - 45,000	$Y = 0.00002 Q^2 + 3.2395 Q + 35,800$
	Lined Pile	$> 45,000$	$Y = 4.0924 Q + 27,676$

SL = Sludge, BP = By-Product, SM = Spent Material

Exhibit G-18 shows the storage units used in the minimum, expected, and maximum value cases for the eight waste streams generated in the titanium sector. For example, scrap milling scrubber water is stored in an unlined surface impoundment in the pre-rule maximum value case because it is a liquid waste (a wastewater), classified as a sludge, and the quantity stored prior to recycling (1200 mt/yr) exceeds the threshold quantity of 500 mt/yr needed to store liquids in an unlined surface impoundment.

G.4.2 Storage Costs

Exhibit G-19 shows the storage costs for each of the eight titanium waste streams. Exhibit G-19 is created by plugging the quantity of waste stored prior to recycling (Exhibit G-11) into the appropriate cost function from Exhibit G-17. For example, leach liquor and sponge wash water is stored in a tank in all three costing scenarios under Option 3. Therefore the cost equation for the minimum, expected, and maximum value case are as follows:

$$\bullet \quad \text{Cost} = -9 \times 10^{-7} Q^2 + 0.55 Q + 1,795.7$$

Inserting 28,500 mt/yr, 36,000 mt/yr, and 43,500 mt/yr into the minimum, expected, and maximum cost equations, respectively, yields a storage cost of \$16,740 in the minimum value case, \$20,429 in the expected value case, and \$24,018 in the maximum value case.

Exhibit G-18
Storage Units Used in the Modified Prior Treatment Baseline and Option 3

Titanium Waste Stream	Storage Unit		
	Minimum	Expected	Maximum
Pre-Rule			
Pickle Liquor and Wash Water	Not Recycled	Drum	Drum
Scrap Milling Scrubber Water	Not Recycled	Unlined S.I.	Unlined S.I.
Smut from Mg Recovery	Drum	Unlined Pile	Unlined Pile
Leach Liquor and Sponge Wash Water	Unlined S.I.	Unlined S.I.	Unlined S.I.
Spent Surface Impoundment Liquids	Not Recycled	Drum	Unlined S.I.
Spent Surface Impoundment Solids	Not Recycled	Not Recycled	Not Recycled
Waste Acids (Sulfate Process)	Not Recycled	Not Recycled	Not Recycled
WWTP Sludges/Solids	Not Recycled	Not Recycled	Not Recycled
Post-Rule			
Pickle Liquor and Wash Water	Not Recycled	Drum	Drum
Scrap Milling Scrubber Water	Not Recycled	Tank	Tank
Smut from Mg Recovery	Drum	Building	Building
Leach Liquor and Sponge Wash Water	Tank	Tank	Tank
Spent Surface Impoundment Liquids	Not Recycled	Drum	Tank
Spent Surface Impoundment Solids	Not Recycled	Not Recycled	Not Recycled
Waste Acids (Sulfate Process)	Not Recycled	Not Recycled	Not Recycled
WWTP Sludges/Solids	Not Recycled	Not Recycled	Not Recycled

Exhibit G-19
Average Facility Storage Costs

Titanium Waste Stream	Average Facility Storage Cost (\$)		
	Minimum	Expected	Maximum
Modified Prior Treatment Baseline			
Pickle Liquor and Wash Water	Not Recycled	983	1,873
Scrap Milling Scrubber Water	Not Recycled	1,000	1,000
Smut from Mg Recovery	1,190	63,865	103,167
Leach Liquor and Sponge Wash Water	1,000	1,000	1,000
Spent Surface Impoundment Liquids	Not Recycled	1,828	1,000
Spent Surface Impoundment Solids	Not Recycled	Not Recycled	Not Recycled
Waste Acids (Sulfate Process)	Not Recycled	Not Recycled	Not Recycled
WWTP Sludges/Solids	Not Recycled	Not Recycled	Not Recycled
Option 3 (PT)			
Pickle Liquor and Wash Water	Not Recycled	780	1,517
Scrap Milling Scrubber Water	Not Recycled	2,002	2,290
Smut from Mg Recovery	1,067	63,887	96,162
Leach Liquor and Sponge Wash Water	16,740	20,429	24,018
Spent Surface Impoundment Liquids	Not Recycled	1,670	2,190
Spent Surface Impoundment Solids	Not Recycled	Not Recycled	Not Recycled
Waste Acids (Sulfate Process)	Not Recycled	Not Recycled	Not Recycled
WWTP Sludges/Solids	Not Recycled	Not Recycled	Not Recycled

G.4.3 Total Sector Storage Cost

To obtain a total sector storage cost, pre-rule (Modified Prior Treatment baseline) and post-rule (Option 3) total sector storage costs must be calculated for each waste stream and summed. Total sector pre- and post-rule storage costs are calculated by multiplying the minimum, expected, and maximum average facility storage cost for each titanium waste stream (Exhibit G-19) by the number of facilities generating the waste stream. Using leach liquor and sponge wash water as an example, the Option 3 total sector storage cost is \$42,792 (\$21,396 x 2 facilities) in the minimum value case, \$52,244 (\$26,122 x 2 facilities) in the expected value case, and \$60,916 (30,458 x 2 facilities) in the maximum value case. Exhibit G-20 shows the total sector storage cost for each waste stream and the total sector storage cost for the entire sector.

Exhibit G-20
Total Sector Storage Costs

Baseline or Option	Number of Facilities	Storage Cost (\$)		
		Minimum	Expected	Maximum
Modified Prior Treatment Baseline	-			
Pickle Liquor and Wash Water	3	0	2,949	5,619
Scrap Milling Scrubber Water	1	0	1,000	1,000
Smut from Mg Recovery	2	2,380	127,730	206,334
Leach Liquor and Sponge Wash Water	2	2,000	2,000	2,000
Spent Surface Impoundment Liquids	7	0	12,796	7,000
Spent Surface Impoundment Solids	7	0	0	0
Waste Acids (Sulfate Process)	2	0	0	0
WWTP Sludges/Solids	7	0	0	0
Pre-Rule Total Sector		4,380	146,475	221,953
Option 3 (PT)	-			
Pickle Liquor and Wash Water	3	0	2,340	4,551
Scrap Milling Scrubber Water	1	0	2,002	2,290
Smut from Mg Recovery	2	2,134	127,774	192,324
Leach Liquor and Sponge Wash Water	2	33,480	40,858	48,036
Spent Surface Impoundment Liquids	7	0	11,690	15,330
Spent Surface Impoundment Solids	7	0	0	0
Waste Acids (Sulfate Process)	2	0	0	0
WWTP Sludges/Solids	7	0	0	0
Post-Rule Total Sector		35,614	184,664	262,531

G.4.4 Total Sector Incremental Storage Cost

The total titanium sector incremental storage cost is calculated by subtracting the pre-rule total sector storage cost from the post-rule total sector storage cost. In this example (where the pre-rule scenario is the Modified Prior Treatment baseline, and the post-rule scenario is Option 3), the total titanium sector incremental storage cost is \$31,234 in the minimum value case, \$38,189 in the expected value case, and \$40,578 in the maximum value case.¹³

¹³ In the minimum value case, there is a saving in storage cost due to a slight decrease in the amount of material recycled.

G.5. Incremental Cost Calculations

This section of the appendix shows how the model calculates the total incremental cost of the rulemaking for the titanium sector. The total incremental cost is calculated by adding the total sector incremental treatment cost (calculated in Section G.3), the total sector incremental storage cost (calculated in Section G.4), and a recordkeeping cost of \$1,411 per facility generating waste in the sector. The recordkeeping cost of \$1,411 per facility translates to a total sector recordkeeping cost of \$2,822 (\$1,411 x 2 facilities) in the minimum value case, and \$9,877 (\$1,411 x 7 facilities) in the expected and maximum value cases. Thus, for the titanium and titanium dioxide sector, the incremental cost of this rulemaking is equal to **\$76,374** (\$42,318 incremental treatment cost + \$31,234 incremental storage cost + \$2,822 recordkeeping cost) in the minimum value case, **\$237,232** (\$189,266 incremental treatment cost + \$38,189 incremental storage cost + \$9,877 recordkeeping cost) in the expected value case, and **\$379,847** (\$329,392 incremental treatment cost + \$40,578 incremental storage cost + \$9,877 recordkeeping cost) in the maximum value case.

The total cost incurred by an average facility in this sector is \$38,248 in the minimum value case, \$33,943 in the expected value case, and \$54,375 in the maximum value case. Average facility costs are calculated by dividing the total sector incremental cost by the maximum number of facilities in this sector. Note that in this example the *average* facility cost in the minimum value case (\$38,248) is larger than the average facility cost in the expected value case (\$33,943). This is due to the fact that there are only two facilities producing waste in the minimum value case, and seven facilities producing waste in the expected and maximum value cases. This results in a higher average facility cost because the *total* sector incremental cost is divided by two rather than seven.

RISK AND BENEFITS ASSESSMENT FOR THE STORAGE OF RECYCLED MATERIALS

APPENDIX H

This appendix presents a brief summary of the groundwater (Section H.1) and the multipathway (Section H.2) risk assessment for the land storage of newly-identified mineral processing wastes under the modified prior treatment baseline. This effort builds on previous efforts on the identification of recycled waste streams, the estimation of recycled volumes, the identification of waste management strategies, and in the development of waste constituent concentration data, described in the December 1995¹ and August 1996² Draft RIAs for the Phase IV LDRs and in the Technical Memorandum reporting the Revised Risk Assessment Results for groundwater submitted to EPA in July, 1996³.

The analyses presented in this appendix differ from the previous risk assessments for mineral processing wastes, first, in that risks from land storage, rather than ultimate disposal, are evaluated. The assessment is limited to only those waste streams that have been identified as being recycled by the Agency. This effort also differs from previous risk assessments in that it only addresses risks under the modified prior treatment baseline, and does not quantitatively evaluate residual risks under any of the proposed regulatory alternatives. This is because, under three of the regulatory alternatives, requirements would be imposed requiring the storage of recycled materials in either buildings or tanks, rather than on the ground, and release and transport models appropriate to evaluating risks associated with these technologies are not available. Thus, the assessment presented below evaluates only "baseline" risks by identifying specific waste streams and constituents posing risks of regulatory concern under the modified prior treatment assumptions. These risks would be reduced under the proposed regulatory controls, but quantitative estimates of the benefits of these regulatory controls (e.g. the numbers of facilities going from high-risk to low-risk categories) are not developed. Under Option 4, no controls would be imposed on the storage of recycled materials, so there would be no health benefits.

Finally, the risk assessment described in this appendix differs from previous risk assessments for mineral processing wastes in that risks are evaluated for pathways other than groundwater ingestion. As in previous risk assessments, we evaluate leachate releases from land-based units to groundwater and subsequent groundwater ingestion. However, in Section H.2 we evaluate the risks associated with other release events, transport and exposure media, and exposure pathways. This multipathway analysis evaluates risks associated with air particulate and surface runoff releases from waste piles, and risks arising

¹ ICF Incorporated, *Regulatory Impact Analysis of the Supplemental Proposed Rules Applying Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes*, Submitted to the Office of Solid Waste, US Environmental Protection Agency, December 1995.

² ICF Incorporated, *Regulatory Impact Analysis of the Application of Phase IV Land Disposal Restrictions to Newly Identified Mineral Processing Wastes*, Submitted to the Office of Solid Waste, US Environmental Protection Agency, August 1996.

³ ICF Incorporated, *Revised Results of Mineral Processing Wastes Risk and Benefits Assessments Using Constituent-Specific DAFs Derived for Mineral Processing Waste*, Submitted to the Office of Solid Waste, US Environmental Protection Agency, July 1, 1996.

from surface impoundment runoff events and inlet/outlet control failures. The transport and exposure media that are evaluated include air, soil and surface water, as well as home-grown crops and game fish.

H.1 RISK ASSESSMENT METHODS AND RESULTS FOR THE GROUNDWATER PATHWAY

This section of Appendix H presents a brief summary of the groundwater pathway risk assessment for the land storage of newly identified mineral processing wastes under the Modified Prior Treatment baseline. The analyses presented below employ very similar methods for estimating constituent releases, groundwater exposure concentrations, and health risks as were employed in the previous analyses. The only major differences from previous efforts are that groundwater DAFs have been derived using constituent concentration data for only those facilities and waste streams identified as being involved in recycling, and that the DAFs have been derived assuming a release duration of 20 years, corresponding to the assumed life of the recycling storage facilities, instead of the much longer release period assumed for disposal facilities. This section addresses only those potential health risks arising from exposures through consumption of contaminated groundwater. Potential risks associated with other release, transport, and exposure pathways are evaluated in Section H.2.

H.1.1 Methods and Assumptions

H.1.1.1 Regulatory Scenarios

As noted previously, risks have been assessed for the modified prior treatment baseline. Under this baseline, it is assumed that recycled spent materials and sludges and byproducts from mineral processing will be stored land-based units prior to recycling. Nonwastewaters would be stored in unlined waste piles, and wastewater and liquid nonwastewater streams would be stored in unlined surface impoundments. Unlike the situation for disposal facilities, it is assumed that, where two or more recycled streams are generated at a facility, the streams would be stored in separate units prior to recycling, and that there would be no comanagement. Also, it has been assumed that the storage units would be sized to just accommodate the required amount of recycled material; three months' generation rates in the case of nonwastewaters, and one month's generation in the case of wastewaters and liquid nonwastewaters. The assumptions used to evaluate the size and configuration of storage facilities are described in detail in the December 1995 RIA and in Appendix D of this RIA.

H.1.1.2 Identification of Waste Streams

Under the modified prior treatment baseline, it is assumed that all recycled spent materials and recycled sludges and byproducts would be managed in land-based units. Thus, all of these waste streams were candidates for the storage risk assessment. Constituent concentration data were available for only some of these streams, however. Risks were therefore evaluated only for the 14 recycled waste streams listed in Exhibit H-1. Two of the waste streams (aluminum and alumina cast house dust and zinc waste ferrosilicon) are nonwastewaters, and the remainder are wastewaters or liquid nonwastewaters.

Although groundwater pathway risks were calculated for only 14 of the 118 total mineral processing waste streams, these streams represent substantial proportions of the total generated wastes and an even higher proportion of the recycled wastes. Depending on which estimate of waste generation is used (minimum, expected, or maximum), the 14 recycled streams included in the risk analysis represent between 32 and 42 percent of the total waste generation, and account for between 57 and 68 percent of the total recycled volume. This is because constituent concentration data are available for a substantial proportion of the high-volume waste streams. The extent of coverage of the storage risk assessment for the various commodity sectors is summarized in Attachment H.A to this appendix.

H.1.1.3 Waste Characterization Data and Release Concentration Estimates

The original source of constituent concentration data for the recycled materials used in the pre-LDR risk estimates is the same as that used in the RIA sample-specific risk assessment. These data are summarized in Appendix K of the December 1995 RIA. Consistent with the previous risk assessment, constituent concentration data from both bulk samples and EP extraction analysis were used in the risk assessment, when they were available, to develop separate risk estimates for the same waste streams. This was done in order to make the best possible use of the available data, and because in many cases we could not be sure that EP and bulk analyses from a given waste stream were from the same samples or batch of waste.

EXHIBIT H-1. RECYCLED STREAMS INCLUDED IN THE STORAGE RISK ANALYSIS

Commodity	Recycled Stream
Aluminum and Alumina	Cast House Dust
Beryllium	Chip Treatment Wastewater
Copper	Acid Plant Blowdown
Elemental Phosphorus	AFM Rinsate
Elemental Phosphorus	Furnace Scrubber Blowdown
Rare Earths	Process Wastewater
Selenium	Plant Process Wastewater
Tantalum, Columbium, and Ferrocolumbium	Process Wastewater
Titanium and Titanium Oxide	Leach Liquor and Sponge Wastewater
Titanium and Titanium Oxide	Scrap Milling Scrubber Water
Zinc	Waste Ferrosilicon
Zinc	Spent Surface Impoundment Liquids
Zinc	Waste Water Treatment Plant Liquid Effluent
Zinc	Process Wastewater

Constituent data from 187 waste samples were used to develop DAF values and to evaluate risks from land storage. Exhibit H-2 presents a breakdown of the samples by facility and types of analysis. It can be seen that the large majority of the data come from bulk samples, and the majority of the samples are from facilities whose identities and locations are unknown. Only three of the 185 samples are from nonwastewater streams managed in waste piles, with the remainder from wastewater and liquid nonwastewater streams managed in surface impoundments.

EXHIBIT H-2. DISTRIBUTION OF SAMPLES BY WASTE, SAMPLE, AND FACILITY TYPE

Waste Type	Bulk Samples	EP Extraction Sample	Known Facilities	Unknown Facilities
Nonwastewater	2	1	0	3
Wastewater	92	25	63	54
Liquid Nonwastewater	51	16	12	55

Arsenic concentration data were available for 75 of the waste samples, allowing the calculation of cancer risks for these samples. Noncarcinogen concentration data for constituents having DAF values and RfDs were available for 135 samples, which include all 75 of those with arsenic data. For WW streams, the bulk concentration sample results were used directly as release concentration estimates. For LNWW and NWW, EP leachate concentrations were also used directly as release concentrations. For LNWW and WW bulk samples, release concentrations (mg/l) were conservatively estimated as being equal to the bulk constituent concentrations (mg/kg) divided by 20. This approach conservatively assumes that all waste constituents are 100 percent leachable.

All of the analytical results from every sample were used to evaluate risks, with one exception. A single bulk analytical result for selenium (100,000 mg/l) in zinc process wastewater was omitted from the risk analysis because this value far exceeds the maximum solubility of most naturally occurring selenium compounds, and is clearly spurious, based on the results for other samples from the same waste stream.

H.1.1.4 Exposure Assessment

Analogous to the procedures used in previous risk assessments, two sets exposure of exposure estimates were developed. Central tendency (CT) exposure concentrations were estimated by dividing the release concentrations of each constituent from each waste stream by the 75th percentile DAF value derived for that constituent. High-end (HE) exposure concentrations were estimating by dividing the release concentrations by the 95th percentile DAF values. The rationale for using the 75th percentile DAFs rather than, for example, the 50th percentile value was that the EPACMTP model used to derive DAFs does not consider fractured or channeled flow or other facilitated transport mechanisms which may occur at some sites, resulting in higher groundwater concentrations than those predicted for homogeneous flow processes modeled by EPACMTP. The 75th percentile of the DAF distribution was therefore judged by EPA to be more nearly representative of dilution conditions for the entire population of facilities than the 50th percentile. The 95th percentile constituent-specific DAF values were used to estimate high-end (HE) groundwater concentrations in keeping with the definition of a high-end receptor as someone exposed at levels between the 90th and 99th percentiles of all exposed individuals. Separate exposure and risk estimates were developed for each waste sample, analogous to the approach used for the analysis of disposal risks. DAF values were derived separately for waste piles and surface impoundments, and used to estimate exposure concentrations for nonwastewaters and liquid nonwastewaters/wastewaters, respectively. The DAF values derived by EPA for use in the mineral processing recycled materials storage risk assessment are shown in Exhibit H-3.

It can be seen from this exhibit that the DAF values (both the 75th and 95th percentile) derived for the management of recycled materials in waste piles are generally very much higher than those derived for surface impoundments. This is due primarily to the lower leachate volume generated by the waste piles than by surface impoundments. In the waste piles, leachate generation is limited by rainfall (and a large

proportion of the facilities are in relatively dry areas), whereas surface impoundments provide their own leachate source to drive releases, in the form of the aqueous liquid wastes which they contain.

For all of the constituents, the CT DAF values for waste piles are greater than 10^{12} , implying, as will be seen below, such high dilutions of leachate that CT risks from all the constituents released from waste piles are well below levels of regulatory concern. The HE DAF value for waste piles are much lower for most constituents (in the range of 10^4 to 10^6), but still generally several orders of magnitude above even the corresponding HE values for surface impoundments. Thus, even the HE exposure concentrations associated with releases from waste piles result in relatively low risks.

The CT surface impoundment DAF values for all of the constituents but cyanide, lead, and mercury are all around 1000. The HE DAF values surface impoundments are mostly less than 100, with the exceptions being vanadium, cyanide and lead. As will be seen below, these lower DAF values imply higher risks for given constituent concentrations than do the DAF values for waste piles.

EXHIBIT H-3. DAF VALUES USED IN THE STORAGE RISK ASSESSMENT

Constituent	Waste Pile DAF		Surface Impoundment DAF	
	75th Percentile	95th Percentile	75th Percentile	95th Percentile
Antimony	$>10^{12}$	2.0×10^6	2.7×10^3	5.3×10^1
Arsenic	$>10^{12}$	1.8×10^5	1.1×10^3	3.37×10^1
Barium	$>10^{12}$	1.2×10^4	1.5×10^2	2.9
Cadmium	$>10^{12}$	2.4×10^6	2.1×10^3	1.3×10^1
Chromium (+6)	$>10^{12}$	9.9×10^4	6.3×10^2	2.4×10^1
Cyanide	NA*	NA	2.9×10^9	1.8×10^3
Lead	$>10^{12}$	$>10^{12}$	$>10^{12}$	1.2×10^3
Mercury	$>10^{12}$	3.3×10^6	1.5×10^3	2.6×10^1
Nickel	$>10^{12}$	3.4×10^6	1.6×10^3	1.2×10^1
Selenium	$>10^{12}$	2.4×10^4	1.9×10^2	6.2
Silver	$>10^{12}$	2.5×10^4	4.3×10^2	4.2
Thallium	NA	NA	3.5×10^3	9.0×10^1
Vanadium	NA	NA	$>10^{12}$	$>10^{12}$
Zinc	$>10^{12}$	5.8×10^6	6.7×10^2	3.9

* DAFs were not derived for these constituents because no analytical data were reported for these constituents in any of the wastes disposed in waste piles.

H.1.1.5 Risk Characterization

Daily intakes of the waste constituents due to groundwater ingestion are estimated in precisely the same way as described in the July memorandum.² For arsenic, (the only constituent considered to be carcinogenic by ingestion), lifetime daily intake is calculated for a 70-kg adult drinking 1.4 liters per day of contaminated groundwater 350 days per year for nine years, assuming a 70-year life-span for averaging purposes. Daily intakes of noncarcinogens are calculated using the same assumptions, except that the dose is averaged over the period of exposure, rather than over a lifetime.

Lifetime cancer risks are calculated by multiplying the lifetime daily arsenic intake (from those waste streams having arsenic as a constituent) by the ingestion Cancer Slope Factor for arsenic of 1.5 (mg/kg-day)⁻¹. Noncancer hazard quotients for exposure to waste constituents are calculated by dividing the daily constituent intake of each constituent by its ingestion pathway Reference Dose (RfD). The toxicity values used in the assessment all come from EPA's IRIS database, and are current as of December 1996.

H.1.2 Estimation of Numbers of Facilities at Specific Risk Levels

In the previous risk and benefits assessments performed for the disposal of mineral processing wastes, the measure of the benefits of the regulatory alternatives was the reduction in the number of facilities at which waste management would result in risks above levels of regulatory concern. As noted previously, no risk assessment has been performed for the storage of recycled materials under any of the regulatory alternatives. Thus, a similar quantitative benefits assessment is not possible for waste storage under the various regulatory alternatives.

This risk assessment, however, does provide an estimate of the numbers of facilities in the various commodity sectors at which risks exceed levels of regulatory concern under the modified prior treatment baseline. This estimate presents an upper bound limit on the possible regulatory benefits; e.g., if regulation reduced releases of all waste constituents to zero, then all of the baseline risks greater than levels of regulatory concern would go to zero as well. Less than perfect control of releases would result in correspondingly smaller reductions in the number of facilities at high risk levels (yielding lower benefits), although the magnitude of risk reduction has not been quantified.

H.1.2.1 Estimation of the Numbers of Facilities Storing Recycled Materials

Risks have been assessed for all of the commodity sectors and waste stream which have been identified by the Agency as being involved in recycling under the modified prior treatment baseline, and for which constituent concentration data are available, as identified in Exhibit H-1. In this analysis, it has been assumed that all of the facilities in each commodity sector not only generate but store recycled sludges, byproducts, and spent materials. Thus, the numbers of facilities included in the assessment are simply equal the estimated numbers of facilities in the commodity sector, which is exactly analogous to the approach taken in the analysis of the risks associated with waste disposal.

In this analysis, it has been assumed that all of the facilities identified as generating the recycled streams also recycle them, under both CT and HE assumptions. Thus, the number of waste stream-facility combinations in each commodity sector is the same for the HE and CT risk estimates. Analogous to the previous analysis, where a single facility stores more than one waste stream, it is counted as more than one "waste stream-facility combination."

H.1.2.2 Attribution of Risks to Facility-Waste Stream Combinations

As was the case for the analysis of disposal risks, the number of risk estimates (one from each sample) does not always equal (in fact, rarely equals) the number of facilities storing the wastes. Thus, in estimating the distribution of risks across a commodity sector it is necessary to apportion the risks from individual samples to the CT and HE numbers of facilities.

The procedures used to do this are described in detail in Section 2.2.2 of the July memorandum. Basically, the approach involves distributing risk levels across the facilities in commodity sector in as close to the same proportions as they are distributed across the individual waste samples from the waste generated by that sector. For example, if there are two samples of a given waste stream in the data base, one with an estimated cancer risk of 10^{-6} and one with an estimated risk of 10^{-2} , half the facilities in the commodity sector would be placed in the " $<10^{-5}$ " category, and half would fall into the " 10^{-3} to 10^{-2} " category. One of the outcomes of using this approach is that not every risk result above a level of concern translates into a waste stream-facility combination. For example if there is only a very small proportion of samples (for example, one in 20) giving high risks, this may translate into zero waste stream facility combinations if there are, for example, only two or three total facilities in the industry. The July memo describes the approaches used for rounding the estimates of facilities in the various risk categories, where apportionment cannot be done evenly, and for combining risk estimates from multiple samples from a single facility so, so as not to give them undue weight across an entire industry.

H.1.3 Results of the Groundwater Risk Assessment

H.1.3.1 Risk Assessment Results by Sample

Exhibit H-4 summarizes the carcinogenic groundwater risk results for the 75 samples identified as containing arsenic, the sole ingestion pathway carcinogen among the waste constituents. Using the central tendency DAF values, the calculated cancer risks for 49 of these samples were less than 10^{-5} , the level of regulatory concern, and the risks for 26 of the samples exceeded this value. Cancer risks exceeded 10^{-5} for one or more samples from only four waste streams; copper acid plant blowdown, elemental phosphorous furnace scrubber blowdown, tantalum, columbium, and ferrocolumbium process wastewater, and zinc spent surface impoundment liquids. The highest risks cancer risks were associated with three samples of copper acid plant blowdown (10^{-3} to 10^{-2}). This waste stream accounted for 14 of the 16 samples with the highest CT cancer risks. The next highest risks (in the 10^{-4} to 10^{-3} range) were associated with one sample each from tantalum process wastewater and zinc spent surface impoundment liquids.

Using the high-end (CT) DAF values, cancer risks calculated for the groundwater pathway exceeded 10^{-5} for 50 of the 75 samples. Under this set of assumptions, risks for at least one sample exceeded 10^{-5} for 10 of the 14 waste streams evaluated. The highest risks (25 of 30 samples $> 10^{-5}$, highest risk category $>10^{-1}$) were again associated with copper acid plant blowdown, with the next highest risk (10^{-2} to 10^{-1}) being associated with the single sample of zinc spent surface impoundment liquids. Of the wastes whose CT cancer risks were below 10^{-5} for all samples, six (elemental phosphorous AFM rinsate, rare earths process wastewater, selenium plant wastewater, titanium/ TiO_2 leach liquor and sponge wash water and scrap milling scrubber water, and zinc process wastewaters), had at least one sample with HE cancer risks above this level.

Cancer risks for most of the samples increased about two orders of magnitude from the CT to HE case. This is consistent with the difference between the CT and HE DAF values for arsenic managed in surface

H-8

EXHIBIT H-4

Distribution of Samples by Groundwater Risk Category: Ca

Commodity	Waste Stream	Number of Samples with Cancer Risk	Central Tendency						
			10-5 to <10-5	10-4 to 10-4	10-3 to 10-3	10-2 to 10-2	10-1 to 10-1	>10-1	<10-5
Aluminum and Alumina	Cast house dust	2	2	0	0	0	0	0	2
Beryllium	Chip treatment WW	1	1	0	0	0	0	0	1
Copper	Acid plant blowdown	30	9	7	8	3	3	0	5
Elemental Phosphorus	AFM rinsate	2	2	0	0	0	0	0	0
Elemental Phosphorus	Furnace scrubber blowdown	8	7	1	0	0	0	0	3
Rare Earths	PWW	2	2	0	0	0	0	0	0
Selenium	Plant PWW	2	2	0	0	0	0	0	0
Tantalum, Columbium, and Ferrocolumbium.	PWW	13	10	2	1	0	0	0	7
Titanium and TiO ₂	Leach liquor & sponge wash water	2	2	0	0	0	0	0	0
Titanium and TiO ₂	Scrap milling scrubber water	1	1	0	0	0	0	0	0
Zinc	Waste ferrosilicon	0	0	0	0	0	0	0	0
Zinc	Spent s.i. liquids	1	0	0	1	0	0	0	0
Zinc	WWTP liquid effluent	0	0	0	0	0	0	0	0
Zinc	Process wastewater	11	11	0	0	0	0	0	7
Totals		75	49	10	10	3	3	0	25

April 15, 1997

impoundments. In the case of the NWW waste streams managed in piles, both the CT and HE cancer risks for all samples were below 10^{-5} . For aluminum/alumina cast house dust, this reflected the much higher CT and HE DAF values for arsenic managed in waste piles, compared to surface impoundments, as well on the relatively small mass of arsenic present in the waste pile. Arsenic was not detected in the single sample of waste ferrosilicon from zinc production. Thus, no carcinogenic risks were calculated for this waste. The two other streams for which all HE sample-specific cancer risks were below 10^{-5} were beryllium chip treatment wastewater and zinc wastewater treatment plant liquid effluent.

Noncancer hazard quotient values for groundwater pathway for the individual samples of recycled materials are summarized in Exhibit H-5. Using the CT DAF values, hazard quotient values exceeding 1.0 were calculated for 43 of 135 total samples from the 14 waste streams. As was the case for cancer risks, copper acid plant blowdown had the highest number of samples with noncancer hazard quotients above 1.0 (18 of 35 samples), and had the highest number of samples (4) in the highest risk category (HQ = 100 to 1000). Samples from zinc production (11 of 22 for spent surface impoundment liquids and 8 of 16 for process wastewater) account for the bulk of the remaining hazard quotients above 1.0. The only other waste streams with CT hazard quotients above 1.0 included beryllium chip treatment wastewater (one sample), elemental phosphorous furnace scrubber blowdown (one sample), tantalum, etc., process waste water (three samples), and zinc wastewater treatment plant liquid effluent (one sample).

When the HE DAF values are used to calculate exposures, hazard quotients exceed 1.0 for 100 of the 135 samples. As was the case for cancer risks, most of the hazard quotient values for individual samples are increased one to two orders of magnitude in the HE case compared to the CT case, reflecting the changes in the DAF values for the risk driving constituents managed in surface impoundments. As for cancer risks, both the CT and HE DAF values for waste piles for all of the constituents are so high, and the masses of constituents are so low, that no samples of the two waste streams managed in waste piles have hazard quotients exceeding 1.0 in either the CT or HE case. Hazard quotient values for five waste streams which were all below 1.0 in the CT case exceeded 1.0 in the HE case for at least one sample (elemental phosphorous AFM rinsate, rare earth process wastewater, selenium process wastewater, and titanium/TiO₂ leach liquor and sponge wash water and scrap milling scrubber sludge).

H.1.3.2 Risk Driving Constituents

For all of the cancer risk calculations, arsenic, being the only ingestion pathway carcinogen among the constituents evaluated, was always the risk driver. In the case of noncancer risks, many constituents drove risks (had the highest hazard quotients) for the samples evaluated. The noncancer risk driving constituents (constituents with the highest HE hazard quotients) for the various waste streams are identified in Exhibit H-6.

Overall, cadmium was the most common driving constituent, having the highest hazard quotient for one-half (50/100) of the samples with hazard quotients above 1.0. Arsenic and zinc (16 samples each) were the next most common drivers, followed by thallium (8 samples), and chromium (6 samples). None of the other constituents were noncancer risk drivers for more than one sample. Among the recycled streams with the highest numbers of samples, arsenic and cadmium were the predominant risk drivers for copper acid plant blowdown (26 out of 30 samples), cadmium was the dominant driver for elemental phosphorous furnace scrubber blowdown (8 of 10 samples), and cadmium and zinc were the predominant risk drivers for the three liquid recycled streams from zinc production.

H-10

EXHIBIT H-5

Distribution of Samples by Groundwater Hazard Category: Non-Cancer Hazards

Commodity	Waste Stream	Number of Samples with Non-cancer Hazard	Central Tendency						High End					
			1	10	100	1k			1	10	100	1k		
			to	to	to	to	>10k	<1	to	to	to	to	>10k	<1
			<1	10	100	1k	10k	>10k	<1	10	100	1k	10k	>10k
Aluminum and Alumina	Cast house dust	2	2	0	0	0	0	0	2	0	0	0	0	0
Beryllium	Chip treatment WW	1	0	0	1	0	0	0	0	0	0	0	1	0
Copper	Acid plant blowdown	35	17	10	4	4	0	0	3	7	12	7	4	2
Elemental Phosphorus	AFM rinsate	2	2	0	0	0	0	0	0	0	2	0	0	0
Elemental Phosphorus	Furnace scrubber blowdown	14	13	1	0	0	0	0	4	4	5	1	0	0
Rare Earths	PWW	4	4	0	0	0	0	0	2	2	0	0	0	0
Selenium	Plant PWW	2	2	0	0	0	0	0	0	2	0	0	0	0
Tantalum, Columbium, and Ferrocolumbium	PWW	21	18	3	0	0	0	0	13	3	0	5	0	0
Titanium and TiO ₂	Leach liquor & sponge wash water	2	2	0	0	0	0	0	0	1	1	0	0	0
Titanium and TiO ₂	Scrap milling scrubber water	1	1	0	0	0	0	0	0	1	0	0	0	0
Zinc	Waste ferrosilicon	1	1	0	0	0	0	0	1	0	0	0	0	0
Zinc	Spent s.i. liquids	22	11	5	4	2	0	0	4	3	2	7	2	4
Zinc	WWTP liquid effluent	3	2	0	0	1	0	0	0	1	1	0	0	1
Zinc	Process wastewater	24	16	7	1	0	0	0	5	4	5	8	2	0
Totals		134	91	26	10	7	0	0	34	28	28	28	9	7

April 15, 1997

EXHIBIT H-6

Constituents Driving Non-Cancer Hazard Quotients in Recycled Streams

Commodity	Waste Stream	Driving Constituent (number of samples)
Aluminum and Alumina	Cast house dust	2 samples total; no hazard quotients greater than 1
Beryllium	Chip treatment WW	Beryllium (1/1)
Copper	Acid plant blowdown	Arsenic (15/35), Cadmium (11), Chromium (1), Lead (1), Selenium (1), Thallium (1), Zinc (2)
Elemental Phosphorus	AFM rinsate	Cadmium (2/2)
Elemental Phosphorus	Furnace scrubber blowdown	Cadmium (8/14), Chromium (1), Thallium (1)
Rare Earths	PWW	Thallium (2/4)
Selenium	Plant PWW	Arsenic (½), Thallium (1)
Tantalum, Columbium, and Ferrocolumbium	PWW	Antimony (1/21), Cadmium (3), Chromium (4)
Titanium and TiO ₂	Leach liquor & sponge wash water	Thallium (2/2)
Titanium and TiO ₂	Scrap milling scrubber water	Thallium (1/1)
Zinc	Waste ferrosilicon	1 sample total; no hazard quotients greater than 1
Zinc	Spent s.i. liquids	Cadmium (12/22), Zinc (6)
Zinc	WWTP liquid effluent	Cadmium (2/3), Zinc (1)
Zinc	Process wastewater	Cadmium (12/24*), Zinc (7)

* A sample with a selenium concentration of 100,000 ppm was excluded from the analysis

H.1.2.3 Risk Assessment Results by Facility

The cancer risk results for the individual samples, distributed across the numbers of facilities generating and storing the wastes, are summarized in Exhibit H-7. Using the methods described in Section H.1.1.2, it was estimated that CT groundwater pathway cancer risks would exceed 10^{-5} at 11 of the 57 waste stream-facility facilities⁴. All of these waste stream-facility combinations were managing either copper acid plant blowdown (7 facility-waste stream combinations) or zinc spent surface impoundment liquids (3 combinations). These results, of course generally reflect the pattern of sample-specific risk results for the various waste sectors. It will be noted, however, that for two waste streams, findings of one or more sample with greater than 10^{-5} risks did not translate into any facility-waste combinations above 10^{-5} risks. In the case of elemental phosphorous furnace scrubber blowdown, only one of seven samples had a cancer risk of just above 10^{-5} . Distributed across two facilities estimated to be storing this waste, this result (one-seventh of the samples having risks above 10^{-5}) was rounded down to zero. Similarly, in the case of tantalum, etc., process wastewater, three of thirteen samples with risks above 10^{-5} was again rounded downward to zero of two facility-waste stream combinations. This occurrence is the almost inevitable result of having so few facilities in so many industries, and the fact that non-integral numbers of waste-stream facility combinations are meaningless as risk or benefit indicators. It would be reasonable to interpret these results as indicating that either zero or one facility in these industries might have CT cancer risk above 10^{-5} .

When HE DAF values are used, the number of facility-waste stream combinations with cancer risks above 10^{-5} increases to 24 of 57 facilities. Under HE assumptions, most of the waste streams show one or more facilities at risk levels above 10^{-5} , the exceptions being the four low-risk waste streams identified in Exhibit H-4. These include both the two NWW streams that would be stored in waste piles, as well as beryllium chip treatment wastewater and zinc wastewater treatment plant liquid effluent. As noted previously, arsenic is not reported as a constituent of the latter waste.

The distribution of facility-waste stream combinations by noncancer risk category is summarized in Exhibit H-8. Using the CT DAF values, 12 waste stream-facility combinations are identified as having noncancer hazard quotients greater than 1.0. Five of these facilities are managing copper acid plant blowdown, two are managing beryllium chip treatment wastewater, and two of the facility-waste stream combinations are associated with the management of zinc spent surface impoundment liquids.

Using HE DAF values, 28 waste stream-facility combinations are identified as being associated with noncancer hazard quotients above 1.0. Again, four waste streams have no facility-waste stream combinations with hazard quotients above levels of concern: aluminum/alumina cast house dust; rare earth chip treatment wastewater, tantalum, etc., process wastewater, and zinc spent waste ferrosilicon.

⁴ Note that the totals in the risk categories do not sum exactly due to rounding. This is true for the following exhibit as well.

H-13

EXHIBIT H-7

Distribution of Waste Stream-Facility Combinations by Groundwater Risk Category: Cancer Risks

Commodity	Waste Stream	Number of Waste Stream/ Facility Combinations* #		Central Tendency						High End					
		Central Tendency	High End	10-5	10-4	10-3	10-2	>10-1	<10-5	10-5	10-4	10-3	10-2	>10-1	<10-5
				to	to	to	to			to	to	to	to		
Aluminum and Alumina	Cast house dust	23	23	23	0	0	0	0	0	23	0	0	0	0	0
Beryllium	Chip treatment WW	2	2	2	0	0	0	0	0	2	0	0	0	0	0
Copper	Acid plant blowdown	10	10	3	2	3	1	1	0	2	1	2	2	2	2
Elemental Phosphorus	AFM rinsate	2	2	2	0	0	0	0	0	0	1	1	0	0	0
Elemental Phosphorus	Furnace scrubber blowdown	2	2	2	0	0	0	0	0	1	1	1	0	0	0
Rare Earths	PWW	1	1	1	0	0	0	0	0	0	1	0	0	0	0
Selenium	Plant PWW	2	2	2	0	0	0	0	0	0	1	1	0	0	0
Tantalum, Columbium, and Ferrocolumbium	PWW	2	2	2	0	0	0	0	0	1	1	0	0	0	0
Titanium and TiO ₂	Leach liquor & sponge wash water	2	2	2	0	0	0	0	0	0	1	1	0	0	0
Titanium and TiO ₂	Scrap milling scrubber water	1	1	1	0	0	0	0	0	0	1	0	0	0	0
Zinc	Waste ferrosilicon	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Zinc	Spent s.i. liquids	3	3	0	0	3	0	0	0	0	0	0	0	3	0
Zinc	WWTP liquid effluent	3	3	0	0	0	0	0	0	0	0	0	0	0	0
Zinc	Process wastewater	3	3	3	0	0	0	0	0	2	0	1	0	0	0
TOTALS*		57	57	42	3	6	1	1	0	30	8	6	3	5	2

* Sums by risk category may not add to the number of central or high-end waste stream/facility combinations due to rounding.

Includes waste stream/facility combinations with no cancer risk (but with an associated non-cancer hazard)

April 15, 1997

EXHIBIT H-8

Distribution of Waste Stream-Facility Combinations by Groundwater Hazard Category: Non-Cancer Hazards

Commodity	Waste Stream	Number of Waste Stream/ Facility Combinations*		Central Tendency							High End					
		Central Tendency	High End													
				<1	1 to 10	10 to 100	100 to 1k	1k to 10k	>10k		<1	1 to 10	10 to 100	100 to 1k	1k to 10k	>10k
Aluminum and Alumina	Cast house dust	23	23	23	0	0	0	0	0		23	0	0	0	0	0
Beryllium	Chip treatment WW	2	2	0	0	2	0	0	0		0	0	0	0	2	0
Copper	Acid plant blowdown	10	10	4	3	1	1	0	0		1	2	3	2	1	1
Elemental Phosphorus	AFM rinsate	2	2	2	0	0	0	0	0		0	0	2	0	0	0
Elemental Phosphorus	Furnace scrubber blowdown	2	2	2	0	0	0	0	0		1	1	1	0	0	0
Rare Earths	PWW	1	1	1	0	0	0	0	0		1	0	0	0	0	0
Selenium	Plant PWW	2	2	2	0	0	0	0	0		0	2	0	0	0	0
Tantalum, Columbium, and Ferrocolumbium	PWW	2	2	2	0	0	0	0	0		1	0	0	0	0	0
Titanium and TiO ₂	Leach liquor & sponge wash water	2	2	2	0	0	0	0	0		0	1	1	0	0	0
Titanium and TiO ₂	Scrap milling scrubber water	1	1	1	0	0	0	0	0		0	1	0	0	0	0
Zinc	Waste ferrosilicon	1	1	1	0	0	0	0	0		1	0	0	0	0	0
Zinc	Spent s.i. liquids	3	3	2	0	1	1	0	0		0	0	0	1	0	1
Zinc	WWTP liquid effluent	3	3	2	0	0	1	0	0		0	1	1	0	0	1
Zinc	Process wastewater	3	3	2	1	0	0	0	0		1	1	1	1	0	0
TOTALS*		57	57	45	5	4	3	0	0		29	9	9	4	4	2

* Sums by hazard category may not add to the number of central or high-end waste stream-facility combinations due to rounding.

H.1.4 Summary of Groundwater Pathway Risk Results

The preceding analysis indicates that the storage of some mineral processing recycled materials in land-based units under modified prior treatment baseline assumptions may be associated with significant health risks due to groundwater consumption. Cancer risks greater than 10^{-5} and hazard quotients greater than 1.0 are predicted for the minority of waste streams and individual samples under CT exposure assumptions and for the majority of waste streams and samples under HE exposure assumptions. Estimated cancer risks range up to 10^{-1} for some samples under CT exposure assumptions and exceed 10^{-1} under HE assumptions. Hazard quotient values similarly approach 1,000 under CT assumptions and exceed 10,000 for a few waste streams using the HE DAF values.

Copper acid plant blowdown has the largest number of samples with high cancer risks, and the highest cancer risks for this recycled stream exceed those for the next highest stream by one to two orders of magnitude. This stream also has the largest number of samples with hazard quotients above 1.0, followed by zinc spent surface impoundment liquids and process wastewater.

Aluminum/alumina cast house dust and zinc waste ferrosilicon are the only two waste streams for which no samples exceed 10^{-5} cancer risk or noncancer hazard quotient value of 1.0 under either CT or HE assumptions. These are the only two nonwastewater streams evaluated, and the low risk results are primarily a function of the very high DAF values for waste piles compared to the values derived for surface impoundments. Two other waste streams (beryllium chip treatment wastewater and zinc wastewater treatment plant liquid effluent) have low cancer risks even under HE assumptions, but one or more samples of each of these wastes is associated with hazard quotients greatly exceeding 1.0, even under CT assumptions.

Aluminum and alumina cast house dust (23 facilities) and copper acid plant blowdown (10 facilities) account for almost half the facilities evaluated in the analysis. As noted above, risks for the former stream are all low, so cast house dust has no waste stream-facility combinations above risk levels of concern. The majority of the waste stream-facility combinations managing copper acid plant blowdown, in contrast, are placed into risk categories above levels of concern under both CT and HE assumptions, and this waste stream contributes the largest number of waste stream-facility combinations at high risk levels of any waste stream.

On a volume basis, two streams (copper acid plant blowdown and zinc process wastewater) account for approximately 80 percent of the total recycled materials volume for which constituent concentration data are available. As noted above, copper acid plant blowdown is one of the highest-risk waste streams. While the cancer risks estimated for zinc process wastewater generally fall into the low-risk categories, the noncancer hazard indices associated with this waste stream are generally quite high, especially under HE assumptions.

H.1.5 Uncertainties/Limitation of Analysis

Most of the major sources of uncertainty for this risk assessment of storage of mineral processing recycled materials are the same as those for the previous analyses of mineral processing waste disposal. These uncertainties are discussed in detail in the cited references. To summarize briefly, the major uncertainties include:

- Limitations in data concerning the identities, amounts, constituent concentrations, and leaching behavior of the recycled materials.

- Limitations in data concerning the amounts of the specific recycled streams generated at specific facilities and the management methods used during storage.
- Limitation in knowledge concerning the locations, climatic, and hydrogeological settings at mineral processing facilities.
- Uncertainties and variability in the methods used to model leaching and groundwater transport (DAFs) of the toxic constituents of recycled materials.
- Uncertainties in the methods used to identify exposed receptors, estimate human exposures, and in characterizing the toxicological impacts of exposure to toxic constituents of recycled materials.

All of these sources of uncertainty (and variability) apply at least as much to the evaluation of storage risks as they did to the evaluation of risks from waste disposal. As noted above, the number of samples used to derive DAFs, and for estimating risks for the recycled materials, is quite limited, even more so than in the case of the waste disposal risk assessment. This is especially true for the nonwastewaters managed in waste piles, for which only three samples from two waste streams (all from unknown facilities) were available.

H.2 RISK ASSESSMENT METHODS AND RESULTS FOR NON-GROUNDWATER PATHWAYS

This section presents a summary of the risk assessment for the land storage of newly-identified mineral wastes under the non-groundwater modified prior treatment baseline.

H.2.1 Methods and Assumptions

H.2.1.1 Overview of Risk Assessment Methods

The multimedia risk assessment for the storage of mineral processing wastes employs many of the methods and assumptions used by EPA to develop the proposed risk-based exit levels for the Hazardous Waste Identification Rule (HWIR-Waste). The HWIR-Waste Technical Support Document⁵ provides a detailed description of methods for evaluating releases, characterizing transport, and estimating exposures and risks associated with a number of non-hazardous waste management units. Individual algorithms and equations from HWIR-Waste are used to evaluate human exposures and risks associated with specific types of release events from land-based units (waste piles and landfills) that manage mineral processing recycled materials. In most cases, the HWIR-Waste methods are used without significant modification. However, in some instances, models were adjusted or simplified to reflect the specific characteristics of the facilities and constituents being modeled. For example, since none of the constituents addressed in this effort are appreciably volatile, the volatilization release and depletion equations from the HWIR-Waste models were not used and, since the recycling storage units were assumed to operate for only 20 years, the long-term steady-state assumptions employed in HWIR-Waste to estimate media concentrations were not valid, and time-dependent methods were substituted. Because of the shorter operating life spans of the storage units, compared to the assumptions made in HWIR-Waste, we also eliminated the soil depletion algorithms related to leaching and runoff. Thus, all soil contaminants were assumed to be fully conserved

⁵ USEPA, *Technical Support Document for the Hazardous Waste Identification Rule: Risk Assessment for Human and Ecological Receptors*, Office of Solid Waste, August 1995.

for the entire exposure period. Finally, particulate release and transport models were used which differed slightly from those used in HWIR-Waste, and generic climatic assumptions were used in the evaluation of air transport. These methods are described in detail in Attachment H-B.

The same general assumptions regarding receptors and receptor behavior were employed in this analysis as were used in HWIR-Waste. With a few exceptions, the same values for exposure frequency and duration and other exposure factors are used as were employed in HWIR-Waste. Most of the exposure factors corresponded either to the adult resident, child resident, subsistence farmer, or subsistence fisher receptors defined in HWIR-Waste, depending on whichever had the highest exposures and risks. The only major exception was again related to the characteristics of the facilities being evaluated, in that release and exposure durations were adjusted to 20 years for "direct" pathways, corresponding to the assumed life-span of the management units. A full 30 years high-end exposure assumption is employed, however, for exposures to persistent constituents in soils.

Input data for the release models come from the database of waste constituent concentrations developed in support of the RIA (see Section H.1.1.3). In this case, however, only those streams are included which EPA has identified as having non-zero recycled volumes in the expected cost scenario of the modified prior treatment baseline. Facility characteristics and sizes from the least-cost management strategies developed in the RIA are used, as discussed in Section 3.0 of this RIA.

The exposure and risk assessment algorithms are applied in a screening mode to identify those management units, release events, and exposure pathways that may be associated with risks exceeding regulatory levels of concern. In the screening mode, relatively conservative assumptions regarding releases, exposures, and the toxicity characteristics of the waste constituents are used to provide a high degree of assurance that exposures that could be associated with significant risks are not missed. For most of the release events, high-end (HE) assumptions are first used to identify the highest risks pathways and constituents. If HE assumptions indicate that all risks are below levels of concern for a given pathway, no further risk assessment is performed. If HE risks are above levels of concern, central tendency (CT) assumptions are used to determine whether risks are still of concern for particular waste management units, waste streams, and constituents, and to help characterize the variability in risks that is associated with changes in key variables.

The risk assessment presented below summarizes risks for single-release events and exposure pathways. Risks are not summed across exposure pathways, unless it clear that exposure through one pathway would reasonably be associated with exposure through another pathway for the same receptor (risks from the ingestion of home-grown root and above ground vegetables are summed, for example). The risk assessment has not been structured to consider detailed mass balances across release events or exposure media, although each release event is evaluated to determine if it would result in a substantial reduction of the amount of constituent available for release by other events. As will be seen in Section H.2.2, no individual events were found that release substantial portions of the annual recycled volumes from any of the management units.

H.2.1.2 Regulatory Scenarios

As for the groundwater pathway, risks have been assessed for the modified prior treatment baseline. Under this baseline, it is assumed that recycled spent materials, sludges, and byproducts from mineral processing will be stored in land-based units prior to recycling. Nonwastewaters would be stored in unlined waste piles, and wastewater and liquid nonwastewater streams would be stored in unlined surface impoundments. Unlike the situation for disposal facilities, it is assumed that where two or more recycled streams are generated at a facility, the streams would be stored in separate units prior to recycling, and that

there would be no comanagement. Also, it has been assumed that the storage units would be sized to just accommodate the required amount of recycled material — three months' recycled volume in the case of nonwastewaters, and one month's recycled volume in the case of wastewaters and liquid nonwastewaters. The assumptions used to evaluate the size and configuration of storage facilities are described in detail in the August 1996 RIA.

H.2.1.3 Identification of Recycled Waste Streams

The same 14 waste streams were evaluated as in the groundwater pathway assessment. As noted previously, the 14 streams which are evaluated account for between approximately 32 and 42 percent of the total waste generated, and for between about 57 and 68 percent of the annual recycled volume, depending on which estimates are used, from the mineral processing industries that have been evaluated. The extent of coverage of waste streams from the individual industry sectors is summarized in Attachment H.A to this appendix.

H.2.1.4 Waste Characterization Data

The same data sources related to waste constituent concentration were used as described for the groundwater pathway assessment in Section H.1. No data were available related to the particulate characteristics of the two waste streams managed in waste piles. A reasonably conservative set of assumptions were therefore developed regarding waste silt content, particle size distribution, and particle size density, based partially on assumptions used in HWIR-Waste and on assumptions made by EPA as part of previous risk assessment efforts for similar mineral processing waste streams. These assumptions are described in more detail in Attachment H.B.

H.2.1.5 Facility Characterization Data

As noted above, facility size and configuration were determined for each recycled waste stream as part of the cost and economic impact analysis for the proposed Mineral Processing LDR. These methods are described in detail of Appendix E of the August 1996 RIA. Under the modified prior treatment scenario, it is assumed that all 14 recycled streams will be managed in unlined land-based units, nonwastewaters in waste piles and wastewaters and liquid nonwastewaters in surface impoundments. The management units were assumed to be sized to just meet the needs of the recycling units. Based on the Agency's evaluation of recycling practices, and considering the constraints on the duration of storage under existing regulations, it was assumed that all recycling storage piles would be sized to accommodate one quarter of the annual recycled volumes for typical facilities in the various commodity sectors, and that surface impoundments would be sized to accommodate one-twelfth of the annual recycled volumes of liquid streams. Thus, all units disposing of the same waste streams in any given commodity sector are assumed to be the same size. Further, it is assumed that no comanagement of multiple waste streams would occur in any management units.

For costing purposes, waste piles have been assumed to be conical, with side slopes of 2:1. Piles are assumed to be unlined and uncovered, with no special controls of runoff or particulate suspension. For purposes of emissions estimation, it is assumed that the piles are at full capacity at all times, and that the entire annual recycled volumes of the waste streams pass through the units each year, being added and removed at uniform rates on every day of operation throughout the year. It is assumed that, below a minimum recycled volume (500 mt/yr per facility) it is cheaper to store recycled materials in roll-off containers than in piles, and recycled streams with an annual recycled volume less than this amount were therefore not included in the risk assessment for waste piles. There was also an upper limit on the height

and area of a single pile, but none of the recycled nonwastewater streams were recycled in large enough volumes to reach this limit.

Surface impoundments used for recycling were assumed to be rectangular in shape, with a 2:1 length:width ratio and a rectangular prism-shaped bottom with a maximum depth of seven feet. Again, streams with annual recycled volumes of less than 500 mt/year per facility were assumed to be managed in tanks or containers, rather than impoundments. All of the recycled wastewater and liquid nonwastewater streams for which constituent data were available equaled or exceeded this volume, and thus all of them were included in the risk assessment.

The characteristics of the units used to store the recycled streams prior to recycling are summarized in Exhibit H-9. It can be seen that the two nonwastewater streams are both relatively low-volume, and the management units are correspondingly small. The sizes of the surface impoundments for the storage of liquid waste streams, on the other hand, span the range of the smallest possible facility size (42 cubic meters for titanium/TiO₂ scrap milling scrubber water) to extremely large (99,167 cubic meters for zinc process wastewater).

H.2.1.6 Identification of Release Pathways

The screening-level risk assessment addressed non-groundwater release events from waste piles and surface impoundments managing mineral processing recycled streams. As an initial step in the risk assessment, release events and pathways were identified and screened to determine which would be the most likely to result in significant health risks to human receptors. The initial menu of events that were considered came from the HWIR-Waste Technical Background Document. The results of the screening are summarized in Exhibit H-10. As noted previously, many release events were screened out because of the characteristics of the units or the wastes involved. For example, volatilization release were eliminated for all management units and streams, because none of the toxic constituents, in the chemical forms that they are likely to be present, would be appreciably volatile.

The release events that have been addressed include the generation of air particulates and runoff from waste piles, and the releases of liquid recycled streams from surface impoundments due to inlet/outlet failures and runoff events during large storms. Groundwater releases from these units have been addressed previously and are not further evaluated here.

H.2.1.7 Transport and Exposure Pathways

After releases from the land storage units, waste constituents may be transported or appear as contaminants in various environmental media, depending on the characteristics of the release event, the facility characteristics, and the environmental fate and transport properties of the constituents. In HWIR-waste, a large number of transport and exposure pathways were identified for the various units and waste/constituent types, only a minority of which were evaluated in this risk assessment. Reasons for excluding transport and exposure pathways from the assessment included (1) the pathways were not relevant to the units and waste being evaluated, (2) pathway models were not adequately developed or were too complex to apply in the context of this screening level assessment, or (3) it became apparent that the transport and exposure routes were very unlikely to be associated with significant risks. In some cases, simple screening-level models were substituted for the more detailed transport and exposure models from HWIR-Waste. Exhibit H-11 summarizes the fate and transport pathways that were evaluated in this assessment and provides a general description of the exposure and risk modeling procedures used to evaluate them.

EXHIBIT H-9. FACILITY SIZES FOR THE RECYCLED WASTE STREAMS

Commodity	Recycled Stream	Facility Type¹	Facility Volume (m³)	Facility Area (m²)
Aluminum and Alumina	Cast House Dust	WP	107	108
Beryllium	Chip Treatment Wastewater	SI	417	558
Copper	Acid Plant Blowdown	SI	22,083	10,441
Elemental Phosphorous	AFM Rinsate	SI	167	415
Elemental Phosphorous	Furnace Scrubber Blowdown	SI	17,500	8,429
Rare Earths	Process Wastewater	SI	117	385
Selenium	Plant Process Wastewater	SI	550	631
Tantalum, Columbium, and Ferrocolumbium	Process Wastewater	SI	4,375	2,517
Titanium and Titanium Oxide	Leach Liquor and Sponge Wastewater	SI	4,000	2,341
Titanium and Titanium Oxide	Scrap Milling Scrubber Water	SI	42	340
Zinc	Waste Ferrosilicon	WP	1,093	509
Zinc	Spent Surface Impoundment Liquids	SI	10,500	5,319
Zinc	Waste Water Treatment Plant Liquid Effluent	SI	7,250	3,850
Zinc	Process Wastewater	SI	99,167	43,384

Notes: 1. SI = Surface Impoundment, WP = Waste Pile

EXHIBIT H-10. RELEASE EVENTS RETAINED IN THE MINERAL PROCESSING SCREENING RISK ASSESSMENT

Management Unit	Release Events
Waste Pile	Particulate Generation by Wind
	Particulate Generation by Materials Handling
	Surface Runoff due to Rain Events
Surface Impoundments	Releases Due to Inlet/Outlet Failures
	Releases Due to Runon Events

**EXHIBIT H-11. EXPOSURE PATHWAY MODELING SUMMARY FOR MINERAL
PROCESSING STORAGE RISK ASSESSMENT**

Unit Type	Release Event/ Medium	Transport Medium I	Transport Medium II	Transport Medium III	Exposure Pathway	Receptors	Modeling Approaches
Waste Pile	Particulate Generation by Wind, Materials Handling	Air	--	--	Inhalation	Adult Resident	SCREEN3 (Emissions) ISCST3 (Deposition) HWIR (Exposure/Risk)
		Air	Soil (deposition)	--	Ingestion	Child/Adult Resident	HWIR-Waste (Exposure/Risk)
					Dermal	Child Resident	HWIR-Waste
		Air	Soil (deposition)	Crops	Ingestion	Subsistence Farmer	HWIR-Waste, modified for non-steady-state conditions (concentration in crops, vegetable intake, risk)
		Air	Soil/Water	Surface Water/Fish	Ingestion	Subsistence Fisher	Bounding analysis (100 percent deposition in water body)
Waste Pile	Runoff	Soil	--	--	Ingestion	Child Resident	Bounding analysis; 100 percent runoff to adjacent garden/yard, HWIR-Waste (exposure and risk)
					Dermal	Child Resident	Bounding analysis; 100 percent runoff to adjacent garden/yard, HWIR-Waste (exposure and risk)
		Soil	Crops	--	Ingestion	Subsistence Farmer	Bounding Analysis; HWIR-Waste
		Soil	--	Surface Water/Fish	Ingestion	Subsistence Fisher	Bounding analysis; 100 percent deposition to surface water; HWIR- Waste
Surface Impoundment	Control/ Berm Failure	Surface Water	--	--	Ingestion	Adult Resident	HWIR-Waste (Release algorithms, exposure, drinking water ingestion)
		Surface Water	Fish	--	Ingestion	Subsistence Fisher	HWIR-Waste (Releases, dilution, fish ingestion, risk)

Probably the most significant transport pathway that was omitted from the assessment was the discharge of groundwater to surface water. This pathway was not considered because of the absence of applicable DAF values and groundwater discharge volume estimates that would have allowed EPA to estimate surface water exposure concentrations.

H.2.1.8 Release, Transport, and Exposure Modeling

H.2.1.8.1 Air Particulate Generation, Meteorological Modeling, and Deposition on Soils

Airborne particulates generation from waste piles storing the two nonwastewater streams was estimated using EPA's SCREEN3 model. Long-term concentrations of particulates in air and long-term particulate deposition rates were calculated using the more detailed ISCST3 model. Because the locations of the facilities managing these streams are not known (all the analytical data come from facilities without identifiers), it was not possible to use site-specific meteorological or climatic data in the modeling of particulate generation and transport. Therefore, the models were run using a generic "worst-case" set of meteorological input data that is provided on part of ISCST3 for use in screening level analyses. High-End (HE) exposure concentrations (air and deposition values) were estimated for the point of maximal long-term impact (111 meters from the unit boundary in the case of aluminum cast house dust, and 248 meters in the case of zinc waste ferrosilicon), and the central tendency (CT) exposure estimates were deriving using the air concentrations and deposition rates averaged at every 100 meters from the unit boundary out to a distance of 2000 meters in the direction of maximal impact. The procedures and assumptions used in particulate generation and transport modeling are described in more detail in Attachment H-B.

As was the case for the meteorological data, very little information was available related to the physical characteristics (fraction of particulate present in waste, particle size distribution, particle density) of the nonwastewater streams. Data developed by EPA in previous analyses of potential risks from similar mineral processing wastes⁶ known to be managed in piles were used in the absence of information specific to aluminum cast house dust and zinc waste ferrosilicon. These data are summarized in Exhibit H-11, along with the other parameter values used to estimate exposure concentrations in soil resulting from particulate deposition.

Accumulation of particulate materials in soils was assumed to occur for the entire 20-year lifespan of the waste piles. Exposure to the contaminated soil was assumed to begin at the end of the deposition period (when soil concentrations of deposited constituents would be the greatest), and it was assumed that the deposited constituents would not be depleted from the soil by leaching, runoff, or volatilization ($k_s = \text{zero}$). This latter assumption adds a degree of conservatism to the estimation of soil concentrations, as some proportion of the deposited inorganics might, in the real world, be removed by runoff or leaching.

The soil concentrations from soil deposition were calculated using a variation of Equation 6-1 in the HWIR-Waste Technical Support Document. The equation was first rearranged to allow the calculation of soil concentrations from deposition rates, instead of vice-versa, and the exponential terms relating to the depletion of deposited material from the soil were eliminated from the equation. The result is a simple relationship describing the dilution of the deposited constituents uniformly in the mass of soil represented by the mixed layer. Consistent with HWIR-Waste, shallow mixing depths (1 and 2.5 cm) were used to calculate exposure concentrations for use in the soil ingestion and dermal contact pathways, and greater mixing depths (10 and 20 cm), corresponding to tilled depths, were used to calculate soil concentrations

⁶ USEPA, *Risk Screening Analysis of Mining Wastes, Appendix F: Development of Particulate Emission Factors*, (Draft), Office of Solid Waste, October 25, 1987.

for the root vegetable consumption pathway. All other parameter values were the same as those to calculate soil concentration in the HWIR-Waste assessment.

H.2.1.8.2 Deposition of Airborne Particulates into Surface Water

The parameter values used in the estimation of particulate pathway emissions and transport modeling are summarized in Exhibit H-12. In HWIR-Waste, the relationship between airborne particulates and surface water contamination is modeled by a complex set of equations that simulate the both the direct deposition of particulates to surface water, and the deposition to soils onto a watershed, followed by overland transport to surface water bodies. Given the lack of knowledge about the locations of the storage piles relative to watersheds and surface water bodies, the relatively small size of the piles, and the relatively small mass of particulate that is generated, we have employed a much simpler screening approach to estimate the maximum long-term surface water concentrations that could result from the deposition of airborne particulates.

The methods simply assumes that, ultimately, all of the particulate emitted from the storage piles will end up in surface water. This is equivalent to making the conservative assumption that all of the particulates will either be directly deposited onto a surface water body, or that for that fraction of particulates that are initially deposited to soil, the sediment delivery ratio for the watershed will be equal to 1.0.

An additional simplifying assumption has been made regarding the behavior of deposited particulate in the surface water bodies, and regarding the speciation and solubility of particle-bound constituents. To estimate surface water concentrations, it is assumed that all of the constituents will be in the dissolved or suspended phase, and that none will remain bound to, or buried in, bottom sediment. This assumption probably overestimates the concentrations of some constituents in the water column, as some proportion of them would probably remain insoluble and bound to sediment.

Following the HWIR-Waste methodology, the airborne particulate matter is assumed to be deposited in either a "fifth order" or "third order" stream. These are streams or rivers of a given size and annual flow rate that have been selected (HWIR-Waste Technical Background Document Section 7.7.6.2) as the HE and CT surface water bodies, respectively. The long-term average concentration of constituents in surface water resulting from airborne particulate deposition is thus:

$$C_{sw} \text{ (mg/l)} = \frac{PG * C_{waste}}{DV * 1000 \text{ L/m}^3} \quad (1)$$

where PG is the annual particulate generation rate (in kg) from the waste pile, and DV is the surface water annual dilution volume as defined in Exhibit H-12. Since deposition is assumed to occur continuously throughout the year into a continuously flowing stream, there is no need to multiply by the 20-year facility life span.

**EXHIBIT H-12. PARAMETER VALUES USED IN PARTICULATE PATHWAY EMISSIONS
AND TRANSPORT MODELING**

Variable	Description	CT Value	HE Value	Units	Source
SC	Silt Content (both streams)	1.6	9.1	percent	Footnote 5
--	Particulate Size Distribution	66 49 32 18	66 49 32 18	percent < 15 um percent < 10 um percent < 5 um percent < 2.5 um	Footnote 5
PD	Particle Density	2.65	2.65	gm/cc	Value for SiO ₂ (sand)
Achd	Area of Waste Pile (Cast House Dust)	108	108	m ²	Waste data base, cost/economic impact methodology
Afesi	Area of Waste Pile (Ferrosilicon)	509	509	m ²	Waste data base, cost/economic impact methodology
Z	Soil Mixing Depth (Dermal and Ingestion Exposures)	2.5	1	cm	Typical values for untilled soils
Z	Soil Mixing Depth (Root Vegetable Ingestion)	20	10	cm	Typical tillage depths
BD	Soil Bulk Density	1.5	1.2	gm/cm ³	Typical for U.S. soils
ks	Soil Loss Constant	0	0	years ⁻¹	Assumes no soil depletion of deposited materials
t	Deposition Period	20	20	years	Assumes unit lifespan of 20 years
DV	Surface Water Dilution Volume	3.0X10 ⁸	1.3X10 ⁷	m ³ /year	Third- and Fifth- Order Stream Flow, respectively, HWIR- Waste Equation 7-69

H.2.1.8.3 Runoff to Surface Soils

The amount of waste released to surrounding soils from waste piles through runoff events was calculated using the Universal Soil Loss Equation (USLE), in a manner very similar to that described for waste piles in Section 7-4 of the HWIR-Waste Technical Support Document. As in the case of particulate releases, some of the assumptions and parameter values that were used were changed to reflect the characteristics of the units and wastes being addressed, and to address the specific geometry of the delivery of sediment to the surrounding soils.

The parameter values used in the estimation of releases to soils from the waste piles and the resulting concentrations of constituents in soils and surface water are summarized in Exhibit H-13. In calculating runoff releases, in the absence of data related to the specific wastes and pile configurations being evaluated, we used the same values for soil erodability (k) and length-slope factors (LS) as were used for Subtitle D waste piles in HWIR-Wastes. The rainfall factor values (R) were changed slightly, however. The CT value used in the analysis was selected from the data in Table 7-42 of the HWIR-Waste Technical Support Document to reflect rainfall frequencies in the western US (where the majority of mineral processing waste, by volume, is managed), while the HE value was selected to be more representative of nationally-averaged conditions. In this analysis, the values for the USLE cover factor © and control practices factor were increased to 1.0 in both the CT and HE cases. These values reflect the likelihood that an active storage pile would not have any vegetative cover, and the conservative assumption (consistent with the cost and economic analysis) that there would be no special precautions taken to prevent runoff losses.

A very simple sediment delivery model was used to estimate the concentrations of waste constituents in soils resulting from runoff. Currently, the sediment delivery model in the HWIR-Waste modeling system is under review, and final decisions about the configurations of waste management units, buffer zones, and receiving areas have not been made. In the absence of a definitive model, soil concentrations were simply calculated by assuming that the conical waste piles would generate circular "plumes" of runoff that would deposit evenly within defined distances from the center of the piles. For HE exposure estimates, the area of soil contaminated by runoff was assumed to be 100 meters in diameter, while for CT exposures, the area of contaminated soil was assumed to be 200 meters in diameter, or four times larger. This approach assumes that a storage pile would be located near the edge of a facility, that exposed receptors would reside directly adjacent to the facility boundary, and that there would be no preferred runoff path or deposition areas. As was the case for air particulate deposition, it was again assumed that deposition would occur for 20 years, and that the deposited constituents would not be further depleted by runoff or leaching after initial deposition.

The soil concentration resulting from surface runoff from waste piles was thus calculated using the following equation:

$$C_{\text{soil}} \text{ (mg/kg)} = \frac{X_e \text{ (kg/m}^2\text{-year)} * A_{\text{chd (or } A_{\text{fesi)}} \text{ (m}^2\text{)} * C_{\text{waste}} \text{ (mg/kg)} * t \text{ (years)}}{BD \text{ (gm cm}^3\text{)} * Z \text{ (cm)} * X * r^2 \text{ (cm}^2\text{)} * 0.001 \text{ kg/gm}} \quad (2)$$

where the variable definitions and values are given in Exhibit H-13.

EXHIBIT H-13
PARAMETER VALUES USED IN RUNOFF RELEASE AND TRANSPORT
MODELING FROM WASTE PILES

Variable	Description	CT Value	HE Value	Units	Source
Xe	Runoff loss from waste pile	calculated	calculated	kg/m ² -year	HWIR-Waste equation 7-52
Achd	Area of Waste Pile (Cast House Dust)	108	108	m ²	Waste data base, cost/economic impact methodology
Afesi	Area of Waste Pile (Ferrosilicon)	509	509	m ²	Waste data base, cost/economic impact methodology
R	USLE Rainfall Factor	50	110	years ⁻¹	CT= Typical of western US HE = US Median value
LS	Length-Slope Factor	1	3		HWIR-Waste value for Subtitle D ash piles
K	Soil Erodability Factor	0.25	0.25	unitless	HWIR-Waste value for Subtitle D ash piles
C	Cover Factor	1	1	unitless	Assumes no vegetative cover on waste piles
P	Control Practices Factor	1	1	unitless	Assumes no measures to control runoff
r	Radius of area contaminated by runoff	5,000	10,000	cm	Contamination is assumed to be distributed uniformly in a circular area around the conical piles
DV	Surface Water Dilution Volume	3.0X10 ⁸	1.3X10 ⁷	m ³ /year	Third- and Fifth-Order Stream Flow, respectively, HWIR-Waste Equation 7-69

This approach to estimating soil concentrations from waste pile runoff greatly simplifies the potentially complex processes that would, in the real world, govern the generation and distribution of runoff contamination. It is intended only as a conservative screening tool to provide indications of the relative risks associated with the various waste and constituents, and to provide a high degree of assurance in ruling out wastes and constituents that pose no significant risks through this pathway.

H.2.1.8.4 Runoff To Surface Water

The deposition of runoff to surface water bodies was evaluated using a screening approach analogous to that used to evaluate the impacts of airborne particulate deposition on surface water quality. Again, it was assumed that 100 percent of the runoff-borne constituents would eventually find their way into the CT or HE streams. Thus, the equation used to estimate the concentration of runoff-borne constituents in surface water during the operation of the storage piles is:

$$C_{sw} \text{ (mg/l)} = \frac{X_e \text{ (kg/m}^2\text{-year)} * A_{chd} \text{ (or Afesi)} \text{ (m}^2\text{)} * C_{waste} \text{ (mg/kg)}}{DV \text{ (m}^3\text{/year)} * 1000 \text{ L/m}^3} \quad (3)$$

The annual average runoff from the piles is again released to surface water and diluted in the CT or HE stream dilution volume (DV, see Exhibit H-13) to provide a long-term average water concentration. Again, it is assumed that none of the runoff materials would become buried in bottom sediment.

H.2.1.8.5 Surface Impoundment Releases to Surface Water

To evaluate surface water concentrations associated with releases from surface impoundments, we used precisely the same method as used in HWIR-Waste (Equation 7-70). Again, the release model has been simplified by removal of all of the equations related to volatilization.

The equation from HWIR-Waste estimates releases to surface water from runoff events (overtopping due to unusually high rainfall) and from inlet-outlet control failures. It does not include releases due to berm failure or leakage. The model is probabilistic, estimating long-term average releases of impoundment contents as a function of annual event probabilities. As was the case for air deposition and runoff from waste piles, the average surface water concentrations during facility operations are calculated assuming that the annual waste releases due to the two types of events (summed) are diluted into the annual flow of the CT and HE streams, without partitioning to sediment. The major variables used to estimate surface water concentrations of constituents from impoundment failure are summarized in Exhibit H-14.

The uncertainty associated with release and exposure estimates from this pathway must be regarded as very high. The model was originally intended to estimate long-term average releases from rare acute events occurring over the course of very many years. Thus, it may not be appropriate for estimating releases from rather short-lived storage impoundments (20 years) being evaluated in this assessment. In addition, the model does not capture the effects of the single acute releases on water quality in the short-term. Finally, the model and the parameter values used to estimate releases were originally derived by EPA based on data from a sample of surface impoundments in the pulp and paper industry.⁷ It is likely

⁷ DPRA, *Surface Water Control Berms for Pulp and Paper Mill Sludge Landfills and Surface Impoundments*, Memo to Priscilla Halloran, OSW, July 18 1991.

**EXHIBIT H-14. PARAMETERS USED IN THE ESTIMATION OF SURFACE IMPOUNDMENT
RELEASES TO SURFACE WATER AND SOILS**

Variable	Description	CT Value	HE Value	Units	Source
RV	Release volume (annual average)	Calculated	Calculated	m ³ /year	HWIR-Waste, equation 7-70
Prunon	Probability of runon event	2X10 ⁻⁴	2X10 ⁻⁴	years ⁻¹	DPRA, 1991 (see text)
Tflood	Duration of Flooding	21,600	21,600	seconds	DPRA, 1991
Vrunon	Runon velocity	0.5	0.5	m/sec	DPRA, 1991
-h	Difference in height between flood and berm	0.0127	0.0127	m	DPRA, 1991
A	Area of surface impoundment	Waste- specific	Waste- specific	m ²	Mineral Processing data base, cost/economic analysis
Pio	Probability of inlet/outlet control event	0.0107	0.0107	years ⁻¹	DPRA, 1991
h	Berm height	0.457	0.457	m	DPRA, 1991

that the designs, sizes and operating parameters for impoundments in the mineral processing industry are substantially different, and the expected releases could also be different. One feature of the model that tends to result in conservatism in the exposure estimates from this pathway is that no dilution of recycled materials by runon events is assumed. In an actual extreme runon event, dilution of the wastes could be substantial, lowering the concentration of released materials.

H.2.1.9 Exposure and Risk Characterization

H.2.1.9.1 Toxicological Criteria

With a single exception, quantitative risk estimates have been developed using toxicity criteria values obtained from USEPA's IRIS data base or the HEAST tables and updates. To calculate inhalation pathway cancer risks and noncancer hazard quotients, inhalation Unit Risk and chronic inhalation pathway Reference Concentration (RfC) values are used. For the ingestion pathways, Cancer Slope Factors (CSFs) and chronic Reference Doses (RfDs) are used. The IRIS values are current as of December 1996. These values are summarized in Exhibit H-15.

**EXHIBIT H-15. TOXICITY CRITERIA VALUES USED IN THE MINERAL PROCESSING
STORAGE RISK ASSESSMENT**

Constituent	Ingestion Pathway Cancer Slope Factor (mg/kg-day) ⁻¹	Inhalation Pathway Unit Risk (ug/m ³) ⁻¹	Chronic Ingestion Pathway Reference Dose (mg/kg-day)	Chronic Inhalation Pathway Reference Concentration (mg/m ³)
Antimony			4X10 ⁻⁴	
Arsenic	1.5	4.3x10 ⁻³		
Barium			7X10 ⁻²	5X10 ⁻⁴
Beryllium	4.3 ¹	2.4X10 ⁻³	5X10 ⁻³	
Cadmium		1.8X10 ⁻³	5X10 ⁻⁴	
Chromium (VI)		1.2X10 ⁻²	5X10 ⁻³	
Lead			0.015 mg/L ²	
Mercury			3X10 ⁻⁴	3X10 ⁻⁴
Nickel		4.8X10 ⁻⁴	2X10 ⁻²	
Selenium			5X10 ⁻³	
Silver			5X10 ⁻³	
Thallium			8X10 ⁻⁵	
Vanadium			7X10 ⁻³	
Zinc			3X10 ⁻¹	

Notes:

1. Not used in risk assessment because of low weight of evidence
2. Based on the Safe Drinking Water Act MCL for inorganic lead.

Ingestion pathway RfD values are available for all of the constituents except lead (see below). Arsenic is the only constituent that is considered to be an ingestion pathway carcinogen in this assessment, so it is the only constituent with an ingestion pathway CSF. Inhalation pathway RfCs were available for only two of the constituents (barium and mercury), so inhalation pathway hazard quotients could be calculated only for these elements. Inhalation cancer Unit Risk values are available for five constituents considered to be inhalation pathway carcinogens, however.

Inorganic lead was the only constituent for which a different approach to risk characterization was employed. Since there is no RfD or RfC value for lead, the toxicity criterion that was used to evaluate potential noncancer risks associated with lead exposure was the Clean Water Act MCL of 15 ug/L. This value was used to evaluate concentrations in surface water arising from particulate deposition and runoff, assuming, in effect, that the water body would be used as a drinking water supply. Risks associated with lead exposure through other pathways were not evaluated because of the lack of acceptable toxicity criteria for these pathways.

For purposes of the assessment, it was assumed that all of the chromium present in the stored waste streams would be in the more toxic hexavalent form. This assumption will overstate risks when (as in most cases) the bulk of the chromium is in lower oxidation states.

H.2.1.9.2 Inhalation

Risks associated with inhalation pathway exposure to particulates released from waste piles are calculated directly from the estimated particulate concentrations in air generated by the ISCST3 model. Lifetime cancer risks associated with exposure to airborne particulates are calculated as:

$$\text{Risk} = C_{\text{part}} (\text{ug}/\text{m}^3) * C_{\text{waste}} (\text{mg}/\text{kg}) * 10^{-6} \text{ kg}/\text{mg} * \text{UR} (\text{ug}/\text{m}^3)^{-1} \quad (4)$$

where C_{part} is the particulate concentration from the ISCST model, C_{waste} is the concentration of arsenic in the waste sample, and UR is the unit risk value constituent.

Inhalation noncancer hazard quotients are calculated as:

$$\text{HQ} = \frac{C_{\text{part}} (\text{ug}/\text{m}^3) * C_{\text{waste}} (\text{mg}/\text{kg}) * 10^{-6} \text{ kg}/\text{mg} * 10^{-3} \text{ mg}/\text{ug}}{\text{RfC} (\text{mg}/\text{m}^3)} \quad (5)$$

In both cases, the receptor is an adult resident, residing at either the point of maximum long-term air concentration (HE estimate), or at the point of average concentration within 2000 m of the facility (CT estimate). For screening purposes, exposure is assumed to be continuous for 365 days per year, and for carcinogenic constituents, the exposure duration is assumed to be the 20-year operating lifespan of the facility. As will be seen in Section H.2.1, in both the CT and HE cases, cancer risks were all below 10^{-5} and inhalation hazard quotients were all below 1.0 under these very conservative screening assumptions, so more refined modeling scenarios were not developed for this pathway.

H.2.1.9.3 Soil Ingestion and Dermal Contact

Cancer and chronic noncancer risks were evaluated for dermal and incidental ingestion exposures to soil contaminated by particulate deposition (Section H.2.1.9.3) and by deposition of surface runoff (Section H.2.1.9.4). For each pathway, the soil concentrations after 20 years of deposition were used as inputs to the risk assessment, assuming no depletion of deposited materials from soils by volatilization, leaching, or runoff. For both the dermal and ingestion pathways, the shallower soil mixing depths (1.0 and 2.5 cm) were used to estimate soil concentrations of constituents consistent with the assumption of no tillage or soil disturbance.

Risks associated with soil ingestion were calculated using Equation 5-6 from the HWIR-Waste Technical Support Document, adapted to calculate risk as a function of concentration, instead of vice versa, and with the soil constituent depletion terms removed. Cancer risks were calculated for lifetime exposures to a child/adult resident, consistent with the HWIR-Waste approach, and noncancer hazard quotients were calculated for the child resident receptors, who receive the highest dose per body weight by this pathway. The exposure parameter values used to calculate contaminant intake and risks from soil ingestion are summarized in Exhibit H-16.

For the most part, these are standard values used in Agency rulemaking and risk assessments for contaminated sites. Differences from the HWIR-Waste assumptions include more frequent exposures (350 days/year) for adults and children, and a slightly shorter HE exposure duration (30 years, as opposed to 40 years in HWIR-Waste).

EXHIBIT H-16. EXPOSURE FACTOR VALUES FOR SOIL INGESTION AND DERMAL CONTACT PATHWAYS

Variable	Description	CT Value	HE Value	Units	Source
AT	Averaging time (carcinogens)	70	70	years	Assumed full life span
EF	Exposure frequency	350	350	days/year	Worst-case assumption of year-round residency
IRc	Soil ingestion rate (child)	200	200	mg/day	HWIR-Waste Equation 5-6
IRa	Soil Ingestion rate (adult)	100	100	mg/day	HWIR-Waste Equation 5-6
BWc	Body weight (child)	15	15	kg	HWIR-Waste Equation 5-6
BWa	Body weight (adult)	70	70	kg	HWIR-Waste Equation 5-6
EDc	Exposure duration (child)	6	6	years	HWIR-Waste Equation 5-6
EDa	Exposure duration (adult)	3	24	years	Assumes 30 years' total residential tenure, six as a child, remainder as an adult
Kpw	Skin permeability constant for water	0.001	0.001	cm/hr	HWIR-Waste Equation 5-14
Y	Soil particle density	2.65	2.65	gm/cc	HWIR-Waste Equation 5-14
AF	Adherence factor	0.2	1.0	gm/cm ²	HWIR-Waste Equation 5-23
Tevent	Event Duration	5	12	hours	HWIR-Waste Equation 5-23

Risks from dermal exposures to contaminated soils were likewise calculated using equations based on the HWIR-Waste methodology. Specifically, equations 5-14 and 5-20 through 5-23 (adjusted as for the ingestion pathway) were used to calculate dermal contact rates with soil, dermal permeability constants, dermal absorbed doses, and risks from dermal exposures.

The soil concentration inputs were again the concentrations resulting from 20 years of contamination by runoff or air particulate deposition. As was the case for soil ingestion, exposure factor values were essentially the same as those used in the HWIR-Waste methodology. These values are summarized in the bottom rows of Exhibit H-16. All of the values for body weights, exposure duration, and exposure frequency are the same as those used for the ingestion pathway.

H.2.1.9.3 Ingestion of Home-Grown Vegetable

Crops grown near waste piles may become contaminated either from being grown in contaminated soil or from the deposition of particulates directly on the above-ground portions of the vegetables. In this analysis, risks were calculated for vegetable consumption by a subsistence farmer on soils contaminated either by particulate deposition or runoff. In each case, the methods used to calculate the intake of toxic constituents and risks were the same as those used in Equations 5-58, 5-59, 6-48, and 6-49 in the HWIR-Waste Technical Support Document.

Soil concentrations used to calculate root vegetable constituent concentrations were calculated as described previously. In the case of the root vegetable pathway, the soil mixing depths were either 20 cm (CT) or 10 cm (HE) instead of the shallower values used for the ingestion and dermal contact pathways. The exposure factor values used to estimate intake and risks for this pathway are summarized in Exhibit H-17. These values are essentially the same as those used on HWIR-Waste, the primary exception being the use of an HE exposure duration of 20 years, corresponding to the assumed life of the storage units, rather than the 40-year value used in HWIR-Waste.

H.2.1.9.4 Ingestion of Surface Water

Releases to surface water from surface impoundment failures and runoff from waste piles have been modeled. For both types of releases, the methods used to estimate constituent intakes and health risk are the same, and consistent with that used in the HWIR-Waste methodology.

As described previously, releases to surface water are assumed to be diluted into either a typical third-order (CT) or fifth-order (HE) stream. In this analysis, it is assumed that the surface water body in question would be used as a drinking water source, without further treatment to reduce exposure concentrations. Adult residents would then ingest either 1.4 liters (CT) or 2.0 liters (HE) of surface water for 350 days per year for 20 years. Lifetime doses of carcinogens are calculated based on an assumed lifespan (averaging time) of 70 years as for the other pathways, with residential exposure durations of either 9 (CT) or 30 (HE) years. Cancer risks are calculated as follows:

$$\text{Risk} = \frac{C_{\text{water}} (\text{mg/l}) * \text{WI} (\text{l/day}) * \text{EF} (\text{days/year}) * \text{ED} (\text{years}) * \text{CSF} (\text{mg/kg-day})^{-1}}{\text{BW} (\text{kg}) * \text{AT} (\text{years}) * 365 (\text{days/year})} \quad (6)$$

where WI is the daily water intake, in liters. Noncancer hazard quotients are calculated as:

$$\text{Hazard Quotient} = \frac{C_{\text{water}} (\text{mg/l}) * \text{WI} (\text{l/day}) * \text{EF} (\text{days/year})}{\text{BW} (\text{kg}) * 365 (\text{days/year}) * \text{RfD} (\text{mg/kg-day})} \quad (7)$$

In the actual risk assessment, these equations were used, similar to the approach taken in HWIR-Waste, to calculate water concentrations of the constituents that would result in lifetime cancer risks of 10^{-5} or hazard quotients of 1.0 under CT and HE assumptions. These health-based levels (HBLs) were then used as a screening tool to determine which, if any, waste samples or constituents exceeded cancer risks or hazard quotient values of concern under either the CT or HE assumptions, so that more detailed analysis could be confined only to those wastes posing significant risks.

EXHIBIT H-17. EXPOSURE FACTOR VALUES USED FOR CROP INGESTION PATHWAY

Variable	Description	CT Value	HE Value	Units	Source
t	Deposition period	20	20	years	20 years = facility life span
kd	Soil-Water Dissociation Constant	constituent- specific	constituent- specific	l/kg	HWIR-Waste data base
RCF	Root Concentration Factor	constituent- specific	constituent- specific	mg/kg (veg.) mg/kg (soil)	HWIR-Waste data base
Vg	Surface correction factor for volatiles	1	1	unitless	All constituents are inorganic
Br	Plant-Soil BCF	constituent- specific	constituent- specific	ug/kg (veg.) ug/kg (soil)	HWIR-Waste data base
Rp	Interception fraction	0.05	0.05	unitless	HWIR-Waste Equation 6-48
kp	Plant surface loss coefficient	18	18	years ⁻¹	HWIR-Waste Equation 6-48
tp	Plant exposure to deposition	0.16	0.16	years	HWIR-Waste Equation 6-48
Yp	Crop yield	1.7	1.7	kg/m ² (DW)	HWIR-Waste Equation 6-48
BWa	Adult Body Weight	70	70	kg	Standard Assumption
F	Fraction from contaminated soil	0.4	0.9	unitless	HWIR-Waste Subsistence Farmer
Cra	Consumption of above-ground vegetables	19.7	19.7	gm/day	HWIR-Waste Subsistence Farmer
Crr	Consumption of root vegetables	28	28	gm/day	HWIR-Waste Subsistence Farmer
EF	Exposure Frequency	350	350	days/year	HWIR-Waste Subsistence Farmer
ED	Exposure duration	9	20	years	HWIR-Waste (CT), = deposition period (HE)
AT	Averaging time	70	70	years	full life span

H.2.1.9.5 Ingestion of Fish from Contaminated Surface Water Bodies

In addition to being screened for potential risks associated with ingestion, the estimated surface water concentrations resulting from air particulate deposition, runoff, and surface impoundment failure were also screened to determine the potential risks associated with ingestion of fish from the contaminated surface water bodies. The primary inputs to this analysis were the surface water concentrations resulting from the

various release pathways. The concentrations of toxic constituents in fish tissue were calculated as follows:

$$C_{\text{fish}} \text{ (mg/kg)} = C_{\text{water}} \text{ (mg/l)} * \max(\text{BCF, BAF}) \text{ (l/kg)}$$

To calculate fish tissue concentrations, the estimated surface water concentrations were multiplied by the higher of either the fish bioconcentration factor (BCF) or fish bioaccumulation factor (BAF) values for the constituents. The primary source of these values was the chemical-specific data base from HWIR-Waste, but the values from that source were supplemented by values from other literature sources, as summarized in Attachment H-C. Where both a BCF and a BAF value were available for a constituent, the higher of the two values was chosen. Where multiple BCF values were found, we generally took what we considered to be the highest reliable value from either HWIR or the literature. Since the values in HWIR were intended to be representative, rather than conservative, this procedure resulted in our using higher BCF values for a number of constituents than were used in HWIR-Waste risk calculations, and the resultant hazard-based levels (HBLs) for this pathway were thus lower than those derived in HWIR-Waste for some constituents.

Constituent intakes and risks from fish ingestion were calculated using equations 5-67 and 5-68 from HWIR-Waste. Consistent with the HWIR-Waste approach, health-based levels (HBLs) were calculated for surface water exposures through fish ingestion for the adult subsistence fisher who is assumed to consume 60 gms (CT) or 130 gms (HE) of fish per day for 350 days per year, using a target cancer risk level of 10^{-5} and a target hazard quotient value of 1.0. These HBLs were then used to screen the surface water concentrations resulting from air deposition, runoff, and surface impoundment failures.

H.2.2 Results of Multipathway Risk Assessment

This section presents the results of the multimedia risk assessment for the storage of mineral processing recycled streams. It begins with a review of the release modeling from the point of view of mass balance considerations, and then presents discussions of the risk results for each of the release events, exposure media, and pathways.

H.2.2.1 Mass Balance for Release Pathways

As noted above, the risks associated with releases from for mineral processing facilities presented in this analysis have been evaluated separately. In other words, it has been assumed that releases occur independently of one another, and that all of the materials in the storage units are available for release by all release pathways. In this section, we review whether this assumption is valid by comparing the amounts of materials released from the storage units by the different release events.

The masses of recycled materials released from the various storage units are summarized in Exhibit H-18. It can be seen that only a very small proportion of the total annual recycled volume of all of the waste streams are released from waste piles. In the case of the two nonwastewater streams managed in piles, the annual release volumes from the two types of release events (particulate generation and runoff) are both far below one percent of the total annual recycled volume. Thus, depletion of material by these pathways will not seriously affect the total mass of material remaining in the piles, and thus the release estimates for runoff and particulate generation do not bias each other significantly. Similarly, releases from these pathways do not deplete the amount of materials available for leaching to groundwater.

EXHIBIT H-18
MASSES AND PROPORTIONS OF RECYCLED STREAMS RELEASED BY SPECIFIC
RELEASE EVENTS

Commodity	Recycled Stream	Management Unit	Annual Recycled Volume (kg/year)	Release Event	HE Amount Released (kg/year)	Proportion of Annual Volume
Aluminum and Alumina	Cast House Dust	Waste Pile	581,000	Air Particulate Generation	324	0.06%
				Runoff	5,416	0.93%
Zinc	Waste Ferrosilicon	Waste Pile	5,950,000	Air Particulate Generation	1,520	0.03%
				Runoff	25,527	0.43%
Beryllium	Chip Treatment Wastewater	Surface Impoundment	2,500,000	Runon, Inlet/Outlet Control Failure	2,012	0.08%
Copper	Acid Plant Blowdown	Surface Impoundment	265,000,000	Runon, Inlet/Outlet Control Failure	28,330	0.01%
Elemental Phosphorous	AFM Rinsate	Surface Impoundment	2,000,000	Runon, Inlet/Outlet Control Failure	1,573	0.08%
Elemental Phosphorous	Furnace Scrubber Blowdown	Surface Impoundment	210,000,000	Runon, Inlet/Outlet Control Failure	23,127	0.01%
Rare Earths	Process Wastewater	Surface Impoundment	700,000	Runon, Inlet/Outlet Control Failure	1,480	0.21%
Selenium	Plant Process Wastewater	Surface Impoundment	3,300,000	Runon, Inlet/Outlet Control Failure	2,232	0.07%
Tantalum, Columbium, Ferrocolumbium	Process Wastewater	Surface Impoundment	37,500,000	Runon, Inlet/Outlet Control Failure	7,530	0.02%
Titanium, TiO ₂	Leach Liquor, Sponge Wash Water	Surface Impoundment	24,000,000	Runon, Inlet/Outlet Control Failure	7,050	0.03%
Titanium, TiO ₂	Scrap Milling Scrubber Water	Surface Impoundment	5,00,000	Runon, Inlet/Outlet Control Failure	1,337	0.27%
Zinc	Spent Surface Impoundment Liquids	Surface Impoundment	63,000,000	Runon, Inlet/Outlet Control Failure	15,005	0.02%
Zinc	Wastewater Treatment Plant Liquid Effluents	Surface Impoundment	43,500,000	Runon, Inlet/Outlet Control Failure	11,115	0.03%
Zinc	Process Wastewater	Surface Impoundment	850,000,000	Runon, Inlet/Outlet Control Failure	111,784	0.01%

April 15, 1997

Likewise, the estimated annual releases from surface impoundments also represent very small proportions of the total impoundment capacities and the annual recycled volumes. Thus, releases due to these events will not in the long run seriously deplete the amount of materials available for release by other pathways. For surface impoundments, the only other significant release pathway is infiltration to groundwater, since particulate generation and runoff are not important. The issue of whether leaching to groundwater might reduce the concentration of some constituents in the storage units has not been specifically addressed. EPA does not believe that, given the short operation life of these units and their continual replenishment with recycled materials, leaching to groundwater would seriously deplete any of the constituents.

H.2.2.2 Risk Results for Inhalation of Particulate

The estimated health risks associated with inhalation of particulates released from storage waste piles are quite low, as summarized in Exhibit H-19. Because of the lack of inhalation toxicity criteria, cancer risks could only be calculated for four constituents, and noncancer hazard quotients could be calculated for only two constituents. Since no inhalation toxicity criteria were available for the only two constituents analyzed for in zinc waste ferrosilicon (lead and zinc), no inhalation pathway risks could be calculated for that waste.

Exhibit H-19

Estimated Inhalation Pathway Risks for Aluminum Cast House Dust						
Constituent	CT Constituent Concentration in Air (ug/m3)	HE Constituent Concentration in Air (ug/m3)	CANCER RISK		HAZARD QUOTIENT	
			CT	HE	CT	HE
Antimony	1.73E-05	2.42E-04				
Arsenic	7.36E-05	1.03E-03	3.90E-13	1.22E-11		
Barium	2.30E-05	3.23E-04			1.92E-01	1.92E-01
Cadmium	1.66E-05	2.33E-04	3.67E-14	1.15E-12		
Chromium(VI)	2.53E-04	3.55E-03	3.74E-12	1.17E-10		
Lead	3.91E-05	5.49E-04				
Mercury	2.30E-10	3.23E-09			3.20E-06	3.20E-06
Nickel	5.98E-04	8.40E-03	3.54E-13	1.10E-11		
Selenium	2.12E-06	2.97E-05				
Silver	4.37E-06	6.14E-05				
Zinc	2.76E-04	3.88E-03				

In the case of aluminum cast house dust, the highest cancer risks were associated with exposures to chromium (VI), followed by arsenic, nickel, and cadmium exposures. The HE cancer risk estimates for these constituents ranged from 10^{-12} to 10^{-10} , far below the 10^{-5} cancer risk level of regulatory concern, and the CT risks were even lower. As noted previously, the assumption that all of the chromium present would be hexavalent is very conservative, and risks for chromium exposures are likely to substantially overestimated for this reason.

The estimated inhalation hazard quotient values for aluminum cast house dust are also below levels that indicate the potential for significant adverse effects. The highest HE hazard quotient value (for barium) is 0.2, while for mercury the HE hazard quotient is less than 10^{-5} . Both of these values are below the 1.0 value, which indicates the potential for adverse effects, although the HE hazard quotient for barium approaches the level of concern.

H.2.2.3 Risk Results for Soil Particulate Deposition

Particulate matter generated from waste piles may also be deposited onto soils and crops, resulting in direct exposure to contaminated soils and through the consumption of home-grown vegetables. In addition, impacts of particulate deposition to surface water have also been modeled. The risk results for these pathways are discussed in the following sections.

H.2.2.3.1 Incidental Ingestion and Dermal Contact Pathways

Risk results for the incidental ingestion and dermal contact pathways for soils contaminated by particulate deposition are summarized in Exhibit H-20. As was the case for the inhalation pathway, estimated cancer risks and hazard quotients for all of the constituents in both nonwastewater streams are below levels of concern for exposure by both pathways. The cancer risks and hazard quotients for the two pathways are generally within about one order of magnitude of each other, with higher risks for the ingestion pathways in some cases and higher risks for dermal contact in others.

The HE lifetime cancer risk associated with soil ingestion exposures to arsenic in aluminum cast house dust is 7×10^{-7} , while the CT value is 4×10^{-8} . In comparison, the HE and CT cancer risk estimates for dermal exposures are 1×10^{-6} and 1×10^{-8} , respectively. The highest HE hazard quotient for ingestion exposures (again associated with exposures to arsenic) is 1×10^{-2} , while the highest HE hazard quotient for dermal exposures is 4×10^{-2} (for arsenic). Hazard quotients for the remaining constituents range downward by many orders of magnitude from these values.

Zinc is the only constituent in zinc waste ferrosilicon for which a toxicity value is available for the ingestion and dermal pathway. Hazard quotient values for ingestion and dermal exposures to zinc from this stream are on the order of 10^{-4} to 10^{-2} , which is similar to the values for aluminum cast house dust.

While there is no ingestion pathway toxicity parameter for lead, it should be noted that the predicted HE soil concentration (48 mg/kg) is about ten times lower than EPA's recommended risk-based cleanup standard for lead in residential soils of 500 mg/kg.

Exhibit H-20

Soil Ingestion and Dermal Contact Pathway Risk Assessment Results for Particulate Deposition										
Constituent	CT Soil Concentration at 20 Years (mg/kg)	HE Soil Concentration at 20 Years (mg/kg)	Ingestion				Dermal Contact			
			CANCER RISK		HAZARD QUOTIENT		CANCER RISK		HAZARD QUOTIENT	
			CT	HE	CT	HE	CT	HE	CT	HE
Aluminum Cast House Dust										
Antimony	5.26E-03	7.12E-02			1.75E-04	2.37E-03			2.98E-04	2.01E-02
Arsenic	2.24E-02	3.04E-01	3.88E-08	7.13E-07	9.97E-04	1.35E-02	1.34E-08	1.44E-06	9.79E-04	3.89E-02
Barium	7.01E-03	9.49E-02			1.33E-06	1.81E-05			1.05E-07	3.44E-06
Cadmium	5.05E-03	6.83E-02			1.35E-04	1.82E-03			3.31E-05	1.12E-03
Chromium(VI)	7.71E-02	1.04E+00			2.06E-04	2.78E-03			2.62E-04	1.15E-02
Lead	1.19E-02	1.61E-01								
Mercury	7.01E-08	9.49E-07			3.11E-09	4.22E-08			1.39E-12	4.53E-11
Nickel	1.82E-01	2.47E+00			1.21E-04	1.64E-03			5.43E-05	1.90E-03
Selenium	6.45E-04	8.73E-03			1.72E-06	2.33E-05			2.91E-06	1.86E-04
Silver	1.33E-03	1.80E-02			3.55E-06	4.81E-05			6.04E-06	4.09E-04
Zinc	8.41E-02	1.14E+00			3.74E-06	5.06E-05			2.95E-06	1.12E-04
Zinc Waste Ferrosilicon										
Lead	3.50E+00	4.75E+01								
Zinc	2.80E+01	3.80E+02			1.25E-03	1.69E-02			9.84E-04	3.72E-02

These values in and of themselves are, as noted above, below the levels of concern. In fact, the values are low enough so that simultaneous exposures to all of the contaminants through both pathways results in a summed cancer risk less than 10^{-5} and a combined hazard index of less than 1. Given the conservative methods used to derive these values, and the small size of the units being evaluated, these results provide a high degree of assurance that risks for actual receptors would be below levels of concern.

H.2.2.3.2 Ingestion of Home-Grown Crops

The risk results for exposures to particulates deposited on soils and crops are summarized in Exhibit H-21. The HE estimated cancer risks associated with exposures to arsenic in aluminum cast house dust (7×10^{-7}) is very close to that for the ingestion pathway. The CT cancer risk for this pathway is 3×10^{-8} . The highest HE noncancer hazard quotient for this pathway is 6×10^{-3} , again associated with arsenic exposures, and the CT value for arsenic is one order of magnitude lower (5×10^{-4}). Hazard quotient values for the other constituents through the ingestion of home-grown crops are all much lower than the corresponding values for arsenic.

H.2.2.3.5 Particulate Deposition to Surface Water

Because the releases to air are so small and the surface water dilution volumes are so high, risks associated with surface water deposition are evaluated using a screening approach not unlike that used in the HWIR-Waste Technical Background Document to establish media concentrations corresponding to risk levels of concern. In this analysis, the methods and assumptions described in Section H.2.1 were used to calculate concentrations in surface water that corresponded to calculated cancer risk levels of 1×10^{-5} and hazard quotients of 1.0. HE exposure assumptions were used to evaluate exposures through the drinking water and fish ingestion pathways. These HE health-based levels were then used as a basis for comparison with the results of the concentration modeling for particulate deposition to surface water, as shown in Exhibit H-22.

As can be seen from the exhibit, the predicted surface water concentrations of the toxic waste constituents associated with air particulate deposition are all many orders of magnitude below the HBLs for drinking water or fish ingestion (corresponding to 10^{-5} cancer risk and hazard quotient equal to 1.0). Cadmium, with an HE predicted concentration of about two orders of magnitude below the HBL for fish ingestion, and chromium (VI), with an HE concentration of about four orders of magnitude below the HBL for drinking water ingestion, come the closest to any of the HBLs among the constituents of aluminum cast house dust. In the case of zinc waste ferrosilicon, the HE surface water concentration of zinc is about two orders of magnitude below the HBL for fish ingestion, and the HE concentration of lead is about thirty-fold below the drinking water HBL, which is based on the Clean Water Act MCL. All of these results indicate little cause for concern for adverse health effects through this pathway, especially considering the conservativeness of the exposure assumptions (e.g., 100 percent of the particulate is deposited in surface water).

Exhibit H-21

Home-Grown Crop Ingestion Pathway Risk Assessment Results for Particulate Deposition										
Constituent	CT Soil Concentration at 20 Years (mg/kg)	HE Soil Concentration at 20 Years (mg/kg)	CT Concentration in Above-Ground Vegetables (mg/kg)	HE Concentration in Above-Ground Vegetables (mg/kg)	CT Concentration in Root Vegetables (mg/kg)	HE Concentration in Root Vegetables (mg/kg)	CANCER RISK		HAZARD QUOTIENT	
							CT	HE	CT	HE
Aluminum Cast House Dust										
Antimony	6.57E-04	7.12E-03	4.35E-04	2.74E-03	9.86E-06	1.07E-04			1.26E-04	1.83E-03
Arsenic	2.80E-03	3.04E-02	1.40E-03	6.71E-03	7.73E-07	8.38E-06	2.91E-08	7.00E-07	5.25E-04	5.67E-03
Barium	8.76E-04	9.49E-03	5.36E-04	3.18E-03	2.48E-08	2.69E-07			8.63E-07	1.15E-05
Cadmium	6.31E-04	6.83E-03	5.19E-04	3.72E-03	2.52E-07	2.73E-06			1.17E-04	1.89E-03
Chromium(VI)	9.64E-03	1.04E-01	4.53E-03	2.01E-02	2.41E-06	2.61E-05			1.02E-04	1.02E-03
Lead	1.49E-03	1.61E-02	6.89E-04	2.98E-03	4.79E-11	5.19E-10				
Mercury	8.76E-09	9.49E-08	4.12E-09	1.83E-08	1.29E-15	1.40E-14			1.55E-09	1.55E-08
Nickel	2.28E-02	2.47E-01	1.13E-02	5.35E-02	2.22E-06	2.41E-05			6.34E-05	6.78E-04
Selenium	8.06E-05	8.73E-04	3.86E-05	1.75E-04	4.12E-07	4.47E-06			8.81E-07	9.21E-06
Silver	1.66E-04	1.80E-03	1.44E-04	1.05E-03	4.16E-05	4.51E-04			4.56E-06	8.59E-05
Zinc	1.05E-02	1.14E-01	7.49E-03	4.95E-02	1.16E-05	1.25E-04			2.82E-06	4.20E-05
Zinc Waste Ferrosilicon										
Lead	4.38E-01	4.75E+00	2.03E-01	8.78E-01	1.41E-08	1.53E-07				
Zinc	3.50E+00	3.80E+01	2.50E+00	1.65E+01	3.85E-03	4.18E-02			9.39E-04	1.40E-02

EXHIBIT H-22

Screening Results for Particulate Deposition to Surface Water										
Constituent	Concentrations Resulting from Releases of Aluminum Cast House Dust			Concentrations Resulting from Releases of Zinc Waste ferrosilicon			Surface Water HBL Concentrations (mg/L) ¹			
	Maximum Concentration in Waste (mg/kg)	CT Water Concentration (mg/L)	HE Water Concentration (mg/L)	Maximum Concentration in Waste (mg/kg)	CT Water Concentration (mg/L)	HE Water Concentration (mg/L)	Fish - Noncancer	Fish - Cancer	Drinking Water - Noncancer	Drinking Water - Cancer
Antimony	7.5	8.10E-09	8.77E-07						1.40E-02	
Arsenic	32	3.46E-08	3.74E-06					7.40E-04		8.40E-04
Barium	10	1.08E-08	1.17E-06				3.77E-01		2.45E+00	
Beryllium							2.84E-02		1.75E-01	
Cadmium	7.2	7.78E-09	8.42E-07				7.35E-05		3.50E-02	
Chromium(VI)	110	1.19E-07	1.29E-05				9.00E-01		1.75E-01	
Lead	17	1.84E-08	1.99E-06	5000	5.40E-06	5.85E-04			1.50E-02	
Mercury	0.0001	1.08E-13	1.17E-11						1.05E-02	
Nickel	260	2.81E-07	3.04E-05				1.02E-01		7.00E-01	
Selenium	0.92	9.94E-10	1.08E-07				8.40E-03		1.75E-01	
Silver	1.9	2.05E-09	2.22E-07				1.80E-02		1.75E-01	
Thallium							3.02E-05		2.80E-03	
Vanadium									2.45E-01	
Zinc	120	1.30E-07	1.40E-05	40000	4.32E-05	4.68E-03	3.12E-01		1.05E+01	

¹ HBLs correspond to an estimated lower risk of 10^{-5} , a noncancer hazard quotient of 1.0; or for lead, the MCL.

H.2.2.4 Risk Results for Runoff Releases to Surface Soils

The screening methods used to estimate constituent concentrations in surface soils due to runoff release from waste piles are summarized in Section H.2.1.8.3. Risks from this pathway were again evaluated by comparison of the resultant concentrations to HBLs. In this case, however, the HBLs were soil concentrations derived for the incidental ingestion and dermal contact pathways, and for the ingestion of contaminated root vegetables. The results of this analysis are summarized in Exhibit H-23.

As was the case for the air deposition pathway, the concentrations of toxic constituents in soils resulting from runoff releases are all below levels that would be associated with concern for adverse health effects. Both in the case of the ingestion and dermal exposure pathways, where shallow mixing depths were used, and in the case of the root vegetable ingestion pathway, where greater mixing depths were used, the estimated HE and CT concentrations of toxic constituents in soils are generally several orders of magnitude below the levels that might be associated with significant adverse health effects. (In the case of arsenic, the HBLs correspond to soil concentrations that would be associated with an HE cancer risk of 10^{-5} . For the other constituents, the HBLs correspond to soil concentrations resulting in HE noncancer hazard quotient values of 1.0.)

These results hold true both for aluminum cast house dust and zinc waste ferrosilicon, even though, in the latter case, the predicted HE concentration of zinc is quite high (4,000 mg/kg). This finding is a result of zinc's relatively low human toxicity. The predicted HE concentration of lead (497 mg/kg) is just below EPA's recommended risk-based cleanup standard for lead in residential soils.

H.2.2.5 Risk Results for Runoff Deposition to Surface Water

Runoff from the waste piles may also be deposited into surface water. Long-term concentrations of waste constituents in surface water resulting from runoff loading were calculated for both waste streams, as described previously, and the resulting concentrations were compared to HBLs for surface water in the same fashion as was done for deposition of airborne particulates.

The results of that analysis are summarized in Exhibit H-24. As might be expected, since the amounts of materials released through surface runoff are roughly comparable to the amounts of air particulate generated, the results of the screening surface water risk analysis for this pathway are similar to those for air particulate deposition, in that all of the calculated concentrations of constituents in the surface water bodies are far below the HBLs for either surface water ingestion or the ingestion of fish.

For aluminum cast house dust, the highest HE surface water concentrations (of antimony, arsenic, chromium, lead, and nickel) associated with runoff releases were all in the range of 10^{-6} to 10^{-5} mg/l, all of which were lower than the corresponding HBLs. In the case of zinc waste ferrosilicon, the estimated HE concentrations of lead and zinc, the two constituents for which concentration data were available, are both about ten-fold lower than the lowest HBLs. These results indicate that runoff releases to surface water are unlikely to be associated with significant risks to human health.

EXHIBIT H-23

COMPARISON OF SOIL CONCENTRATIONS FROM RUNOFF RELEASES TO HEALTH-BASED LEVELS											
Constituent	Soil Ingestion Health-Based Level (mg/kg)	Soil Dermal Contact Health-Based Level (mg/kg)	Home-Grown Vegetable Consumption Health-Based Level (mg/kg)	Aluminum Cast House Dust				Zinc Waste Ferrosilicon			
				CT Soil Concentration (Ingestion and Dermal) (mg/kg)	HE Soil Concentration (Ingestion and Dermal Contact) (mg/kg)	CT Soil Concentration (Ingestion of Home-Grown Vegetables) (mg/kg)	HE Soil Concentration (Ingestion of Home-Grown Vegetables) (mg/kg)	CT Soil Concentration (Ingestion and Dermal) (mg/kg)	HE Soil Concentration (Ingestion and Dermal Contact) (mg/kg)	CT Soil Concentration (Ingestion of Home-Grown Vegetables) (mg/kg)	HE Soil Concentration (Ingestion of Home-Grown Vegetables) (mg/kg)
Antimony	30	3.54	74.1	1.92E-03	1.58E-01	2.39E-04	1.58E-02				
Arsenic	4.26	2.11	24.5	8.17E-03	6.74E-01	1.02E-03	6.74E-02				
Barium	525	27,600	>1,000,000	2.55E-03	2.11E-01	3.19E-04	2.11E-02				
Beryllium	NA	NA	NA								
Cadmium	37.5	61.1	3470	1.84E-03	1.52E-01	2.30E-04	1.52E-02				
Chromium	375	90.7	55600	2.81E-02	2.32E+00	3.51E-03	2.32E-01				
Cyanide	NA	NA	NA								
Lead	NA	NA	NA	4.34E-03	3.58E-01	5.43E-04	3.58E-02	6.02E+00	4.97E+02	7.52E-01	4.97E+01
Mercury	22.5	21,000	>1,000,000	2.55E-08	2.11E-06	3.19E-09	2.11E-07				
Nickel	1,500	1,300	569,000	6.64E-02	5.48E+00	8.30E-03	5.48E-01				
Selenium	375	47	2,710	2.35E-04	1.94E-02	2.94E-05	1.94E-03				
Silver	375	44.1	55.6	4.85E-04	4.00E-02	6.07E-05	4.00E-03				
Thallium	NA	NA	NA								
Vanadium	NA	NA	NA								
Zinc	22,500	10,200	758,000	3.07E-02	2.53E+00	3.83E-03	2.53E-01	4.82E+01	3.97E+03	6.02E+00	3.97E+02

EXHIBIT H-24

COMPARISON OF SURFACE WATER CONCENTRATIONS DUE TO SOIL RUNOFF RELEASES TO HEALTH-BASED LEVELS						
Constituent	Drinking Water Health-Based Level (mg/l) ¹	Fish Ingestion Health-Based Level (mg/l)	Aluminum Cast House Dust		Zinc Waste Ferrosilicon	
			Maximum High-End Surface Water Concentration, Bulk Samples (mg/l)	Maximum Central Tendency Surface Water Concentration, Bulk Samples (mg/l)	Maximum High-End Surface Water Concentration, Bulk Samples (mg/l)	Maximum Central Tendency Surface Water Concentration, Bulk Samples (mg/l)
Antimony	0.014	NA	7.52E-09	1.15E-06		
Arsenic	0.00084	0.00074	3.21E-08	4.89E-06		
Barium	2.45	0.377	1.00E-09	1.53E-06		
Beryllium	0.175	0.0284				
Cadmium	0.035	0.0000735	7.22E-09	1.10E-06		
Chromium	0.175	0.9	1.10E-07	1.68E-05		
Cyanide	0.7	36.5				
Lead	0.015	NA	1.71E-08	2.60E-06	2.36E-05	3.60E-03
Mercury	0.0105	0.00000125	1.00E-13	1.53E-11		
Nickel	0.7	0.102	2.61E-07	3.97E-05		
Selenium	0.175	0.0084	9.23E-10	1.41E-07		
Silver	0.175	0.018	1.91E-09	2.90E-07		
Thallium	0.0028	0.0000302				
Vanadium	0.245	NA				
Zinc	10.5	0.312	1.20E-07	1.83E-05	1.89E-04	2.88E-02

¹ HBLs correspond to a lower risk of 10^{-5} , a noncancer hazard quotient of 1.0, or, for lead, the MCL value.

H.2.2.6 Risk Results for Surface Impoundment Releases to Surface Water

The surface water concentrations of toxic constituents resulting from surface impoundment releases were also compared to surface water HBLs. Unlike the other pathways evaluated, the screening comparison indicates the potential for adverse effects on human health above levels of concern for a few constituents from some samples from several waste streams. These results are summarized below.

H.2.2.6.1 Ingestion of Surface Water

Exhibit H-25 summarizes the results of the comparison of surface water concentrations from impoundment releases to HBLs. Because there are multiple samples available for most of the waste streams managed in surface impoundments, the results of the comparison to HBLs are reported in terms of

EXHIBIT H-25

COMPARISON OF SURFACE WATER CONCENTRATIONS FROM SURFACE IMPOUNDMENT RELEASES TO HEALTH-BASED LEVELS												
DRINKING WATER												
				Maximum High-End Surface Water Concentration, Bulk Samples		Maximum High-End Surface Water Concentration, EP Samples ²			Central Tendency Surface Water Concentration, Bulk Samples		Central Tendency Surface Water Concentration, EP Samples ²	
				Compared to HBL ¹		Compared to HBL			Compared to HBL		Compared to HBL	
Constituent	Commodity	Wastestream	Total No. Samples	1-10x	10-100x	1-10x	10-100x	100-1000x	1-10x	10-100x	1-10x	10- 100x
Arsenic	Copper	Acid plant blowdown	40	3	1			1			1	
Cadmium	Zinc	Spent surface impoundment liquids	24	1								
Lead	Copper	Acid plant blowdown	40	1								
	Zinc	Spent surface impoundment liquids	24	1	1							

NOTES:

1. HBLs correspond to a lower risk of 10^{-5} , a noncancer hazard quotient of 1.0, or, for lead, the MCL value.
2. EP samples are adjusted (i.e., have been multiplied by 1.95) to extrapolate to bulk concentrations.

the numbers of samples and recycled streams for which the HE and CT surface water concentrations from impoundment releases exceed the HBLs, presented in order-of-magnitude categories.

Releases from surface impoundment failures were modeled as resulting in potential exceedences of HBLs for water ingestion for three constituents: arsenic, cadmium, and lead. Under high-end dilution assumptions, the arsenic concentrations in five samples (four bulk samples, one EP extraction) would exceed the drinking water HBL by up to one thousand-fold. (This is equivalent, in this case, to saying that the estimated cancer risks under HE assumptions would exceed the 10^{-5} level of concern by up to a factor of 1000.) All of these samples came from the copper acid plant blowdown stream, and under CT dilution assumptions the surface water concentration for arsenic exceeds the HBL for only one of the 40 total samples from this stream.

The concentration of cadmium in one of 24 samples from the zinc spent surface impoundment liquid stream results in surface water concentrations exceeding the drinking water HBL under HE assumptions. The HBL is exceeded by a factor of ten or less. Under CT assumptions, there are no HBL exceedences for cadmium. For cadmium, an HBL exceedence corresponds to a hazard quotient value exceeding 1.0 for its critical toxic effect on kidney function.

The lead concentrations in bulk samples from two waste streams result in calculated surface water concentrations exceeding the drinking water HBL. One sample of copper acid plant blowdown shows a concentration of lead such that the HE concentrations exceeds the HBL by a factor of less than ten. Under CT assumptions, this sample no longer exceeds the HBL. Two bulk samples of zinc spent surface impoundment liquids result in HE lead concentrations in surface water that exceed the HBL by a factor of up to 100. Again, under the CT dilution assumptions, the predicted lead concentrations in surface water are reduced to below the drinking water HBL. As noted previously, the HBL for lead is simply the Drinking Water MCL of 15 ug/l.

H.2.2.6.2 Ingestion of Contaminated Fish

The predicted surface water concentrations of six contaminants released from surface impoundments also were such that HBLs derived for the ingestion of fish by subsistence fishers were exceeded. The results are presented in Exhibit H-26. Six arsenic samples (again all from copper acid plant blowdown) were associated with HE surface water concentrations exceeding the fish consumption HBLs by up to a factor of 1000. Four of these were bulk samples, and the remainder were EP extraction samples. Under CT assumptions, only one sample exceeded the arsenic fish ingestion HBL.

A total of 20 samples (one EP extraction, the rest bulk) contained cadmium concentrations which resulted in surface water concentrations exceeding the fish ingestion HBL by a up to 1000-fold. These samples came from zinc spent surface impoundment liquids (10), zinc process wastewater (6), copper acid plant blowdown (2 samples), and one sample each from rare earths process wastewater and zinc wastewater treatment plant liquid effluent. Under CT dilution assumptions, the number of samples exceeding the cadmium HBL is reduced to 3 samples, and the maximum level of exceedence is reduce to less than 100-fold.

EXHIBIT H-26

COMPARISON OF SURFACE WATER CONCENTRATIONS FROM SURFACE IMPOUNDMENT RELEASES TO HEALTH-BASED LEVELS													
FISH INGESTION				Maximum High-End Surface Water Concentration, Bulk Samples			Central Tendency Surface Water Concentration, Bulk Samples		Maximum High-End Surface Water Concentration, EP Samples ²			Central Tendency Surface Water Concentration, EP Samples ²	
Constituent	Commodity	Wastestream	Total No. Samples	Compared to HBL ¹			Compared to HBL		Compared to HBL			Compared to HBL	
				1-10x	10-100x	100-1000x	1-10x	10-100x	1-10x	10-100x	100-1000x	1-10x	10-100x
Arsenic	Copper	Acid plant blowdown	40	2	2				1		1	1	
Cadmium	Copper	Acid plant blowdown	40	2									
	Rare Earths	Process wastewater	8						1				
	Zinc	Process wastewater	40	6									
	Zinc	Spent surface impoundment liquids	24	6	3	1	1	1					
Mercury	Zinc	WWTP liquid effluent	5			1		1					
	Copper	Acid plant blowdown	40	2					1				
	Zinc	Spent surface impoundment liquids	24	1	1								
Selenium	Copper	Acid plant blowdown	40	1									
Thallium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	8	1									
	Copper	Acid plant blowdown	40						1				
Zinc	Zinc	Spent surface impoundment liquids	24	5									
	Zinc	WWTP liquid effluent	5	1									

NOTES:

1. HBL = health-based level derived for fish ingestion based on worst-case subsistence fisher.
2. EP samples are adjusted (i.e., have been multiplied by 1.95) to extrapolate to bulk concentrations.

Under HE assumptions, five samples give mercury concentrations in surface water exceeding the fish ingestion HBL. These samples come from copper acid plant blowdown (3) and zinc spent surface impoundment liquids (2), and under CT assumptions, none of these samples exceeds the fish HBL. In the case of mercury, an HBL exceedence is equivalent to a hazard quotient greater than 1.0 for reproductive effects.

A single sample result for selenium in copper acid plant blowdown results in surface water concentrations above the HBL, as do two thallium results (one each from titanium/TiO₂ leach liquor and sponge wash water and from copper acid plant blowdown). For all of these samples, no exceedences occur under CT dilution assumptions. The same is true for the six analytical results for zinc (all from zinc commodity streams); all six samples exceed the fish ingestion HBL under HE but not under CT dilution assumptions.

H.2.2.7 Summary of Non-Groundwater Pathway Risk Assessment Results

The findings of this analysis parallel the results of the groundwater risk assessment for the storage of mineral processing wastes, which found generally very low risks for the nonwastewater streams disposed in waste piles, and higher risks (exceeding 10⁻⁵ cancer risk and hazard quotients of 1.0 in some instances) for the wastewaters and liquid nonwastewater streams disposed in surface impoundments.

In the groundwater analysis, the major reasons for the relatively low estimated risks were the generally low DAF values for waste piles, and the relatively low masses of toxic constituents in the relatively small piles. In this analysis, the small size of the waste piles (corresponding to the low recycled volumes of these streams) is again decisive in determining the generally low risks for the nonwastewater streams. None of the release events and exposure pathways that were evaluated for waste piles resulted in risks greater than the previously-noted levels of concern under either CT or HE assumptions. Estimated releases from both runoff and air particulate generation were low (in the range of a few hundred to a few thousand kilograms per year total mass), and even moderate dilution in exposure media was enough to reduce exposure concentrations below levels of concern with regard to adverse health effects.

The comparatively higher risks associated with waste managed in surface impoundments was primarily a function of the larger volumes of waste being managed and correspondingly larger release volumes. Even though the proportions of the recycled materials released from impoundments were relatively low, there was still enough mass present in the impoundments to result in surface water concentrations exceeding HBLs. It should be noted, however, that even for these high-volume wastes, exceedences of HBLs were limited to only a small minority of the constituents, samples and waste streams, and the greatest numbers of exceedences were for the fish ingestion pathway, where the HBLs for several constituents have been derived quite conservatively. Under HE assumptions, only nine samples (out of 135 having analytical data) resulted in exceedences of the drinking water HBL, and this number dropped to one under CT assumptions. Under HE assumptions, a total of 40 samples exceeded the far more stringent fish ingestion HBLs, and this number dropped to 4 under CT assumptions.

Two of the twelve wastewater and liquid nonwastewater streams evaluated in the analysis accounted for the bulk of the HBL exceedences. Under HE assumptions, samples from copper acid plant blowdown accounted for six of the nine exceedences of the drinking water HBL, and zinc spent surface impoundment liquids accounted for the remaining three. Between them, these two streams also accounted for 34 of the 40 HE exceedences of the fish ingestion HBLs (copper acid plant blowdown 13, zinc spent surface impoundment liquids 21). Two other streams from the zinc commodity sector (six samples from process

wastewater and two samples from waste water treatment plant liquid effluent) also accounted for one or more exceedences of the fish consumption HBL. Beyond that, only two other commodity sectors (rare earths and titanium/TiO₂) had any exceedences (one each, only under HE assumptions).

Thus, this analysis clearly identifies two commodity sectors and four waste streams as dominant in driving potential risks from the storage of mineral processing wastes, at least among the streams for which analytical data are available. Whether there are other streams and commodities for which non-groundwater risks might also exceed levels of concern cannot be determined without additional data concerning waste characteristics and composition.

H.2.2.8 Uncertainties/Limitations of the Analysis

As discussed in Section H.2.1, the multipathway risk assessment for the storage of mineral processing recycled materials relies on relatively simple, generic models of contaminant releases, transport, exposures, and risks. As such, this screening level analysis shares the general limitations of all generic analyses in that high levels of uncertainty and variability may not be adequately treated, since only a limited number of generally applicable models and generally representative data are used to model risks from a wide range of units, wastes, and constituents. Many of these generic sources of uncertainty have been addressed in our previous work on mineral processing wastes, and the following discussion is limited to limitations specific to the multipathway analysis

Constituent concentration data are available for only 14 recycled waste streams, and for some wastes only small numbers of samples are available. It is interesting to note that two of the wastes for which estimated risks are the highest (copper acid plant blowdown and zinc spent surface impoundment liquids) also are those for which the largest number of samples are available. It is not possible to estimate which of the other wastes might also show risks above levels of concern if more data were available.

Limited data are also available concerning waste characteristics, including constituent speciation, solubility, and bioavailability. Throughout this analysis, we have assumed that all constituents would behave in such a manner as to maximize exposure potential. For example, we have assumed that none of the constituents would leach from soils after their initial deposition, and that all of the constituents would be bioavailable in the water column. Generally these assumptions increase the level of conservatism in the risk assessment.

Release events and amounts were simulated mostly using the general methods adopted in HWIR-Waste. The one exception is air particulate generation, which was estimated using the SCREEN3 model, rather than the model recommended in HWIR-Waste. SCREEN3 is a widely-accepted screening level EPA model, however, and EPA believes that it is appropriate for the types of release events that were modeled. The use of SCREEN3 is unlikely to have biased the results of the risk assessment significantly compared to other methods. However, as noted previously, no data were available concerning the particle size characteristics of the two wastes streams that were modeled, so we relied on data from an earlier study of mineral processing wastes stored in waste piles. Based on limited information, we believe that the particle size distribution that was used may overstate the potential for particulate release of the more coarse-grained, high-density zinc waste ferrosilicon, while more accurately describing the potential for particulate releases of aluminum cast house dust.

Runoff releases were evaluated using the same model (USLE) applied in HWIR-Waste, with input parameters varied slightly to reflect the operating characteristics of the waste piles being simulated and the likely geographic distribution of the recycling facilities. The risk results are not particularly sensitive to these changes, as exposure concentrations for runoff events are below the levels of concern for all of the runoff exposure pathways.

The ISCST3 model used to predict particulate air concentrations and deposition rates is a state-of-the-art model that has been used in many regulatory proceedings by EPA. The input data that were used, the "worst-case" meteorological conditions that are supplied with ISCST3 specifically for use in screening level assessments, were somewhat more conservative than the meteorological data used in HWIR-Waste with a similar model. Thus, our estimates of air impacts are likely to be higher than those that would have been achieved had we replicated the HWIR-Waste approach. Again, however, all risks associated with this pathway were far below levels of concern.

The modeling of releases from surface impoundments reproduced exactly the approach used in HWIR-Waste. This release model and its input parameters were derived based on data from management units in the pulp and paper industry, and just how reliably they predict releases from surface impoundments in the mineral processing industries is not known. This is clearly a major source of uncertainty in the risk assessment, as these release events are the only non-groundwater releases for which health risks are predicted to be above levels of concern.

Because of resource limitations and the specific characteristics of the facilities that were evaluated, simplified approaches were developed to estimate the concentrations of waste constituents in surface soils and surface water to substitute for the much more elaborate methods used in HWIR-Waste. In the case of surface runoff, in the absence of site-specific data, we conservatively assume that soil contamination would be limited to relatively small distances (50 or 100 meters) from the piles in arbitrarily defined circular plumes. This is only intended as a bounding analysis, and the finding that this pathway is not a major concern can be supported by the fact that, even with these relatively small exposure areas (and the resultant high soil concentrations), constituent concentrations due to runoff events were below levels of health concern.

Similarly, to be conservative, we assumed that all of the runoff and all of the particulate generated by the waste piles would be deposited on the watershed in such a way that all of these materials would rapidly find their way into surface water. This approach, while it resulted in surface water concentrations far below levels of health concern, may be less conservative than the approach taken for surface soils, in that the CT and HE streams are both rather large, and the model does not take into account possible runoff or deposition into smaller streams, lakes, or ponds where constituents may accumulate in surface water or sediment.

The approach we took in evaluating fish tissue concentrations was also somewhat more conservative than that taken in HWIR-Waste, in that we used the highest reliable BCF or BAF values, rather than representative values, in our calculations. For some constituents (arsenic, cadmium, mercury, thallium), this approach resulted in considerably higher tissue concentrations than would have been calculated had we used the HWIR-Waste values, and considerably lower HBLs. This may be a major source of uncertainty in this analysis, since the fish ingestion pathway resulted in the highest risks for several of the constituents.

ATTACHMENT H.A

Proportion of Mineral Processing Wastes Covered by the Storage Risk Assessment

ATTACHMENT H.A-1

PROPORTION OF RECYCLED MINERAL PROCESSING WASTE STREAMS ADDRESSED IN THE RISK ASSESSMENT FOR RECYCLED MATERIALS STORAGE

Commodity	Waste Stream	Total Recycled Volume			Recycled Volume Analyzed in Risk Assessment	Percent Analyzed in Risk Assessment		
		Min.	Ave.	Max.		Exp./Min.	Expect./Ave.	Exp./Max.
Aluminum, Alumina	Cast House Dust	16,227	16,227	16,227	16,227	100.00%	100.00%	100.00%
	Electrolysis Waste		24,438	48,875				
	Sector	16,227	40,665	65,102	16,227	100.00%	39.90%	24.93%
Beryllium	Chip Treatment Wastewater		10,000	400,000	10,000		100.00%	2.50%
	Sector		10,000	400,000	10,000		100.00%	2.50%
Copper	Acid Plant Blowdown	3,975,000	3,975,000	3,975,000	3,975,000	100.00%	100.00%	100.00%
	WWTP Sludge		2,250	4,500				
	Sector	3,975,000	3,977,250	3,979,500	3,975,000	100.00%	99.94%	99.89%
Elemental Phosphorus	AFM Rinsate	4,000	4,000	4,000	4,000	100.00%	100.00%	100.00%
	Furnace Scrubber Blowdown	420,000	420,000	420,000	420,000	100.00%	100.00%	100.00%
	Furnace Building Washdown	700,000	700,000	700,000				
	Sector	1,124,000	1,124,000	1,124,000	424,000	37.72%	37.72%	37.72%
Rare Earths	Electrol. Cell Caustic Wet APC Slud.		350	7,000				
	Process Wastewater	1,400	1,400	1,400	1,400	100.00%	100.00%	100.00%
	Spent Scrubber Liquor	20	100,000	200,000				
	Wastewater from APC		50,000	200,000				
	Sector	1,420	151,750	408,400	1,400	98.59%	0.92%	0.34%
Selenium	Spent Filter Cake		217	4,335				
	Plant Process Wastewater	13,200	13,200	13,200	13,200	100.00%	100.00%	100.00%
	Slag		51	1,020				
	Tellurium Slime Wastes		217	4,335				
	Sector	13,200	13,685	22,890	13,200	100.00%	96.46%	57.67%
Tantalum, Ferrocolumbium, etc.	Process Wastewater	127,500	127,500	127,500	127,500	100.00%	100.00%	100.00%
	Sector	127,500	127,500	127,500	127,500	100.00%	100.00%	100.00%
Titanium, Titanium Oxide	Pickel Liquor and Wash Water		270	660				
	Scrap Milling Scrubber Water		500	1,200	500		100.00%	41.67%
	Smut from Mg Recovery	85	18,700	39,100				
	Leach Liquor, Sponge Wash Water	78,000	96,000	118,000	96,000	128.32%	100.00%	82.76%
	Spent Surface Impoundment Liquids		1,458	5,712				
	Sector	78,085	116,928	162,672	96,500	126.83%	82.53%	59.32%
Zinc	Acid Plant Blowdown	130,000	130,000	130,000				
	Waste Ferrisilicon		7,225	14,450	7,225		100.00%	50.00%
	Process Wastewater	4,335,000	4,335,000	4,335,000	4,335,000	100.00%	100.00%	100.00%
	Spent Clothes, Bags, and Filters		75	150				
	Spent Goethite, Leach Cake Residues	15,000	15,000	15,000				
	Spent Surface Impoundment Liquids	378,000	378,000	378,000	378,000	100.00%	100.00%	100.00%
	WWTP Solids		281	563				
	TAC Tower Blowdown		94	188				
	WWTP Liquid Effluent		261,000	522,000	261,000		100.00%	50.00%
	Sector	4,858,000	5,128,675	5,395,351	4,981,225	102.54%	97.16%	92.32%
All Sectors		14,099,602	14,843,809	16,805,223	9,645,052	68.41%	64.96%	57.39%

Notes:

Proportion of streams covered = 14/73 = 19.2 percent

Commodities not covered = Antimony, Bismuth, Cadmium, Calcium, Coal Gas, Fluorspar and Hydrofluoric Acid, Germanium, Lead, Magnesium and Magnesia, Mercury, Platinum Group Metals, Pyrobitumens, Rhenium, Scandium, Synthetic Rutile, Tellurium, Tungsten, Uranium, Zirconium and Hafnium

ATTACHMENT H.A-2

PROPORTION OF MINERAL PROCESSING WASTE STREAMS ADDRESSED IN THE RISK ASSESSMENT FOR RECYCLED MATERIALS STORAGE										
Commodity	Waste Stream	Generation Rate			Recycled Volume			Percent Recycled		
		Min.	Ave.	Max.	Min.	Expect.	Max.	Min./Min.	Expect./Ave.	Max./Max.
Aluminum, Alumina	Cast House Dust	19,000	19,000	19,000	16,227	16,227	16,227	85.41%	85.41%	85.41%
	Electrolysis Waste	58	58	58						
	Sector	19,058	19,058	19,058	16,227	16,227	16,227	85.15%	85.15%	85.15%
Beryllium	Chip Treatment Wastewater	200	100,000	2,000,000	0	10,000	400,000	0.00%	10.00%	20.00%
	Filtration Discard	200	450	90,000						
	Sector	400	100,450	2,090,000	0	10,000	400,000	0.00%	9.98%	19.14%
Copper	Acid Plant Blowdown	5,300,000	5,300,000	5,300,000	3,975,000	3,975,000	3,975,000	75.00%	75.00%	75.00%
	WWTP Sludge	6,000	6,000	6,000						
	Sector	5,306,000	5,306,000	5,306,000	3,975,000	3,975,000	3,975,000	74.92%	74.92%	74.92%
Elemental Phosphorus	Anderson Filter Media	460	460	460						
	APM Rinse	4,000	4,000	4,000	4,000	4,000	4,000	100.00%	100.00%	100.00%
	Furnace Scrubber Blowdown	410,000	410,000	410,000	420,000	420,000	420,000	102.44%	102.44%	102.44%
	Furnace Building Washdown	700,000	700,000	700,000						
	Sector	1,114,460	1,114,460	1,114,460	424,000	424,000	424,000	38.05%	38.05%	38.05%
Rare Earths	Spent NH ₄ NO ₃ Solution	14,000	14,000	14,000						
	Electrol. Cell Cautic Wet APC Slud.	70	70	700						
	Process Wastewater	7,000	7,000	7,000	1,400	1,400	1,400	20.00%	20.00%	20.00%
	Spent Scrubber Liquor	100	500,000	1,000,000						
	Solvent Extraction Crud	100	2,300	4,500						
	Wastewater from APC	100	500,000	1,000,000						
	Sector	21,370	1,023,370	2,026,200	1,400	1,400	1,400	6.55%	0.14%	0.07%
Selenium	Spent Filter Cake	50	500	5,000						
	Plant Process Wastewater	66,000	66,000	66,000	13,200	13,200	13,200	20.00%	20.00%	20.00%
	Slag	50	500	5,000						
	Tellurium Slime Wastes	50	500	5,000						
	Waste Solids	50	500	5,000						
	Sector	66,200	66,000	66,000	13,200	13,200	13,200	19.94%	19.41%	15.35%
Tantalum, Ferromolybdenum, etc.	Digester Sludge	1,000	1,000	1,000						
	Process Wastewater	150,000	150,000	150,000	127,500	127,500	127,500	85.00%	85.00%	85.00%
	Spent Raffinate Solids	2,000	2,000	2,000						
	Sector	153,000	153,000	153,000	127,500	127,500	127,500	83.33%	83.33%	83.33%
Titanium, Titanium Oxide	Pickel Liquor and Wash Water	2,200	2,700	3,200						
	Scrap Milling Scrubber Water	4,000	5,000	6,000		500	1,200	0.00%	10.00%	20.00%
	Smelt from Mg Recovery	100	22,000	45,000						
	Leach Liquor/Sponge Wash Water	380,000	480,000	580,000	76,000	96,000	116,000	20.00%	20.00%	20.00%
	Spent Surface Impoundment Liquids	630	3,400	6,700						
	Waste Acids (Sulfate Process)	200	39,000	77,000						
	WWTP Sludges/Solids	420,000	420,000	420,000						
	Sector	807,130	972,100	1,137,900	76,000	96,500	117,200	9.42%	9.93%	10.30%
Zinc	Acid Plant Blowdown	130,000	130,000	130,000						
	Waste Ferriallcon	17,000	17,000	17,000	0	7,225	14,450	0.00%	42.50%	85.00%
	Process Wastewater	5,000,000	5,000,000	5,000,000	4,335,000	4,335,000	4,335,000	86.70%	86.70%	86.70%
	Discarded Refractory Brick	1,000	1,000	1,000						
	Spent Clothes, Bags, and Filters	150	150	150						
	Spent Goethite, Leach Cake Residues	15,000	15,000	15,000						
	Spent Surface Impoundment Liquids	1,900,000	1,900,000	1,900,000	378,000	378,000	378,000	19.89%	19.89%	19.89%
	WWTP Solids	750	750	750						
	Spent Synthetic Gypsum	16,000	16,000	16,000						
	TAC Tower Blowdown	250	250	250						
	WWTP Liquid Effluent	2,600,000	2,600,000	2,600,000	0	261,000	522,000	0.00%	10.04%	20.08%
	Sector	9,680,150	9,680,150	9,680,150	4,713,000	4,991,225	5,249,450	49.89%	51.46%	54.23%
All Sectors		21,523,000	24,411,000	32,246,000	9,346,327	9,648,062	10,323,977	43.42%	39.51%	32.02%

Notes:

Proportion of streams covered = 14/118 = 11.9 percent

Commodities not covered = Antimony, Bismuth, Cadmium, Calcium, Coal Gas, Fluorspar and Hydrofluoric Acid, Germanium, Lead, Magnesium and Magnesia, Mercury,

Molybdenum, Ferromolybdenum, and Ammonium Molybdate, Pyroblumens, Rhenium, Scandium, Synthetic Rutile, Tellurium, Tungsten, Uranium

ATTACHMENT H.B

Summary of Particulate Generation, Air Transport, and Deposition Modeling

ATTACHMENT H.B. Air Quality Modeling in Support of Mineral Processing Storage Analysis

Model Selection and Options

The Industrial Source Complex Short Term (ISC3ST- version 96113) was used to model the impacts of fugitive emissions from materials handling and wind erosion at the mineral processing facilities. The ISC3ST model is the model recommended by EPA in the Guideline On Air Quality Models (Revised), EPA-450/2-78-027R, Appendix W of 40 CFR Part 51 and Part 52. As stated in the guidance document:

“Fugitive emissions are usually defined as emissions that come from an industrial source complex. They include the emissions resulting from the industrial process that are not captured and vented through a stack but may be released from various locations within the complex. Where such fugitive emissions can be properly specified, the ISC model, with consideration of gravitational settling and dry deposition, is the recommended model.”

The ISC3ST model was set-up to run using the following regulatory default options:

- Final plume rise
- Stack-tip downwash
- Buoyancy-induced dispersion
- Calms processing
- Default wind profile exponents
- Default vertical potential temperature gradients
- No exponential decay.

However, since the only sources included were fugitive area sources, the options applicable to stack point sources (e.g. stack-tip downwash) were not applied.

Emission Estimates

Emissions associated with the storage of mineral processing waste (aluminum/alumina cast house dust and ferrosilicon waste from zinc production) were estimated to occur from the aggregate handling of the waste materials and from the wind erosion of the waste piles. Emissions from the aggregate handling of the waste piles vary in proportion to the mean wind speed and the moisture content of the waste. Emissions generated by wind erosion of the waste piles were related to threshold friction velocity and the wind gusts of the highest magnitude routinely measured as the fastest mile. Because the lack of data, we made a few assumptions in estimating these emissions:

- a) The material in the storage piles has a moisture content of 4.8 percent
- b) The threshold friction velocity for the waste piles is the same as the threshold friction velocity for fine coal dust stored on a concrete pad. This assumption would overestimate emissions for the waste piles since fine coal dust on concrete pad has a greater erosion potential than the waste piles.
- c) The fastest mile, (i.e., the wind gusts of the highest magnitude) occurs during period between disturbances to the piles.

- d) The surface area of the storage pile which is disturbed during each work day is equal to 25 percent of the total pile surface area.
- e) Data for the annual mean wind speed and for the fastest mile were taken for Kansas City which has an average values of the cities surveyed in "Extreme Wind Speed at 129 Stations in the Contiguous United States".

Emissions from handling of the waste materials and from the wind erosion of the waste piles were estimated using equations from EPA's AP-42, Compilation of Air Pollution Emission Factors, Volume I: Stationary Point and Area Sources. As previously stated, these equations relate parameters such as exposed surface area, moisture content, mean wind speed, threshold friction velocity, fastest mile to total TSP and PM₁₀ emissions.

Meteorological Assumptions

In addition to the meteorological assumptions needed to estimate emissions from mineral processing waste piles, meteorological data was required to complete the air quality dispersion modeling analysis using ISC3ST. To conservatively predict the impacts of the emission sources, worst-case meteorological data was used in ISC3ST.

The worst-case meteorological data is similar to that incorporated in the EPA model, SCREEN3. The worst-case meteorological data set contains an array of all possible combinations of wind speed, wind direction and stability class that could exist in an actual location. The data set of meteorological conditions consisted of:

- Mixing heights of 1000 meters
- Ambient temperatures of 298 DegK
- Wind directions varying from 10 to 360 degrees
- Wind speeds (varying from 1.0 m/sec to 20.0 m/sec) assigned to stability classes A through F

A few additional parameters are required to estimate deposition using the ISC3ST model. Those parameters include: The variables are: friction velocity at the application site (m/s), Monin-Obukhov length at the application site (m) and roughness length at the application site (m). The EPA model RAMMET, version 95227 was used to estimate these parameters. RAMMET requires data on surface roughness length at application site, noon time albedo and Bowen ratio, which vary by season and land-use type. Values by season and land-use type (10% urban, deciduous forest, coniferous forest, grassland and desert shrubland share the 90%, i.e., 22.5% each) were estimated. The appropriate friction velocity, Monin-Obukhov length and roughness length values were extracted from the RAMMET output and added to worst case meteorological data for the deposition calculations.

Location of Maximum and Area-Average Concentrations and Concentrations

As with many Gaussian dispersion models, ISC3ST results are accurate no closer than 100 meters from each source. Thus to calculate impacts of the two sets of storage piles, both piles were placed in a prototypical facility with property boundaries located approximately 100 meters from the edge of each storage pile. Two sets of receptor grids were used to determine maximum peak 24 hour and annual average concentration and deposition values at points located around the property boundary. To pinpoint the maximum values, a grid of receptor points, with receptors located from 100 meters to 250 meters in each direction, with a resolution of 50 meters was input to ISC3ST. An array of polar receptors, at 45 degree intervals, from 200 to 3,000 meters was used to estimate area average concentrations.

ATTACHMENT H.C

Fish Bioconcentration and Bioaccumulation Factor Values and Data Sources

Attachment H.C
Fish BCF, and Toxicity Values

Chemical	Cas Number	BAF fish (L/kg body weight) (total)	Source	BCF fish (L/kg) (dissolved)	Source	RfD (mg/kg/day)	Source	Oral CSF (mg/kg/day)-1	Source	RfC (mg/m3)	Source	Inhal URF (ug/m3)-1	Source
Antimony	7440-36-0	NA		not significant	Barrows et. al 1980 (in EPA 1988)*	4.00E-04	IRIS	NA		NA		NA	
Arsenic	7440-38-2	NA		4	Barrows et al. 1978*	3.00E-04	IRIS	1.50E+00	IRIS	NA		4.30E-03	IRIS
Barium	7440-39-3	NA		100	Schroeder 1970*	7.00E-02	IRIS	NA		5.00E-04	HEAST	NA	
Beryllium	7440-41-7	NA		19	Barrows et al. 1978*	5.00E-03	IRIS	4.30E+00	IRIS	NA		2.40E-03	IRIS
Cadmium	7440-43-9	NA		3-7,440	Benoit et al. 1976 (in EPA 1985a)*; Giesy et al. 1977 (in Eisler 1985)*	5.00E-04	IRIS	NA		NA		1.80E-03	IRIS
Chromium (VI)	18540-29-9	NA		3	EPA 1985b	5.00E-03	IRIS	NA		NA		1.20E-02	IRIS
Cyanide	57-12-5			0.3	Kenaga 1980 (KCN)*	2.00E-02	IRIS	NA		NA		NA	
Lead	7439-92-1	8		1-726	Maddock and Taylor 1980 (in Eisler 1988)*; Wong et al. 1981 (in Eisler 1988)*		NA	NA		NA		NA	
Mercury	7439-97-6	6.00E+04	EPA 1993b	129-10,000 (mercury(II)); 10,000-85,700 (methylmercury)	Various refs. in EPA 1985c*	3.00E-04	IRIS (HgCl2)	NA		3.00E-04	IRIS	NA	
Nickel	7440-02-0	NA		47-106	Lind et al. manuscript (in EPA 1986)*	2.00E-02	IRIS (soluble salts)	NA		NA		NA	
Selenium	7482-49-2	0.5-1.0	Cleveland et. al 1993	5-322	Cleveland et. al 1993*; Ingersoll et. al 1990*	5.00E-03	IRIS	NA		NA		NA	
Silver	7440-22-4	NA		11-150	EPA 1987	5.00E-03	IRIS	NA		NA		NA	
Thallium	7440-28-0	NA		27-1430	Zitko et al. 1975; Barrows et al. 1978*	8.00E-05	IRIS (Ti2Ch2 O3, TiCl, or Ti2H2S O4)	NA		NA		NA	
Vanadium	7440-62-2	NA		NA		7.00E-03	HEAST	NA		NA		NA	
Zinc	7440-66-6	4.4		275-519	Xu and Pascoe 1993*	3.00E-01	IRIS	NA		NA		NA	

ATTACHMENT H.D

Risk Characterization and Screening Spreadsheets

H.D-1 Inhalation Pathway

H.D-2 Particulate Deposition Soil Ingestion and Dermal Contact

H.D-3 Particulate Deposition to Surface Water Risk Screening Results

H.D-4 Runoff Deposition to Soils Screening Results

H.D-5 Runoff Deposition to Surface Water Screening Results

H.D-6 Surface Impoundment Releases to Surface Soils Screening Results

ATTACHMENT H.D-1 Inhalation Pathway

Exposure and Risk Calculations for Particulate Deposition

COMMODITY: Alumina and Aluminum
WASTE STREAM: Cast house dust
CT PM 10 Concentration 2.3 ug/m3
HE PM10 Concentration 32.3 ug/m3

Constituent	RIC (mg/m3)	Unit Risk (ug/m3)-1	Maximum Concentration in Waste (mg/kg)	CT Constituent Concentration in Particulate (ug/m3)	HE Constituent Concentration in Particulate (ug/m3)	CT Cancer Risk	HE Cancer Risk	CT Noncancer Hazard Quotient	HE Noncancer Hazard Quotient
Antimony			7.5	1.73E-05	2.42E-04	0.00E+00	0.00E+00		
Arsenic		4.30E-03	32	7.36E-05	1.03E-03	3.90E-13	1.22E-11		
Barium	5.00E-04		10	2.30E-05	3.23E-04	0.00E+00	0.00E+00	1.92E-01	1.92E-01
Beryllium		2.40E-03	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
Cadmium		1.80E-03	7.2	1.66E-05	2.33E-04	3.67E-14	1.15E-12		
Chromium(VI)		1.20E-02	110	2.53E-04	3.55E-03	3.74E-12	1.17E-10		
Lead			17	3.91E-05	5.49E-04	0.00E+00	0.00E+00		
Mercury	3.00E-04		0.0001	2.30E-10	3.23E-09	0.00E+00	0.00E+00	3.20E-06	3.20E-06
Nickel		4.80E-04	260	5.98E-04	8.40E-03	3.54E-13	1.10E-11		
Selenium			0.92	2.12E-06	2.97E-05	0.00E+00	0.00E+00		
Silver			1.9	4.37E-06	6.14E-05	0.00E+00	0.00E+00		
Thallium			0	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
Vanadium			0	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
Zinc			120	2.76E-04	3.88E-03	0.00E+00	0.00E+00		

Exposure Variables

		CT	HE	Units
EF	Exposure Frequency	350	350 days/year	
EDa	Exposure Duration (Adult)	9	20 years	

Cancer Risk = U.R. * PM10 * Max Conc. * 10⁻⁶ * (EF/365) * (ED/70)

Hazard Quotient = (EF/365) * (Max. Conc. * 10⁻⁶) / RIC

ATTACHMENT H.D-2

Particulate Deposition - Soil Ingestion and Dermal Contact

Exposure and Risk Calculations for Particulate Deposition

COMMODITY:	Alumina and Aluminum
WASTE STREAM:	Cell house dust
CT Long-Term Deposition	1.50E-04 g/m2-hour
HE Long-Term Deposition	5.50E-04 g/m2-hour

1. Soil Ingestion

Constituent	Ingestion CSF	Ingestion RfD	Maximum Concentration in Waste (mg/kg)	CT Constituent Concentration in Deposition (mg/kg)	HE Constituent Concentration in Deposition (mg/kg)	CT Soil Concentration at 20 Years (mg/kg)	HE Soil Concentration at 20 Years (mg/kg)	CT Lifetime Constituent Combined Intake Due to Soil Ingestion (mg/kg-day)	HE Lifetime Constituent Combined Intake Due to Soil Ingestion (mg/kg-day)	CT Constituent Child Intake Due to Soil Ingestion-Hazard (mg/kg-day)	HE Constituent Child Intake Due to Soil Ingestion-Hazard (mg/kg-day)	CT Lifetime Cancer Risk	HE Lifetime Cancer Risk	CT Noncancer Hazard Quotient (Child)	HE Noncancer Hazard Quotient (Child)
Antimony	0.00E+00	4.00E-04	7.5	3.13E-13	1.36E-12	5.26E-03	7.12E-02	6.07E-08	1.11E-07	7.01E-08	9.49E-07	0.00E+00	0.00E+00	1.75E-04	2.37E-03
Arsenic	1.50E+00	3.00E-04	32	1.33E-12	5.79E-12	2.24E-02	3.04E-01	2.59E-08	4.76E-07	2.99E-07	4.06E-06	3.88E-06	7.13E-07	9.97E-04	1.35E-02
Beryllium	0.00E+00	7.00E-02	10	4.17E-13	1.81E-12	7.01E-03	9.49E-02	8.08E-09	1.49E-07	9.34E-08	1.37E-06	0.00E+00	0.00E+00	1.33E-06	1.81E-05
Bismuth	0.00E+00	5.00E-03	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	5.00E-04	7.2	3.00E-13	1.30E-12	6.06E-03	8.33E-02	6.83E-08	1.07E-07	6.73E-08	9.11E-07	0.00E+00	0.00E+00	1.36E-04	1.82E-03
Chromium(VI)	0.00E+00	5.00E-03	110	4.66E-13	1.98E-11	7.71E-02	1.04E+00	8.90E-08	1.63E-06	1.03E-06	1.39E-06	0.00E+00	0.00E+00	2.06E-04	2.78E-03
Cobalt	0.00E+00	0.00E+00	17	7.00E-13	3.07E-12	1.19E-02	1.61E-01	1.39E-08	2.53E-07	1.59E-07	2.16E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	3.00E-04	0.0001	4.17E-10	1.81E-17	7.01E-08	9.49E-07	8.08E-14	1.49E-12	9.34E-13	1.37E-11	0.00E+00	0.00E+00	3.11E-06	4.22E-06
Nickel	0.00E+00	2.00E-02	280	1.00E-11	4.98E-11	1.02E-01	2.47E+00	2.10E-07	3.89E-06	2.43E-06	3.29E-05	0.00E+00	0.00E+00	1.21E-04	1.64E-03
Selenium	0.00E+00	5.00E-03	0.82	3.03E-14	1.30E-13	6.45E-04	8.73E-03	7.44E-08	1.37E-06	8.60E-06	1.19E-07	0.00E+00	0.00E+00	1.72E-06	2.33E-06
Silver	0.00E+00	5.00E-03	1.9	7.92E-14	3.43E-13	1.33E-03	1.80E-02	1.54E-08	2.82E-06	1.79E-06	2.40E-07	0.00E+00	0.00E+00	3.55E-06	4.81E-06
Thallium	0.00E+00	5.00E-06	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vanadium	0.00E+00	7.00E-03	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zinc	0.00E+00	3.00E-01	120	5.00E-12	2.17E-11	9.41E-02	1.14E+00	9.71E-08	1.78E-06	1.12E-06	1.52E-06	0.00E+00	0.00E+00	3.74E-06	5.08E-06

2. Soil Dermal Contact

Constituent	Ingestion CSF	Ingestion RfD	Soil Water Partition Coefficient (cm/kg)	CT Soil Concentration at 20 Years (mg/kg)	HE Soil Concentration at 20 Years (mg/kg)	Soil Permeability Constant (cm/hr)	CT Soil Disappearance Rate Constant (1/hr)	HE Soil Disappearance Rate Constant (1/hr)	CT Absorption Fraction (unitless)	HE Absorption Fraction (unitless)	CT Absorbed Dose, Carcinogens (mg/kg-day)	HE Absorbed Dose, Carcinogens (mg/kg-day)	CT Absorbed Dose, Noncarcinogens (mg/kg-day)	HE Absorbed Dose, Noncarcinogens (mg/kg-day)	CT Cancer Risk	HE Cancer Risk	CT Noncancer Hazard Quotient	HE Noncancer Hazard Quotient
Antimony	0.00E+00	4.00E-04	2.00E+00	5.26E-03	7.12E-02	1.89E-04	2.50E+00	6.00E-01	1.00E+00	9.99E-01	3.64E-09	4.81E-07	1.19E-07	8.06E-08	0.00E+00	0.00E+00	2.89E-04	2.01E-02
Arsenic	1.50E+00	3.00E-04	2.90E+01	2.24E-02	3.04E-01	1.30E-06	1.72E-01	3.45E-02	5.79E-01	3.29E-01	9.99E-09	9.99E-07	2.94E-07	1.17E-06	1.34E-06	1.44E-06	9.79E-04	3.89E-02
Beryllium	0.00E+00	7.00E-02	5.30E+02	7.01E-03	9.49E-02	7.12E-07	1.89E-03	1.89E-03	4.61E-02	2.24E-02	2.23E-10	1.99E-08	7.32E-09	2.41E-07	0.00E+00	0.00E+00	1.05E-07	3.44E-06
Bismuth	0.00E+00	5.00E-03	7.00E+01	0.00E+00	0.00E+00	6.39E-06	7.14E-02	1.43E-02	3.00E-01	1.99E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	5.00E-04	1.60E+02	6.06E-03	8.33E-02	2.39E-06	3.13E-02	6.25E-03	1.45E-01	7.23E-02	6.05E-10	4.80E-08	1.85E-08	5.80E-07	0.00E+00	0.00E+00	3.31E-05	1.12E-03
Chromium(VI)	0.00E+00	5.00E-03	1.80E+01	7.71E-02	1.04E+00	2.10E-06	2.78E-01	5.94E-02	7.61E-01	4.87E-01	4.00E-06	4.73E-06	1.31E-06	5.78E-06	0.00E+00	0.00E+00	2.62E-04	1.15E-02
Cobalt	0.00E+00	0.00E+00	2.90E+05	1.19E-02	1.61E-01	1.35E-06	1.79E-06	3.87E-06	9.93E-06	4.29E-06	7.36E-13	6.44E-11	2.41E-11	7.84E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mercury	0.00E+00	3.00E-04	9.50E+04	7.01E-06	9.49E-07	3.97E-06	5.29E-06	1.05E-06	2.63E-04	1.26E-04	1.29E-17	1.12E-15	4.19E-16	1.36E-14	0.00E+00	0.00E+00	1.39E-12	4.53E-11
Nickel	0.00E+00	2.00E-02	8.20E+01	1.82E-01	2.47E+00	4.80E-06	6.10E-02	1.22E-02	2.63E-01	1.99E-01	3.31E-06	3.13E-06	1.09E-06	3.81E-06	0.00E+00	0.00E+00	5.43E-06	1.90E-03
Selenium	0.00E+00	5.00E-03	4.30E+00	6.45E-04	8.73E-03	8.79E-05	1.19E+00	2.33E-01	9.97E-01	9.39E-01	4.45E-10	7.63E-08	1.48E-08	9.29E-07	0.00E+00	0.00E+00	2.91E-06	1.86E-04
Silver	0.00E+00	5.00E-03	4.00E-01	1.33E-03	1.80E-02	9.43E-06	1.25E+01	2.60E+00	1.00E+00	1.00E+00	8.21E-10	1.66E-07	3.04E-06	2.04E-06	0.00E+00	0.00E+00	6.04E-06	4.08E-04
Thallium	0.00E+00	5.00E-06	7.40E+01	0.00E+00	0.00E+00	6.10E-06	6.79E-02	1.36E-02	2.97E-01	1.60E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vanadium	0.00E+00	7.00E-03	5.00E+01	0.00E+00	0.00E+00	7.56E-06	1.00E-01	2.00E-02	3.93E-01	2.13E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zinc	0.00E+00	3.00E-01	4.00E+01	9.41E-02	1.14E+00	9.43E-06	1.25E-01	2.60E-02	4.66E-01	2.69E-01	2.70E-06	2.78E-06	8.84E-07	3.35E-06	0.00E+00	0.00E+00	2.99E-06	1.12E-04

Pathway Variables				CT				HE				Units			
Soil Permeability Constant (S-14)				Dermal Absorbed Dose (S-20, S-21, S-22)				Intake/Cancer Risk due to Soil Ingestion (S-6)							
Kov	Soil Perm. Constant for H2O	0.001	0.001 cm/hr	BWc	Body Weight (Child)	15	15 kg	AT	Averaging Time	70	70 years				
rho	Soil Particle Density	2.65	2.65 gm/cc	EV	Event Frequency	1	1 events/day	EF	Exposure Frequency	350	350 days/year				
				A	Exposed Surface Area	1700	1700 cm2	IRc	Ingestion Rate (Child)	200	200 mg/day				
Dermal Absorption Fraction (Child) (S-23)				EF	Exposure Frequency	130	360 days/year	IRa	Ingestion Rate (Adult)	100	100 mg/day				
				EDc	Exposure Duration (Child)	8	8 years	BWc	Body Weight (Child)	15	15 kg				
				AT	Averaging Time	70	70 years	BWa	Body Weight (Adult)	70	70 kg				
AF	Adherence Factor	0.2	1 mg/cm2					EDa	Exposure Duration (Child)	8	8 years				
rho	Soil Particle Density	2.65	2.65 gm/cc					EDa	Exposure Duration (Adult)	3	24 years				
ks	Soil Loss Constant	0	0 1/years	Soil Concentration due to Deposition Dermal and Ingestion (S-1)				CSF	Oral Cancer Slope Factor	chemical specific	(mg/kg-day)-1				
lvcl	Volatilization Loss Constant	0	0 1/years												
lvend	Event Duration	8	12 hours	Z	Mixing Depth	2.5	1 cm								
				BD	Soil Bulk Density	1.5	1.2 gm/cc								
				ks	Soil Loss Constant	0	0 1/years								
				I	Deposition Period	9	20 years								

Dermal Absorbed Dose (S-20, S-21, S-22)

Intake/Cancer Risk due to Soil Ingestion (S-6)

ATTACHMENT H.D-2 (Continued)

Particulate Deposition - Vegetable Ingestion

Exposure and Risk Calculations for Particulate Deposition

COMMODITY:	Alumina and Aluminum					
WASTE STREAM:	Coal house dust					
CT Long-Term Deposition	1.80E-04	g/m2-hour	4.17E-08	g/m2-sec	1.31E+00	g/m2-year
HE Long-Term Deposition	8.80E-04	g/m2-hour	1.81E-07	g/m2-sec	5.88E+00	g/m2-year

Constituent	Ingestion CSF	Ingestion FID	Root Concentration Factor (RCF) (mg/kg)/(mg/kg) DW	Plant Soil Bioconcentration Factor (Bt) (mg/kg)/(mg/kg) DW	CT Soil Concentration at 20 Years (mg/kg)	HE Soil Concentration at 20 Years (mg/kg)	CT Concentration in Above Ground Vegetables (mg/kg)	HE Concentration in Above Ground Vegetables (mg/kg)	CT Concentration in Root Vegetables (mg/kg)	HE Concentration in Root Vegetables (mg/kg)	CT Absorbed Dose, Carcinogens (mg/kg-day)	HE Absorbed Dose, Carcinogens (mg/kg-day)	CT Absorbed Dose, Noncarcinogens (mg/kg-day)	HE Absorbed Dose, Noncarcinogens (mg/kg-day)	CT Cancer Risk for Vegetable Consumption	HE Cancer Risk for Vegetable Consumption	CT Noncancer Hazard Quotient from Vegetable Consumption	HE Noncancer Hazard Quotient from Vegetable Consumption
Antimony	0.00E+00	4.00E-04	3.00E-02	2.00E-01	8.67E-04	7.12E-03	4.35E-04	2.74E-03	8.88E-08	1.07E-04	8.23E-08	2.01E-07	8.08E-08	7.32E-07	0.00E+00	0.00E+00	1.26E-04	1.83E-03
Arsenic	1.50E+00	3.00E-04	8.00E-08	3.00E-02	3.80E-03	3.04E-02	1.40E-03	8.71E-03	7.73E-07	8.38E-08	1.94E-08	4.86E-07	1.57E-07	1.70E-08	2.81E-08	7.00E-07	5.25E-04	8.87E-03
Barium	0.00E+00	7.00E-02	1.50E-02	1.50E-01	9.78E-04	9.48E-03	5.38E-04	3.18E-03	2.48E-08	2.88E-07	7.45E-09	2.21E-07	8.04E-08	8.05E-07	0.00E+00	0.00E+00	8.63E-07	1.15E-06
Beryllium	0.00E+00	5.00E-03	1.50E-03	1.50E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	5.00E-04	4.00E-02	3.00E-01	8.31E-04	8.83E-03	5.18E-04	3.72E-03	2.82E-07	2.73E-08	7.20E-09	2.94E-07	5.84E-08	8.44E-07	0.00E+00	0.00E+00	1.17E-04	1.89E-03
Chromium(VI)	0.00E+00	5.00E-03	4.00E-03	7.00E-03	8.84E-03	1.04E-01	4.83E-03	2.01E-02	2.41E-08	2.81E-08	8.28E-09	1.40E-08	5.10E-07	5.10E-08	0.00E+00	0.00E+00	1.02E-04	1.02E-03
Lead	0.00E+00	8.00E+08	8.00E-03	1.50E-05	1.48E-03	1.81E-02	8.88E-04	2.88E-03	4.78E-11	5.19E-10	9.88E-09	2.07E-07	7.75E-08	7.86E-07	0.00E+00	0.00E+00		
Mercury	0.00E+00	3.00E-04	1.40E-03	8.00E-03	8.78E-08	9.48E-08	4.12E-08	1.83E-08	1.29E-16	1.40E-14	6.72E-14	1.27E-12	4.84E-13	4.84E-12	0.00E+00	0.00E+00	1.55E-08	1.55E-08
Nickel	0.00E+00	2.00E-02	8.00E-03	3.00E-02	2.38E-02	2.47E-01	1.13E-02	6.34E-02	2.22E-08	2.41E-08	1.86E-07	3.72E-08	1.27E-08	1.38E-08	0.00E+00	0.00E+00	8.34E-05	8.78E-04
Selenium	0.00E+00	5.00E-03	2.30E-02	1.80E-02	8.88E-05	8.73E-04	3.88E-05	1.75E-04	4.12E-07	4.47E-08	6.43E-19	1.28E-08	4.41E-08	4.80E-08	0.00E+00	0.00E+00	8.81E-07	8.21E-08
Silver	0.00E+00	5.00E-03	1.00E-01	4.00E-01	1.88E-04	1.80E-03	1.44E-04	1.05E-03	4.18E-08	4.81E-04	2.81E-08	1.18E-07	2.28E-08	4.29E-07	0.00E+00	0.00E+00	4.84E-08	8.84E-08
Thallium	0.00E+00	8.00E-06	4.00E-04	4.00E-08	8.00E+00	8.00E+00	8.00E+00	8.00E+00	8.00E+00	8.00E+00	8.00E+00	8.00E+00	8.00E+00	8.00E+00	8.00E+00	8.00E+00	8.00E+00	8.00E+00
Vanadium	0.00E+00	7.00E-03	3.00E-03	8.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Zinc	8.00E+00	3.00E-01	4.40E-02	2.80E-01	1.08E-02	1.14E-01	7.48E-03	4.95E-02	1.18E-08	1.28E-04	1.04E-07	3.45E-08	8.48E-07	1.28E-06	0.00E+00	0.00E+00	2.82E-04	4.20E-06

Pathway Variables	CT	HE	Units	CT	HE	Units	CT	HE	Units
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Soil Concentration due to Deposition Root Vegetables (B-54)				Above Ground Vegetable Concentrations from Combined Deposition (B-54)				Crop Intake (Subsistence Farmer Noncarcinogen) (B-54, B-55)			
Z	Mixing Depth	20	10 cm	Bt	Plant Soil BCF	chemical-specific	(ug/kg)/(ug/kg) (DW)	BWa	Body Weight (Adult)	70	70 kg
BD	Soil Bulk Density	1.5	1.2 g/cc	Is	Soil Loss Constant	0	0 1/year	F	Fraction From Contaminated Soil	0.4	0.8 unless
Is	Soil Loss Constant	0	0 1/year	I	Deposition Period	8	20 years	CRa	Consumption Rate (Above Ground)	18.7	18.7 g/day
I	Deposition Period	8	20 years	Z	Mixing Depth	20	10 cm	CRv	Consumption Rate (Root)	28	28 g/day
				BD	Soil Bulk Density	1.5	1.2 g/cc	EF	Exposure Frequency	360	350 days/year
Root Vegetable Concentration (B-57)				Rp	Interception Fraction	0.05	0.05 unless	Crop Intake (Subsistence Farmer Carcinogen) (B-54, B-57)			
Is	soil-water distribution coefficient	chemical-specific	mg	lp	Plant Soil Loss Coef	18	18 year-1	BWa	Body Weight (Adult)	70	70 kg
RCF	Root Concentration Factor		(mg/kg)/(mg/kg)	lp	Plant Exposure to Deposition	0.18	0.18 years	F	Fraction From Contaminated Soil	0.4	0.8 unless
Vg	Conversion Factor	1	1 unless	Yp	Yield	1.7	1.7 kg/ha (DW)	CRa	Consumption Rate (Above Ground)	18.7	18.7 g/day
								CRv	Consumption Rate (Root)	28	28 g/day
								EF	Exposure Frequency	350	350 days/year
								ED	Exposure Duration	8	20 years
								AT	Averaging Time	70	70 years

ATTACHMENT H.D-3

Air Emissions to Surface Water - Risk Screening Results

Exposure and Risk Calculations for Air Emissions

COMMODITY:	Alumina and Aluminum			
WASTE STREAM:	Cast house dust		<u>Flow Rate</u>	
CT Long-Term Emissions	3.24E+08	mg/year	3.00E+11	L/year
HE Long-Term Emissions	1.52E+09	mg/year	1.30E+10	L/year

Constituent	Maximum Concentration in Waste (mg/kg)	CT Water Concentration (mg/L)	HE Water Concentration (mg/L)	<u>Surface Water HBL Concentrations (mg/L)</u>			
				Fish - Noncancer	Fish - Cancer	Drinking Water - Noncancer	Drinking Water - Cancer
Antimony	7.5	8.10E-09	8.77E-07	NA	NA	1.40E-02	NA
Arsenic	32	3.46E-08	3.74E-06	NA	7.40E-04	NA	8.40E-04
Barium	10	1.08E-08	1.17E-06	3.77E-01	NA	2.45E+00	NA
Beryllium	0	0.00E+00	0.00E+00	2.84E-02	NA	1.75E-01	NA
Cadmium	7.2	7.78E-09	8.42E-07	7.35E-05	NA	3.50E-02	NA
Chromium(VI)	110	1.19E-07	1.29E-05	9.00E-01	NA	1.75E-01	NA
Lead	17	1.84E-08	1.99E-06	NA	NA	1.50E-02	NA
Mercury	0.0001	1.08E-13	1.17E-11	NA	NA	1.05E-02	NA
Nickel	260	2.81E-07	3.04E-05	1.02E-01	NA	7.00E-01	NA
Selenium	0.92	9.94E-10	1.08E-07	8.40E-03	NA	1.75E-01	NA
Silver	1.9	2.05E-09	2.22E-07	1.80E-02	NA	1.75E-01	NA
Thallium	0	0.00E+00	0.00E+00	3.02E-05	NA	2.80E-03	NA
Vanadium	0	0.00E+00	0.00E+00	NA	NA	2.45E-01	NA
Zinc	120	1.30E-07	1.40E-05	3.12E-01	NA	1.05E+01	NA

ATTACHMENT H.D-4

Runoff Deposition to Soils Screening Results

Release, Exposure Risk Calculations for Waste Piles

1. Aluminum Cast House Dust

Constituent	Ingestion Pathway Cancer Slope Factor (mg/kg-day) ⁻¹	Ingestion Pathway RfD (mg/kg-day)	Maximum Bulk Concentration in Waste (mg/kg)	CT Soil Concentration (Ingestion and Dermal) (mg/kg)	HE Soil Concentration (Ingestion and Dermal Contact) (mg/kg)	CT Soil Concentration (Ingestion of Home- Grown Vegetables) (mg/kg)	HE Soil Concentration (Ingestion of Home- Grown Vegetables) (mg/kg)
Antimony		0.0004	7.5	1.92E-03	1.58E-01	2.39E-04	1.58E-02
Arsenic	1.5	0.0003	32	8.17E-03	6.74E-01	1.02E-03	6.74E-02
Barium		0.07	10	2.55E-03	2.11E-01	3.19E-04	2.11E-02
Beryllium		0.07					
Cadmium		0.0005	7.2	1.84E-03	1.52E-01	2.30E-04	1.52E-02
Chromium(VI)		0.005	110	2.81E-02	2.32E+00	3.51E-03	2.32E-01
Lead			17	4.34E-03	3.58E-01	5.43E-04	3.58E-02
Mercury		0.0003	0.0001	2.55E-08	2.11E-06	3.19E-09	2.11E-07
Nickel		0.02	260	6.64E-02	5.48E+00	8.30E-03	5.48E-01
Selenium		0.005	0.92	2.35E-04	1.94E-02	2.94E-05	1.94E-03
Silver		0.005	1.9	4.85E-04	4.00E-02	6.07E-05	4.00E-03
Thallium		0.00008					
Vanadium		0.009					
Zinc		0.3	120	3.07E-02	2.53E+00	3.83E-03	2.53E-01

Pathway Variables	CT	HE	Units
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USLE Release Modeling (7-52)

AWPd	Area of Waste Pile (Dust)	108	108 m2
AWPI	Area of Waste Pile (Ferrosilicon)	509	509 m2
R	Rainfall factor	50	110 1/year
K	Soil Erodability Factor	0.25	0.25 t/year
LS	Length-Slope Factor	1	3 unitless
C	Cover Factor	1	1 unitless
P	Control Practices Factor	1	1 unitless
SL	Total Soil Loss (Dust)	301	1986 kg/year
SL	Total Soil Loss (Ferrosilicon)	1418	9360 kg/year

Soil Delivery

r	Radius of contaminated area	10000	5000 cm
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Soil Concentration due to Deposition: Dermal and Ingestion (8-1)

Z	Mixing Depth	2.5	1 cm
BD	Soil Bulk Density	1.5	1.2 gm/cc
ks	Soil Loss Constant	0	0 1/years
t	Deposition Period	20	20 years
SM	Mixed Soil Mass (Dermal and Ingestion)	1.18E+06	9.42E+04 kg

Soil Concentration due to Deposition: Root Vegetables (8-58)

Z	Mixing Depth	20	10 cm
BD	Soil Bulk Density	1.5	1.2 gm/cc
ks	Soil Loss Constant	0	0 1/years
t	Deposition Period	20	20 years
SM	Mixed Soil Mass (Root Vegetables)	9.42E+06	9.42E+05 kg

Release, Exposure Risk Calculations for Waste Piles

Constituent	Ingestion Pathway Cancer Slope Factor (mg·kg ⁻¹ ·day ⁻¹)	Ingestion Pathway RfD (mg/kg·day)	Maximum Bulk Concentration in Waste (mg/kg)	CT Soil Concentration (Ingestion and Dermal) (mg/kg)	HE Soil Concentration (Ingestion and Dermal Contact) (mg/kg)	CT Soil Concentration (Ingestion of Home- Grown Vegetables) (mg/kg)	HE Soil Concentration (Ingestion of Home- Grown Vegetables) (mg/kg)
Antimony		0.0004					
Arsenic	1.5	0.0003					
Barium		0.07					
Beryllium		0.07					
Cadmium		0.0005					
Chromium(VI)		0.005					
Lead			5000	6.018874429	496.5571404	0.752359304	49.65571404
Mercury		0.0003					
Nickel		0.02					
Selenium		0.005					
Silver		0.005					
Thallium		0.00008					
Vanadium		0.009					
Zinc		0.3	40000	48.15099543	3972.457123	6.018874429	397.2457123

CT	HE	Units
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AWPd	Area of Waste Pile (Dust)	108	108 m2
AWPf	Area of Waste Pile (Ferrosilicon)	509	509 m2
R	Rainfall factor	50	110 1/year
K	Soil Erodability Factor	0.25	0.25 t/year.
LS	Length-Slope Factor	1	3 unitless
C	Cover Factor	1	1 unitless
P	Control Practices Factor	1	1 unitless
SL	Total Soil Loss (Dust)	301	1986 kg/year
SL	Total Soil Loss (Ferrosilicon)	1418	9360 kg/year

r	Radius of contaminated area	10000	5000 cm
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Z	Mixing Depth	2.5	1 cm
BD	Soil Bulk Density	1.5	1.2 gm/cc
ks	Soil Loss Constant	0	0 1/years
t	Deposition Period	20	20 years
SM	Mixed Soil Mass (Dermal and Ingestion)	1.18E+06	9.42E+04 kg

Z	Mixing Depth	20	10 cm
BD	Soil Bulk Density	1.5	1.2 gm/cc
ks	Soil Loss Constant	0	0 1/years
t	Deposition Period	20	20 years
SM	Mixed Soil Mass (Root Vegetables)	9.42E+06	9.42E+05 kg

ATTACHMENT H.D-5

Runoff Deposition to Surface Water Screening Results

Release, Exposure Risk Calculations for Waste Piles

1. Aluminum Cast House Dust

Constituent	Ingestion Pathway Cancer Slope Factor (mg-kg-day) ⁻¹	Ingestion Pathway RfD (mg/kg-day)	Maximum Bulk Concentration in Waste (mg/kg)	CT Waterbody Concentration (mg/l)	HE Waterbody Concentration (mg/l)
Antimony		0.0004	7.5	7.52E-09	1.15E-06
Arsenic	1.5	0.0003	32	3.21E-08	4.89E-06
Barium		0.07	10	1.00E-08	1.53E-06
Beryllium		0.07			
Cadmium		0.0005	7.2	7.22E-09	1.10E-06
Chromium(VI)		0.005	110	1.10E-07	1.68E-05
Lead			17	1.71E-08	2.60E-06
Mercury		0.0003	0.0001	1.00E-13	1.53E-11
Nickel		0.02	260	2.61E-07	3.97E-05
Selenium		0.005	0.92	9.23E-10	1.41E-07
Silver		0.005	1.9	1.91E-09	2.90E-07
Thallium		0.00008			
Vanadium		0.009			
Zinc		0.3	120	1.20E-07	1.83E-05

Pathway Variables	CT	HE	Units
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USLE Release Modeling (7-52)

AWPd	Area of Waste Pile (Dust)	108	108 m2
AWPf	Area of Waste Pile (Ferrosilicon)	509	509 m2
R	Rainfall factor	50	110 1/year
K	Soil Erodability Factor	0.25	0.25 t/year
LS	Length-Slope Factor	1	3 unitless
C	Cover Factor	1	1 unitless
P	Control Practices Factor	1	1 unitless
SL	Total Soil Loss (Dust)	301	1986 kg/year
SL	Total Soil Loss (Ferrosilicon)	1418	9360 kg/year

Surface Water Characteristics

Flow Rate	3.00E+11	1.30E+10 liter/year
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ATTACHMENT H.D-5 (Continued)

Runoff Deposition to Surface Water Screening Results

Release, Exposure Risk Calculations for Waste Piles

2. Zinc Waste Ferrosilicon

Constituent	Ingestion Pathway Cancer Slope Factor (mg-kg-day) ⁻¹	Ingestion Pathway RfD (mg/kg-day)	Maximum Bulk Concentration in Waste (mg/kg)	CT Waterbody Concentration (mg/l)	HE Waterbody Concentration (mg/l)
Antimony		0.0004			
Arsenic	1.5	0.0003			
Barium		0.07			
Beryllium		0.07			
Cadmium		0.0005			
Chromium(VI)		0.005			
Lead			5000	2.36361E-05	0.003599954
Mercury		0.0003			
Nickel		0.02			
Selenium		0.005			
Silver		0.005			
Thallium		0.00008			
Vanadium		0.009			
Zinc		0.3	40000	0.000189089	0.028799636
Pathway Variables			CT	HE	Units

USLE Release Modeling (7-52)

AWPd	Area of Waste Pile (Dust)	108	108 m2
AWPf	Area of Waste Pile (Ferrosilicon)	509	509 m2
R	Rainfall factor	50	110 1/year
K	Soil Erodability Factor	0.25	0.25 t/year
LS	Length-Slope Factor	1	3 unitless
C	Cover Factor	1	1 unitless
P	Control Practices Factor	1	1 unitless
SL	Total Soil Loss (Dust)	301	1986 kg/year
SL	Total Soil Loss (Ferrosilicon)	1418	9360 kg/year

Surface Water Characteristics

Flow Rate	3.00E+11	1.30E+10 liter/year
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ATTACHMENT H.D-6
Surface Impoundment Releases to Surface Water Screening Results

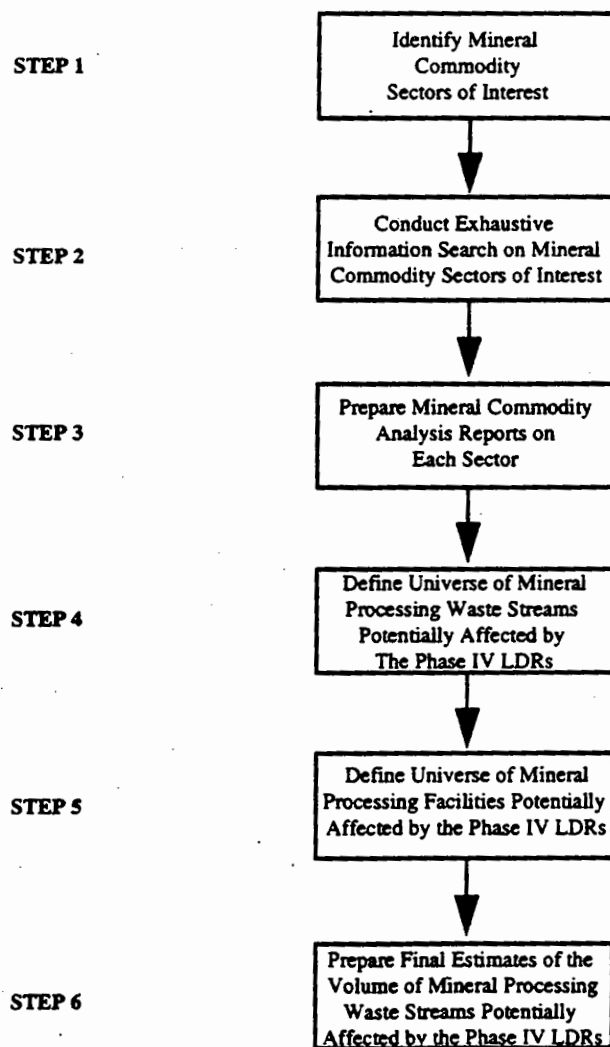
COMPARISON OF SURFACE WATER CONCENTRATIONS FROM SURFACE IMPOUNDMENT RELEASES TO HEALTH-BASED LEVELS														
FISH INGESTION														
						Maximum High-End Surface Water Concentration, Bulk Samples		Central Tendency Surface Water Concentration, Bulk Samples		Maximum High-End Surface Water Concentration, EP Samples			Central Tendency Surface Water Concentration, EP Samples	
						Compared to HBL		Compared to HBL		Compared to HBL			Compared to HBL	
Constituent	Hazard-Based Level (mg/l)	Commodity	Wastestream	Facility	State	1-10x	10-100x	1-10x	10-100x	1-10x	10-100x	100-1000x	1-10x	10-100x
Arsenic	0.00084	Copper	Acid plant blowdown	Unknown	Unknown		x							
		Copper	Acid plant blowdown	Unknown	Unknown	x								
		Copper	Acid plant blowdown	Unknown	Unknown	x								
		Copper	Acid plant blowdown	Unknown	Unknown	x								
		Copper	Acid plant blowdown	Magma, San Manuel	AZ							x	x	
Cadmium	0.035	Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA	x								
Lead	0.015	Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA		x							
		Copper	Acid plant blowdown	Unknown	Unknown	x								
		Zinc	Spent surface impoundment liquids	Big River Zinc	IL	x								

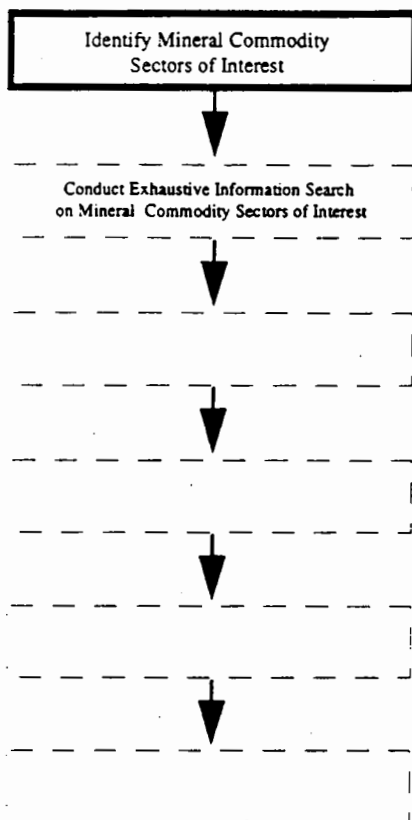
ATTACHMENT H.D-6 (Continued)

Surface Impoundment Releases to Surface Water Screening Results

COMPARISON OF SURFACE WATER CONCENTRATIONS FROM SURFACE IMPOUNDMENT RELEASES TO HEALTH-BASED LEVELS																
FISH INGESTION							Maximum High-End Surface Water Concentration, Bulk Samples			Central Tendency Surface Water Concentration, Bulk Samples		Maximum High-End Surface Water Concentration, EP Samples			Central Tendency Surface Water Concentration, EP Samples	
Constituent	Hazard-Based Level (mg/l)	Source	Commodity	Wastestream	Facility	State	Compared to HBL			Compared to HBL		Compared to HBL			Compared to HBL	
							1-10x	10-100x	100-1000x	1-10x	10-100x	1-10x	10-100x	100-1000x	1-10x	10-100x
Arsenic	0.00074	HBL	Copper	Acid plant blowdown	Unknown	Unknown		x								
			Copper	Acid plant blowdown	Unknown	Unknown		x								
			Copper	Acid plant blowdown	Unknown	Unknown	x									
			Copper	Acid plant blowdown	Unknown	Unknown	x									
			Copper	Acid plant blowdown	Magma, San Manuel	AZ								x		x
			Copper	Acid plant blowdown	CBI	CBI						x				
Cadmium	0.0000735	HBL	Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA			x		x					
			Zinc	WWTP liquid effluent	Zinc Corp of America	OK			x		x					
			Zinc	Spent surface impoundment liquids	Big River Zinc	IL		x			x					
			Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA		x								
			Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA		x								
			Copper	Acid plant blowdown	Unknown	Unknown	x									
			Zinc	Spent surface impoundment liquids	Big River Zinc	IL	x									
			Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	x									
			Zinc	Process wastewater	Unknown	Unknown	x									
			Copper	Acid plant blowdown	Unknown	Unknown	x									
			Zinc	Process wastewater	Unknown	Unknown	x									
			Zinc	Spent surface impoundment liquids	Zinc Corp of America	OK	x									
			Zinc	Process wastewater	Zinc Corp, Monaca	PA	x									
			Zinc	Spent surface impoundment liquids	Zinc Corp of America	OK	x									
			Zinc	Process wastewater	Unknown	Unknown	x									
			Zinc	Process wastewater	Unknown	Unknown	x									
			Zinc	Spent surface impoundment liquids	Zinc Corp of America	OK	x									
			Rare Earths	Process wastewater	Unknown	Unknown							x			
Mercury	0.00000125	HBL	Zinc	Spent surface impoundment liquids	Big River Zinc	IL		x								
			Zinc	Spent surface impoundment liquids	Big River Zinc	IL	x									
			Copper	Acid plant blowdown	Unknown	Unknown	x									
			Copper	Acid plant blowdown	Unknown	Unknown	x									
			Copper	Acid plant blowdown	CBI	CBI							x			
Selenium	0.0084	HBL	Copper	Acid plant blowdown	Unknown	Unknown	x									
Thallium	0.0000302	HBL	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	x									
			Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ								x		
Zinc	0.312	HBL	Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA	x									
			Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA	x									
			Zinc	Spent surface impoundment liquids	Big River Zinc	IL	x									
			Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA	x									
			Zinc	WWTP liquid effluent	Zinc Corp of America	OK	x									
			Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA	x									

This appendix details EPA's step-wise methodology for defining the universe of mineral processing sectors, facilities, and waste streams potentially affected by the proposed Phase IV Land Disposal Restrictions. The Agency developed a step-wise methodology that began with the broadest possible scope of inquiry in order to assure that EPA captured all of the potentially affected mineral commodity sectors and waste streams. The Agency then narrowed the focus of its data gathering and analysis at each subsequent step. The specific steps and sources of data employed throughout this analysis are described below, and are summarized in Exhibit I-1.

EXHIBIT I-1**Overview of the Agency's Methodology for Defining the Universe of Potentially Affected Mineral Processing Waste Streams**

Step One**I.1 Identify Mineral Commodity Sectors of Interest**

EPA reviewed the 36 industrial sectors (commodities) and 97 different general categories of wastes previously developed and published in the October 21, 1991 Advanced Notice of Proposed Rule Making (ANPRM). EPA also reviewed the U.S. Bureau of Mines's 1991 Minerals Yearbook, 1995 Mineral Commodities Summary, and the 1985 Mineral Facts and Problems. The Agency reviewed this comprehensive listing of all of the mineral commodity sectors and removed from further consideration all non-domestically produced mineral commodities; all inactive mineral commodities, such as nickel; and all mineral commodities generated from operations known not to employ operations that meet the Agency's definition of mineral processing.¹ As a result of this process, EPA identified a total of 62 mineral commodities that potentially generate "mineral processing" waste streams of interest. These mineral commodity sectors are listed below in Exhibit I-2.

The Agency notes that Exhibit I-2 represents EPA's best efforts at identifying mineral commodities which may generate mineral processing wastes. Omission or inclusion on this list does not relieve the generator from managing wastes that would be subject to RCRA Subtitle C requirements.

I.2 Conduct Exhaustive Information Search on Mineral Commodity Sectors of Interest

EPA researched and obtained information characterizing the mineral processing operations and wastes associated with the mineral commodities listed in Exhibit I-2. This information was used by EPA both to update existing data characterizing mineral processing wastes obtained through past Agency efforts and to obtain characterization information on newly identified waste streams not previously researched.

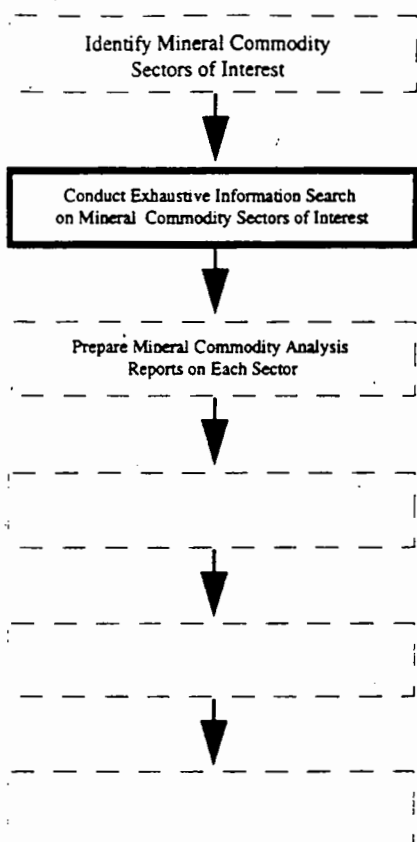
To provide the necessary foundation to develop a fully comprehensive inventory of mineral commodity sectors, facilities, and waste streams that might be affected by the Phase IV LDRs program, EPA embarked on an ambitious information collection program. Specifically, to

¹ Sectors that employ operations that mill (e.g., grind, sort, wash), physically separate (e.g., magnetic, gravity, or electrostatic separation, froth flotation), concentrate using liquid separation (e.g., leaching followed by ion exchange), and/or calcine (i.e., heat to drive off water or carbon dioxide), and use no techniques that the Agency considers to be mineral processing operations (e.g., smelting or acid digestion) are unaffected by the proposed Phase IV LDRs.

EXHIBIT I-2

MINERAL COMMODITIES OF POTENTIAL INTEREST

1) Alumina	32) Lightweight Aggregate
2) Aluminum	33) Lithium (from ores)
3) Ammonium Molybdate	34) Lithium Carbonate
4) Antimony	35) Magnesia (from brines)
5) Arsenic Acid	36) Magnesium
6) Asphalt (natural)	37) Manganese and MnO ₂
7) Beryllium	38) Mercury
8) Bismuth	39) Mineral Waxes
9) Boron	40) Molybdenum
10) Bromine (from brines)	41) Phosphoric Acid
11) Cadmium	42) Platinum Group Metals
12) Calcium Metal	43) Pyrobitumens
13) Cerium, Lanthanides, and Rare Earths	44) Rhenium
14) Cesium/Rubidium	45) Scandium
15) Chromium	46) Selenium
16) Coal Gas	47) Silicomanganese
17) Copper	48) Silicon
18) Elemental Phosphorus	49) Soda Ash
19) Ferrochrome	50) Sodium Sulfate
20) Ferrochrome-Silicon	51) Strontium
21) Ferrocolumbium	52) Sulfur
22) Ferromanganese	53) Synthetic Rutile
23) Ferromolybdenum	54) Tantalum/Columbium
24) Ferrosilicon	55) Tellurium
25) Gemstones	56) Tin
26) Germanium	57) Titanium/TiO ₂
27) Gold and Silver	58) Tungsten
28) Hydrofluoric Acid	59) Uranium
29) Iodine (from brines)	60) Vanadium
30) Iron and Steel	61) Zinc
31) Lead	62) Zirconium/Hafnium

Step Two

capitalize on information collected through past efforts, as well as to collect more recent data, the Agency conducted the following activities:

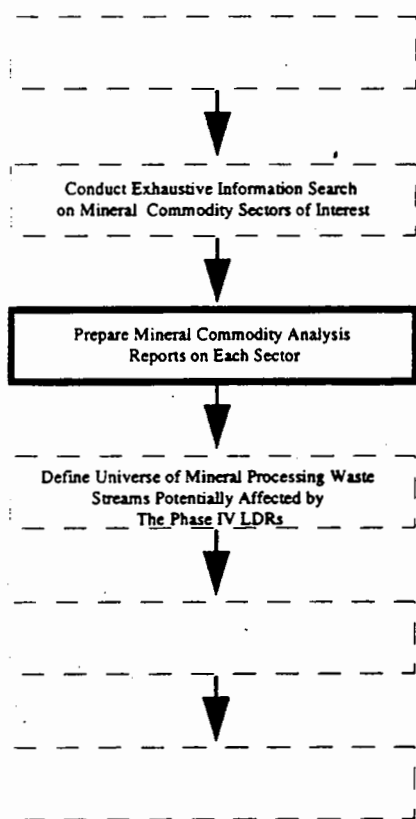
- Reviewed the National Survey of Solid Wastes From Mineral Processing Facilities (NSSWMPF) survey instruments and public comments (submitted in response to the 1991 ANPRM) for process-related information (e.g., process flow diagrams, waste characterization data, and waste management information).
 - Reviewed numerous documents (e.g., Bureau of Mines publications, the Randol Mining Directory and other Industrial Directories, and various Agency contractor reports) for process-related information.
 - Reviewed trip reports prepared both by EPA and its contractors from sampling visits and/or inspections conducted at approximately 50 mineral processing sites located throughout the United States.
 - Reviewed sampling data collected by EPA's Office of Research and Development (ORD), EPA's Office of Water (OW), and Agency survey data collected to support the preparation of the 1990 Report to Congress.
-
- Reviewed both the 1993, 1994, and 1995 "Mineral Commodity Summaries" prepared by the U.S. Bureau of Mines (BOM) for salient statistics on commodity production.
 - Partially reviewed and summarized damage case information presented in the "Mining Sites on the National Priorities List, NPL Site Summary Reports" to support work on assessing the appropriateness of the Toxicity Characteristic Leaching Procedure (TCLP) for mineral processing wastes.
 - Contacted the BOM Commodity Specialists associated with the commodity sectors of interest to (1) obtain current information on mining companies, processes, and waste streams, and (2) identify other potential sources of information.
 - Retrieved applicable and relevant documents from the BOM's FAXBACK document retrieval system. Documents retrieved included monthly updates to salient statistics, bulletins, and technology review papers.
 - Conducted an electronic query of the 1991 Biennial Reporting System (BRS) for waste generation and management information on 34 mineral processing-related Standard Industrial Classification (SIC) numbers.

- Conducted an electronic literature search for information related to mineral processing and waste treatment technologies contained in numerous technical on-line databases, including: NTIS, Compendex Plus, METADEX, Aluminum Industry Abstracts, ENVIROLINE, Pollution Abstracts, Environmental Bibliography, and GEOREF.

EPA focused its search for relevant information (published since 1990) on the mineral commodities listed in Exhibit I-2. The Agency chose 1990 as the cutoff year so as not to duplicate past information collection activities conducted by EPA and its contractors, and to obtain information on mineral processes "retooled" since clarification of the Bevill Amendment to cover truly "high volume, low hazard" wastes. After an exhaustive search through both the publicly available and Agency-held information sources, EPA assembled and organized all of the collected information by mineral commodity sector.

I.3 Prepare Mineral Commodity Analysis Reports on Each of the Identified Sectors

Step Three



As discussed above, EPA embarked on a very ambitious information collection program to collect current information on relevant mineral processes, salient statistics, waste characteristics, waste generation rates, and waste management information. All of the publicly available information was collected, evaluated for relevance (both applicability and age), and compiled to prepare 49 analyses covering 62 mineral commodities. Each mineral commodity analysis report consists of:

- A commodity summary describing the uses and salient statistics of the particular mineral commodity.
- A process description section with detailed, current process information and process flow diagram(s).
- A process waste stream section that identifies -- to the maximum extent practicable -- individual waste streams, sorted by the nature of the operation generating the waste stream (i.e., extraction/beneficiation or mineral processing).² Within this section, EPA also identified:

² EPA strongly cautions that the process information and identified waste streams presented in the commodity analysis reports should not be construed to be the authoritative list of processes and waste streams. These reports represent a best effort, and clearly do not include every potential process and waste stream. Furthermore, the omission of an actual waste stream (and thus its not being classified as either an extraction/beneficiation or mineral processing waste in this report) does not relieve the generator from its responsibility of correctly determining whether the particular waste is covered by the Mining Waste Exclusion.

- waste stream sources and form (i.e., wastes with less than 1 percent solids and total organic content, wastes with 1 to 10 percent solids, and wastes with greater than 10 percent solids);
- Bevill-Exclusion status of the waste stream (i.e., extraction/beneficiation waste stream, mineral processing waste stream, or non-uniquely associated waste stream).
- waste stream characteristics (total constituent concentration data, and statements on whether the waste stream exhibited one of the RCRA hazardous waste characteristics of toxicity, ignitability, corrosivity, or reactivity);
- annual generation rates (reported or estimated);
- management practices (e.g., tank treatment and subsequent NPDES discharge, land disposal, or in-process recycling); and
- whether the waste stream was being (or could potentially be) recycled, and be classified as either as a sludge, by-product, or spent material.

The collection and documentation of the commodity summary and process description sections of the mineral commodity analysis reports was relatively straight-forward and involved little interpretation on the part of EPA. However, the preparation of the process waste stream sections of the mineral commodity analysis reports required extensive analysis and substantive interpretation of the publicly available information by the Agency. The process used by EPA to develop descriptions of waste stream sources, form, characteristics, management, and recyclability is described below.

Waste Stream Sources and Form

EPA reviewed process descriptions and process flow diagrams obtained from numerous sources including, Kirk-Othmer, EPA's Effluent Guideline Documents, EPA survey instruments, and the literature. As one would expect, the available process descriptions and process flow diagrams varied considerably in both quality and detail, both by commodity and source of information. Therefore, EPA often needed to interpret the information to identify specific waste streams. For example, process descriptions and process flow charts found through the Agency's electronic literature search process often focused on the production process of the mineral product and omitted any description or identification of waste streams (including their point of generation). In such cases, the Agency used professional judgment to determine how and where wastes were generated.

Bevill-Exclusion Status

EPA used the Agency's established definitions and techniques for determining which operations and waste streams might be subject to LDR standards. EPA decisions concerning whether individual wastes are within the scope of the RCRA Mining Waste Exclusion were based upon a number of different factors. The Agency examined these factors in sequence, in such a way as to yield unambiguous and consistent decisions from sector to sector. The step-wise methodology used for this analysis is presented below and summarized in Exhibit I-3:

- Ascertain whether the material is considered a solid waste under RCRA.
- Determine whether the waste is generated by a primary mineral production step, and, more generally, whether or not primary production occurs in the sector/within a process type.
- Establish whether the waste and the operation that generates it are uniquely associated with mineral production.
- Determine whether the waste is generated by a mineral extraction, beneficiation, or processing step.
- Check to see whether the waste, if a processing waste, is one of the 20 special wastes from mineral processing.

This analytical sequence results in one of three outcomes:

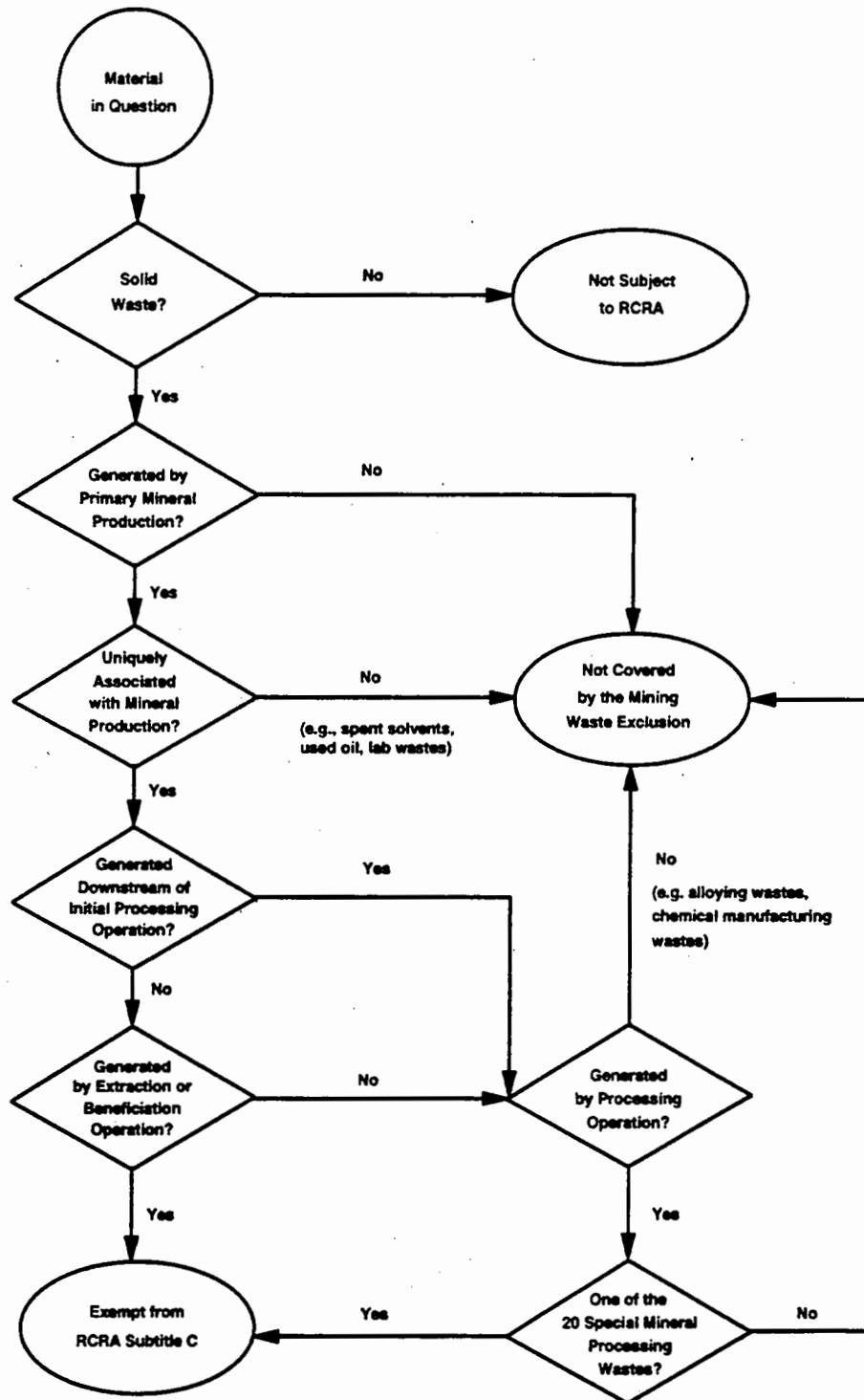
- (1) the material is not a solid waste and hence, not subject to RCRA;
- (2) the material is a solid waste but is exempt from RCRA Subtitle C because of the Mining Waste Exclusion; or
- (3) the material is a solid waste that is not exempt from RCRA Subtitle C and is subject to regulation as a hazardous waste if it is listed as a hazardous waste or it exhibits any of the characteristics of hazardous waste.³

Waste Stream Characteristics

EPA used waste stream characterization data obtained from numerous sources to document whether a particular waste stream exhibited one (or more) of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity). In cases where actual data indicated that a waste did exhibit one of the characteristics of a hazardous waste, the specific characteristic(s) was designated with a Y. However, despite more than ten years of Agency research on mineral processing operations, EPA was unable to find waste characterization

³ RCRA Subtitle C regulations define toxicity as one of the four characteristics of a hazardous waste. EPA uses the Toxicity Characteristic Leaching Procedure (TCLP) to assess whether a solid waste is a hazardous waste due to toxicity. The TCLP as applied to mineral processing wastes was recently remanded to the Agency, for further discussion, see the Applicability of TCLP Technical Background Document in the docket for the January 1996 Supplemental Proposed Rule.

EXHIBIT I-3
PROCESS SUMMARY FOR EXCLUSION DETERMINATIONS



data for many waste streams. To present mineral commodity profiles that were as complete as possible, EPA used a step-wise methodology for estimating waste characteristics for individual waste streams when documented waste generation rates and analytical data were not available. Specifically, due to the paucity of waste characterization data (particularly, TCLP data), EPA used total constituent data (if available) or professional judgment to determine whether a particular waste exhibited one of the characteristics of a RCRA hazardous waste (i.e., toxicity, corrosivity, ignitability, and reactivity).

To determine whether a waste might exhibit the characteristic of toxicity, EPA first compared 1/20th of the total constituent concentration of each TC metal to its respective TC level.⁴ In cases where total constituent data were not available, EPA then used professional judgment to evaluate whether the waste stream could potentially exhibit the toxicity characteristic for any of the TC metals. For example, if a particular waste stream resulted through the leaching of a desired metal from an incoming concentrated feed, the Agency assumed that the precipitated leach stream contained high total constituent (and therefore, high leachable) concentrations of non-desirable metals, such as arsenic. Continuing through the step-wise methodology, EPA relied on professional judgment to determine, based on its understanding of the nature of a particular processing step that generated the waste in question, whether the waste could possibly exhibit one (or more) of the characteristics of ignitability, corrosivity, or reactivity. Waste streams that EPA determined could potentially exhibit one or more of the characteristics of a RCRA hazardous waste were designated by Y?. The Agency acknowledges the inherent limitations of this conservative, step-wise methodology and notes that it is possible that EPA may have incorrectly assumed that a particular waste does (or does not) exhibit one or more of the RCRA hazardous waste characteristics.

The Agency stresses that the results and information presented in the individual commodity analysis reports are based on the review of publicly available information. The accuracy and representativeness of the collected information are only as good as the source documents. As a result of this limited data quality review, EPA notes that in some instances, Extraction Procedure (EP) leachate data reported by various sources are greater than 1/20th of the total constituent concentration. Generally one would expect, based on the design of the EP testing procedure, the total constituent concentrations to be at least 20-times the EP concentrations. This apparent discrepancy, however, can potentially be explained if the EP results were obtained from total constituent analyses of liquid wastes (i.e., EP tests conducted on wastes that contain less than one-half of one percent solids content are actually total constituent analyses).

Waste Stream Generation Rates

As data were available, EPA used actual waste generation rates reported by facilities in various Agency survey instruments and background documents. However, due to the general lack of data for many of the mineral commodity sectors and waste streams, the Agency needed to develop a step-wise method for estimating mineral processing waste stream generation rates when actual data were unavailable.

Specifically, EPA developed an "expected value" estimate for each waste generation rate using draft industry profiles, supporting information, process flow diagrams, and professional judgment. From the "expected value" estimate, EPA developed upper and lower bound estimates, which reflect the degree of uncertainty in our data and understanding of a particular sector, process, and/or waste in question. For

⁴ Based on the assumption of a theoretical worst-case leaching of 100 percent and the design of the TCLP extraction test, where 100 grams of sample is diluted with two liters of extractant, the maximum possible TCLP concentration of any TC metal would be 1/20th of the total constituent concentration.

example, EPA obtained average or typical commodity production rates from published sources (e.g., BOM Mineral Commodity Summaries) and determined input material quantities or concentration ratios from published market specifications. In parallel with this activity, EPA reviewed process flow diagrams for information on flow rates, waste-to-product ratios, or material quantities. The Agency then calculated any additional waste generation rates and subtracted out known material flows, leaving a defined material flow, which was allocated among the remaining unknown waste streams using professional judgment. Finally, EPA assigned a minimum, expected, and maximum volume estimate for each waste stream.

A key element in developing waste generation rates was the fact that by definition, average facility level generation rates of solids and sludges are less than 45,000 metric tons/year, and generation rates of wastewaters are less than 1,000,000 metric tons/year. Using this fact, in the absence of any supporting information, maximum values for solids and sludges were set at the highest waste generation rate found in the sector in question or 45,000 metric tons/year/facility, whichever was lower.

The precise methodology for determining waste generation rates varied depending on the quantity and quality of available information. The waste streams for which EPA had no published annual generation rate were divided into five groups and a methodology for each group was assigned as follows.

1. **Actual generation rates for the waste in question from one or more facilities were available.** EPA extrapolated from the available data to the sector on the basis of waste-to-product ratios to develop the expected value, and used a value of plus or minus 20 percent of the expected value to define the upper and lower bounds.
2. **A typical waste-to-product ratio for the waste in question was available.** EPA multiplied the waste-to-product ratio by sector production (actual or estimated) to yield a sector wide waste generation expected value, and used one-half and twice this value for the lower and upper bounds, respectively.
3. **No data on the waste in question were available, but generation rates for other generally comparable wastes in the sector were.** EPA used the maximum and minimum waste generation rates as the upper and lower bounds, respectively, and defined the expected value as the midpoint between the two ends of the range. Adjustments were made using professional judgment if unreasonable estimates resulted from this approach.
4. **No data were available for any analogous waste streams in the sector, or information for the sector generally was very limited.** EPA drew from information on other sectors using analogous waste types and adjusting for differences in production rates/material throughput. The Agency used upper and lower bound estimates of one order of magnitude above and below the expected value derived using this approach. Results were modified using professional judgment if the results seemed unreasonable.
5. **All EPA knew (or suspected) was the name of the waste.** The Agency used the high value threshold (45,000 metric tons/year/facility or 1,000,000 metric tons/year/facility) as the maximum value, 0 or 100 metric tons per year as the minimum, and the midpoint as the expected value.

Waste Stream Management Practices

EPA reviewed process descriptions and process flow diagrams obtained from numerous sources including, Kirk-Othmer, EPA's Effluent Guideline Documents, EPA survey instruments, and the literature. As noted earlier, the available process descriptions and process flow diagrams varied considerably in both quality and detail, both by commodity and source of information. Therefore, EPA often needed to interpret the information to determine how specific waste streams were managed. For example, process descriptions and process flow charts found through the Agency's electronic literature search process often focused on the production process of the mineral product and omitted any description or identification of how or where waste streams were managed. In such cases, the Agency used professional judgment to determine how and where specific waste streams were managed. For example, EPA considered (1) how similar waste streams were managed at mineral processing facilities for which the Agency had management information, (2) the waste form and whether it was amenable to tank treatment, (3) generation rates, and (4) proximity of the point of waste generation to the incoming raw materials, intermediates, and finished products to predict the most likely waste management practice.

Waste Stream Recyclability and Classification

As was the case for the other types of waste stream-specific information discussed above, EPA was unable to locate published information showing that many of the identified mineral processing waste streams were being recycled. When information showing that a particular waste stream was being either fully or partially recycled was found, the recyclability of the waste stream was designated by Y and YS, respectively.

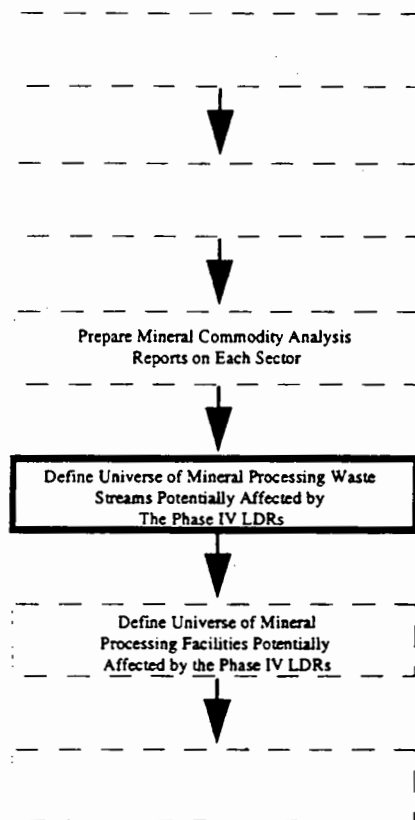
However, due to the paucity of data for many of the mineral commodity sectors and waste streams, the Agency developed a method for determining whether a particular mineral processing waste stream was expected to be either fully or partially recycled, designated by Y? and YS?, respectively. This method was designed to capture the various types of information that could allow one, when using professional judgment, to determine whether a particular waste stream could be recycled or if it contained material of value.

If EPA determined that the waste stream was or could be fully/partially recycled, it used the definitions provided in 40 CFR §§ 260.10 and 261.1 to categorize the waste stream as either a by-product, sludge, or spent material.

EPA, through the process of researching and preparing mineral commodity analysis reports for the mineral commodities listed in Exhibit I-2, identified a total of 526 waste streams that are believed to be generated at facilities involved in mineral production operations.

I.4 Define the Universe of "Mineral Processing" Waste Streams Potentially Affected by the Phase IV LDRs

Step Four



The Agency then evaluated each of the waste streams using the process outlined in Exhibit I-4, to remove waste streams that would not be affected by the Phase IV LDRs. Specifically, EPA removed:

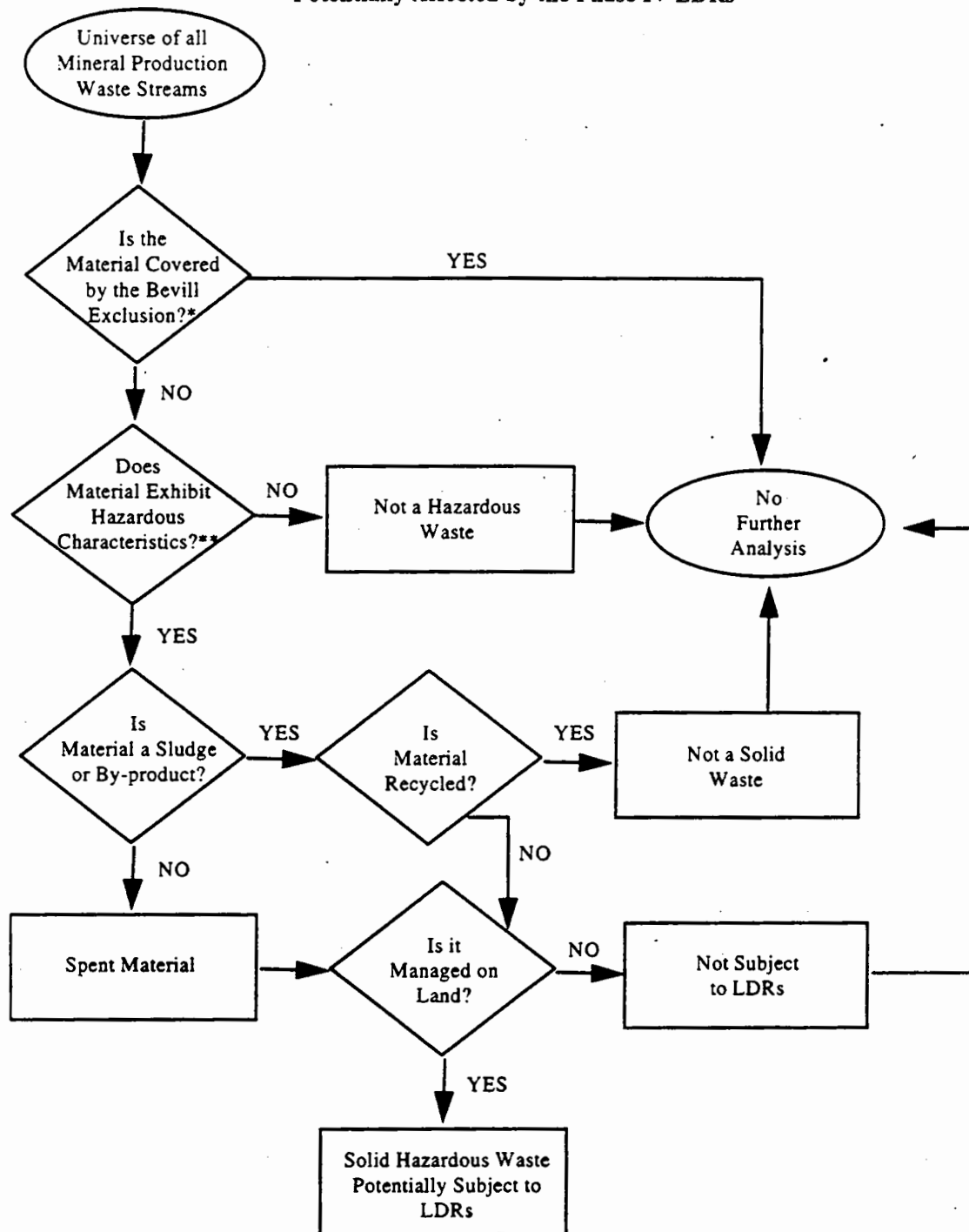
- All of the extraction and beneficiation waste streams;
- The "Special 20" Bevill-Exempt mineral processing waste streams;
- Waste streams that were known to be fully recycled in process; and
- All of the mineral processing waste streams that did not exhibit one or more of the RCRA characteristics of a hazardous waste (based on either actual analytical data or professional judgment).

As a result of this evaluation process, EPA narrowed the potential universe of waste streams that could potentially be affected by the proposed Phase IV LDRs to the 118 hazardous mineral processing waste streams presented below in Exhibit I-5.⁵

⁵ EPA strongly cautions that the list of waste streams presented in Exhibit I-5 should not be construed to be the authoritative list of hazardous mineral processing waste streams. Exhibit I-5 represents EPA's best effort, and clearly does not include every potential waste stream. Furthermore, the omission of an actual waste stream (and thus its not being classified as a hazardous mineral processing waste does not relieve the generator from its responsibility of correctly determining whether the particular waste is subject to Subtitle C requirements.

EXHIBIT I-4

**Schematic of the Agency's Process for Defining the Universe of Mineral Processing Waste Streams
Potentially Affected by the Phase IV LDRs**



* Includes Extraction/Beneficiation and the "Special 20" Waste Streams

** Listed hazardous wastes are excluded from further analysis because they are already subject to all relevant Subtitle C requirements

EXHIBIT I-5

POTENTIALLY HAZARDOUS MINERAL PROCESSING WASTE STREAMS BY COMMODITY SECTOR

Alumina and Aluminum		Copper
Cast house dust		Acid plant blowdown
Electrolysis waste		WWTP sludge
Antimony		Elemental Phosphorus
Autoclave filtrate		Andersen Filter Media
Slag and furnace residue		AFM rinsate
Stripped anolyte Solids		Furnace building washdown
Beryllium		Furnace scrubber blowdown
Chip treatment wastewater		Fluorspar and Hydrofluoric Acid
Filtration discard		Off-spec fluosilicic acid
Bismuth		Germanium
Alloy residues		Waste acid wash and rinse water
Spent caustic soda		Chlorinator wet air pollution control
Electrolytic slimes		sludge
Lead and zinc chlorides		Hydrolysis filtrate
Metal chloride residues		Leach residues
Slag		Spent acid/leachate
Spent electrolyte		Waste still liquor
Spent soda solution		Lead
Waste acid solutions		Acid plant sludge
Waste acids		Baghouse incinerator ash
Cadmium		Slurried APC dust
Caustic washwater		Solid residues
Copper and lead sulfate filter cakes		Spent furnace brick
Copper removal filter cake		Stockpiled miscellaneous plant waste
Iron containing impurities		Wastewater treatment plant liquid effluent
Spent leach solution		Wastewater treatment plant sludges/solids
Lead sulfate waste		Magnesium and Magnesia from Brines
Post-leach filter cake		Cast house dust
Spent purification solution		Smut
Scrubber wastewater		Mercury
Spent electrolyte		Dust
Zinc precipitates		Furnace residue
Calcium		Quench water
Dust with quick lime		Molybdenum, Ferromolybdenum, and Ammonium
Coal Gas		Molybdate
Multiple effects evaporator concentrate		Flue dust/gases
		Liquid residues

EXHIBIT I-5 (Continued)**Platinum Group Metals**

Slag
Spent acids
Spent solvents

Pyrobitumens, Mineral Waxes, and Natural Asphalts

Still bottoms
Waste catalysts

Rare Earths

Spent ammonium nitrate processing solution
Electrolytic cell caustic wet APC sludge

Process wastewater
Spent scrubber liquor
Solvent extraction crud
Wastewater from caustic wet APC

Rhenium

Spent barren scrubber liquor
Spent rhenium raffinate

Scandium

Spent acids
Spent solvents from solvent extraction

Selenium

Spent filter cake
Plant process wastewater
Slag
Tellurium slime wastes
Waste solids

Synthetic Rutile

Spent iron oxide slurry
APC dust/sludges
Spent acid solution

Tantalum, Columbium, and Ferrocolumbium

Digester sludge
Process wastewater
Spent raffinate solids

Tellurium

Slag
Solid waste residues
Waste electrolyte
Wastewater

Titanium and Titanium Dioxide

Pickle liquor and wash water
Scrap milling scrubber water
Smut from Mg recovery
Leach liquor and sponge wash water
Spent surface impoundment liquids
Spent surface impoundments solids
Waste acids (Sulfate process)
WWTP sludge/solids

Tungsten

Spent acid and rinse water
Process wastewater

Uranium

Waste nitric acid from UO_2 production
Vaporizer condensate
Superheater condensate
Slag
Uranium chips from ingot production

Zinc

Acid plant blowdown
Waste ferrosilicon
Process wastewater
Discarded refractory brick
Spent cloths, bags, and filters
Spent goethite and leach cake residues
Spent surface impoundment liquids
Spent synthetic gypsum
TCA tower blowdown
Wastewater treatment plant liquid effluent
WWTP solids

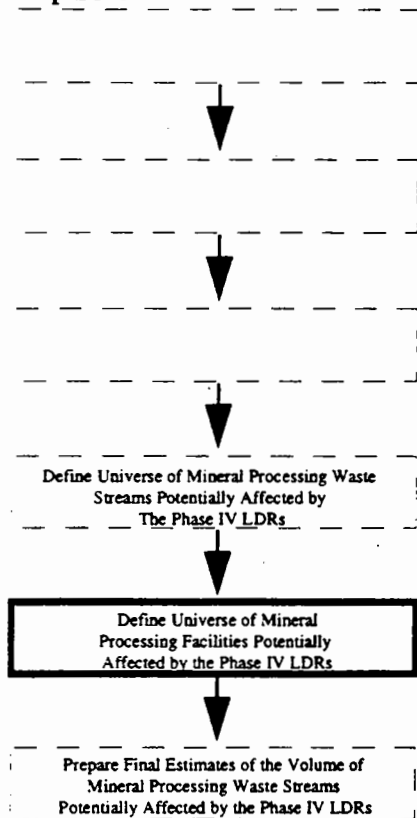
Zirconium and Hafnium

Spent acid leachate from zirconium alloy production
Spent acid leachate from zirconium metal production
Leaching rinse water from zirconium alloy production
Leaching rinse water from zirconium metal production

Note: EPA was unable to collect sufficient information to determine whether the production of Bromine, Gemstones, Iodine, Lithium and Lithium Carbonate, Soda Ash, Sodium Sulfate, and Strontium produce mineral processing wastes.

I.5 Define the Universe of "Mineral Processing" Facilities Potentially Affected by the Phase IV LDRs

Step Five



EPA then used the information contained in the individual sector analysis reports to identify the number of facilities, by commodity, that potentially generated the hazardous mineral processing wastes listed in Exhibit I-5. As discussed earlier, the individual sector analysis reports listed the facilities involved in the production of a particular mineral commodity. In addition, as the available information allowed, the Agency also (1) identified the specific processes used by each facility and (2) identified the specific waste streams generated by process. However, in cases where the Agency had insufficient information to determine which of the individual facilities generated a particular waste stream, EPA assumed that the waste stream was generated at all of the reported facilities known to be using the same process.

The Agency then used the individual sector analysis reports, various U.S. Bureau of Mines documents, the Randol Mining Directory, and the Mine Safety and Health Administration (MSHA) address/employment database to determine which of the mineral processing facilities were collocated with mining and/or extraction/beneficiation facilities.

Lastly, the Agency used the 1990 Report to Congress and the individual commodity sector analysis reports to identify the mineral processing facilities that also generate one (or more) of the special 20 Bevill-Exempt mineral processing wastes.

Appendix B presents a summary of the mineral processing facilities by mineral commodity sector that generate hazardous mineral processing wastes. Appendix B also indicates whether the mineral processing facilities are collocated and/or generate one (or more) of the "Special 20" waste streams.

I.6 Prepare Final Estimates of the Volume of Mineral Processing Waste Streams Potentially Affected by the Phase IV LDRs

The Agency compiled the information in the previous steps to arrive at the final data set. Exhibit I-6 presents for each potentially affected waste stream in all affected sectors, the reported and/or estimated generation rate, the hazardous characteristics, information about recycling status, RCRA waste type, and treatment type (physical form).

Exhibit I-6
Final Mineral Processing Waste Stream Database - Baseline Analysis

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	Average Facility Generation (mt/yr)		
			Min	Avg.	Max		Minimum	Expected	Maximum
Alumina and Aluminum	Cast house dust	19	19	19	19	23	830	830	830
	Electrolysis waste	58	58	58	58	23	2,500	2,500	2,500
Antimony	Autoclave filtrate	NA	0.32	27	54	6	53	4,500	9,000
	Stripped anolyte solids	0.19	0.19	0.19	0.19	2	95	95	95
	Slag and furnace residue	21	21	21	21	6	3,500	3,500	3,500
Beryllium	Chip treatment wastewater	NA	0.2	100	2000	2	100	50,000	1,000,000
	Filtration discard	NA	0.2	45	90	2	100	23,000	45,000
Bismuth	Alloy residues	NA	0.1	3	6	1	100	3,000	6,000
	Spent caustic soda	NA	0.1	6.1	12	1	100	6,100	12,000
	Electrolytic slimes	NA	0	0.02	0.2	1	0	20	200
	Lead and zinc chlorides	NA	0.1	3	6	1	100	3,000	6,000
	Metal chloride residues	3	3	3	3		3,000	3,000	3,000
	Slag	NA	0.1	1	10	1	100	1,000	10,000
	Spent electrolyte	NA	0.1	6.1	12	1	100	6,100	12,000
	Spent soda solution	NA	0.1	6.1	12	1	100	6,100	12,000
	Waste acid solutions	NA	0.1	6.1	12	1	100	6,100	12,000
	Waste acids	NA	0	0.1	0.2	1	0	100	200
Cadmium	Caustic washwater	NA	0.19	1.9	19	2	95	950	9,500
	Copper and lead sulfate filter cakes	NA	0.19	1.9	19	2	95	950	9,500
	Copper removal filter cake	NA	0.19	1.9	19	2	95	950	9,500
	Iron containing impurities	NA	0.19	1.9	19	2	95	950	9,500
	Spent leach solution	NA	0.19	1.9	19	2	95	950	9,500
	Lead sulfate waste	NA	0.19	1.9	19	2	95	950	9,500
	Post-leach filter cake	NA	0.19	1.9	19	2	95	950	9,500
	Spent purification solution	NA	0.19	1.9	19	2	95	950	9,500
	Scrubber wastewater	NA	0.19	1.9	19	2	95	950	9,500
	Spent electrolyte	NA	0.19	1.9	19	2	95	950	9,500
	Zinc precipitates	NA	0.19	1.9	19	2	95	950	9,500
Calcium	Dust with quicklime	0.04	0.04	0.04	0.04	1	40	40	40
Coal Gas	Multiple effects evaporator concentrate	NA	0	0	65	1	0	0	65,000
Copper	Acid plant blowdown	5300	5300	5300	5300	10	530,000	530,000	530,000
	WWTP sludge	6	6	6	6	10	600	600	600

Exhibit I-6
Final Mineral Processing Waste Stream Database - Baseline Analysis

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	Average Facility Generation (mt/yr)		
			Min	Avg.	Max		Minimum	Expected	Maximum
Elemental Phosphorus	Andersen Filter Media	0.46	0.46	0.46	0.46	2	230	230	230
	AFM rinsate	4	4	4	4	2	2,000	2,000	2,000
	Furnace scrubber blowdown	410	410	410	410	2	210,000	210,000	210,000
	Furnace Building Washdown	700	700	700	700	2	350,000	350,000	350,000
Fluorspar and Hydrofluoric Acid	Off-spec fluosilicic acid	NA	0	15	44	3	0	5,000	15,000
Germanium	Waste acid wash and rinse water	NA	0.4	2.2	4	4	100	550	1,000
	Chlorinator wet air pollution control sludge	NA	0.01	0.21	0.4	4	3	53	100
	Hydrolysis filtrate	NA	0.01	0.21	0.4	4	3	53	100
	Leach residues	0.01	0.01	0.01	0.01	3	3	3	3
	Spent acid/leachate	NA	0.4	2.2	4	4	100	550	1,000
	Waste still liquor	NA	0.01	0.21	0.4	4	3	53	100
Lead	Acid plant sludge	14	14	14	14	3	4,700	4,700	4,700
	Baghouse incinerator ash	NA	0.3	3	30	3	100	1,000	10,000
	Slurried APC Dust	7	7	7	7	3	2,300	2,300	2,300
	Solid residues	0.4	0.4	0.4	0.4	3	130	130	130
	Spent furnace brick	1	1	1	1	3	330	330	330
	Stockpiled miscellaneous plant waste	NA	0.4	88	180	4	100	22,000	45,000
	WWTP liquid effluent	3500	3500	3500	3500	4	880,000	880,000	880,000
	WWTP sludges/solids	380	380	380	380	4	95,000	95,000	95,000
Magnesium and Magnesia from Brines	Cast house dust	NA	0.076	0.76	7.6	1	76	760	7,600
	Smut	26	26	26	26	2	13,000	13,000	13,000
Mercury	Dust	0.007	0.007	0.007	0.007	7	1	1	1
	Quench water	NA	63	77	420	7	9,000	11,000	60,000
	Furnace residue	0.077	0.077	0.077	0.077	7	11	11	11
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	Flue dust/gases	NA	1.1	250	500	11	100	23,000	45,000
	Liquid residues	1	1	1	1	2	500	500	500
Platinum Group Metals	Slag	NA	0.0046	0.046	0.46	3	2	15	150
	Spent acids	NA	0.3	1.7	3	3	100	570	1,000
	Spent solvents	NA	0.3	1.7	3	3	100	570	1,000

Exhibit I-6
Final Mineral Processing Waste Stream Database - Baseline Analysis

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	Average Facility Generation (mt/yr)		
			Min	Avg.	Max		Minimum	Expected	Maximum
Pyrobitumens, Mineral Waxes, and Natural Asphalts	Still bottoms	NA	0.002	45	90	2	1	23,000	45,000
	Waste catalysts	NA	0.002	10	20	2	1	5,000	10,000
Rare Earths	Spent ammonium nitrate processing solution	14	14	14	14	1	14,000	14,000	14,000
	Electrolytic cell caustic wet APC sludge	NA	0.07	0.7	7	1	70	700	7,000
	Process wastewater	7	7	7	7	1	7,000	7,000	7,000
	Spent scrubber liquor	NA	0.1	500	1000	1	100	500,000	1,000,000
	Solvent extraction crud	NA	0.1	2.3	4.5	1	100	2,300	4,500
	Wastewater from caustic wet APC	NA	0.1	500	1000	1	100	500,000	1,000,000
Rhenium	Spent barren scrubber liquor	NA	0	0.1	0.2	2	0	50	100
	Spent rhenium raffinate	88	88	88	88	2	44,000	44,000	44,000
Scandium	Spent acids	NA	0.7	3.9	7	7	100	560	1,000
	Spent solvents from solvent extraction	NA	0.7	3.9	7	7	100	560	1,000
Selenium	Spent filter cake	NA	0.05	0.5	5	3	17	170	1,700
	Plant process wastewater	66	66	66	66	2	33,000	33,000	33,000
	Slag	NA	0.05	0.5	5	3	17	170	1,700
	Tellurium slime wastes	NA	0.05	0.5	5	3	17	170	1,700
	Waste solids	NA	0.05	0.5	5	3	17	170	1,700
Synthetic Rutile	Spent iron oxide slurry	45	45	45	45	1	45,000	45,000	45,000
	APC dust/sludges	30	30	30	30	1	30,000	30,000	30,000
	Spent acid solution	30	30	30	30	1	30,000	30,000	30,000
Tantalum, Columbium, and Ferrocolumbium	Digester sludge	1	1	1	1	2	500	500	500
	Process wastewater	150	150	150	150	2	75,000	75,000	75,000
	Spent raffinate solids	2	2	2	2	2	1,000	1,000	1,000
Tellurium	Slag	NA	0.2	2	9	2	100	1,000	4,500
	Solid waste residues	NA	0.2	2	9	2	100	1,000	4,500
	Waste electrolyte	NA	0.2	2	20	2	100	1,000	10,000
	Wastewater	NA	0.2	20	40	2	100	10,000	20,000

Exhibit I-6
Final Mineral Processing Waste Stream Database - Baseline Analysis

Commodity	Waste Stream	Reported Generation (1000mt/yr)	Est./Reported Generation (1000mt/yr)			Number of Facilities with Process	Average Facility Generation (mt/yr)		
			Min	Avg.	Max		Minimum	Expected	Maximum
Titanium and Titanium Dioxide	Pickle liquor and wash water	NA	2.2	2.7	3.2	3	730	900	1,100
	Scrap milling scrubber water	NA	4	5	6	1	4,000	5,000	6,000
	Smut from Mg recovery	NA	0.1	22	45	2	50	11,000	23,000
	Leach liquor and sponge wash water	NA	380	480	580	2	190,000	240,000	290,000
	Spent surface impoundment liquids	NA	0.63	3.4	6.7	7	90	490	960
	Spent surface impoundments solids	36	36	36	36	7	5,100	5,100	5,100
	Waste acids (Sulfate process)	NA	0.2	39	77	2	100	20,000	39,000
	WWTP sludge/solids	420	420	420	420	7	60,000	60,000	60,000
Tungsten	Spent acid and rinse water	NA	0	0	21	6	0	0	3,500
	Process wastewater	NA	2.2	4.4	9	6	370	730	1,500
Uranium	Waste nitric acid from UO ₂ production	NA	1.7	2.5	3.4	17	100	150	200
	Vaporizer condensate	NA	1.7	9.3	17	17	100	550	1,000
	Superheater condensate	NA	1.7	9.3	17	17	100	550	1,000
	Slag	NA	0	8.5	17	17	0	500	1,000
	Uranium chips from ingot production	NA	1.7	2.5	3.4	17	100	150	200
Zinc	Acid plant blowdown	130	130	130	130	1	130,000	130,000	130,000
	Waste ferrosilicon	17	17	17	17	1	17,000	17,000	17,000
	Process wastewater	5000	5000	5000	5000	3	1,700,000	1,700,000	1,700,000
	Discarded refractory brick	1	1	1	1	1	1,000	1,000	1,000
	Spent cloths, bags, and filters	0.15	0.15	0.15	0.15	3	50	50	50
	Spent goethite and leach cake residues	15	15	15	15	3	5,000	5,000	5,000
	Spent surface impoundment liquids	1900	1900	1900	1900	3	630,000	630,000	630,000
	WWTP Solids	0.75	0.75	0.75	0.75	3	250	250	250
	Spent synthetic gypsum	16	16	16	16	3	5,300	5,300	5,300
	TCA tower blowdown	0.25	0.25	0.25	0.25	1	250	250	250
	Wastewater treatment plant liquid effluent	2600	2600	2600	2600	3	870,000	870,000	870,000
Zirconium and Hafnium	Spent acid leachate from Zr alloy prod.	NA	0	0	850	2	0	0	430,000
	Spent acid leachate from Zr metal prod.	NA	0	0	1600	2	0	0	800,000
	Leaching rinse water from Zr alloy prod.	NA	34	42	51	2	17,000	21,000	26,000
	Leaching rinse water from Zr metal prod.	NA	0.2	1000	2000	2	100	500,000	1,000,000

*** EPA does not have enough information to determine whether Bromine, Gemstones, Iodine, Lithium and Lithium Carbonate, Soda Ash, Sodium Sulfate, and Strontium produce mineral processing wastes

Exhibit I-6
Final Mineral Processing Waste Stream Database - Baseline Analysis

Commodity	Waste Stream	TC Metals								Corr	Ignit	Rctv	Recycled to Bevill Unit	Haz?	Current Recycle	RCRA Waste Type			Treatment Type		
		As	Ba	Cd	Cr	Pb	Hg	Se	Ag							By- Prod.	Spent Mat'l	Slud- ge	Waste Water	1-10% Solids	Solid
Alumina and Aluminum	Cast house dust			Y			Y			N?	N?	N?	0	1	Y?			1	0	0	1
	Electrolysis waste					Y?				N?	N?	N?	0	0.5	Y?			1	0	0	1
Antimony	Autoclave filtrate	Y?		Y?		Y?	Y?			Y?	N?	N?	0	0.5	YS?		1		1	0	0
	Stripped anolyte solids	Y?								N?	N?	N?	0	0.5	Y	1			0	0	1
	Slag and furnace residue					Y?				N?	N?	N?		0.5	N				0	0	1
Beryllium	Chip treatment wastewater				Y?					N?	N?	N?	0	0.5	YS?		1		1	0	0
	Filtration discard					Y?				N?	N?	N?		0.5	N				0	0	1
Bismuth	Alloy residues					Y?				N?	N?	N?		0.5	N				0	0	1
	Spent caustic soda					Y?				N?	N?	N?	0	0.5	Y?		1		0	1	0
	Electrolytic slimes					Y?				N?	N?	N?	0	0.5	Y?	1			0	0	1
	Lead and zinc chlorides					Y?				N?	N?	N?		0.5	N				0	0	1
	Metal chloride residues					Y?				N?	N?	N?		0.5	N				0	0	1
	Slag					Y?				N?	N?	N?		0.5	N				0	0	1
	Spent electrolyte					Y?				N?	N?	N?		0.5	N				0	1	0
	Spent soda solution					Y?				Y?	N?	N?	0	0.5	Y?		1		1	0	0
	Waste acid solutions									Y?	N?	N?		0.5	N				1	0	0
	Waste acids									Y?	N?	N?	0	0.5	YS?		1		1	0	0
Cadmium	Caustic washwater			Y?						Y?	N?	N?	0	0.5	Y?		1		1	0	0
	Copper and lead sulfate filter cakes			Y?		Y?				N?	N?	N?	0	0.5	Y?	1			0	0	1
	Copper removal filter cake			Y?						N?	N?	N?	0	0.5	Y?	1			0	0	1
	Iron containing impurities			Y?						N?	N?	N?		0.5	N				0	0	1
	Spent leach solution	Y?		Y?		Y?				Y?	N?	N?	2	0.5	Y?		1		0	1	0
	Lead sulfate waste			Y?		Y?				N?	N?	N?	0	0.5	Y?	1			0	0	1
	Post-leach filter cake			Y?						N?	N?	N?		0.5	N				0	0	1
	Spent purification solution			Y?						Y?	N?	N?		0.5	N				1	0	0
	Scrubber wastewater			Y?						Y?	N?	N?	2	0.5	Y?			1	1	0	0
	Spent electrolyte			Y?						Y?	N?	N?		0.5	N				0	1	0
	Zinc precipitates			Y?						N?	N?	N?	0	0.5	Y?	1			0	0	1
Calcium	Dust with quicklime									Y?	N?	N?	1	0.5	Y			1	0	0	1
Coal Gas	Multiple effects evaporator concentrate	Y						Y		N?	N?	N?	1	1	YS	1			0	1	0
Copper	Acid plant blowdown	Y		Y	Y	Y	Y	Y	Y	Y	N?	N?	1	1	YS			1	0	1	0
	WWTP sludge			Y?		Y?				N?	N?	N?	0	0.5	YS			1	0	0	1

Exhibit I-6
Final Mineral Processing Waste Stream Database - Baseline Analysis

Commodity	Waste Stream	TC Metals								Corr	Ignit	Rctv	Recycled to Bevill Unit	Haz?	Current Recycle	RCRA Waste Type			Treatment Type		
		As	Ba	Cd	Cr	Pb	Hg	Se	Ag							By- Prod.	Spent Mat'l	Sludge	Waste Water	1-10% Solids	Solid
Elemental Phosphorus	Andersen Filter Media			Y						N?	N?	N?		1	N				0	0	1
	AFM rinsate			Y				Y		N?	N?	N?	2	1	Y		1		0	1	0
	Furnace scrubber blowdown			Y						Y	N?	N?	2	1	Y			1	1	0	0
	Furnace Building Washdown			Y						N?	N?	N?	2	1	Y		1		1	0	0
Fluorspar and Hydrofluoric Acid	Off-spec fluosilicic acid									Y?	N?	N?	0	0.5	YS	1			1	0	0
Germanium	Waste acid wash and rinse water	Y?		Y?	Y?	Y?		Y?	Y?	Y?	N?	N?	0	0.5	YS?		1		1	0	0
	Chlorinator wet air pollution control sludge	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?	0	0.5	YS?			1	0	0	1
	Hydrolysis filtrate	Y?		Y?	Y?	Y?		Y?	Y?	N?	N?	N?		0.5	N				0	0	1
	Leach residues			Y?		Y?				N?	N?	N?		0.5	N				0	0	1
	Spent acid/leachate	Y?				Y?				Y?	N?	N?	0	0.5	YS?		1		1	0	0
	Waste still liquor	Y?		Y?	Y?	Y?		Y?	Y?	N?	Y?	N?		0.5	N				0	0	1
Lead	Acid plant sludge									Y?	N?	N?	1	0.5	Y?			1	0	0	1
	Baghouse incinerator ash			Y		Y				N?	N?	N?		1	N				0	0	1
	Slurried APC Dust			Y		Y				N?	N?	N?	1	1	Y			1	0	0	1
	Solid residues					Y?				N?	N?	N?	1	0.5	Y?	1			0	0	1
	Spent furnace brick					Y				N?	N?	N?	1	1	Y		1		0	0	1
	Stockpiled miscellaneous plant waste			Y		Y				N?	N?	N?	1	1	YS?		1		0	0	1
	WWTP liquid effluent					Y?				Y?	N?	N?	1	0.5	Y		1		1	0	0
	WWTP sludges/solids			Y?		Y?				Y	N?	N?	1	1	Y			1	0	0	1
Magnesium and Magnesia from Brines	Cast house dust		Y?							N?	N?	N?	0	0.5	Y?			1	0	0	1
	Smut		Y							N?	N?	N?		1	N				0	0	1
Mercury	Dust						Y?			N?	N?	N?		0.5	N				0	0	1
	Quench water					Y?	Y?			N?	N?	N?	1	0.5	Y?		1		1	0	0
	Furnace residue						Y?			N?	N?	N?		0.5	N				0	0	1
Molybdenum, Ferromolybdenum, and Ammonium Molybdate	Flue dust/gases					Y?				N?	N?	N?		0.5	N				0	0	1
	Liquid residues	Y?		Y?		Y?		Y?		N?	N?	N?		0.5	N				1	0	0
Platinum Group Metals	Slag					Y?		Y?		N?	N?	N?	0	0.5	Y?	1			0	0	1
	Spent acids					Y?			Y?	Y?	N?	N?		0.5	N				1	0	0
	Spent solvents					Y?			Y?	N?	Y?	N?		0.5	N				1	0	0

Exhibit I-6
Final Mineral Processing Waste Stream Database - Baseline Analysis

Commodity	Waste Stream	TC Metals								Corr	Ignlt	Rctv	Recycled to Bevill Unit	Haz?	Current Recycle	RCRA Waste Type			Treatment Type		
		As	Ba	Cd	Cr	Pb	Hg	Se	Ag							By- Prod.	Spent Mat'l	Slud- ge	Waste Water	1-10% Solids	Solid
Pyrobitumens, Mineral Waxes, and Natural Asphalts	Still bottoms									N?	Y?	N?		0.5	N				0	0	1
	Waste catalysts			Y?				Y?		N?	N?	N?	0	0.5	Y?		1		1	0	0
Rare Earths	Spent ammonium nitrate processing solution									Y	N?	N?		1	N				1	0	0
	Electrolytic cell caustic wet APC sludge									Y?	N?	N?	0	0.5	Y			1	0	0	1
	Process wastewater					Y				Y?	N?	N?	1	1	YS?		1		1	0	0
	Spent scrubber liquor									Y?	N?	N?	1	0.5	YS?			1	1	0	0
	Solvent extraction crud									N?	Y?	N?		0.5	N				0	0	1
	Wastewater from caustic wet APC				Y?	Y?				Y?	N?	N?	1	0.5	YS?			1	1	0	0
Rhenium	Spent barren scrubber liquor							Y?		N?	N	N	2	0.5	Y?			1	1	0	0
	Spent rhenium raffinate					Y?				N?	N?	N?		0.5	N				0	0	1
Scandium	Spent acids									Y?	N?	N?		0.5	N				1	0	0
	Spent solvents from solvent extraction									N?	Y?	N?	0	0.5	Y?		1		1	0	0
Selenium	Spent filter cake							Y?		N?	N?	N?	0	0.5	Y?	1			0	0	1
	Plant process wastewater					Y				Y	N?	N?	2	1	YS?		1		1	0	0
	Slag							Y?		N?	N?	N?	0	0.5	YS?	1			0	0	1
	Tellurium slime wastes							Y?		N	N?	N?	0	0.5	Y?	1			0	0	1
	Waste solids							Y?		N?	N?	N?		0.5	N				0	0	1
Synthetic Rutile	Spent iron oxide slurry			Y?	Y?					N?	N?	N?	0	0.5	YS?	1			0	0	1
	APC dust/sludges			Y?	Y?					N?	N?	N?	0	0.5	Y			1	0	0	1
	Spent acid solution			Y?	Y?					Y?	N?	N?	0	0.5	Y		1		1	0	0
Tantalum, Columbium, and Ferrocolumbium	Digester sludge									Y?	N?	N?		0.5	N				0	0	1
	Process wastewater	Y?		Y?	Y?	Y?		Y?		Y	N?	N?	0	1	Y?		1		0	1	0
	Spent raffinate solids									Y?	N?	N?		0.5	N				0	0	1
Tellurium	Slag							Y?		N?	N?	N?	0	0.5	YS?	1			0	0	1
	Solid waste residues							Y?		N?	N?	N?		0.5	N				0	0	1
	Waste electrolyte					Y?		Y?		N?	N?	N?		0.5	N				1	0	0
	Wastewater							Y?		Y?	N?	N?	0	0.5	Y		1		1	0	0

Exhibit I-6
Final Mineral Processing Waste Stream Database - Baseline Analysis

Commodity	Waste Stream	TC Metals								Corr	Ignit	Rctv	Recycled to Bevill Unit	Haz?	Current Recycle	RCRA Waste Type			Treatment Type		
		As	Ba	Cd	Cr	Pb	Hg	Se	Ag							By- Prod.	Spent Mat'l	Sludge	Waste Water	1-10% Solids	Solid
Titanium and Titanium Dioxide	Pickle liquor and wash water			Y?	Y?	Y?				Y?	N?	N?	0	0.5	YS?		1		1	0	0
	Scrap milling scrubber water			Y?	Y?	Y?		Y?		N?	N?	N?	0	0.5	YS?			1	1	0	0
	Smut from Mg recovery									N?	N?	Y	0	1	Y?	1			0	0	1
	Leach liquor and sponge wash water				Y?	Y?				Y	N?	N?	0	1	YS?		1		1	0	0
	Spent surface impoundment liquids				Y?	Y?				N?	N?	N?	0	0.5	Y?		1		1	0	0
	Spent surface impoundments solids				Y?	Y?				N?	N?	N?		0.5	N				0	0	1
	Waste acids (Sulfate process)	Y			Y			Y	Y	Y	N	N		1	N				1	0	0
	WWTP sludge/solids				Y?					N	N	N		0.5	N				0	0	1
Tungsten	Spent acid and rinse water									Y?	N?	N?	2	0.5	YS?		1		1	0	0
	Process wastewater									Y?	N?	N?	2	0.5	YS?		1		1	0	0
Uranium	Waste nitric acid from UO2 production									Y?	N?	N?	0	0.5	YS?		1		1	0	0
	Vaporizer condensate									Y?	N?	N?		0.5	N				1	0	0
	Superheater condensate									Y?	N?	N?		0.5	N				1	0	0
	Slag									N?	Y?	N?	0	0.5	Y	1			0	0	1
	Uranium chips from ingot production									N?	Y?	N?	0	0.5	Y?	1			0	0	1
Zinc	Acid plant blowdown	Y		Y	Y	Y?	Y?	Y	Y	Y	N	N	0	1	Y			1	1	0	0
	Waste ferrosilicon					Y?				N?	N?	N?	0	0.5	Y?	1			0	0	1
	Process wastewater	Y		Y	Y	Y		Y	Y	Y	N?	N?	0	1	Y?		1		1	0	0
	Discarded refractory brick	Y?		Y?	Y?	Y?				N?	N?	N?		0.5	N				0	0	1
	Spent cloths, bags, and filters			Y?		Y?	Y?	Y?	Y?	N?	N?	N?	0	0.5	Y		1		0	0	1
	Spent goethite and leach cake residues	Y		Y	Y	Y?	Y?	Y	Y	N?	N?	N?	0	1	Y				0	0	1
	Spent surface impoundment liquids			Y?						Y	N?	N?	0	1	YS?		1		1	0	0
	WWTP Solids	Y?		Y?		Y?	Y?	Y?	Y?	N?	N?	N?	1	0.5	YS			1	0	0	1
	Spent synthetic gypsum	Y?		Y		Y?				N?	N?	N?		1	N				0	0	1
	TCA tower blowdown			Y?		Y?	Y?	Y?		Y?	N?	N?	0	0.5	YS		1		1	0	0
Wastewater treatment plant liquid effluent			Y?						N?	N?	N?	0	0.5	YS?		1		1	0	0	
Zirconium and Hafnium	Spent acid leachate from Zr alloy prod.									Y?	N?	N?		0.5	N				1	0	0
	Spent acid leachate from Zr metal prod.									Y?	N?	N?		0.5	N				1	0	0
	Leaching rinse water from Zr alloy prod.									Y?	N?	N?	0	0.5	YS?		1		1	0	0
	Leaching rinse water from Zr metal prod.									Y?	N?	N?	0	0.5	YS?		1		1	0	0

**CONSTITUENT CONCENTRATION DATA
FOR RECYCLED MATERIALS**

APPENDIX J

April 15, 1997

SUMMARY OF BULK AND EP ANALYSIS RESULTS FOR MINERAL PROCESSING WASTE (RECYCLED PORTION)

November, 1996

Bulk Samples. Nonwastewaters.

Constituents	Number of Detections	Commodity	Waste Stream	Facility Identifier	State	Constituent Concentration in Waste (mg/kg)	Volume of Waste Pile (m ³) (1)	Constituent Mass per Waste Pile (kg) (2)	Area of Waste Pile (m ²)
Antimony	1	Alumina and Aluminum	Cast house dust	Unknown	Unknown	7.5	107	1,08938	108
Arsenic	1	Alumina and Aluminum	Cast house dust	Unknown	Unknown	32	107	4,648	108
Barium	1	Alumina and Aluminum	Cast house dust	Unknown	Unknown	10	107	1,4525	108
Cadmium	1	Alumina and Aluminum	Cast house dust	Unknown	Unknown	7.2	107	1,0458	108
Chromium	1	Alumina and Aluminum	Cast house dust	Unknown	Unknown	110	107	15,9775	108
Lead	2	Alumina and Aluminum	Cast house dust	Unknown	Unknown	17	107	2,46925	108
Lead		Zinc	Waste ferrosilicon	Unknown	Unknown	5000	1093	7437.5	509
Mercury	1	Alumina and Aluminum	Cast house dust	Unknown	Unknown	0.0001	107	0.00001	108
Nickel	1	Alumina and Aluminum	Cast house dust	Unknown	Unknown	260	107	37,765	108
Selenium	1	Alumina and Aluminum	Cast house dust	Unknown	Unknown	0.92	107	0.13363	108
Silver	1	Alumina and Aluminum	Cast house dust	Unknown	Unknown	1.9	107	0.27598	108
Zinc	2	Alumina and Aluminum	Cast house dust	Unknown	Unknown	120	107	17.43	108
Zinc		Zinc	Waste ferrosilicon	Unknown	Unknown	40000	1093	59500	509

Bulk Samples. Wastewaters and Liquid Nonwastewaters

Constituents	Number of Detections	Commodity	Waste Stream	Facility Identifier	State	Constituent Concentration in Waste (mg/l)	Volume of Surface Impoundment (m ³) (3)	Constituent Mass in Surface Impoundment (kg) (4)	Area of Surface Impoundment (m ²)
Antimony	31	Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	0.003	417	0.00125	558
Antimony		Copper	Acid plant blowdown	Unknown	Unknown	140	22083	3091.66667	1044
Antimony		Copper	Acid plant blowdown	Unknown	Unknown	5	22083	110.41667	1044
Antimony		Copper	Acid plant blowdown	Unknown	Unknown	0.5	22083	11.04167	1044
Antimony		Copper	Acid plant blowdown	Unknown	Unknown	0.263	22083	5.80792	1044
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	4.8	17500	84	8429
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	2.4	17500	42	8429
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	2	17500	35	8429
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	1.16	17500	20.3	8429
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.016	17500	0.28	8429
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.016	17500	0.28	8429
Antimony		Rare Earths	Process wastewater	MolyCorp, Louvers	CO	0.5	117	0.05833	385
Antimony		Rare Earths	Process wastewater	MolyCorp, Louvers	CO	0.5	117	0.05833	385
Antimony		Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.5	550	0.275	631
Antimony		Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unnamed Facility	Unknown	0.1	4375	0.4375	2517
Antimony		Leach liquid & sponge wash water	Timet, Henderson	NV	2.5	4000	10	2341	
Antimony		Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	0.074	4000	0.296	2341
Antimony		Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.5	42	0.02083	340
Antimony		Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.933	99167	92.5225	43384
Antimony		Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.5	99167	49.58333	43384
Antimony		Zinc	Process wastewater	Zinc Corp, Monaca	PA	1	99167	49.58333	43384
Antimony		Zinc	Process wastewater	Unknown	Unknown	0.5	99167	49.58333	43384
Antimony		Zinc	Process wastewater	Unknown	Unknown	0.5	99167	49.58333	43384
Antimony		Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.155	99167	15.37083	43384
Antimony		Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Antimony		Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Antimony		Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Antimony		Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Antimony		Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Arsenic	44	Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	0.003	417	0.00125	558
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	5800	22083	128083.33333	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	3400	22083	75083.33333	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	2410	22083	53220.83333	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	700	22083	15458.33333	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	334	22083	7375.83333	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	116	22083	2561.66667	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	32.9	22083	726.54167	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	30	22083	662.5	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	5.41	22083	119.47083	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	3	22083	66.25	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	3	22083	66.25	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	1.5	22083	33.125	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	0.5	22083	11.04167	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	0.05	22083	1.10417	1044
Arsenic		Copper	Acid plant blowdown	Unknown	Unknown	0.05	22083	1.10417	1044
Arsenic		Elemental Phosphorus	AFM rinseate	Unknown	Unknown	1	167	0.16667	411
Arsenic		Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	8.7	17500	152.25	8429
Arsenic		Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	1	17500	17.5	8429
Arsenic		Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.501	17500	8.7675	8429
Arsenic		Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.5	17500	8.75	8429
Arsenic		Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.4	17500	7	8429

April 15, 1997

Arsenic	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Arsenic	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Arsenic	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.016	17500	0.28	8429
Arsenic	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.5	117	0.05833	385
Arsenic	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.5	117	0.05833	385
Arsenic	Selenium	Plant process wastewaters	Climax Molyb.	IA	2.4	550	1.32	631
Arsenic	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.5	550	0.275	631
Arsenic	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	2.5	4000	10	2341
Arsenic	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown Plant	Unknown	0.1	4000	0.4	2341
Arsenic	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.5	42	0.02083	340
Arsenic	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	2.54	99167	251.88333	43384
Arsenic	Zinc	Process wastewater	Zinc Corp, Monaca	PA	1	99167	136.85	43384
Arsenic	Zinc	Process wastewater	Unknown	Unknown	1.1	99167	109.08333	43384
Arsenic	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.5	99167	49.58333	43384
Arsenic	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Arsenic	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Arsenic	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Arsenic	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Arsenic	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Arsenic	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.002	99167	0.19833	43384
Arsenic	Zinc	Process wastewater	Unknown	Unknown	0.002	99167	0.19833	43384
Arsenic	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	214	10500	2247	5319
Barium	Copper	Acid plant blowdown	Unknown	Unknown	5.9	22083	130.29167	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	5.8	22083	128.08333	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	1.4	22083	30.91667	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	1.2	22083	26.5	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	1	22083	22.08333	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	0.5	22083	11.04167	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	0.25	22083	5.52083	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	0.2	22083	4.41667	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	0.126	22083	2.7825	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	0.05	22083	1.10417	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	0.05	22083	1.10417	10441
Barium	Copper	Acid plant blowdown	Unknown	Unknown	0.05	22083	1.10417	10441
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	280	17500	4900	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	12	17500	210	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.71	17500	12.425	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.5	17500	8.75	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.26	17500	4.55	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Barium	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.5	117	0.05833	385
Barium	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.5	117	0.05833	385
Barium	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.5	550	0.275	631
Barium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	2.5	4000	10	2341
Barium	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.5	42	0.02083	340
Barium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.5	99167	49.58333	43384
Barium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	1	99167	49.58333	43384
Barium	Zinc	Process wastewater	Unknown	Unknown	0.5	99167	49.58333	43384
Barium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.223	99167	22.11417	43384
Barium	Zinc	Process wastewater	Unknown	Unknown	0.2	99167	19.83333	43384
Barium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.074	99167	7.33833	43384
Barium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Barium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Barium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Barium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Barium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Beryllium	Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	3300	417	1375	558
Beryllium	Copper	Acid plant blowdown	Unknown	Unknown	0.125	22083	2.76042	10441
Beryllium	Copper	Acid plant blowdown	Unknown	Unknown	0.005	22083	0.11042	10441
Beryllium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.93	17500	16.275	8429
Beryllium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.18	17500	2.8	8429
Beryllium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.05	17500	0.875	8429
Beryllium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.011	17500	0.1925	8429
Beryllium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.005	17500	0.0875	8429
Beryllium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.005	17500	0.0875	8429
Beryllium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.002	17500	0.035	8429
Beryllium	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.05	117	0.00583	385
Beryllium	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.05	117	0.00583	385
Beryllium	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.05	550	0.0275	631
Beryllium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	0.25	4000	1	2341
Beryllium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown Plant	Unknown	0.0002	4000	0.0008	2341
Beryllium	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.152	42	0.00633	340
Beryllium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Beryllium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0	99167	4.95833	43384
Beryllium	Zinc	Process wastewater	Unknown	Unknown	0.01	99167	0.99167	43384
Beryllium	Zinc	Process wastewater	Unknown	Unknown	0.01	99167	0.99167	43384
Beryllium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.005	99167	0.49583	43384
Beryllium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.005	99167	0.49583	43384
Beryllium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.005	99167	0.49583	43384
Beryllium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.005	99167	0.49583	43384
Beryllium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.005	99167	0.49583	43384
Beryllium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.005	99167	0.49583	43384
Beryllium	Zinc	Process wastewater	Unknown	Unknown	0.063	417	0.02625	558
Cadmium	Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	0.063	417	0.02625	558
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	620	22083	13691.66667	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	290	22083	6404.16667	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	25.1	22083	554.29167	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	19	22083	419.58333	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	11	22083	242.91667	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	10.8	22083	238.5	10441

Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	10	22083	220.83333	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	6	22083	132.5	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	5.4	22083	119.25	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	5	22083	110.41667	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	1.3	22083	28.70833	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	1.18	22083	26.05833	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	1	22083	22.08333	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	0.52	22083	11.48333	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	0.43	22083	9.49583	10441
Cadmium	Copper	Acid plant blowdown	Unknown	Unknown	0.2	22083	4.41667	10441
Cadmium	Elemental Phosphorus	AFM rinsate	Unknown	Unknown	4	167	0.66667	415
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	9.6	17500	168.	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	4.75	17500	83.125	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	4	17500	70.	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	3.7	17500	64.75	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	3	17500	52.5	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Silver Bow	MT	2.86	17500	50.05	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	1.9	17500	33.25	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	1.3	17500	22.75	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.6675	17500	11.68125	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.593	17500	10.3775	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.024	17500	0.42	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.005	17500	0.0875	8429
Cadmium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.001	17500	0.0175	8429
Cadmium	Rare Earths	Process wastewater	D.S. Chemical, Chattanooga	TN	0.054	117	0.0063	385
Cadmium	Rare Earths	Process wastewater	MolyCorp, Louvers	CO	0.05	117	0.00583	385
Cadmium	Rare Earths	Process wastewater	MolyCorp, Louvers	CO	0.05	117	0.00583	385
Cadmium	Rare Earths	Process wastewater	D.S. Chemical, Chattanooga	TN	0.0005	117	0.00006	385
Cadmium	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.05	550	0.0275	631
Cadmium	Selenium	Plant process wastewaters	Climax Molyb.	IA	0.017	550	0.00935	631
Cadmium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unnamed Facility	Unknown	0.2	4375	0.875	2517
Cadmium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	0.25	4000	1.	2341
Cadmium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	0.16	4000	0.64	2341
Cadmium	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.05	42	0.00208	340
Cadmium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	555	99167	55037.5	43384
Cadmium	Zinc	Process wastewater	Unknown	Unknown	410	99167	4058.33333	43384
Cadmium	Zinc	Process wastewater	Unknown	Unknown	160	99167	15866.66667	43384
Cadmium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	113	99167	11205.83333	43384
Cadmium	Zinc	Process wastewater	Unknown	Unknown	93	99167	9222.5	43384
Cadmium	Zinc	Process wastewater	Unknown	Unknown	71.3	99167	7070.58333	43384
Cadmium	Zinc	Process wastewater	Jersey Miners, Clarksville	TN	62.5	99167	6197.91667	43384
Cadmium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	44	99167	4363.33333	43384
Cadmium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	38.4	99167	3808.	43384
Cadmium	Zinc	Process wastewater	Jersey Miners, Clarksville	TN	25	99167	2479.16667	43384
Cadmium	Zinc	Process wastewater	Unknown	Unknown	4	99167	396.66667	43384
Cadmium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	3.09	99167	306.425	43384
Cadmium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	2.71	99167	268.74167	43384
Cadmium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.454	99167	45.02167	43384
Cadmium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.0562	99167	5.57317	43384
Cadmium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.0185	99167	1.83458	43384
Cadmium	Zinc	Process wastewater	Unknown	Unknown	0.003	99167	0.2975	43384
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA	40000	10500	420000.	5319
Cadmium	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	5492	10500	57666.	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA	870	10500	9135.	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA	650	10500	6825.	5319
Cadmium	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	600	10500	6300.	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America	OK	160	10500	1680.	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America	OK	100	10500	1050.	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America	OK	93	10500	976.5	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America	OK	90	10500	945.	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America	OK	70	10500	735.	5319
Cadmium	Zinc	Spent surface impoundment liquids	Jersey Miners	TN	45	10500	472.5	5319
Cadmium	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	5.2	10500	54.6	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America	OK	1.3	10500	13.65	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America	OK	1.3	10500	13.65	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA	0.3	10500	3.15	5319
Cadmium	Zinc	Spent surface impoundment liquids	Zinc Corp of America, Monaca	PA	0.2	10500	2.1	5319
Cadmium	Zinc	WWTP liquid effluent	Zinc Corp of America	OK	24200	7250	175450.	3850
Cadmium	Zinc	WWTP liquid effluent	Zinc Corp of America	OK	1	7250	7.25	3850
Chromium	45 Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	7.4	417	3.08333	558
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	21	22083	463.75	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	19	22083	419.58333	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	2.37	22083	52.3375	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	1.8	22083	39.75	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	1.4	22083	30.91667	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	1.2	22083	26.5	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	1.05	22083	23.1875	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	1	22083	22.08333	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	0.78	22083	17.225	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	0.4	22083	8.83333	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	0.259	22083	5.71958	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	0.16	22083	3.53333	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	0.13	22083	2.87083	10441
Chromium	Copper	Acid plant blowdown	Unknown	Unknown	0.1	22083	2.20833	10441
Chromium	Elemental Phosphorus	AFM rinsate	Unknown	Unknown	1	167	0.16667	415
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	940	17500	16450.	8429
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	41	17500	717.5	8429
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	2	17500	35.	8429
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	1.6	17500	28.	8429
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	1.53	17500	26.775	8429

Chromium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	1.2	17500	21	8429
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Silver Bow	MT	0.07	17500	1,225	8429
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.0005	17500	0.00875	8429
Chromium	Rare Earths	Process wastewater	MolyCorp, Louvers	CO	0.5	117	0.05833	385
Chromium	Rare Earths	Process wastewater	MolyCorp, Louvers	CO	0.5	117	0.05833	385
Chromium	Rare Earths	Process wastewater	D.S. Chemical, Chattanooga	TN	0.041	117	0.00478	385
Chromium	Rare Earths	Process wastewater	D.S. Chemical, Chattanooga	TN	0.0005	117	0.00006	385
Chromium	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.5	550	0.275	631
Chromium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	2.5	4000	10	2341
Chromium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown Plant	Unknown	1.2	4000	4.8	2341
Chromium	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.5	42	0.02083	340
Chromium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.5	99167	49.58333	43384
Chromium	Zinc	Process wastewater	Zinc Corp. Monaca	PA	1	99167	49.58333	43384
Chromium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.388	99167	38.27833	43384
Chromium	Zinc	Process wastewater	Unknown	Unknown	0.06	99167	5.95	43384
Chromium	Zinc	Process wastewater	Zinc Corp. Monaca	PA	0.05	99167	4.95833	43384
Chromium	Zinc	Process wastewater	Zinc Corp. Monaca	PA	0.05	99167	4.95833	43384
Chromium	Zinc	Process wastewater	Zinc Corp. Monaca	PA	0.05	99167	4.95833	43384
Chromium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.05	99167	4.95833	43384
Chromium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.05	99167	4.95833	43384
Chromium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.045	99167	4.4625	43384
Chromium	Zinc	Process wastewater	Unknown	Unknown	0.001	99167	0.09917	43384
Cyanide	3 Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.9	17500	15.75	8429
Cyanide	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown Facility	Unknown	0.009	4375	0.03938	2517
Cyanide	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.005	99167	0.49583	43384
Lead	56 Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	0.2	417	0.08333	558
Lead	Copper	Acid plant blowdown	Unknown	Unknown	17900	22083	395291.66667	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	710	22083	15679.16667	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	700	22083	15458.33333	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	640	22083	14133.33333	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	100	22083	2208.33333	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	42.5	22083	938.54167	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	19	22083	419.58333	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	9.87	22083	217.9625	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	8	22083	176.66667	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	6.23	22083	137.57917	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	5.6	22083	123.66667	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	5	22083	110.41667	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	4.9	22083	108.20833	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	4	22083	88.33333	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	3.15	22083	69.5625	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	2.8	22083	61.83333	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	2.5	22083	55.20833	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	0.53	22083	11.70417	10441
Lead	Copper	Acid plant blowdown	Unknown	Unknown	0.2	22083	4.41667	10441
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	150	17500	2625	8429
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	52	17500	910	8429
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	1.4	17500	24.5	8429
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.955	17500	16.7125	8429
Lead	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.6	17500	10.5	8429
Lead	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.523	17500	9.1525	8429
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.037	17500	0.6475	8429
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.004	17500	0.07	8429
Lead	Rare Earths	Process wastewater	MolyCorp, Louvers	CO	8.45	117	0.98583	385
Lead	Rare Earths	Process wastewater	MolyCorp, Louvers	CO	1.23	117	0.1435	385
Lead	Rare Earths	Process wastewater	D.S. Chemical, Chattanooga	TN	0.33	117	0.0385	385
Lead	Rare Earths	Process wastewater	D.S. Chemical, Chattanooga	TN	0.0005	117	0.00006	385
Lead	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	16.9	550	9.295	631
Lead	Selenium	Plant process wastewaters	Cimax Molyb.	IA	1.42	550	0.781	631
Lead	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown Plant	Unknown	2.8	4000	11.2	2341
Lead	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	1.25	4000	5	2341
Lead	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.25	42	0.01042	340
Lead	Zinc	Process wastewater	Unknown	Unknown	300	99167	29750	43384
Lead	Zinc	Process wastewater	Zinc Corp. Monaca	PA	17	99167	1636.25	43384
Lead	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	10.9	99167	1080.91667	43384
Lead	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	9.6	99167	952	43384
Lead	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	8.3	99167	823.08333	43384
Lead	Zinc	Process wastewater	Zinc Corp. Monaca	PA	6.58	99167	652.51667	43384
Lead	Zinc	Process wastewater	Unknown	Unknown	5.8	99167	575.16667	43384
Lead	Zinc	Process wastewater	Zinc Corp. Monaca	PA	0.348	99167	34.51	43384
Lead	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.0577	99167	5.72192	43384
Lead	Zinc	Process wastewater	Zinc Corp. Monaca	PA	0.025	99167	2.47917	43384
Lead	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.025	99167	2.47917	43384
Lead	Zinc	Process wastewater	Unknown	Unknown	0.0005	99167	0.04958	43384
Lead	Zinc	Spent surface impoundment liquids	Zinc Corp. of America, Monaca	PA	200000	10500	2100000	5319
Lead	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	13950	10500	146475	5319
Lead	Zinc	Spent surface impoundment liquids	Zinc Corp. of America, Monaca	PA	7000	10500	73500	5319
Lead	Zinc	Spent surface impoundment liquids	Zinc Corp. of America, Monaca	PA	5000	10500	52500	5319
Lead	Zinc	Spent surface impoundment liquids	Zinc Corp. of America, Monaca	PA	2500	10500	26250	5319
Lead	Zinc	Spent surface impoundment liquids	Zinc Corp. of America, Monaca	PA	0.7	10500	7.35	5319
Lead	Zinc	WWTP liquid effluent	Zinc Corp. of America	OK	6100	7250	44225	3850
Mercury	42 Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	0.0002	417	0.00008	558
Mercury	Copper	Acid plant blowdown	Unknown	Unknown	1.5	22083	33.125	10441
Mercury	Copper	Acid plant blowdown	Unknown	Unknown	1.5	22083	33.125	10441
Mercury	Copper	Acid plant blowdown	Unknown	Unknown	0.36	22083	7.95	10441
Mercury	Copper	Acid plant blowdown	Unknown	Unknown	0.082	22083	1.36917	10441
Mercury	Copper	Acid plant blowdown	Unknown	Unknown	0.0428	22083	0.94517	10441
Mercury	Copper	Acid plant blowdown	Unknown	Unknown	0.0125	22083	0.27604	10441

Mercury	Copper	Acid plant blowdown	Unknown	Unknown	0.005	22083	0.11042	1044.1
Mercury	Copper	Acid plant blowdown	Unknown	Unknown	0.005	22083	0.11042	1044.1
Mercury	Copper	Acid plant blowdown	Unknown	Unknown	0.0046	22083	0.10158	1044.1
Mercury	Copper	Acid plant blowdown	Unknown	Unknown	0.0022	22083	0.04858	1044.1
Mercury	Copper	Acid plant blowdown	Unknown	Unknown	0.0018	22083	0.03975	1044.1
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.1	17500	1.75	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.05	17500	0.875	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.0002	17500	0.0035	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.00015	17500	0.00263	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Silver Bow	MT	0.00012	17500	0.0021	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.0001	17500	0.00175	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.0001	17500	0.00175	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.0001	17500	0.00175	8429
Mercury	Rare Earths	Process wastewater	Molycorp, Louvers	CO	0.0001	117	0.00001	385
Mercury	Rare Earths	Process wastewater	Molycorp, Louvers	CO	0.0001	117	0.00001	385
Mercury	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.00072	550	0.0004	631
Mercury	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	0.0016	4000	0.0064	2341
Mercury	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	0.0002	4000	0.0008	2341
Mercury	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.0001	42	0.	340
Mercury	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0	99167	34.51	43384
Mercury	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.0274	99167	2.71717	43384
Mercury	Zinc	Process wastewater	Unknown	Unknown	0.018	99167	1.785	43384
Mercury	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.00999	99167	0.99098	43384
Mercury	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.0065	99167	0.64458	43384
Mercury	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.0031	99167	0.30742	43384
Mercury	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.0019	99167	0.18842	43384
Mercury	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.00075	99167	0.07438	43384
Mercury	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.0001	99167	0.00992	43384
Mercury	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.0001	99167	0.00992	43384
Mercury	Zinc	Process wastewater	Unknown	Unknown	0.0001	99167	0.00992	43384
Mercury	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	23.8	10500	249.9	5319
Mercury	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	3.538	10500	37.149	5319
Mercury	Zinc	Spent surface impoundment liquids	Jersey Miniere	TN	1	10500	10.5	5319
Mercury	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	1	10500	10.5	5319
Mercury	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	0.17	10500	1.785	5319
Nickel	43 Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	0.78	417	0.325	551
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	1450	22083	32020.83333	1044.1
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	940	22083	20758.33333	1044.1
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	20	22083	441.66667	1044.1
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	16	22083	353.33333	1044.1
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	2	22083	44.16667	1044.1
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	1.95	22083	43.0625	1044.1
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	1.8	22083	39.75	1044.1
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	1.2	22083	26.5	1044.1
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	1.2	22083	26.5	1044.1
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	0.481	22083	10.62208	1044.1
Nickel	Copper	Acid plant blowdown	Unknown	Unknown	0.006	22083	0.11042	1044.1
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	530	17500	927.5	8429
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	19	17500	332.5	8429
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	1.3	17500	22.75	8429
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.5	17500	8.75	8429
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.2	17500	3.5	8429
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.009	17500	0.1575	8429
Nickel	Rare Earths	Process wastewater	D.S. Chemical, Chattanooga	TN	4	117	0.46667	385
Nickel	Rare Earths	Process wastewater	Molycorp, Louvers	CO	0.5	117	0.05833	385
Nickel	Rare Earths	Process wastewater	Molycorp, Louvers	CO	0.5	117	0.05833	385
Nickel	Rare Earths	Process wastewater	D.S. Chemical, Chattanooga	TN	0.008	117	0.00093	385
Nickel	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.5	550	0.275	631
Nickel	Selenium	Plant process wastewaters	Cimax Molyb.	IA	0.1	550	0.055	631
Nickel	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unnamed Facility	Unknown	1	4375	4.375	2517
Nickel	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	7	4000	28.	2341
Nickel	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	2.5	4000	10.	2341
Nickel	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.5	42	0.02083	340
Nickel	Zinc	Process wastewater	Zinc Corp, Monaca	PA	11	99167	1041.25	43384
Nickel	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	8.12	99167	805.23333	43384
Nickel	Zinc	Process wastewater	Unknown	Unknown	6.3	99167	624.75	43384
Nickel	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	1.6	99167	158.66667	43384
Nickel	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.5	99167	49.58333	43384
Nickel	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Nickel	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Nickel	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Nickel	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Nickel	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Nickel	Zinc	Process wastewater	Unknown	Unknown	0.03	99167	2.975	43384
Nickel	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	257	10500	2698.5	5319
Nickel	Zinc	WWTP liquid effluent	Zinc Corp of America	OK	410	7250	2972.5	3851
Selenium	43 Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	0.003	417	0.00125	551
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	1000	22083	22083.33333	1044.1
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	11.9	22083	262.79167	1044.1
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	9.1	22083	200.95833	1044.1
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	2.1	22083	46.375	1044.1
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	2	22083	44.16667	1044.1
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	0.761	22083	16.80542	1044.1
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	0.5	22083	11.04167	1044.1
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	0.12	22083	2.65	1044.1
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	0.1	22083	2.20833	1044.1
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	0.005	22083	0.11042	1044.1
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	0.005	22083	0.11042	1044.1

Selenium	Copper	Acid plant blowdown	Unknown	Unknown	0.005	22083	0.11042	10441
Selenium	Copper	Acid plant blowdown	Unknown	Unknown	0.002	22083	0.04417	10441
Selenium	Elemental Phosphorus	AFM rinsate	Unknown	Unknown	1	167	0.16667	415
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	1	17500	17.5	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.5	17500	8.75	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.045	17500	0.7875	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Silver Bow	MT	0.045	17500	0.7875	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.0025	17500	0.04375	8429
Selenium	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.5	117	0.05833	385
Selenium	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.5	117	0.05833	385
Selenium	Selenium	Plant process wastewaters	Climax Molyb.	IA	3.6	550	1.98	631
Selenium	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.5	550	0.275	631
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unnamed Facility	Unknown	0.01	4375	0.04375	2517
Selenium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	2.5	4000	10	2341
Selenium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	0.014	4000	0.056	2341
Selenium	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.5	42	0.02083	340
Selenium	Zinc	Process wastewater	Unknown	Unknown	100000	99167	9916666.66667	43384
Selenium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.5	99167	49.58333	43384
Selenium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	1	99167	49.58333	43384
Selenium	Zinc	Process wastewater	Unknown	Unknown	0.39	99167	38.675	43384
Selenium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Selenium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Selenium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Selenium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Selenium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Selenium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Selenium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.01	99167	0.99167	43384
Selenium	Zinc	Process wastewater	Unknown	Unknown	0.0025	99167	0.24792	43384
Selenium	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	11	10500	115.5	5319
Silver	Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	0.04	417	0.01667	558
Silver	Copper	Acid plant blowdown	Unknown	Unknown	124	22083	2738.33333	10441
Silver	Copper	Acid plant blowdown	Unknown	Unknown	1	22083	22.08333	10441
Silver	Copper	Acid plant blowdown	Unknown	Unknown	1	22083	22.08333	10441
Silver	Copper	Acid plant blowdown	Unknown	Unknown	0.5	22083	11.04167	10441
Silver	Copper	Acid plant blowdown	Unknown	Unknown	0.05	22083	1.10417	10441
Silver	Copper	Acid plant blowdown	Unknown	Unknown	0.04	22083	0.88333	10441
Silver	Copper	Acid plant blowdown	Unknown	Unknown	0.03	22083	0.6625	10441
Silver	Copper	Acid plant blowdown	Unknown	Unknown	0.022	22083	0.48583	10441
Silver	Copper	Acid plant blowdown	Unknown	Unknown	0.02	22083	0.44167	10441
Silver	Copper	Acid plant blowdown	Unknown	Unknown	0.01	22083	0.22083	10441
Silver	Copper	Acid plant blowdown	Unknown	Unknown	0.0025	22083	0.05521	10441
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	1.6	17500	28	8429
Silver	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	1.03	17500	18.025	8429
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.6	17500	10.5	8429
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.001	17500	0.0175	8429
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.001	17500	0.0175	8429
Silver	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.5	117	0.05833	385
Silver	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.5	117	0.05833	385
Silver	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.5	550	0.275	631
Silver	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	2.5	4000	10	2341
Silver	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	0.034	4000	0.136	2341
Silver	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.5	42	0.02083	340
Silver	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.5	99167	49.58333	43384
Silver	Zinc	Process wastewater	Zinc Corp, Monaca	PA	1	99167	49.58333	43384
Silver	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Silver	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Silver	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.05	99167	4.95833	43384
Silver	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Silver	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Silver	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.05	99167	4.95833	43384
Silver	Zinc	Process wastewater	Unknown	Unknown	0.01	99167	0.99167	43384
Silver	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	0.0025	99167	0.24792	43384
Silver	Zinc	Process wastewater	Unknown	Unknown	0.0015	99167	0.14875	43384
Silver	Zinc	Spent surface impoundment liquids	Big River Zinc	IL	185.2	10500	1944.6	5319
Silver	Zinc	WWTP liquid effluent	Zinc Corp of America	OK	58.286	7250	422.5735	3850
Thallium	Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	0.002	417	0.00083	558
Thallium	Copper	Acid plant blowdown	Unknown	Unknown	2.5	22083	55.20833	10441
Thallium	Copper	Acid plant blowdown	Unknown	Unknown	0.25	22083	5.52083	10441
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	4.5	17500	78.75	8429
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	4.5	17500	78.75	8429
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	2.5	17500	43.75	8429
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.25	17500	4.375	8429
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.25	17500	4.375	8429
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.0455	17500	0.79625	8429
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.045	17500	0.7875	8429
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.04	17500	0.7	8429
Thallium	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	2.5	117	0.29167	385
Thallium	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	2.5	117	0.29167	385
Thallium	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	2.5	550	1.375	631
Thallium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	12.5	4000	50	2341
Thallium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	2.4	4000	9.6	2341
Thallium	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	2.5	42	0.10417	340
Thallium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	3.59	99167	356.00833	43384
Thallium	Zinc	Process wastewater	Zinc Corp, Bartlesville	OK	2.5	99167	247.91667	43384
Thallium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	3	99167	247.91667	43384
Thallium	Zinc	Process wastewater	Zinc Corp, Monaca	PA	0.25	99167	24.79167	43384

Thallium	Zinc	Process wastewater	Zinc Corp. Monaca	PA	0.25	99167	24.79167	43384
Thallium	Zinc	Process wastewater	Zinc Corp. Monaca	PA	0.25	99167	24.79167	43384
Thallium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.25	99167	24.79167	43384
Thallium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.25	99167	24.79167	43384
Thallium	Zinc	Process wastewater	Unknown	Unknown	0.17	99167	16.85833	43384
Thallium	Zinc	Process wastewater	Unknown	Unknown	0.05	99167	4.95833	43384
Thallium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.024	99167	2.38	43384
Vanadium	Copper	Acid plant blowdown	Unknown	Unknown	2.72	22083	60.06667	10441
Vanadium	Copper	Acid plant blowdown	Unknown	Unknown	0.05	22083	1.10417	10441
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	710	17500	12425	8429
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	35	17500	612.5	8429
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	1.5	17500	26.25	8429
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	1.27	17500	22.225	8429
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	0.8	17500	14	8429
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Silver Bow	MT	0.53	17500	9.275	8429
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	0.05	17500	0.875	8429
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.015	17500	0.2625	8429
Vanadium	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.5	117	0.05833	385
Vanadium	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	0.5	117	0.05833	385
Vanadium	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.5	550	0.275	631
Vanadium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	2.5	4000	10	2341
Vanadium	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	1.51	42	0.06292	340
Vanadium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.5	99167	49.58333	43384
Vanadium	Zinc	Process wastewater	Zinc Corp. Monaca	PA	1	99167	49.58333	43384
Vanadium	Zinc	Process wastewater	Zinc Corp. Monaca	PA	0.05	99167	4.95833	43384
Vanadium	Zinc	Process wastewater	Zinc Corp. Monaca	PA	0.05	99167	4.95833	43384
Vanadium	Zinc	Process wastewater	Zinc Corp. Monaca	PA	0.05	99167	4.95833	43384
Vanadium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.05	99167	4.95833	43384
Vanadium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.05	99167	4.95833	43384
Vanadium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.05	99167	4.95833	43384
Vanadium	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	0.03	99167	2.975	43384
Vanadium	Zinc	Process wastewater	Unknown	Unknown	0.005	99167	0.49583	43384
Vanadium	Zinc	Process wastewater	Unknown	Unknown	0.005	99167	0.49583	43384
Zinc	Beryllium	Chip treatment wastewater	One Unnamed Facility	Unknown	7.2	417	3	558
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	10000	22083	220833.33333	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	9200	22083	203166.66667	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	2030	22083	44829.16667	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	856	22083	18903.33333	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	115	22083	2539.58333	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	100	22083	2208.33333	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	91.13	22083	2012.45417	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	73.2	22083	1616.5	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	51	22083	1126.25	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	48.2	22083	1064.41667	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	7.79	22083	172.02917	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	5.7	22083	125.875	10441
Zinc	Copper	Acid plant blowdown	Unknown	Unknown	5.1	22083	112.625	10441
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	211	17500	3692.5	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	196	17500	3430	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	160	17500	2800	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	130	17500	2275	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	77	17500	1347.5	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	69	17500	1207.5	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	FMC, Pocatello	ID	50	17500	875	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Monanto, Soda Springs	ID	47	17500	822.5	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	3.94	17500	68.95	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Silver Bow	MT	3.94	17500	68.95	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Stauffer, Mt. Pleasant	TN	1.38	17500	24.15	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown American Plant	Unknown	0.023	17500	0.4025	8429
Zinc	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	14.2	117	1.65667	385
Zinc	Rare Earths	Process wastewater	MolyCorp, Louviers	CO	1.98	117	0.231	385
Zinc	Selenium	Plant process wastewaters	AMAX, Fort Madison	IA	0.5	550	0.275	631
Zinc	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Timet, Henderson	NV	2.5	4000	10	2341
Zinc	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown Plant	Unknown	0.54	4000	2.16	2341
Zinc	Titanium and Titanium Dioxide	Scrap milling scrubber water	SCM, Baltimore	MD	0.5	42	0.02083	340
Zinc	Zinc	Process wastewater	Unknown	Unknown	60000	99167	5950000	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	25000	99167	2479166.66667	43384
Zinc	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	20100	99167	1993250	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	11000	99167	1090833.33333	43384
Zinc	Zinc	Process wastewater	Zinc Corp. Monaca	PA	10,200	99167	1011500	43384
Zinc	Zinc	Process wastewater	Jersey Miniare, Clarksville	TN	6000	99167	595000	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	4900	99167	485916.66667	43384
Zinc	Zinc	Process wastewater	Jersey Miniare, Clarksville	TN	2840	99167	281633.33333	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	2430	99167	240975	43384
Zinc	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	1800	99167	158666.66667	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	1130	99167	112058.33333	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	640	99167	63466.66667	43384
Zinc	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	410	99167	40658.33333	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	144.2	99167	14299.83333	43384
Zinc	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	91.8	99167	9103.5	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	87	99167	8627.5	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	50	99167	4958.33333	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	50	99167	4958.33333	43384
Zinc	Zinc	Process wastewater	Unknown	Unknown	50	99167	4958.33333	43384
Zinc	Zinc	Process wastewater	Zinc Corp. Monaca	PA	31.9	99167	3163.41667	43384
Zinc	Zinc	Process wastewater	Big River Zinc	IL	20	99167	1983.33333	43384
Zinc	Zinc	Process wastewater	Zinc Corp. Monaca	PA	14.4	99167	1428	43384
Zinc	Zinc	Process wastewater	Zinc Corp. Monaca	PA	10.9	99167	1080.91667	43384
Zinc	Zinc	Process wastewater	Zinc Corp. Bartlesville	OK	6.37	99167	631.69167	43384

Zinc	Zinc	Process wastewater	Unknown	Unknown	3	99167	297.5	43384
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America, Monaca	PA	800000	10500		8400000.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America, Monaca	PA	650000	10500		6825000.	5319
Zinc	Zinc	Spent surface impoundment liquids Big River Zinc	IL	589000	10500		6184500.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America, Monaca	PA	500000	10500		5250000.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America, Monaca	PA	300000	10500		3150000.	5319
Zinc	Zinc	Spent surface impoundment liquids Big River Zinc	IL	52000	10500		546000.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America, Monaca	PA	10000	10500		105000.	5319
Zinc	Zinc	Spent surface impoundment liquids Jersey Miniere	TN	8100	10500		64050.	5319
Zinc	Zinc	Spent surface impoundment liquids Jersey Miniere	TN	3400	10500		35700.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America	OK	2430	10500		25515.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America	OK	1400	10500		14700.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America	OK	1400	10500		14700.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America	OK	1130	10500		11865.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America	OK	890	10500		9345.	5319
Zinc	Zinc	Spent surface impoundment liquids Big River Zinc	IL	712	10500		7476.	5319
Zinc	Zinc	Spent surface impoundment liquids Big River Zinc	IL	200	10500		2100.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America, Monaca	PA	50	10500		525.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America, Monaca	PA	50	10500		525.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America	OK	19.3	10500		202.65	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America	OK	19.3	10500		202.65	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America, Monaca	PA	10	10500		105.	5319
Zinc	Zinc	Spent surface impoundment liquids Zinc Corp of America, Monaca	PA	0.8	10500		8.4	5319
Zinc	Zinc	WWTP liquid effluent Zinc Corp of America	OK	450000	7250		3262500.	3850
Zinc	Zinc	WWTP liquid effluent Jersey Miniere	TN	2000	7250		14500.	3850
Zinc	Zinc	WWTP liquid effluent Zinc Corp of America	OK	20	7250		145.	3850

EP Analysis Samples. Nonwastewaters.

Constituents	Number of Detections	Commodity	Waste Stream	Facility Identifier	State	Constituent Concentration in Leachate (mg/l)	Volume of Waste Pile (m ³) (1)	Leachable Constituent Mass per Waste Pile (kg) (5)	Area of Waste Pile (m ²)
Antimony	1	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	0.42	107	1.21984	106
Arsenic	3	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	0.001	107	0.0029	106
Arsenic		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.65	1671	29.56881	676
Arsenic		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.1	1671	4.54905	676
Barium	3	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	0.28	107	0.81323	106
Barium		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	149	1671	6778.08037	676
Barium		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	14.9	1671	677.80804	676
Cadmium	3	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	3.5	107	10.16537	106
Cadmium		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.027	1671	1.22824	676
Cadmium		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.01	1671	0.4549	676
Chromium	3	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	0.086	107	0.24978	106
Chromium		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.054	1671	2.45649	676
Chromium		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.023	1671	1.04628	676
Lead	3	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	0.024	107	0.06971	106
Lead		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	3.64	1671	165.58532	676
Lead		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.043	1671	1.95609	676
Mercury	3	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	0.84	107	2.43969	106
Mercury		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.001	1671	0.04549	676
Mercury		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.0008	1671	0.03639	676
Nickel	1	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	0.74	107	2.14929	106
Selenium	3	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	0.001	107	0.0029	106
Selenium		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.016	1671	0.72785	676
Selenium		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.013	1671	0.59138	676
Silver	3	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	0.15	107	0.43566	106
Silver		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.14	1671	6.36887	676
Silver		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.05	1671	2.27452	676
Zinc	3	Alumina and Aluminum	Cast house dust	Facilities Surveyed	Unknown	0.58	107	1.68455	106
Zinc		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.69	1671	31.38843	676
Zinc		Magnesium and Magnesia from Brines	Smut	Unknown American Plant	Unknown	0.02	1671	0.90981	676

EP Analysis Samples. Wastewaters and Liquid Nonwastewaters.

Constituents	Number of Detections	Commodity	Waste Stream	Facility Identifier	State	Constituent Concentration in Leachate (mg/l)	Volume of Surface Impoundment (m ³) (3)	Leachable Constituent Mass in Surface Impoundment (kg) (6)	Area of Surface Impoundment (m ²)
Antimony	25	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	5	22083	215.3125	1044
Antimony		Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.168	22083	7.2345	1044
Antimony		Elemental Phosphorus	AFM rinse	Unknown	Unknown	0.2	167	0.065	41
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	1.6	17500	54.6	842
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	1.17	17500	39.92625	842
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.47	17500	16.03875	842
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.16	17500	5.46	842
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.16	17500	5.46	842
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	842
Antimony		Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	842
Antimony		Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38
Antimony		Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38

Antimony	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Antimony	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Antimony	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Antimony	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Antimony	Selenium	Plant process wastewaters	Unknown	Unknown	0.5	550	0.53625	63
Antimony	Selenium	Plant process wastewaters	Unknown	Unknown	0.5	550	0.53625	63
Antimony	Selenium	Plant process wastewaters	Unknown	Unknown	0.5	550	0.53625	63
Antimony	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.224	4375	1.911	2517
Antimony	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Antimony	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Antimony	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Antimony	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Antimony	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
49	Copper	Acid plant blowdown	Magma, San Manuel	AZ	12800	22083	551200	1044
Arsenic	Copper	Acid plant blowdown	CBI	CBI	193	22083	8311.0625	1044
Arsenic	Copper	Acid plant blowdown	CBI	CBI	126	22083	5425.875	1044
Arsenic	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	32.8	22083	1412.45	1044
Arsenic	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	31.1	22083	1339.24375	1044
Arsenic	Copper	Acid plant blowdown	Magma, San Manuel	AZ	29.9	22083	1287.56875	1044
Arsenic	Copper	Acid plant blowdown	CBI	CBI	21.6	22083	930.15	1044
Arsenic	Copper	Acid plant blowdown	CBI	CBI	14.1	22083	607.18125	1044
Arsenic	Copper	Acid plant blowdown	Magma, San Manuel	AZ	11.2	22083	482.3	1044
Arsenic	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	5	22083	215.3125	1044
Arsenic	Copper	Acid plant blowdown	CBI	CBI	0.19	22083	8.18188	1044
Arsenic	Copper	Acid plant blowdown	CBI	CBI	0.18	22083	7.75125	1044
Arsenic	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.05	22083	2.15313	1044
Arsenic	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.05	22083	2.15313	1044
Arsenic	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.04	22083	1.7225	1044
Arsenic	Elemental Phosphorus	AFM rinsate	Unknown	Unknown	0.14	167	0.0455	415
Arsenic	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.543	17500	18.52988	8429
Arsenic	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.15	17500	5.11875	8429
Arsenic	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.0619	17500	2.11234	8429
Arsenic	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	8429
Arsenic	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	8429
Arsenic	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.00125	17500	0.04266	8429
Arsenic	Rare Earths	Process wastewater	Unknown	Unknown	4.97	117	1.13068	385
Arsenic	Rare Earths	Process wastewater	Unknown	Unknown	1.1	117	0.25025	385
Arsenic	Rare Earths	Process wastewater	Unknown	Unknown	0.945	117	0.21499	385
Arsenic	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Arsenic	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Arsenic	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Arsenic	Selenium	Plant process wastewaters	Unknown	Unknown	0.5	550	0.53625	63
Arsenic	Selenium	Plant process wastewaters	Unknown	Unknown	0.5	550	0.53625	63
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.5	4375	4.26563	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Zinc Corp of America, Monaca	PA	0.5	4375	4.26563	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.15	4375	1.27969	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.132	4375	1.12613	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	AMAX, East St. Louis	IL	0.05	4375	0.42656	2517
Arsenic	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unnamed Plant	Unknown	0.027	4375	0.23034	2517
Arsenic	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown	Unknown	0.01	4000	0.078	234
Arsenic	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown	Unknown	0.01	4000	0.078	234
Arsenic	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	0.005	4000	0.039	234
Arsenic	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	0.003	4000	0.0234	234
Arsenic	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown	Unknown	0.002	4000	0.0156	234
Arsenic	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.02	42	0.00163	34
Arsenic	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.0125	42	0.00102	34
51	Copper	Acid plant blowdown	CBI	CBI	10.9	22083	469.38125	1044
Barium	Copper	Acid plant blowdown	CBI	CBI	9.8	22083	413.4	1044
Barium	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	5	22083	215.3125	1044
Barium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	5	22083	215.3125	1044
Barium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	5	22083	215.3125	1044
Barium	Copper	Acid plant blowdown	CBI	CBI	0.8	22083	34.45	1044
Barium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.4	22083	17.225	1044
Barium	Copper	Acid plant blowdown	CBI	CBI	0.4	22083	17.225	1044
Barium	Copper	Acid plant blowdown	CBI	CBI	0.3	22083	12.91875	1044
Barium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.2	22083	8.6125	1044
Barium	Copper	Acid plant blowdown	CBI	CBI	0.2	22083	8.6125	1044
Barium	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.136	22083	5.8565	1044
Barium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.1	22083	4.30625	1044
Barium	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.05	22083	2.15313	1044
Barium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.05	22083	2.15313	1044
Barium	Elemental Phosphorus	AFM rinsate	Unknown	Unknown	1	167	0.325	411
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	1.2	17500	40.95	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	1	17500	34.125	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.81	17500	27.64125	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.25	17500	8.53125	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.2	17500	6.825	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	8429
Barium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	8429
Barium	Rare Earths	Process wastewater	Unknown	Unknown	10	117	2.275	38
Barium	Rare Earths	Process wastewater	Unnamed Plant	Unknown	6	117	1.365	38
Barium	Rare Earths	Process wastewater	Unknown	Unknown	5	117	1.1375	38
Barium	Rare Earths	Process wastewater	Unnamed Plant	Unknown	3.7	117	0.84175	38
Barium	Rare Earths	Process wastewater	Unknown	Unknown	1.2	117	0.273	38

[illegible]

Cadmium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown	Unknown	0.007	4000	0.0546	234
Cadmium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown	Unknown	0.005	4000	0.039	234
Cadmium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown	Unknown	0.003	4000	0.0234	234
Cadmium	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.03	42	0.00244	34
Cadmium	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.025	42	0.00203	34
48 Chromium	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	5	22083	215.3125	1044
Chromium	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.254	22083	10.93788	1044
Chromium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.25	22083	10.76563	1044
Chromium	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.241	22083	10.37806	1044
Chromium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.171	22083	7.36369	1044
Chromium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.1	22083	4.30625	1044
Chromium	Copper	Acid plant blowdown	CBI	CBI	0.029	22083	1.24881	1044
Chromium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.029	22083	1.24881	1044
Chromium	Copper	Acid plant blowdown	CBI	CBI	0.024	22083	1.0335	1044
Chromium	Copper	Acid plant blowdown	CBI	CBI	0.008	22083	0.3445	1044
Chromium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.005	22083	0.21531	1044
Chromium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.005	22083	0.21531	1044
Chromium	Copper	Acid plant blowdown	CBI	CBI	0.005	22083	0.21531	1044
Chromium	Copper	Acid plant blowdown	CBI	CBI	0.005	22083	0.21531	1044
Chromium	Copper	Acid plant blowdown	CBI	CBI	0.003	22083	0.12919	1044
Chromium	Elemental Phosphorus	AFM rinse	Unknown	Unknown	0.278	167	0.09035	41
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.9	17500	30.7125	842
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.841	17500	28.69913	842
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.5	17500	17.0625	842
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.22	17500	7.5075	842
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	842
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	842
Chromium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.005	17500	0.17063	842
Chromium	Rare Earths	Process wastewater	Unknown	Unknown	6.45	117	1.46738	38
Chromium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38
Chromium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38
Chromium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38
Chromium	Selenium	Plant process wastewaters	Unknown	Unknown	0.5	550	0.53625	63
Chromium	Selenium	Plant process wastewaters	Unknown	Unknown	0.5	550	0.53625	63
Chromium	Selenium	Plant process wastewaters	Unknown	Unknown	0.5	550	0.53625	63
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Zinc Corp of America, Monaca	PA	0.5	4375	4.26563	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.111	4375	0.94697	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.08	4375	0.6825	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.08	4375	0.6825	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.079	4375	0.67397	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.039	4375	0.33272	251
Chromium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.03	4375	0.25594	251
Chromium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	0.012	4000	0.0936	234
Chromium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown	Unknown	0.005	4000	0.039	234
Chromium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	0.001	4000	0.0078	234
Chromium	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unnamed Plant	Unknown	0.001	4000	0.0078	234
Chromium	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.027	42	0.00219	34
Chromium	Titanium and Titanium Dioxide	Scrap milling scrubber water	AMAX, East St. Louis	IL	0.025	42	0.00203	34
44 Lead	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	6.74	22083	290.24125	1044
Lead	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	6.47	22083	278.61438	1044
Lead	Copper	Acid plant blowdown	Magma, San Manuel	AZ	5.71	22083	245.88688	1044
Lead	Copper	Acid plant blowdown	Magma, San Manuel	AZ	3.8	22083	163.6375	1044
Lead	Copper	Acid plant blowdown	Magma, San Manuel	AZ	3.73	22083	160.62313	1044
Lead	Copper	Acid plant blowdown	CBI	CBI	2.89	22083	124.45063	1044
Lead	Copper	Acid plant blowdown	CBI	CBI	2.55	22083	109.80938	1044
Lead	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	2.5	22083	107.65625	1044
Lead	Copper	Acid plant blowdown	Magma, San Manuel	AZ	2.5	22083	107.65625	1044
Lead	Copper	Acid plant blowdown	CBI	CBI	2.49	22083	107.22563	1044
Lead	Copper	Acid plant blowdown	CBI	CBI	1.74	22083	74.92875	1044
Lead	Copper	Acid plant blowdown	CBI	CBI	0.896	22083	38.584	1044
Lead	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.25	22083	10.76563	1044
Lead	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.2	22083	8.6125	1044
Lead	Copper	Acid plant blowdown	CBI	CBI	0.042	22083	1.80863	1044
Lead	Elemental Phosphorus	AFM rinse	Unknown	Unknown	0.19	167	0.06175	41
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.42	17500	14.3325	842
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.42	17500	14.3325	842
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.357	17500	12.18263	842
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.217	17500	7.40513	842
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.125	17500	4.26563	842
Lead	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.11	17500	3.75375	842
Lead	Rare Earths	Process wastewater	Unknown	Unknown	2.5	117	0.56875	38
Lead	Rare Earths	Process wastewater	Unnamed Plant	Unknown	2.36	117	0.5369	38
Lead	Rare Earths	Process wastewater	Unknown	Unknown	1.99	117	0.45273	38
Lead	Rare Earths	Process wastewater	Unknown	Unknown	1	117	0.2275	38
Lead	Selenium	Plant process wastewaters	AMAX, East St. Louis	IL	1	550	1.0725	63
Lead	Selenium	Plant process wastewaters	Unknown	Unknown	0.628	550	0.67353	63
Lead	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.582	4375	4.79456	251
Lead	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.25	4375	2.13281	251
Lead	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.25	4375	2.13281	251
Lead	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.25	4375	2.13281	251
Lead	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.25	4375	2.13281	251
Lead	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.221	4375	1.88541	251
Lead	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.141	4375	1.20291	251
Lead	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.1	4375	0.85313	251
Lead	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.098	4375	0.83606	251

Lead	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.025	4375	0.21328	2517	
Lead	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.025	4375	0.21328	2517	
Lead	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.02	4375	0.17063	2517	
Lead	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown	Unknown	0.01	4000	0.078	2341
Lead	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Unknown	Unknown	0.005	4000	0.039	2341
Lead	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.016	42	0.0013	340
Lead	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.01	42	0.00081	340
Mercury	Copper	Acid plant blowdown	CBI	CBI	0.31	22083	13.34938	10441
Mercury	Copper	Acid plant blowdown	CBI	CBI	0.26	22083	11.19625	10441
Mercury	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.0223	22083	0.96029	10441
Mercury	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.0115	22083	0.49522	10441
Mercury	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.01	22083	0.43063	10441
Mercury	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.007	22083	0.30144	10441
Mercury	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.005	22083	0.21531	10441
Mercury	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.005	22083	0.21531	10441
Mercury	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.005	22083	0.21531	10441
Mercury	Copper	Acid plant blowdown	CBI	CBI	0.0013	22083	0.05598	10441
Mercury	Copper	Acid plant blowdown	CBI	CBI	0.0013	22083	0.05598	10441
Mercury	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.0004	22083	0.01723	10441
Mercury	Copper	Acid plant blowdown	CBI	CBI	0.0003	22083	0.01292	10441
Mercury	Copper	Acid plant blowdown	CBI	CBI	0.0003	22083	0.01292	10441
Mercury	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	0.0001	22083	0.00431	10441
Mercury	Elemental Phosphorus	AFM rinsate	Unknown	Unknown	0.0005	167	0.00016	415
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.0005	17500	0.01706	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.00015	17500	0.00512	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.00015	17500	0.00512	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.0001	17500	0.00341	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.0001	17500	0.00341	8429
Mercury	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.0001	17500	0.00341	8429
Mercury	Rare Earths	Process wastewater	Unknown	Unknown	0.0065	117	0.00148	385
Mercury	Rare Earths	Process wastewater	Unknown	Unknown	0.0029	117	0.00066	385
Mercury	Rare Earths	Process wastewater	Unknown	Unknown	0.0024	117	0.00055	385
Mercury	Rare Earths	Process wastewater	Unknown	Unknown	0.0024	117	0.00055	385
Mercury	Rare Earths	Process wastewater	Unknown	Unknown	0.0023	117	0.00052	385
Mercury	Rare Earths	Process wastewater	Unknown	Unknown	0.0011	117	0.00025	385
Mercury	Selenium	Plant process wastewaters	Unknown	Unknown	0.001	550	0.00107	631
Mercury	Selenium	Plant process wastewaters	Unknown	Unknown	0.001	550	0.00107	631
Mercury	Selenium	Plant process wastewaters	Unknown	Unknown	0.00088	550	0.00094	631
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.00028	4375	0.00239	2517	
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.0001	4375	0.00085	2517	
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.0001	4375	0.00085	2517	
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.0001	4375	0.00085	2517	
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.0001	4375	0.00085	2517	
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.0001	4375	0.00085	2517	
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.0001	4375	0.00085	2517	
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.0001	4375	0.00085	2517	
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.0001	4375	0.00085	2517	
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.0001	4375	0.00085	2517	
Mercury	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.0001	4375	0.00085	2517	
Mercury	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	Zinc Corp of America, Monaca	PA	0.0001	4000	0.00078	234
Mercury	Titanium and Titanium Dioxide	Leach liquid & sponge wash water	AMAX, East St. Louis	IL	0.00005	4000	0.00039	234
Mercury	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.0001	42	0.00001	34
Mercury	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.0001	42	0.00001	34
Nickel	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	5	22083	215.3125	10441
Nickel	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.466	22083	20.06713	10441
Nickel	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.02	22083	0.86125	10441
Nickel	Elemental Phosphorus	AFM rinsate	Unknown	Unknown	0.08	167	0.026	4
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.25	17500	8.53125	84
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.165	17500	5.63063	84
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70825	84
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70825	84
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.03	17500	1.02375	84
Nickel	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.015	17500	0.51188	84
Nickel	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	3
Nickel	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	3
Nickel	Rare Earths	Process wastewater	Unknown	Unknown	0.17	117	0.03868	3
Nickel	Rare Earths	Process wastewater	Unknown	Unknown	0.17	117	0.03868	3
Nickel	Selenium	Plant process wastewaters	Unknown	Unknown	0.05	550	0.05363	3
Nickel	Selenium	Plant process wastewaters	Unknown	Unknown	0.05	550	0.05363	3
Nickel	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2	
Nickel	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2	
Nickel	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2	
Nickel	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2	
Nickel	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.031	4375	0.26447	2	
Nickel	Tantalum, Columbium, and Ferrocolumbium Process wastewater	Unknown	Unknown	0.004	4375	0.03413	2	
Selenium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	7.63	22083	328.56688	10441
Selenium	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	5	22083	215.3125	10441
Selenium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	2.9	22083	124.88125	10441
Selenium	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.668	22083	28.76575	10441
Selenium	Copper	Acid plant blowdown	CBI	CBI	0.61	22083	26.26813	10441
Selenium	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.444	22083	19.11975	10441
Selenium	Copper	Acid plant blowdown	CBI	CBI	0.28	22083	12.0575	10441
Selenium	Copper	Acid plant blowdown	CBI	CBI	0.16	22083	6.89	10441
Selenium	Copper	Acid plant blowdown	CBI	CBI	0.16	22083	6.89	10441
Selenium	Copper	Acid plant blowdown	CBI	CBI	0.088	22083	2.92825	10441
Selenium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.05	22083	2.15313	10441
Selenium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.05	22083	2.15313	10441
Selenium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.05	22083	2.15313	10441
Selenium	Copper	Acid plant blowdown	CBI	CBI	0.028	22083	1.20575	10441

Selenium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.005	22083	0.21531	10441
Selenium	Elemental Phosphorus	AFM rinse	Unknown	Unknown	1.03	167	0.33475	415
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.44	17500	15.015	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.25	17500	8.53125	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.0025	17500	0.08531	8429
Selenium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.0025	17500	0.08531	8429
Selenium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Selenium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Selenium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Selenium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Selenium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Selenium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Selenium	Selenium	Plant process wastewaters	Unknown	Unknown	0.5	550	0.53625	631
Selenium	Selenium	Plant process wastewaters	Zinc Corp of America, Monaca PA	PA	0.5	550	0.53625	631
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	AMAX, East St. Louis	IL	0.2	4375	1.70625	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.095	4375	0.81047	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.036	4375	0.30713	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.023	4375	0.19622	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.01	4375	0.08531	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.01	4375	0.08531	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.0065	4375	0.05545	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.003	4375	0.02559	2517
Selenium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.0025	4375	0.02133	2517
Selenium	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.001	42	0.00008	340
Selenium	Titanium and Titanium Dioxide	Scrap milling scrubber water	Unknown	Unknown	0.001	42	0.00008	340
49	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	5	22083	215.3125	10441
Silver	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.25	22083	10.76563	10441
Silver	Copper	Acid plant blowdown	CBI	CBI	0.2	22083	8.6125	10441
Silver	Copper	Acid plant blowdown	CBI	CBI	0.15	22083	6.45938	10441
Silver	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.1	22083	4.30625	10441
Silver	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.1	22083	4.30625	10441
Silver	Copper	Acid plant blowdown	CBI	CBI	0.1	22083	4.30625	10441
Silver	Copper	Acid plant blowdown	CBI	CBI	0.07	22083	3.01438	10441
Silver	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.05	22083	2.15313	10441
Silver	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.04	22083	1.7225	10441
Silver	Copper	Acid plant blowdown	CBI	CBI	0.015	22083	0.64594	10441
Silver	Copper	Acid plant blowdown	CBI	CBI	0.015	22083	0.64594	10441
Silver	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.005	22083	0.21531	10441
Silver	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.005	22083	0.21531	10441
Silver	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.005	22083	0.21531	10441
Silver	Elemental Phosphorus	AFM rinse	Unknown	Unknown	0.02	167	0.0065	415
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.25	17500	8.53125	842
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	842
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	842
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.02	17500	0.6825	842
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.01	17500	0.34125	842
Silver	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.01	17500	0.34125	842
Silver	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Silver	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Silver	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Silver	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Silver	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Silver	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	385
Silver	Selenium	Plant process wastewaters	Unknown	Unknown	0.5	550	0.53625	631
Silver	Selenium	Plant process wastewaters	Zinc Corp of America, Monaca PA	PA	0.5	550	0.53625	631
Silver	Selenium	Plant process wastewaters	AMAX, East St. Louis	IL	0.07	550	0.07508	6
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.036	4375	0.30713	2517
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.025	4375	0.21328	2
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.025	4375	0.21328	2
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.02	4375	0.17063	2
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.02	4375	0.17063	2
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.015	4375	0.12797	2
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.009	4375	0.07678	2
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.005	4375	0.04266	2
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.005	4375	0.04266	2
Silver	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.0015	4375	0.0128	2
23	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	25	22083	1076.5625	10441
Thallium	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.25	22083	10.76563	10441
Thallium	Copper	Acid plant blowdown	Magma, San Manuel	AZ	0.25	22083	10.76563	10441
Thallium	Elemental Phosphorus	AFM rinse	Unknown	Unknown	0.03	167	0.00975	415
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	1.25	17500	42.65625	8429
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.455	17500	15.52688	8429
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.455	17500	15.52688	8429
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.25	17500	8.53125	8429

Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.25	17500	8.53125	842
Thallium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.014	17500	0.47775	842
Thallium	Rare Earths	Process wastewater	Unknown	Unknown	2.5	117	0.56875	38
Thallium	Rare Earths	Process wastewater	Unknown	Unknown	2.5	117	0.56875	38
Thallium	Rare Earths	Process wastewater	Unknown	Unknown	2.5	117	0.56875	38
Thallium	Rare Earths	Process wastewater	Unknown	Unknown	2.5	117	0.56875	38
Thallium	Rare Earths	Process wastewater	Unknown	Unknown	2.5	117	0.56875	38
Thallium	Rare Earths	Process wastewater	Unknown	Unknown	2.5	117	0.56875	38
Thallium	Selenium	Plant process wastewaters	Unknown	Unknown	0.55	550	0.12513	38
Thallium	Selenium	Plant process wastewaters	Unknown	Unknown	0.25	550	0.58988	63
Thallium	Selenium	Plant process wastewaters	Unknown	Unknown	0.25	550	0.26813	63
Thallium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.25	4375	0.26813	63
Thallium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.25	4375	2.13281	25
Thallium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.25	4375	2.13281	25
Thallium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.25	4375	2.13281	25
Vanadium	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	5	22083	215.3125	1044
Vanadium	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	0.05	22083	2.15313	1044
Vanadium	Elemental Phosphorus	AFM rinse	Unknown	Unknown	0.19	167	0.06175	41
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.794	17500	27.09525	842
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.6	17500	20.475	842
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.58	17500	19.7925	842
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	842
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.05	17500	1.70625	842
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.015	17500	0.51188	842
Vanadium	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.015	17500	0.51188	842
Vanadium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38
Vanadium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38
Vanadium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38
Vanadium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38
Vanadium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38
Vanadium	Rare Earths	Process wastewater	Unknown	Unknown	0.5	117	0.11375	38
Vanadium	Selenium	Plant process wastewaters	Zinc Corp of America, Monaca PA	0.5	117	0.11375	38	
Vanadium	Selenium	Plant process wastewaters	Unknown	Unknown	0.05	550	0.05363	63
Vanadium	Selenium	Plant process wastewaters	Unknown	Unknown	0.05	550	0.05363	63
Vanadium	Selenium	Plant process wastewaters	Unknown	Unknown	0.05	550	0.05363	63
Vanadium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Vanadium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Vanadium	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.05	4375	0.42656	2517
Zinc	Copper	Acid plant blowdown	CBI	CBI	467	22083	20110.1875	1044
Zinc	Copper	Acid plant blowdown	CBI	CBI	385	22083	15717.8125	1044
Zinc	Copper	Acid plant blowdown	Cyprus, Clay Pool	AZ	115	22083	4952.1875	1044
Zinc	Copper	Acid plant blowdown	Magma, San Manuel	AZ	22.25	22083	958.14063	1044
Zinc	Copper	Acid plant blowdown	CBI	CBI	7.47	22083	321.67688	1044
Zinc	Copper	Acid plant blowdown	Kennecott, Bingham Canyon	UT	7.14	22083	307.46625	1044
Zinc	Copper	Acid plant blowdown	Magma, San Manuel	AZ	7.08	22083	304.8825	1044
Zinc	Copper	Acid plant blowdown	CBI	CBI	6.63	22083	285.50438	1044
Zinc	Copper	Acid plant blowdown	CBI	CBI	6.23	22083	268.27938	1044
Zinc	Copper	Acid plant blowdown	CBI	CBI	3.16	22083	136.0775	1044
Zinc	Elemental Phosphorus	AFM rinse	Unknown	Unknown	37.2	167	12.09	415
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	130	17500	4436.25	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	130	17500	4436.25	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	70	17500	2388.75	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	3.8	17500	129.675	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	1.38	17500	46.41	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.58	17500	19.7925	8429
Zinc	Elemental Phosphorus	Furnace scrubber blowdown	Unknown	Unknown	0.55	17500	18.76875	8429
Zinc	Rare Earths	Process wastewater	Unknown	Unknown	24	117	5.46	385
Zinc	Rare Earths	Process wastewater	Unknown	Unknown	19.4	117	4.4135	385
Zinc	Rare Earths	Process wastewater	Unknown	Unknown	12.5	117	2.84375	385
Zinc	Rare Earths	Process wastewater	Unknown	Unknown	10.7	117	2.43425	385
Zinc	Rare Earths	Process wastewater	Unknown	Unknown	8.94	117	2.03385	385
Zinc	Rare Earths	Process wastewater	Unknown	Unknown	6.17	117	1.40368	385
Zinc	Selenium	Plant process wastewaters	Unknown	Unknown	5	550	5.3625	631
Zinc	Selenium	Plant process wastewaters	Unknown	Unknown	1.98	550	2.12355	631
Zinc	Selenium	Plant process wastewaters	Unknown	Unknown	0.599	550	0.64243	631
Zinc	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.54	4375	4.60688	2517
Zinc	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.54	4375	4.60688	2517
Zinc	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.5	4375	4.26563	2517
Zinc	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.5	4375	4.26563	2517
Zinc	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.5	4375	4.26563	2517
Zinc	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.371	4375	3.16509	2517
Zinc	Tantalum, Columbium, and Ferrocolumbium	Process wastewater	Unknown	Unknown	0.207	4375	1.76597	2517

NOTES:

- $V_{\text{av}} (\text{m}^3) = 1/4 \text{ Annual Average Recycled Volume (MT)} \cdot 0.7346 \text{ m}^3$ (Waste density = $85 \text{ lb/ft}^3 = 1361 \text{ kg/m}^3$)
- $M_{\text{av}} (\text{kg}) = C_{\text{av}} (\text{mg/kg}) \cdot V_{\text{av}} (\text{m}^3) \cdot 1.361 \times 10^{-3}$ ($1.361 \times 10^{-3} = 1.361 \text{ MT/m}^3 \cdot 1000 \text{ kg/MT} \cdot 1 \times 10^{-6} \text{ kg/mg}$)
- $V_{\text{e}} (\text{m}^3) = 1/12 \text{ Average Annual Recycled Volume (MT)} \cdot 1.0 \text{ MT/m}^3$ (Waste Density = $62.4 \text{ lb/ft}^3 = 1000 \text{ kg/m}^3$)
- $M_{\text{e}} (\text{kg}) = C_{\text{e}} (\text{mg/l} = \text{mg/kg}) \cdot V_{\text{e}} (\text{m}^3) \cdot 1 \times 10^{-3}$ ($1 \times 10^{-3} = 1.0 \text{ MT/m}^3 \cdot 1000 \text{ kg/MT} \cdot 1 \times 10^{-6} \text{ kg/mg}$)
- $M_{\text{leachate}} (\text{kg}) = C_{\text{leachate}} (\text{mg/l}) \cdot 20 \text{ l/kg} \cdot V (\text{m}^3) \cdot 1.363 \times 10^{-3}$ ($20 \text{ l/kg} = \text{ratio of leachate mass to solid sample mass}$)
- $M_{\text{extraction}} (\text{kg}) = C_{\text{extraction}} (\text{mg/l} = \text{mg/kg}) \cdot 1.95 \text{ l/kg} \cdot V_{\text{sl}} (\text{m}^3) \cdot 1.0 \times 10^{-3}$ ($1.95 \text{ l/kg} = \text{ratio of extraction solvent plus liquid fraction to original sample mass}$)